European Journal of Workplace Innovation
Special Issue

Special Double Issue

Climate change, green jobs and workplace innovations

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Editorial

Egoitz Pomares
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In this special volume of the *European Journal of Workplace Innovation*, we wish to recognise the contributions of Professor Richard Ennals, who served as Editor-in-Chief from 2015 to 2024. His extensive work in workplace innovation, action research, and education has had a significant impact on the field. We acknowledge his leadership in fostering dialogue and advancing inquiry. In this issue, we include an obituary by Professor Peter Totterdill, offering a comprehensive reflection on Professor Ennals' contributions and legacy.

This double issue presents 11 articles exploring key developments in workplace innovation. The contributions examine a range of critical themes, including organisational transformation, digitalisation, sustainability, and employee participation. Together, they offer a rigorous analysis of the challenges and opportunities shaping the evolving world of work and employment. The issue has been curated under the editorial guidance of guest editor Kenneth Abrahamsson.

Many of the topics addressed in this volume build upon discussions from *Sustainable Work in Europe: Concepts, Conditions, Challenges* (Abrahamsson & Ennals, 2022) and the deliberations held at the *European Workplace Innovation Network (EUWIN) International Conference* in October 2024.

By bringing together a diverse range of perspectives, this special issue reaffirms the journal's commitment to fostering high-quality research and informed dialogue on workplace innovation. The *European Journal of Workplace Innovation* remains dedicated to supporting collaboration between researchers, practitioners, and policymakers to advance evidence-based approaches that contribute to organisational and societal progress.

Obituary

Richard Ennals

16th September 1951 - 10th December 2024

Peter Totterdill

We are deeply saddened by news of the death of Professor Richard Ennals, a distinguished social scientist and activist. Richard's contributions to the fields of workplace innovation, action research, and education have left an indelible mark on those who encountered his work, and especially on those who knew him.

The breadth of Richard's career over some fifty years was truly remarkable, embracing research and teaching in countries across the world. As early as the 1980s, his achievements included extensive publications on human centricity in the application of AI and information technology.

Richard was a founding member of the UK Work Organisation Network (UKWON), which from 1997 to 2013 promoted workplace innovation through action research, education and advocacy. The failure of successive British governments to recognise the importance of workplace change in achieving higher productivity and healthier working was a source of continuous frustration to him, and he often remarked that he had "intellectually migrated" to Scandinavia where these matters were much better understood.

As an editor and contributor to the European Journal of Workplace Innovation, his insights and intellectual leadership helped shape the discourse on workplace innovation and its potential for healthier working lives.

Richard's career was characterised by his unwavering commitment to learning from differences and fostering dialogue. His work often emphasised the importance of collaboration and the power of diverse perspectives in driving meaningful change. Richard remained a committed European, working hard to build relationships and establish new coalitions throughout his life.

In addition to his academic achievements, Richard was a much loved colleague and mentor. His dedication to his work was matched only by his kindness and generosity. Richard was known for his ability to inspire and engage those around him, always encouraging others to think critically and creatively. His warm concern for colleagues and students alike was one of his defining characteristics, and there are many, many others whose lives were deeply enriched by him.

Richard's legacy will continue to influence and inspire both current and future generations across Europe and far beyond. His contributions to the field of workplace innovation and his commitment to real social change will be remembered and celebrated for years to come. Richard will be deeply missed by his family, friends, colleagues, and the many individuals whose lives he touched.

Green Skills, Workplace Innovations and Just Transition

Introductory notes

Kenneth Abrahamsson
Richard Ennals
Ulrika Harlin
Christopher Mathieu

Climate change, digitization, rapid transitions, shifting demographics and public health imperatives create new conditions and demands within organisations, driving the need for skill development, workplace innovations, organisational development and updates to occupational health and safety. Technologies such as AI, algorithms, robots and cobots, and new logistic tools in the value chain, are expected to redefine the interface between humans and machines, bringing new opportunities for advanced decision-making as well as unforeseen impacts on job quality. SDG 8 addressing decent work and economic growth, must thus increasingly be seen in a broader context of social, economic, and technological transformation. Ultimately, the green transformation of private life, society, and work at large must encompass a significant role for democracy and civic participation.

The green transformation actualizes various perspectives of relevance for employment, work, and job quality. It is not only about the implementation of non-carbon energy systems and non-fossil approaches. It concerns the importance of green growth and its impact on productivity, organizations, working and employment conditions and employment levels. These concerns also apply to the circular economy, recycling policies, practices, and processes. In a broader societal context, the socio-ecological transition illuminates interdependencies, potential contradicting demands, changing values and lifestyles, mobility, transport systems, and gender equity all weighed in terms of a fair transition.

The twin challenges of green transformation and digitization, compounded by AI-impact, imply a major transformation of our societies, work organisation and job quality, and the interfaces between the private and public sectors around health care, education, city planning and transport infrastructures. The social, economic and technological transformation has various repercussions on larger cities and regions, smaller cities and municipalities, as well as sparsely populated areas. Looking at the development of green jobs, new work organisations and changing labour market contexts must be seen in their broader societal context.

The changes are also in accord with the Agenda 2030 goals for sustainable development. The process of green transformation occurs at various societal levels, i.e., the macro level, the meso level, and the micro level, actualizing various challenges and threats in a local, regional,

and national perspective according to the EU's Green Deal and FitFor55 initiatives. Green jobs and skills are generic and debated concepts mirroring ongoing developments and transformations of the world of work in a global sense.

These connotations differ between continents, countries, and sectors of the labour market. The mission of this call is in part to identify and share definitions of green jobs and green skills (Castillo, ILO 2023, OECD 2023)[1]. How are green jobs and skills defined, and how are they to be pursued, and by whom? Will the green transformation per se lead to good or better jobs? Or will it bring new and unforeseen OSH-risks? The green transformation actualises challenges and risks, which make it more complex to analyse how the various components of a just transition interact and possibly trade off against each other. Do we anticipate goals and institutional support for a just transition with or without workers? Who is forced to carry the social and economic costs of these climate-oriented and low-carbon initiatives, and who will bring home the benefits - governments, enterprises, and/or social partners? And which new skill demands, forms of job strain and OSH-risks are expressed at the workers' level?

Skill formation and competence development via in-service learning, general and vocational education are necessary prerequisites and conditions to support the development of new, adaptive, and socially inclusive work organization configurations. Some familiar jobs will cease to exist, and new jobs will be created in emerging market segments within a globally interconnected and likely volatile economy, yet some of the actual outcomes will be seen in the future. However, the development will certainly lead to new job openings in a re-defined labour market within the primary sectors, as well as in other sectors.

The EU predicts that the green transformation will create around one million new jobs in Europe. Social partners have a crucial role in the greening of the European world of work by setting standards for good and inclusive workplaces. But employee-generated workplace innovations are also needed to drive and ease the adaptation to the greening imperative. Development towards sustainable change processes in the green transformation will require increased collaborations spanning over traditional boundaries. This requires collaboration by broad active ownership towards joint missions, trust, transparency, and solution oriented problem-solving, and continuous organisational learning. Moreover, strategic development towards green transformation requires considerations from perspectives such as gender equity, integration and protection of migrant workers and immigrants, and open inclusionary policies for people outside the labour market.

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1 Castillo, Monica, Green jobs, green economy, just transition and related concepts: A review of definitions developed through intergovernmental processes and international organizations, Geneva: International Labour Office, 2023 and OECD (2023), Assessing and Anticipating Skills for the Green Transition: Unlocking Talent for a Sustainable Future, Getting Skills Right, OECD Publishing, Paris, https://doi.org/10.1787/28fa0bb5-en.

Purpose and content

The purpose of this special Issue of the European Journal of Workplace Innovation is to provide enhanced theoretical and empirical understandings of green jobs, green skills and just transition in the global economy, while also taking Europe as a learning community by illuminating the role of formal, nonformal and informal learning contexts and how they can interact with various forms of workplace innovation, competitiveness, and socially sustainable workplaces and inclusive work organisations. More generally, this special issue aims at a mixture of policy visions and political missions, theoretical approaches as well as historical and contemporary empirical case studies, and examples of ongoing firm-level innovations in various sectors of working life that can inspire organisational strategy.

The ongoing green transformation of societies, industries, and work is a complex process that relates to all parts of human life, societal institutions and the health of our planet. As a field of research, it cuts across all faculties of science, disciplines, and research approaches. The problem of climate change and the urgent need to stop further warming of the planet has major repercussions for institutions, communities and ways of organising everyday life, not the least work. It also concerns politics and policies from UN to Europe, all countries, regions and municipalities. The text by the Swedish scholar **Staffan Laestadius**, professor emeritus in industrial technology, highlights the urgency of a universal roadmap to a future sustainable society.

A great transformation of human activities – and thus of working life - is inevitable for planetary reasons. The climate crisis is now so severe that a continuation of business, and life, as usual (BLAU) is not a realistic alternative on a global scale. Within a few decades, certainly within this century, BLAU will cause living conditions for humanity to deteriorate significantly, accompanied by extreme heat waves, large migration, shortage of food and water and not the least, large-scale conflicts due to the increased competition for land and food.

In his paper, Staffan Laestadius highlights the risks and the enormous negative impact on society, working life and biodiversity of the BLAU-strategy. He argues that industrial development and great economic acceleration post-WWII, has created today's climate crisis. Thus, there is a direct relation between energy systems and climate change. The energy input from coal, oil, and gas, has according to Laestadius, been growing by 3 percent annually. The growing Green House Emissions are a threat to biodiversity, and several tipping points are close, or have even been passed.

Emissions must be reduced by up to ten percent per year to reach climate targets. Substantial and critical adjustments are needed not only at work but also in society, including the everyday activities of citizens. The article discusses various policies to de-carbonize society and work life, and shortened working hours and a reduced growth orientation, is one example. The biggest change, however, is not institutional patterns for the pathways to a post-

fossil society. It is, according to Laestadius, "the transformation of our minds, i.e. the paradigm shift in our understanding of the planetary conditions for human activity and work."

For many years, work was an outlying field in the policy development toward a more sustainable world. Now it is a fully accepted part of the sustainability family. There are still, however, major gaps in the global climate change discourse. Climate change policies could imply and have guidelines for several societal sectors, in which working conditions are embedded factors and not visible at the policy level. In Sweden, the government-supported platform Fossil Free Sweden contains 22 different industries that have produced their own roadmaps to show how they can enhance their competitiveness by going fossil-free or climate-neutral. The working contexts and occupational health risks for employees in these sectors are not so visible, making the challenge of a just transition crucial.

Change is taking place to build bridges between climate change and development in working life. Eurofound has recently published reports looking at the interface between climate change and job quality. The article in this special issue by **Agnes Parent Thirion and Jorge Carbrita** *The job quality side of climate change* is a condensed and augmented version of a Eurofound (2024) report with the same title.[2] It shows that workers will experience the effects of climate change in many ways: job insecurity, changes to their work tasks and responsibilities, and changes in their workplaces that may involve different work practices and the development of new activities and products. Green jobs are found to not always good jobs. In some sectors of the labour market, there could be exposure to hazards such as chemical substances, leading to lower job quality, productivity loss and greater job and work insecurity. According to the report, nearly half of workers in the EU will experience profound changes in their job tasks as economies adapt to climate change and climate mitigation strategies are implemented.

Other changes relate to work organisations and company structures. There are winners and losers among workers in the green transformations of the labour market. More generally, the article by Parent Thirion and Carbrita outlines the complex relationship between job quality and climate change, including the implication of green tasks in selected sectors. Most articles collected in this Special Issue reflect on the concept of the green transition. Greening of work and companies can also take the form of greenwashing. It is not only necessary to be more sustainable as a general societal goal but being green and sustainable could also be a marketing strategy.

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[2] Eurofound (2024), *Job quality side of climate change*, Publications Office of the European Union, Luxembourg. https://www.eurofound.europa.eu/en/publications/2024/job-quality-side-climate-change

Thematic structure of the Special Issue

The first section contains the greening of societies and work from an international comparative approach.

In his article, **Steffen Lehndorff**, professor emeritus in economics at the Institut Arbeit und Qualifikation [Institute for Work, Skills, and Training] at the University of Duisburg/Essen, Germany, looks at what policy lessons Europe's Green Deal can learn from the New Deal in US during the 1930s. Which are the policy lessons to be learnt from the New Deal of the 1930s for the political and societal process that is necessary to drive forward a "Green and Just Transition" in contemporary Europe? He focuses the socio-ecological transformation of industry and the importance of trade unions in this process, exemplified by the case of Germany. In a contemporary comparative sense, unions in the US have a weaker position, but the industrial incentives are stronger. His article actualises the balance of power between investors and industry, and social partners. Was the New Deal mostly bottom-up connected, while the Green Deal seems to be more of a top-down strategy? There are both similarities and differences. The New Deal was a strategy to decrease unemployment, combat poverty and give new energy to the field of work and welfare. The Grean Deal, however, has a much larger field of transformation recognising the role of biodiversity, nature, energy systems and the fight against greenhouse gas emissions.

Mathieu Hocquelet and Nathalie Moncel, Center for Studies and Research on Qualifications (CEREQ), Marseille, highlight the ecologisation of work and firms in France. Their study is based on mixed-method research conducted by a Cereq team from 2020 to 2023 analysing three interconnected levels: employment systems; value chains; and company strategies, occupations, skills, and work activities. Attention is given to the impact of new environmental norms on job structures in three different fields of industry reflected in the dynamics of what is virtuous and what is profitable and how striving for a greener economy interacts with market benefits. Their contribution illuminates the complexity of the green transition on industry and working conditions. The system perspective is applied at three levels: labour market and employment conditions; value chains; and corporate strategies as well as occupation and skills, provides a broader analytic framework than is usually applied. The article also presents the "ecologisation of work" as a generic concept for the analysing the transformation of jobs in a green economy, which can be contrasted with Stroud, et al.'s (2024) concept of "greening"[3]

Another national case is presented by **Warhurst, Harris, Cardenas Rubio, and Anderson**. Their paper reports the findings from an analysis of Scotland, applying the GreenSOC – an adaptation of the green occupation's classification of the US Bureau of Labor Statistics and O*NET. The analysis uses the UK Labour Force Survey and web-scraped job vacancy data to assess the extent and demand for green jobs as well as the pay and gender composition of

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[3] Stroud, Dean, Luca Antonazzo & Martin Weinel. 2024. "Green skills" and the emergent property of "greening", *Policy Studies*, DOI: 10.1080/01442872.2024.2332441

these jobs. The findings are mixed. First, there are few new green jobs but a strong greening of existing jobs. Second, while green jobs offer higher wages, they tend to be dominated by male workers. Their study has several policy implications for a socially inclusive and gender-relevant transition.

The volume comprises further contributions from Finland, Sweden, South Africa and the UK, more focused on work organisation, job quality and green skills. Thus, the second area concerns the impact of green jobs on work organisation, occupational health issues and job quality. Are all green jobs healthy jobs? The green transition builds on a change to fossil-free energy and a circular economy. In a European context, the major policy initiative is the Green Deal. While this transition needs to be rapid, gains and losses of jobs need to be considered. This may have profound positive and negative effects for different occupational groups as greening of the jobs may both eliminate current risks (e.g. associated with fossil fuels) and introduce new ones. The article on safe and healthy green jobs, by **Albin, Håkansta, Bodin, Wadensjö & Broberg** on Sweden provides examples of such risks to occupational safety and health. It also discusses employment conditions and worker bargaining power in relation to the twin digital and green transition. To reduce the negative effects of the green transition on the health and safety of workers, they suggest that there is an urgent need to establish strategies for *Safe and Healthy Green Jobs*. The authors suggest steps towards such a Roadmap and indicate some key knowledge gaps.

One fundamental area of the green transformation is the role of the circular economy and promoting *resource efficiency* through *reduction, reuse,* and *recycling*. The present review article by **Sanne, Johansson, Miliute-Plepiene & Karlsson** synthesises the existing scientific knowledge on a sustainable working life in the transformation towards a circular economy: It is based upon the synthesis and critically explores the knowledge needs in relation to circular economy and working life. Its focus is on barriers and enablers; labour market changes; occupational health and safety management, (OHSM); skills requirements; the role for social partners; and policy challenges. The review ends with policy recommendations for research on creating and upscaling circular business models that promote transparency, collaboration, and value creation across supply chains, developing educational programs for stakeholders and the workforce. The focus should also be directed towards job quality and the role of social partners.

The twin challenges of green transition and digitization differ substantially between existing firms and the creation of new industrial clusters to produce new products needed for the greening of industries.

The article by **Säfsten, Harlin, Johansen & Öhrwall** is a process-oriented study on how manufacturing companies and organisations can attain sustainable and resilient production. It focuses on the fact that green transition necessitates that organisations address climate change and increasing uncertainties and how to incorporate sustainable and resilient solutions into their production development projects. The focus is on development practices

in greenfield projects such as building new factories or production systems, and their relation to active ownership, collaboration and learning potentially supporting lasting impact of change initiatives. Through this, the article contributes a new perspective on production development by emphasizing a learning-oriented approach. This learning approach is increasingly required for production development processes in emerging domains, such as the green transition.

This volume comprises two studies on workplace innovation in Finland. The first article by **Moilanen and Turunen** at FIOSH, looks at the interface between work and societal conditions. They find that although learning and innovation are key drivers of sustainability transitions, workplace innovation has gained little attention in the research area. Workplace innovation has the potential to produce local change and development toward environmentally sustainable working life and society, since employees' ideas and initiatives can foster the adoption of environmentally sustainable work practices and processes both at the workplace and within work-related networks. Their article presents an empirical analysis of findings from a representative sample of Finnish employees collected in 2022 in the Climate change and work survey (n=1917), and analyses the results using a mixed methods approach. However, the lack of environmental workplace innovation efforts in Finland indicates that there is a need to strengthen and support local development efforts on green topics.

The other contribution from Finland by **Teperi, Lyytimäki, Heikkilä, Malve-Ahlroth, Mervaala, Ratinen & Thatcher** aims at analysing workplace innovation from human factors theory combined with an ergonomic perspective. They argue that environmental degradation requires workplaces to undergo a profound shift towards ecologically sustainable work that goes beyond continual growth and holds justice and the well-being of workers as a core value. Workplaces have a critical role in realising policies for a just green transition, their structures provide a link through which this transition could be achieved. However, there is a lack of clear and systemic definition and an easily applicable model to guide workplaces to become both just and green (JGT). In this paper, they aim to define the key characteristics of a just green workplace by using human factors/ergonomics (HF/E) as the underlying theoretical approach. Based on the findings, they present criteria/recommendations for a just green workplace. In addition, the value and development needs of the HF/E approach in fostering sustainability are discussed.

Another theme in this volume concerns the importance and value of green skills.

Gustavsson, Halvarsson Lundkvist and Persson Thunqvist highlight the role of higher vocational education in the green transformation of the labour market, work organisation and jobs. The manufacturing industry is undergoing a significant transformation, characterised by a green transition and rapid digitalisation. Technological advances have dominated Industry 4.0, whereas the transition to Industry 5.0 emphasises improving technology from a human-centric lens. This necessitates focusing on digital and green skills development to accelerate the green transition in industry. Within the context of Swedish higher vocational

education (HVE), this paper aims to investigate HVE providers' experiences of challenges in providing industry with the skills needed for green transition. Interviews were conducted with 22 representatives of HVE providers collaborating with industry. The findings indicate that there was an imbalance in pace between HVE and industry caused by various challenges at three transitional levels, i.e. individual level, company level and, finally at the level of recruitment of students.

Based on research to identify environmental skills needed in the South African mining industry, and other sectors, **Eureta Rosenberg** proposes in her article a few methodological innovations. One is to expand the standard value chain analysis, by using a critical realist methodology that also looks for absences: value that should be there but is currently destroyed or untapped. An example is the restoration of mined land, a form of regenerative economy with the potential to reduce value destruction and create new social, economic and ecological value. Identifying such leverage points can show up the possibility of new or re-configured jobs in the transitions to more sustainable development, in this case a transition away from coal. Another innovation involves the identification of the associated skills requirements. More than technical skills are needed, but just what do so-called 'soft skills' entail, and how can they be developed? The paper concludes with tools to apply at the organisational level for green skills needs analysis, using a framework of technical, relational and transformational competencies, in support of the quest for green growth in senescent or at-risk value chains.

Green transformation at risk? Concluding remarks

At the end of the volume, Kenneth Abrahamsson, guest editor for the special issue, reflects on the future of climate change, green jobs and the green transformation from a policy perspective. In addition to that, Peter Totterdill, Frank Pot and Paul Preenen give their views on theoretical and conceptual approaches to support change in the workplace in an innovative way.

Postscript reflections were authored by **Richard Ennals** on work-life research in retrospect. This paper is written based on a series of concurrent discourses and dialogues over the last 50 years, as a researcher, research manager, writer and editor. This meant starting from a UK perspective on Skill and Justice, with the work of John Bellers, then moving to Scandinavia, and ending with a European synthesis and international systematisation, where we can regard our ongoing differences as a crucial resource for sustainable development.[4]

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[4] As was mentioned previously, Richar Ennals, editor in chief for European Journal of Workplace Innovation, passed away late autumn 2024. His postscript reflects his analytic mind and research interests being part of his life-achievements.

Activities and working life in the coming great transition

Staffan Laestadius

Abstract

This chapter is about that coming process of transformation with focus on human activities and our working life. It is structured as follows: Section two contains some methodological remarks followed by a third section which summarizes "the state of the climate". Section four provides a short analysis of *the great acceleration*, i.e. the rapid global growth process after WW2 and which basically has created the present climate crisis. In section five we analyze the conditions for the great transformation ahead. In section six we leave the general analysis in favor of the specific: we focus on the climate impact of the balance between activities within and outside the formal economy. Section seven is focused on productivity presently and in the post fossil society followed by a section (eight) on the role of coal. After a general discussion on the coming transformation of working life in the ninth section we focus on the role of AI in section ten followed by a competence-related approach in section eleven. Section twelve, which also concludes with the paper, discusses the necessary and probably most important issue in the path ahead towards a post fossil society: the transformation of our minds, i.e. the paradigm shifts in our understanding of the planetary conditions for human activity and work

Keywords:

AI power consumption, artisan small-scale mining, carbon budget, climate and working hours, coal and work, the Great Acceleration, planetary boundaries, productivity decline, working conditions,

Introduction

A great transformation of human activities – and thus of working life - is inevitable for planetary reasons. The climate crisis is now so severe that a continuation of business, and life, as usual (BLAU) is not a realistic alternative on a global scale. Within a few decades, certainly within this century, BLAU will cause living conditions for mankind to deteriorate significantly, accompanied by extreme heat waves, large migration, shortage of food and water and not the least, large scale conflicts due to the increased competition on land and food.

The necessary alternative to BLAU is a primarily proactive transformation of our societies away from their present addiction to fossil carbon. This structural change has to be rapid and far reaching and will, as a part of it, include a large-scale transformation of how human activities are organized: in formal working life as well as in the hours spent in our "free" time.

Methodological remarks

There is a strong scientific consensus as regards the severity of the present climate crisis. We now have a solid knowledge of the history of our planetary climate as well as of its present state. This includes knowledge on relationships and causalities between a significant amount of natural as well as anthropogenic variables related to planetary change. We will return to that in section three below.[1]

The development of the climate crisis hitherto – and the mechanisms behind - is thus well known. The future of the crisis – and of the Planet - is more problematic to assess. For sure there are several modelling activities which forecast potential and more or less *probable* development paths for the global climate based on various assumptions of aggregate human behavior. The present trend of emissions is often used as a basic scenario to which potential alternatives are related. Basically, the present trend is what we here label business and life as usual (BLAU).

BLAU is, however, not probable. That development path will very soon result in dramatic consequences for mankind and necessitate *reactive* policies with significant impact globally as well as on national level. Alternatively, nations and the international community may act *proactively*, i.e. somewhat before the worst-case scenarios are realized. For the moment, also this *proactive window of opportunity* is closing rapidly.

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[1] For comprehensive and authoritative reports, see e.g. *IPCC, 2023; WMO, 2023; WMO, 2024a & b; WMO et al, 2024.*

Several climate policy analyses on the global level have published *conditional scenarios* – sometimes of a *backcasting* character - on how the transformation ahead towards a zero-carbon economy can take place. (See e.g. IEA, 2024c; SEI, et.al., 2023 & UNEP, 2024).

This paper is too short for that kind of analysis. We do not predict how mankind will manage the present severe climate crisis. We discuss how human activities, including those performed within the formal economy, i.e. working life, under certain conditions, may be affected by, and contribute to, a proactive transformation strategy towards a low carbon/fossil free society. As there is a strong connection – and trade off - regarding the climate impact of activities within and outside the formal economy, we here choose to apply a broader activity perspective in our analysis.

One implication of our conditional approach is that we have reduced the usage of empirical data. We do not deliver historical trends or forecasts based on those (i.e. BLAU), we analyze the conditions for deviating from the present, the magnitude of which we discuss in section five below.

It is not obvious whether the transformation ahead should be labelled *re-active* or *pro-active*: On the one hand a rapid decarbonization policy is basically caused by the consequences of greenhouse gas (GHG)-emissions (and thus reactive), on the other, the activities may be directed to reduce those emissions rather than adapting to their consequences and thus labelled proactive. Delaying mitigation activities today will inevitably increase the magnitude of extreme weather and thus necessitate tougher climate policies in the future.

State of the climate

The level of GHG: s in general, and CO_2 in particular, in the atmosphere is significantly higher than it has been for at least 800 000 years (Keeling, 2024). The rate of increase in intensity of these gases is higher than ever (NOAA/GML, 2024). As a consequence, the planet absorbs more heat than it reflects. 90% of this heat is absorbed in the oceans. That energy imbalance causes global temperatures, in the atmosphere as well as in the oceans, to increase. This heating process is primarily the result of anthropogenic GHG emissions which have increased over almost two centuries and resulted in an all-time high in 2023 and early 2024 in both the atmosphere and in the sea (Copernicus, 2024; Friedlingstein, et.al., 2024). The consequences of these still growing human emissions have been more rapid and severe than forecasted just a few years ago (Deng, 2024; Schmidt, 2024). The well-known Paris target from 2015 to keep temperature increase below 1.5°C below preindustrial level during this century is probably already passé. We may persistently pass that level by 2050, probably within a decade already.[2]

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[2] The 1.5°C limit was passed already in the 13 months period Aug. 2023 to Aug. 2024 (Copernicus, 2024).

As a consequence of temperature increase the cryosphere is melting all over the planet with a long-term impact on global sea level as well as on sea currents. The warming atmosphere can accommodate more humidity which in turn can – and will - result in extreme rainfall and storms. Heat waves as well as snowstorms will become more frequent and extreme (WMO, 2024a&b).

The great acceleration towards a global society addicted to (fossil) carbon

Although human planetary impact is as old as mankind we may identify two historical milestones in our growing addiction to carbon. *First*, the origin of the industrial revolution and the introduction of the steam engine around the early 19th century. Primarily in the middle of that century the steam engine became widely used in connection to a rapid increase of coal consumption. In the late 19th century oil was added to coal and soon became the main fuel for the growing transport systems.

Secondly, the period after WW2 has been characterized by a rapid growth of industry, of all kinds of communications, of consumption – not the least of durables - and of new technologies related to that. This *great acceleration* has been fueled by a constantly growing consumption of fossil fuels. The energy input from coal, oil and gas has grown by 3 percent annually since 1945. Fossil fuels still, in spite of the rapidly growing role of renewables, make up to 82 percent of global energy transformation. In fact, the global use of fossil fuels still increased by 1.5 percent in 2023 (EI, 2024).

Almost eight decades of exponential growth of natural resource extraction and burning of fossil fuels have now moved mankind close to what earth scientists label our *Planetary Boundaries*. Recent research indicates that our planet is close to, or has even passed, several tipping points as regards geophysical and climate change (Steffen et al, 2015; Richardson et al, 2023: Rockström et al., 2023). Among the most important anthropogenic threats are the GHG emissions – of which CO_2 is the most important - and our impact on biodiversity.

Both threats necessitate a rapid and far-reaching transformation of human activity, parts of which must take place in the formal economy, and thus in working life. In the rest of the paper, I evaluate the conditions for and potential impacts of that transformation.

The necessary transformation[3]

The necessary speed and magnitude of the transformation ahead is conditioned by the planetary boundaries, i.e. the limits of the (almost) finite planet. The exemption to finiteness is the constant inflow of solar energy. This is an important exemption and the main source of

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[3] More in depth analyses of the magnitude and necessary speed of this transformation are available in my recent monopgraphs, written in Swedish (Laestadius 2018, 2021 & 2023).

hope in the coming transformation. Mankind has used the solar inflow directly and indirectly in all her history as the main source of energy. During the recent two centuries, however, that source has been increasingly marginalized by the combustion of fossil carbon stored underground. The still growing emissions from that combustion are accumulated in the atmosphere with consequences on the radiative force of the planet.4

The basic, and doubtless the most important, parameter to consider as regards climate policy in the years ahead is the Remaining Carbon Budget (RCB). The concept, which was introduced in the IPCC vocabulary already in 2013, is an estimate on how much CO_2 which (given certain conditions) can be emitted globally in the atmosphere if we have the ambition to keep the increase of global atmospheric temperature below a certain level, say 1.5°C above pre-industrial level.

According to the most accurate calculation (from Nov. 2024) on the RCB for a 50% probability to keep global temperature increase below 1.5°C above the preindustrial level is 235 $GtCO_2$ starting from January 2025. That is equal to approx. six years with the present level of CO_2 emissions. Accepting a higher temperature increase, like e.g. 1.7°C (585 Gt) or even 2°C (1110 Gt), will of course give more time for climate policy, 14- & 27-years resp. But the consequences for the planet – and for mankind – of such a retreat of climate mitigation ambitions are enormous (IPCC, 2018; IPCC, 2023; Forster et al, 2024)5. Following a recent UNEP report there is now in reality no hope to keep global temperature increase below 1.5°C and very small hope to stay below 2°C (UNEP, 2024).

The policy implications of the present state of the climate are that society, globally as well as nationally, has to reduce all emissions from human activities by 7 – 10% annually in the rest of this decade (Laestadius, 2021 & 2023). This includes emissions from production as well as from consumption, i.e. from our working life as well as from activities during our "free" time. Whether companies, like e.g. steel plants or aviation companies, are the direct emitters or individuals, like e.g. automobile and boat drivers, is of no importance from a climate perspective.

To approach that activity-related problem further we commence the following analysis with some reflections on the working time question.

Working time

It has been argued that a reduction in working hours will contribute to the transformation towards a low carbon economy. In this section I will focus on that argument. This also means

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[4] The present (Oct. 2024, de-seasonalized) CO_2 intensity in the atmosphere is approx. 426 ppm which is approx. 52 percent above the preindustrial level (280 ppm).

[5] The uncertainties in these calculations are large. Here we follow Friedlingstein (2024) whose calculations landed somewhere between those of IPCC (2023) and Forster et al., (2024).

that I will neglect all other – and in my opinion basically reasonable – arguments for shorter working hours. They belong to another discourse.

European countries differ as regards the activity level of their populations as well as the working hours of those employed. There are differences between the various national labour markets as well as differences in culture and lifestyles. Sweden, e.g., has an activity rate – i.e. part of the population available to the labour market - of 88 per cent in the age 15 – 64 years which is highest in the EU. The average working hours of those employed is 1440 hours annually, which is lower than the EU average (1607 hours). National differences in retirement age add to the complexity. The mechanisms behind these phenomena are not important to analyze in detail here. Enough is to conclude that Swedes, thanks to social/welfare policy and labour market activities, *on the average* for those employed, have reduced their activities in the formal economy to approx. 31h/week, assuming a 46-week working year.

Time not spent as working hours in the formal economy is spent in the informal. For those Swedes who are employed that is approx. 7300 hours annually. For those not employed, the whole year, 8760 hours, is spent in the informal "free" time.

The character of that time spent (of which approx. 3000 hours are used for sleep) may differ between countries, between gender, social classes and professions. Those who have finished their working hours, may spend more time together with their children or build on their second homes, take care of their kitchen gardens, go fishing or hunting, perform music, read books or write their own´s – just to illustrate a few aspects of human life. Retired people may take care of their grandchildren in some countries where preschools are less common. Early retirement and shorter working hours will also make it possible for some to join other working positions and start a second working life.

There is often a correspondence between activities performed by an individual in their working life and in the domain of" freedom". The character of your profession and working conditions may have an impact on how you value your work as well as how you spend your free time. In her classification into *Labour*, *Work* and *Action* Hannah Arendt did draw attention to the different characters of human activities (Arendt, 1958). In short: *labour* is what you have to do, whether in the labour market or in the private sphere. *Work* is skilled and professional tasks which keep you engaged and proud when you build your own house as well as when you do it for a customer or an employer. And *activity*, in the Arendt vocabulary, is when what you do becomes part of your lifestyle, when the distinction between the realm of necessity and freedom disappears.

Although it may be assumed that most people want to reduce their dirty or boring "labour" irrespective of whether they face it in the working condition or their domain of "freedom" this is far from obvious for those who perform "work" or "activities". The engaged farmer will make sure that all important tasks are fulfilled before he/she closes for the day. And so will the professional carpenter. The engaged academic or author may not even make a clear

distinction between the realms. Shorter working hours may also facilitate for some to develop dual activity strategies:" labour for cash and creative work or action for freedom"!

That takes us back to the climate dimension. The climate impact of a general reduction of working hours in the labour market will depend on the marginal difference between the human footprint of the time reduced in working life and the footprint of the increased time spent outside the formal economy. In short: if the increased availability of free time ends up in more GHG-emitting global as well as local travel, more fossil-based material consumption and polluting activities, a reduction of working time is the wrong way to go.

Economic policies and the transformation of the wage structure connected to the working time reduction are important here. Those who argue for shorter working hours often also argue against wage reductions. This is probably neither a good climate strategy nor a possible path to follow.

As regards the climate impact it may be argued that *ceteris paribus*, if aggregate labour income is the same after the reduction in working time, consumption will be the same, and so also the climate impact. More time in the realm of freedom also means more time for fossil-based lifestyle. To pay for that larger consumption potential some people may use a part of their new freedom to earn more money which also may increase their expenditure on GHG-emitting consumption. We may call that phenomenon the *working time rebound effect.*

It is frequently argued that a reduction of working time can be paid for by increased labour productivity, which often is assumed to increase in the future along its historical post WW2-path, i.e. by 2-3 percent annually. A variety of this argument is that wage increases during recent decades have been significantly lower than the increase of labour productivity (see e.g. Bivens & Mishel, 2015; OECD, 2024). Whether historical productivity increases can be relied upon in the transformation to come is the topic of the next section.

Productivity increases historically – and in the future transition to a post-fossil economy

Industrial transformation is – and has always been - connected to either new forms of organization of activities and/or the introduction of new technologies, some of which end up in new outputs or new inputs – energy and material - in the economy. In short, this is what innovations are about.

Good illustrations of the organizational change connected to working life are provided to us from the origin of the industrial revolution. The simple reorganization of tasks, division of labour, as described by Adam Smith among others, contributed to a significant productivity increase. The movement of items in work as well as the movements of the workers were rationalized. More important, however, was the fact that the introduction of a strict sequential

and divided production line favored mechanization and new technologies, i.e. (process) innovations (Laestadius, 1992).

This also opened the door to the introduction of external – nonhuman – power in the production process (Landes, 1969/77; Laestadius, 2018). Although sun, wind and water had been used for centuries, the introduction of coal-based steam power contributed to rapid industrial expansion, mechanization and significant productivity increases during the 19th century already. Around the turn of the century 1900 oil added to the primary sources of external energy. And, as discussed in section 4 above, the Great Acceleration after WW2 has been based on a rapid increase in the use of energy in general and fossil fuels in particular.

This dependence motivates a deeper discussion on our understanding of productivity; in particular on the role of energy input for productivity increase – and thus for growth. Productivity in general is a concept for the relation between output from the processes in a system and the inputs we identify (alt. are interested in) for that process. Historically economists have identified (the quantity of) capital and labour as the significant inputs. After WW2 knowledge and technical change were identified. We may label them brain power. Although Landes, as mentioned above, long ago noticed the importance of external power (i.e. energy) as an important mechanism behind the industrial revolution, economists have been reluctant to identify energy as a separate factor of production rather than an input among others. Energy is normally not included as an input factor in total factor productivity (TFP) analyses.

An analytical problem when analyzing the role of external power (energy), behind productivity increase and economic growth is that it is deeply related to – and can be hidden behind - our brain power, i.e. our innovative ability: we have learnt to excavate fossil fuels deeper and cheaper. We have developed new machines, the capacities of which are dependent on a large and increasing energy input. A significant part of our creativity has thus been directed to deepen our addiction to fossil fuels, which now must be rapidly abandoned. It is not probable that our historical productivity increase – and thus economic growth - can be upheld if we from now on must use most of our human creativity to reduce the dominant form of energy.

It is, in addition, far from obvious how to measure productivity change. For our purpose, the labour productivity concept is highly relevant. That is simply the output of an economy or an industry per working hour or per employee. Other inputs from external power and brain power (like process innovations) are simply statistically allocated to labour. But also, the GDP/capita is a relevant measure. It simply allocates the total production in the formal economy to everyone irrespective of whether they have their activities in the formal or informal economy.6 In addition GDP/capita data is easier to compile.

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[6] In short: house wives, doing unpaid homework in the informal economy to make it possible for the men to be productive in the formal economy, become "included" in the GDP/capita data.

Table 1 below reveals that the Great Acceleration was the golden post WW2 era. During the period 1950 – 1973 labour productivity growth within the OECD area was in the magnitude of 4.5 percent annually and GDP growth per capita in the magnitude of 4 percent annually. This was also a period with rapid growth of fossil fuels input, here approximated with global CO_2 emissions: 4.7 percent annually. Since then, labour productivity has declined to half of the golden level. This is illustrated in graph 1 below.

Table 1: Productivity growth measured as GDP/hour worked and GDP/capita and global carbon emissions 1870 – 2019. [7]

Annual growth rates rounded to one digit accuracy

		1870-1913	1913-1950	1950-1973	1973-2003	1973-2019
GDP/hour	orig.OECD	1.6	1.8	4.5		
	UK	1.2	1.7	3.6	2.2	
	USA	1.9	2.5	2.8	1.7	
GDP/cap	orig.OECD	1.4	1.2	3.8	1.85	
	W.Europe	1.3	0.8	4.0	1.9	1.7
	USA	1.8	1.6	2.5	1.9	1.8
	World		0.9	2.9	1.5	1.6
CO2 em.		4.5[8]	1.4	4.7	1.6	1.8

Sources: GCB (2023); Krantz (2000); Maddison (1991 & 2007); OECD (1985 & 2003); WDI (2024)

Graph 1: Long term productivity decline in advanced economies, 1960 – 2022.
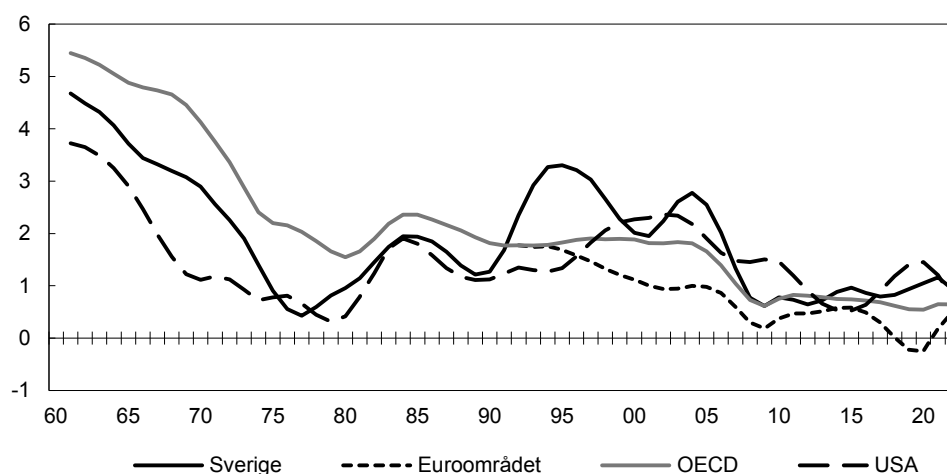
Source: BP 2023/24 and Milicevic (2023)

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[7] The table combines aggregate statistics from various (partly related) sources and over a long period. Our task here is not to get stuck in data details but to provide a historical overview of the productivity/growth phenomenon in the transition to come.
[8] This figure reflects the early phase of the fossil economy. The level of emissions in this period is approx..1% of the level in the last period which by definition creates high growth rates. In addition: during this period coal – which causes higher emissions than other fossil fuels - was dominant.

The reasons behind the significant decline in productivity increase in the old industrial world since the early 70s is an object for intensive discussions among economists and policy makers (Milicevic, 2023). Here is enough to note that this decline has been connected to the stagnation in the growth of fossil fuel inputs. But we are still waiting for a decline in real terms in the use of fossil fuels.

That takes us back to the task ahead, i.e. to reduce global CO_2 emissions – and thus the use of fossil fuels – to the magnitude of 7–10 percent annually. Following our discussion above we may – *ceteris paribus* - assume that the labour productivity increase may be still lower in the coming transition to a fossil free economy than its recent declining trend. To be clear: it is not enough to stabilize the use of fossils, it must be reduced significantly!

A rapid successful transformation may even temporarily cause an absolute decline in (revealed) labour productivity. This may be the case if less productive non-fossil-based solutions substitute for fossil-based ones. An electric truck may e.g. have a lower payload capacity than one fueled by oil.[9] In addition, the post fossil economy may include more of reparations and handling of spare parts in various circular systems than the present wear and tear habits. This may reduce the speed and productivity in the production system. The consequences for working life of this transformation are not obvious and are, of course, open for innovative activities.

The "ceteris paribus condition" stated above is important here. The reduction of fossil fuels will be parallel with other transformations in the economy, the probably most important of which is the rapid introduction of artificial intelligence (AI). We will return to that phenomenon in section 10 below.

Coal and work

An analysis of the impact on working life of the transition to a post fossil economy must necessarily consider the old, tight and cruel relation between coal and work. The excavation of coal - during several centuries primarily for direct heating, from the 19th century increasingly also for transport and prime movers in industry and during the 20th century successively more used for electricity generation – is historically by far the most hazardous and deadly labour activity (Freese, 2003; Malm, 2016). The high frequency of accidents in coal mining is, however, not only history. Globally coal is probably still the most dangerous industrial activity (GEM, 2021).[10] To the accidents in the mining sequence of the value chain for coal we may add accidents in the further handling – historically e.g. for stokers on ships – but also indirect consequences of emissions from fossil-based activities. The smog

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[9] A fair analysis of this problem has methodological difficulties. If the price of fossil-based activities does not reflect the real climate costs (a gigantic *external effect* which is difficult to agree upon) the costs of the fossil economy will be underestimated. This is probably presently the case.

[10] More details are also found in a Wikipedia (2024) text on Mining Accidents from 18th century and onwards. Most accidents relate to coal mining.

phenomenon – nowadays e.g. in Delhi and for centuries in London culminating in the Great Smog 1952 – has primarily its origin in the burning of coal.

There is, however, a cruel symbiosis between coal and work. The introduction of steam engines, and still more electricity generated by coal powered plants, contributed to reducing many heavy burdens in the working process and thus to *improving* working conditions. Still today the clean conditions in high-tech manufacturing sites all over the world depend on electricity produced in plants fueled by coal from dirty and hazardous sites. Not the least is this the case in China and India where 61 and 75 percent respectively of electricity generation (2023) is based on coal. Globally coal´s share in electricity generation (2023) is 35 percent. The country which hitherto has been most successful in transforming away from its heavy dependence on coal is, ironically, the United Kingdom: only one percent of its electricity comes from coal. That does not make it carbon free however: fossil gas still makes up 34 percent. Oil is almost phased out in the UK (EI, 2024).

Electricity is the most efficient and labour friendly form of direct energy in the post fossil working process. However, in 2023, still 60 percent of global electricity generation is based on fossil fuels (EI, 2024). To get free from this addiction to carbon, economizing with electricity in all sectors of the formal as well as the informal economy is a necessary complement to the substitution of renewables for fossils in its generation.

The transformation of working conditions

The transformation ahead to a post-fossil economy will – and has to – be faster and more far reaching than any earlier transformation in the history of mankind. It is not obvious to what extent working conditions will be dramatically different from what we have today. A prima vista it may be assumed that the decline of the still dirty activities in the giant global coal sector may contribute to better working conditions if those presently employed are successfully transformed to new post carbon employments.[11] This is, however, not necessarily the case.

Downscaling policies in several countries for the coal mines often lack good incentives for coal miners who face few alternatives to continue to work informally even in closed mines and under bad conditions. Not the least China faces problems to reduce its coal production and manage a just transition away from coal (Gong & Lewis, 2024). In fact, coal production is still increasing in the non-OECD area.

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[11] A World Bank (2021) report estimates that global employment (2021) in coal and lignite extraction is 4.7 million of which approx. 3.2 million in China (2018). Gong & Lewis (2024) report a Chinese employment level of 3 million forecasted to decline to 1 million before 2030 due to climate transformation. This excludes those employed in the "coal value chain" from equipment to electricity.

As regards the post-fossil solutions "of the future" we already know the technologies and processes of transforming the energy system away from our present addiction to carbon and how to enter upon a path towards sustainability.

Wind power is a rapidly developing technology which already is cheaper than coal and rapidly expanding: a global growth rate of installed capacity of 13 per cent in 2023. The situation is similar for solar energy/photovoltaics which added its global capacity 2023 with 32 percent (EI, 2024). These are mature technologies with well-established routines in production, knowledge formation, professional skills and working conditions. The challenge is the large and necessary upscaling of these electricity generating systems, an upscaling which may create new necessities and opportunities for process innovations as well as in the technologies themselves.

The situation is similar as regards transportation. Also, in this sector we already know more than enough for the take-off in the transport revolution. The IEA strategy *Avoid, Shift, Improve* is a good starting point (IEA, 2013). The solutions, technologies and systems to which we have to shift rapidly are well-known industries, distribution, production processes and human competencies have to transform on a large scale. But basically, we are not transforming to something new under the sun.

Systems for freight and personal transport will transform. Electricity creates new opportunities and conditions for mobility. The great challenge is aviation which – for decades ahead at least - is locked in into non sustainable fuels. Activities related to that sector have to decline rapidly in favor of other solutions for communication.

The hands-on knowledge needed in the transformation to come is thus not new to the world but rather locally new to individuals, to companies and to regions. Several of the necessary tasks are performed already but, in many countries, still in a too small scale compared to the magnitude of the challenge. China, of course is the outlier. Although the largest emitter of CO_2, China is also by far world leading in production as well as installations of post-fossil systems and solutions. In particular this is the case in wind power, solar power, electric vehicles and high-speed trains.[12] These rapidly growing Chinese sectors are setting the standard of the working conditions of the transformation.

There is another side of the coin, however. All solutions we introduce and/or expand in order to develop "low carbon activities" must also be strictly sustainable, ecologically as well as socially. Presently this is often far from the case. The rapidly growing electricity based "industries of the future" are heavily dependent on a large set of "critical" and sometimes "rare" minerals. All of them are not necessarily rare in the Earth´s crust but "wrongly" located from political and economic perspectives.

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[12] In 2023 China added its wind power (solar power) capacity with 21 % (55%). This was 66% (62%) of total global new capacity increase (IRENA, 2024).

The rapidly expanding excavation and production of these critical minerals often take place in developing countries and with *artisan small-scale mining* (ASM) technologies. In theory ASM technologies must not be a bad solution for the environment or for the health of the workers. There is a potential for significant technological improvements. In reality, however, this is a large and rapidly growing global problem. During the period 2009 to 2017 employment in the global ASM industry increased with 170 percent and was 2017 already an order of magnitude higher than the employment in coal mining.[13] The very bad labour conditions in the critical mineral supply chains is more or less an elephant in the room in the discourse on the green transition.[14] The necessary large scale transformation ahead runs the risk of contributing to deteriorating working conditions in many places of the world.

AI and the transformation to a post fossil working life

The impact of AI on human activities in general and on working life in particular motivates an anthology of its own. Here we restrain ourselves to some reflections of the impact of AI on the transformation towards a post fossil society.

AI may be looked upon as another – final? - step in the digitalization of human activities. It adds to, or deepens, the cognitive abilities of the digital devices we have introduced in our life and production for more than half a century. Some of our activities may be taken over by our AI-equipment, others will change in character and/or will be performed faster or better.

Similarly to what was the case when mechanization did enter the production floor in mid-19th century (Giedion, 1948; Landes, 1969), today's digitalization comes together with an increase in energy demand. AI induced improvements in working conditions and increased labour productivity necessitates more electricity, 60 per cent of which still on global level is generated by fossil fuels.

This is not a negligible phenomenon due to the fact that the rapidly expanding AI technology is extremely energy demanding. The energy consumption of the Graphic Processing Units, which have become the platforms for AI operations, has almost doubled within a few years. The new generation GPU from NVIDIA has a 300 per cent increase in power consumption compared with the present. Still, they report that their new chips are 25 times more energy efficient than the older generation (IEA, 2024b). In addition to this higher power consumption per chip, AI increases the demand of GPU: s and in the extension also necessitates more capacity in the data centers. Morgan Stanley e.g. forecasts that annual AI power demand will increase fivefold to 2027 compared to the 2023 level, i.e. to the interval 200 - 250 TWh (Kindig, 2024).

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[13] DELVE, 2024.

[14] See e.g. ILAB (2024) which has identified 12 mineral chains with child labor and forced labor and also performed in depth studies on several of them. See Rouhana et al., 2024 which has a strong focus on the EV sector. For a global health perspective see Schwarz, et.al., 2021.

In an aggregate forecast, including data centers, AI and cryptocurrencies, the IEA forecasts that electricity demand from those activities will double from approx. 460 TWh in 2022 to approx. 800 TWh +/- 200 TWh in 2026.[15] The AI induced increase in electricity demand in AI data centers may, following IEA forecasts, be tenfold between 2022 and 2026, i.e. from 7.3 TWh to > 70 TWh (IEA, 2024a). In an updated forecast IEA concludes that electricity demand from data centers will expand from 1- 1.3 per cent to 1.5 – 3 percent of global electricity. This is a more rapid growth rate forecast as well as a larger share than is the case for electric vehicles (IEA, 2024b).

In summary: unless the AI-revolution will contribute to significant energy/electricity savings in their applications in human activities – a large-scale *energy trade off* – and become much more energy efficient per operation - its rapidly growing energy demand will work against our activities to reduce human addiction to carbon.

The transformation of our competencies

The large-scale transformation ahead will – similar to earlier transformations – necessitate, as well as provide opportunities to, new forms of competencies and skills parallel to the reduction and elimination of others. These processes take place on/in many different levels/dimensions, e.g.:

- *The quantitative dimension:* less people with fossil related competencies is needed in favor of more with knowledge and competencies related to renewable and sustainable solutions. This necessitates large-scale re-education activities but also in many sectors a *downscaling* of the need for service activities. An EV e.g. has approximately one tenth of the moving parts compared to an ICEV, thus significantly reducing the need for maintenance staff.
- *The qualitative dimension:* my conjecture here is that there is a difference in what we may label the qualification profile as regards complexity between the fossil related and post fossil activities and industries. Relatively more skilled people with high theoretical knowledge are needed in the post fossil society. We face not only *re-skilling* but *upgrading* which sometimes may be challenging. In short: abundant coal miners may not easily qualify as wind power technicians.
- *The time dimension.* The necessary high speed in the transition ahead reduces the potential of combining competence shifts with smooth retirement of old staff and the recruitment of new staff. Individuals have to change.
- *The geographical dimension.* The core activities in the carbon economy are still related to the extraction of coal, its transport to coal power plants, and its transformation to electricity. Approx. 35 percent of all electricity is, as mentioned, generated from coal and around 70 per cent of all coal is used for electricity (IEA, 2023a). The coal economy is highly concentrated in specific areas and regions where it often totally dominates

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[15] Just to illustrate the magnitude of this: total electricity generation in France during 2022 was 466 TWh.

the economy, its employment and activities. In short: it is improbable that these regions will manage the enormous shift in competencies and activities and close down of the coal economy in a smooth way. Strong regional policies are needed to get acceptance for a transition.

- *The material dimension.* The mirror image of the steady and rapid growth of fossil energy input in the economic metabolism is its continuously growing material character. The world economy has never been so heavy as the present (Laestadius, 2023). The global reshuffling of material is in the magnitude of six times as heavy as the total weight of all CO_2 emissions. Activities like these must transform radically if we will succeed in getting away from fossil fuels. This necessitates new ways of solving the human welfare problem, economizing with planetary resources rather than expanding the use of them. In short: there is a need for *a new mindset* in how to work and cooperate with the planet.

The transformation of our minds

The fundamental, and most difficult, challenge as regards the transformation of activities and working life along a development path towards a post-fossil society is probably the adaptation of a new mindset: replacing *a linear perspective* on our relation to the planet - connected to a conviction of mankind as master of nature - with a *circular*, and more humble posture. The linear "man as master of nature" world view is normally connected to the post-renaissance intellectual discourse emerging in the early 17th century and personalized with the science-philosopher Francis Bacon and also to the strong *idea of progress* dominating Western philosophy.[16] The revealed treatment, in theory and practice, by mankind of nature as a *cornucopia* was possible as long as human societies were small in relation to their habitats. This is, as discussed in section four above, no longer the case: the habitat for mankind is now global and our exploitation of resources challenges several important *planetary boundaries* (references in section four above). Nature strikes back.

This necessitates the transformation from a mindset implicitly or explicitly based on *exploitation* of nature to a mindset dominated by *bounded circularity*. This will – and must - become a *paradigm shift* – a shift in our fundamental convictions on planetary processes and on the conditions for mankind (Kuhn, 1962/70). In short, this is more than just taming capitalism and reducing the power of profit seeking companies. If the Planetary Boundaries for more than a century was a non-issue for the Fossil Capital in its exploitation of workers (Malm, 2016) this is no longer the case. Today´s investments in and producing fossil fuels, as well as promoting such activities may be understood as ethically non-defendable. But it may also be interpreted as an indicator of the depth of our *hybris* of identifying ourselves as masters of Nature.

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[16] For a summary on this, see Laestadius (2018, chpt 6). Although the chapter is in Swedish most of the references are in English.

We are still in the struggle between paradigms. In many sectors in society – and among all of us - adaption and mitigation activities are presently more of a *green chic* character than fundamental. The new paradigm has to penetrate activities and working life on all levels and in all details. It has to penetrate employers as well as workers and transform the formal economy as well as life in the domain of freedom.

We still have a long way to go. Our shortcomings are everywhere, not only on the aggregate level as we have discussed above, but also in the details shaping our daily (working)life:

- We throw it away instead of repair because it is "cheaper" (but is it?).
- We transport using fossil-based systems because it is more efficient (but isn´t this a question of how we calculate?). And our transport chains are longer than ever – in production as well as in consumption.
- We travel with fossil-based systems because we "have" to (and have organized our lives and activities so we "must".).
- We still use "comfortable" fossil-based solutions – easy, practical and CO_2 emitting.
- We still add more energy input to our activities instead of reducing it.
- Human activities – inside as well as outside our working life - is more material intensive than ever, and with an impact on energy transformation and climate. Material transformation and transportation always use energy.

All this has to change. To have a real impact on everyday solutions in the activity and working life sphere the bounded circularity paradigm must be integrated in human mindsets and culture to a large scale. This is far from the present situation. In fact, I argue that much of present activities as regards climate policy, energy efficiency and reduction of fossil fuels take place "within the old paradigm" rather than transforming along new paths. This policy is rapidly approaching its limits. And probably not enough to lay a sustainable ground for human activities – and working life - in the future.

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Learning from the New Deal for a Green Transformation: The importance of trade unions

Steffen Lehndorff

Abstract

The U.S. New Deal of the 1930s has become a broadly shared historical point of reference for a 'Green New Deal' of the 2020s. In fact, given the enormous, albeit very different, challenges faced by these two massive reform projects, it is worth taking a closer look not only, or primarily at what was done in the 1930s, but above all at how it was put into practice. The present article highlights some of the policy lessons to be learnt by the New Deal of the 1930s for the political and societal process that is necessary to drive forward a 'Green and Just Transition' today — in particular regarding the socio-ecological transformation of industry and the importance of trade unions in this process by the example of Germany.

Key words: New Deal, Green and Just Transition, socio-ecological transformation, trade unions

Introduction

The 1930s U.S. New Deal under President Franklin Delano Roosevelt has become a broadly shared historical point of reference for a 'Green New Deal' of the 2020s, albeit with very different subtexts.[1] True, in many cases this reference serves primarily as an advertisement banner. Nevertheless, it makes sense to think about potential lessons to be taken from the historical experiences of the New Deal.

It is obvious that the reform process in the United States of the 1930s was about very different things as compared to the challenges of climate change today. In 1933 to 1938 more than six million previously unemployed people were put to work building schools, playgrounds, kindergartens, roads, green spaces, and carrying out reforestation and landscape conservation; the banking sector was stabilised and regulated, and the stock exchange was put under state supervision; dam systems for the cultivation, irrigation, and electrification of entire regions were created with extensive infrastructure projects; the first attempts to establish elementary social standards regarding labour market regulation and the foundation of a welfare state were launched; and last but not least, thousands of cultural workers of various disciplines were promoted and brought art to the people.

It should be noted that at that time all this was a courageous experiment with economic and social reform strategies that had never been tried before. What is more, the New Dealers were facing extreme resistance by big business and right-wing campaigns. They could overcome this opposition by a virtually unparalleled democratic dynamic at a time when millions of people in Europe were cheering Mussolini and Hitler or were awestruck by Stalin. To be sure: today the challenge for any Green and Just Transition— or socio-ecological transformation, as it is called in Germany—is even much more fundamental than that facing the New Deal of the 1930s. A far-reaching rupture in economic and societal development and a powerful social dynamic has to be set in motion in a very short time. But this is precisely what the New Deal government succeeded in doing when the momentum of the first 100 days was translated into a farther-reaching reform process.

This is why there is much to learn, in particular with respect to *how* the New Deal was put into practice, rather than just looking at *what* was done. How could the New Dealers initiate a reform process that involved large parts of the society? What were the most important elements of this virtually unparalleled political and societal dynamic? In what follows, I will highlight some lessons to be drawn for the political turnaround required to push through a Green New Deal in the 2020s which are relevant for political and societal actors in general and trade unions in particular.[2]

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[1] For surveys and discussions, cf., among others, Klein (2019) on the USA and EuroMemo Group (2020) on Europe.

[2] The following short review is based on my booklet on the lessons to be taken from the New Deal (Lehndorff 2020) which includes a more detailed description of the political dynamics in the course of those years. The comprehensive references to the literature provided there are largely omitted here for reasons of readability.

What was the policy approach of the New Dealers?

Immediately after taking office in March 1933, the Roosevelt administration began to put the promise of a 'New Deal for the American People' into practice with a huge reconstruction programme. Doing so, the government ventured into new territory that was completely unknown at the time. These were the key features of their policy approach:

The *first* typical characteristic was an undogmatic search for solutions. Nothing was excluded from consideration and measures were changed if they proved ineffective. To learn from experience and to correct errors, however, proved to be an extremely complex and conflictual back and forth maneuvering in some crucial issues such as public debt. Irrespective of occasional zigzagging between progress and relapse, this 'experimentalism' required strong, resolute government, that is: democratic leadership. It is obvious that Roosevelt's role as a both charismatic and democratic leader was of fundamental importance for the ability to break new ground. 'Roosevelt unlocked new energies in a people who had lost faith, not just in government's ability to meet the economic crisis, but almost in the ability of anyone to do anything' (Schlesinger, 2003, p. 22).

The *second* key element were large reform projects as landmarks of change. A major example of what you may call 'lighthouse projects' were highly symbolic large-scale infrastructure programmes. Always supported by an energetic anti-corruption agency, they included thousands of local construction projects as well as large-scale regional development programmes. A flagship here was the Tennessee Valley Authority (TVA), whose innovative combination of central planning and decentralised participation increasingly succeeded in establishing electricity supply as a public task.

A *third* key feature was the—initially involuntary—readiness of the administration for conflict with economic and political elites. This readiness, in turn, could only be successful as it gave way to the *fourth* characteristic of the New Dealers' policy approach—the interaction and mutual reinforcement of public policies and social movements. The way the latter two approaches worked together with the first two ones mentioned can best be illustrated by the example of the fight for elementary labour standards.

Mutual reinforcement of government action and social movements

Shortly after taking office, the government launched the first large-scale attempt to introduce social standards in conjunction with the new employment programmes. A National Recovery Administration (NRA) was established to bring together business organisations, trade unions, and consumer associations to agree on minimum prices, minimum wages, maximum working hours, and the right to collective bargaining and unionisation. This 'keystone of the early New Deal' (Leuchtenburg, 1995, p. 56) triggered widespread public approval and large demonstrations of support under the banner of the NRA's patriotic Blue Eagle symbol. In fact, if with great difficulty, a number of agreements (mostly between NRA and employers' associations) were reached. With regard to social standards, however, this attempt soon

failed. The bosses of major industrial groups torpedoed their operational implementation, and in 1935 the Supreme Court declared the NRA unconstitutional.

This backlash was part of a greater political current. After initial support for the Roosevelt administration by sections of big business, the wind had now changed. Supported by 'anti-Bolshevik' campaigns in leading media, politicians (of both parties!) and heads of large corporations formed an 'American Liberty League' against minimum wages, collective bargaining, and the right to unionise. At the same time, a populist current sympathetic to European fascism grew up. In contrast to standard realpolitik practice, increasing resistance from various sides did not lead to attempts by government to appease and seek compromises. Rather, the government found a way out of the political crisis by being more resolute than in the first phase of the New Deal. It realised that 'self-regulation by industry doesn't work', as a member of the New Deal inner circle, the economist Gardiner Means (1970, p. 249), put it. The most important tailwind for a more offensive policy approach was an enormous strike wave, especially for the right to collective bargaining and unionisation. This dynamic, in turn, gave way to an upheaval of the substantially weakened U.S. trade union movement.

The story of this upheaval is meaningful and instructive. In the wake of the Great Depression trade union density had dropped to merely 6%. The majority of the leadership of the American Federation of Labor (AF of L), sticking to the tradition of craft unionism, followed the idea that government should keep out of labour issues. As Labor Secretary Frances Perkins—one the most important personalities pushing forward the New Deal—remembered, 'the thinkers of the AF of L were blind to future problems' (Perkins, 1946, p. 244).

In contrast, as early as 1933 a small minority amongst the union executives saw the NRA and in particular its clause that stipulated the right to collective bargaining 'as a golden opportunity to capitalise on government support' (Badger, 1989, p. 121). These oppositional unions launched the strike waves in combination with organising campaigns which were 'politically inspired' by the NRA (Fraser, 1989, p. 68). The new 'grassroots unionism', as it was called, ushered in a split of the trade union movement in the mid-1930s which gave rise to the formation of the Confederation of Industrial Organizations (CIO) with strongholds in mass production industries. Union membership rose from around two million in 1933 to over ten million by the end of the decade—with union density in manufacturing industries exceeding one third of all workers.

The fierce opposition of powerful economic and political interest groups on the one hand and the new, strengthened labour movement on the other encouraged the government to turn towards confrontation. It now aimed at a legally binding anchoring of social and employment standards and at creating the foundations of a welfare state, which were enforced by the National Labor Relations Act (the so-called 'Wagner Act') and the Social Securities Act in 1935 and the Fair Labor Standards Act of 1938. For a better understanding of the political lessons to be taken from the New Deal the Wagner Act is particularly

interesting because it 'replaced NRA's statist code-making authorities with the philosophy of countervailing power' (Rauchway, 2008, p. 95). Thus, the bumpy road towards the anchoring of basic labour standards from 1933 to 1938 can be characterised as an interplay of government action and mass movements: first the NRA and the strike waves geared to take advantage of it, then the failure of the NRA that gave the crucial impetus to put the Wagner Act on the agenda, and eventually another—and now successful—strike wave geared to force big companies to apply the rules of the Wagner Act. It was an initially unintended and not foreseen process of mutual reinforcement of public policy and trade union action.

In the course of this process, the Roosevelt administration developed an enormous willingness to engage in conflict. It was not populist campaign bluster when the U.S. president uttered phrases like these in 1936, during his campaign for re-election: 'We know now that Government by organized money is just as dangerous as Government by organized mob. Never before in all our history have these forces been so united against one candidate as they stand today. They are unanimous in their hate for me—and I welcome their hatred' (Roosevelt, 1936).

This readiness for conflict shown by the New Dealers paved the way to the formation of a so-called 'Roosevelt Coalition' in the re-election campaign of 1936. It consisted of broad alliances of grassroots initiatives within and beyond the Democratic Party such as the Democrats' Women's Division, a 'Progressive National Committee' formed by prominent politicians and numerous mayors of different party affiliations, a broad-based 'Good Neighbor League' gathering members of the most diverse religious and ethnic minorities, and many cultural workers. Despite their harsh criticism of the administration's inconsistent fight against institutionalised racism many representatives of the African American population, traditionally pro-Republican as Abraham Lincoln's party, now publicly supported Roosevelt. Last but not least, the newly formed and rapidly growing industrial unions formed the 'Labor's Non-Partisan League'.

All these initiatives, alliances, and activities contributed to transforming the ethnic, religious, cultural, regional, and social diversity of U.S. society into a factor of strength. With over 60% of the vote, Roosevelt's landslide victory in 1936 was even greater than that of 1932.
In a nutshell, it was the administration's readiness to break new ground, to learn from experience, to establish flagship reform projects and to enter into political conflict which opened the door for the interplay of government policies and social movements. This interplay, in turn, drove the administration beyond its original targets.
All this will be equally crucial when it comes to pushing forward a socio-ecological transformation today. Thus, the message is simple and clear: It's about *learning* from the New Deal, not copying it, let alone just using it as an advertising slogan.

Green and Just Transition is highly political and full of conflicts

As mentioned earlier, the differences between the conditions and challenges then and now are enormous. Nevertheless, similar to some 90 years ago, what is at stake today is how to push for a political and social reform dynamic based on a mutually reinforcing interplay of government policy and countervailing societal power.

It is all the more important to bear this in mind as the socio-ecological transformation is often presented as primarily a technological and economic challenge. The terms 'socio-ecological' or 'green and just', however, already signal that this perception falls short. The transformation is linked to major social uncertainties that can very easily be used by reactionary deniers of the climate crisis for political blockades. It is therefore crucial to realise that the ecological can only work with the society, just as the social can only work with the ecological. Only if this connection is taken seriously the transformation can be perceived as a chance, rather than a danger, so that a social basis can be created for mastering the upcoming upheavals. It is highly relevant in all major policy areas of the Green and Just Transition (such as housing, transport etc.), but particularly urgent in the transformation of industry, which is the focus of the present article.

This is precisely where trade unions come into play. True, the economic and political challenges differ across countries, and the political and social importance of trade unions is also different in each country. In many cases, trade unions have lost considerable influence over the past decades of neoliberalism (Lehndorff et al., 2018). Nevertheless, there is a commonality: without trade union involvement, it is difficult to imagine a progressive and dynamic connection between the ecological and the social. And even if this commitment must in many cases be made out of a situation of weakness and a lack of institutional rights, it still offers an opportunity, because the anticipatory, pro-active commitment of trade unions which is needed can strengthen the positive image of trade unions in a wider public, thus offering a steppingstone for revitalisation. Thus, as in the U.S. of the 1930s, a virtuous circle must be set in motion. In what follows, this challenge as well as first steps taken by the trade unions will be outlined by the example of Germany.[3]

Embattled building sites

There is a broad consensus not only among the relevant research institutions, but also among the most important political and social players in Germany about the technological cornerstones necessary to achieve the climate targets of the Paris agreement. At its core, it is always about three tasks: Providing climate-neutral energy sources, increasing energy efficiency, and increasing resource efficiency, i.e. reducing the demand for primary materials. In fact, a number of important political and economic decisions have been taken in this direction in Germany and even more so at EU level in recent years - albeit very late and in many cases by far not radically enough.

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[3] The following is based on my overview of a group of studies on socio-ecological transformation of German manufacturing industries (Lehndorff 2024a). Again, unless otherwise stated, references to the sources cited there are largely omitted here.

These efforts must be tackled or intensified in very different policy fields, such as infrastructure development, financial and industrial policy, regulatory law, labour policy or regional policy. Much of this is controversial, and as is to be expected when breaking new ground: Quite a few central questions are still open. The complexity of this process is due to the obvious fact that—if we take the example of manufacturing—the term 'industry' cannot simply be reduced on the production process. It includes the input of resources and the supply chain as well as the output, i.e. the products and their use. Hence the wide array of issues involved.

Just to give a flavour I will highlight three out of many other conflict-ridden 'building sites' of a Green and Just Transition which are particularly relevant for the unions both in manufacturing and the service sector.

To start with the example of *infrastructure development*, it is undisputed that the sufficient availability of green electricity is the be-all and end-all of all plans to decarbonise industry and the transport sector. The overall demand for electricity will be much higher than today's level because, just to give one example, the switch to hydrogen is very electricity-intensive in the chemical and steel industries. What is more, the production capacities for green hydrogen have to be created at home and abroad (a high proportion of green hydrogen will have to be imported). And all of this will only work if the grid infrastructures for both electricity and hydrogen are expanded massively and quickly at the same time. Added to this, it is obvious that the switch to e-mobility is extremely electricity-intensive, too, and can only succeed with a Europe-wide charging infrastructure. And let's not forget: the transformation of car traffic is not just about electrification, but also about reducing the number of cars, i.e. a mobility turnaround based on an expansion of public transport.

When it comes to master this huge infrastructure expansion, the overarching and particularly conflict-prone challenge—in addition to a reliable long-term regulatory framework[4]—is public financing.

Public funding also plays a central role in *industrial policy*. Significant additional investment and operating costs are incurred in important industrial sectors, which in many cases can only be covered by rising revenues after several years. These so-called market ramp-up costs are often unmanageable without state support, especially for SMEs, but in some cases even for large companies.

Finally, *labour policy* is a policy area that plays an important role in both infrastructure and industrial policy (Bosch, 2023). This is because the transformation is accompanied by structural upheavals in the labour market, which have very different effects on employment depending on the sector, activity, and region. The periods in which positive or negative effects can be expected will also vary greatly. This lack of clarity is causing many industrial employees

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[4] German industry associations rightly emphasise time and again the necessary 'planning security' that is required for medium to long-term investment decisions. At the same time, they try to torpedo binding market regulations in important areas such as the end of the authorisation of combustion vehicles in the EU—which alone could enable such planning security.

to worry about the future, and not without justification. The division of the labour market in Germany since the 1990s (cf. Lehndorff at al., 2009) has created an objectively uncertain and subjectively unsettling environment for the implementation of the necessary climate protection measures in industry and transport. Without a credible offer of realisable and positive alternatives, the danger of such fears being instrumentalised by the far right has to be taken seriously.

While the main players in the transformation process, i.e. governments and other state bodies, companies and their associations, trade unions and environmental organisations, now agree at least in principle on important strategic reorientations, differences of opinion and conflicting interests often erupt as soon as it comes to the question of how. In many of these controversies, it is not only environmental organisations but today (after sometimes difficult and controversial internal debates) also trade unions that take much more far-reaching positions than governments or business associations—in some cases jointly with environmental organisations.[5] This can be shown using the example of the three 'building sites' presented here. The conflicts in these policy areas clearly show that a strong political commitment on the part of the trade unions will be of decisive importance for the success of the transformation.

Political commitment …

The most controversial topic in Germany is *public budgets*. For example, the public investment required over the next ten years to achieve the climate targets is estimated at around 600 billion euros in a—remarkably enough— joint report by economic institutes with close ties to employers' associations and trade unions (Dullien et al., 2024). The biggest obstacle here is the so-called 'debt brake' in the German constitution, which is basically more restrictive than the fiscal rules of the EU (which are largely due to pressure from German governments). This issue has become even more urgent after an extremely strict interpretation of the debt brake by the Federal Constitutional Court in November 2023 which has paved the way towards to the breakup of the German 'traffic light coalition' at the end of 2024.

As a parliamentary majority in favour of changing the constitution and abolishing the debt brake is not to be expected in the foreseeable future, the trade unions and an increasing number of economists including the IMF are calling for its reform or loosening. The unions together with environmental organisations go a step further and call for creating credit-based climate or transformation funds.[6]

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[5] For trade union positions, see e.g. Deutscher Gewerkschaftsbund (2024), IG Metall (2021a and 2024), Stiftung Arbeit und Umwelt der IG BCE (2024) which are representative of numerous trade union documents. For joint demands of trade unions and environmental organisations, see IG Metall / BUND (2020), AWO et al. (2021), ADFC et al. (2024). On the contradictory development processes of the positions of the industrial trade unions in the chemical, steel and automotive industries, see Bendel / Haipeter (2022) and Blöcker (2022a and b).

[6] In 2022, a similar financial instrument was adopted by the German Bundestag for the rapid increase in defence spending in response to the Russian aggression against Ukraine.

It should also be borne in mind that the expansion of public infrastructure—e.g. for the transformation of the mobility system, but even more so for the education sector—not only requires investment in tangible assets, but also significantly higher permanent personnel expenditure. An interesting example of joint action for highlighting this need has been the campaign for higher wages and better working conditions in the public transport sector over recent years organised by the service sector union ver.di together with Fridays for Future under the slogan 'We are riding together' (ver.di, 2023).

Such permanent staff costs should be financed through tax revenues, rather than loans. As demanded by the trade unions, this requires redistribution-based tax reforms. Such reforms are equally crucial for the social cushioning of the costs associated with the transformation for many private households with low and medium incomes.[7]

The trade unions are taking a similarly strong political stance in the area of *industrial and subsidies policy*. In view of the extensive support for private companies from public funds, the question arises as to what companies must provide in return so that risks and costs are not socialised and subsequent profits privatised, as has been usually the case to date. One example of trade union demands is the creation of a large credit-financed transformation fund (Stiftung Arbeit und Umwelt / IMK, 2021). The strategic private investments subsidised by this fund could be linked to conditions on climate-friendly technologies, production processes and products, as well as to conditions on job security, compliance with collective agreements and the expansion of co-determination rights for works councils.[8] In addition, the state could secure participation rights in future profits or even build up investment assets. The European trade unions' demands for a reform of the 'Next Generation EU' investment programme—which urgently needs to be continued—in which compliance with social standards and the involvement of trade unions would have to be made mandatory (ETUC, 2024; Galgóczi, 2024) are aimed in the same direction.

This example makes it clear that such conditionalities are also an important lever for *labour policy*. The strategic importance of vocational education and (further) training for the just transition is undisputed, at least in principle. However, the question of how the division of the German labour market can be overcome in order to enable greater social security in the emerging structural upheavals is highly controversial. The steady decline in collective bargaining coverage over the past 30 years plays a key role here. An important demand of the trade unions is that all public procurement should be linked to the condition that the favoured companies comply with the collective bargaining standards of the respective sector. While there have been individual attempts at reform in this area more recently, another demand is facing even stronger resistance from employers' organisations and neoliberal-conservative parties: Making it easier for collective agreements to be declared generally binding. In principle, the EU's Minimum Wage Directive, which calls for national action plans

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[7] For trade union demands regarding public budgets see, among others, IG Metall (2021b).
[8] The new IG Metall chairwoman, Christiane Benner (2023), summarised this demand in her inaugural speech at the trade union conference: 'We need clear rules: Taxpayers' money only in return for a collective agreement, guaranteed employment and apprenticeships! Only then will there be funding, and not otherwise!'

to achieve 80% collective bargaining coverage, is providing a political tailwind here (Müller / Schulten, 2024). However, a binding and comprehensive implementation of the directive in Germany is not in sight. Overcoming the employers' blockade of declarations of general applicability by law is likely to be the most controversial cornerstone of the socio-ecological transformation in the area of labour policy.

The examples outlined here from the areas of infrastructure, industrial and labour policy show that trade unions must develop (!) an enormous capacity for political conflict if they want to influence the pace and direction of socio-ecological transformation. The word 'develop' emphasises that political commitment goes far beyond resolutions passed at trade union conferences. For trade unions in particular, therefore, it is important be aware of the link between the capacity for conflict 'at the top', i.e. on the political stage, and the capacity for action 'at the bottom', i.e. at company and regional level.

… with a foundation at the workplace

Strengthening the ability to act in bread-and-butter activities on the one side and political commitment on the other are always two sides of the same coin. The better a union is anchored at company, establishment and sectoral level, the greater the chances of being taken seriously as a political player. And vice versa: the greater the political standing of the trade unions in the public eye, the more convincingly they can mobilise at the workplace.

This connection applies to the socio-ecological transformation, too, as can be shown by the emerging challenges and —most importantly—first (!) practical steps on this path.[9]

In the transformation process, two levels are particularly important for strengthening trade union capacity to act 'from below': the company level and the regional level. At *company level*, it is important to develop prospects for 'green jobs' of the future in key industrial sectors. Experience shows that many companies are trying to stick to existing business models for as long as possible. This may still be profitable in the short term, but it is far from sustainable and offers employees no prospects. However, there are numerous skilled both blue- and white-collar workers in the companies whose knowledge and experience can be utilised for developing alternative product strategies. This is particularly important in those industrial sectors that are likely to be most affected by the transformation, such as the automotive supply industry, where new prospects for the 'green jobs of the future' must be developed. This is even more important against the backdrop of the crisis of the German and European automotive industry.

This is where so-called 'future collective agreements' come in, which IG Metall has concluded in a number of companies (Bosch, 2024). Their basic idea is to go beyond usual defensive elements focussing on job security in combination with, for example, reductions in working hours and pay, and to offer works councils new opportunities for initiatives regarding future

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[9] For the following see Lehndorff (2024b).

decisions that go beyond their legally guaranteed co-determination rights well in advance of future upheavals and crises. To this end, works councils—also with external support—can organise workshops at company or establishment level geared to mobilise blue- and white-collar workers' expertise for the development of ideas about potentials for sustainable production in the future.

Such company agreements are sometimes reached cooperatively, but sometimes only after tough disputes. Similarly, the experiences to date with the practical implementation of 'future collective agreements' are also very different, and this is for several reasons. Obviously, even the best ideas from employees will have no effect if employers do not take note of them due to short-term interests, and even more so as from many employers' points of view, this kind of initiative is not part of works councils' remit (which is why trade unions are calling for extended legal co-determination rights on these issues). But equally important is that the debate about alternative production options is a completely new territory for most works' councils. A transformation-oriented works council policy with genuine participation therefore requires both internal trade union training and sufficient resources. On this bumpy road, 'future collective agreements and practical experiments with local 'transformation workshops' offer important starting points for gaining experience and developing the ability to act. The first steps on this difficult path are being taken here.

There are similar difficulties and inspiring experiences at the second level of basic activities, the *region*. In particular, regions that have so far been characterised by so-called 'brown jobs' are facing considerable and difficult to predict restructuring. Innovative regional stakeholder networks are needed to devise alternative development strategies. It is important to develop common guiding ideas and joint projects in order to be able to utilise public funds strategically.

This is where publicly funded 'Regional Transformation Networks' formed on the initiative of IG Metall come into play. In these networks, an exchange on the future of the region is organised among a large number of stakeholders, with offers for small and medium-sized companies on issues of technological innovation often playing the largest role. On the part of IG Metall, as its former chairman put it, such networks are also associated with the political hope of 'being able to create new alliances through debates about regional perspectives and to implement them locally' (Hofmann, 2023, p. 378). In many networks, however, there is still a long way to go to achieve such targeted cooperation on an equal footing, and trade unions and works councils in particular often still lack the 'necessary access to professional and financial resources' (Hoßbach / Bollwein, 2024, p. 54).

This is new territory for everyone involved but is particularly challenging for trade unions and works councils. However, the experience which is being gained here is extremely valuable and will be indispensable for further green and just transition. This is why intra-union exchange on this experience will be crucial, as well as accompanying and comparative

research.[10] The articles in the present issue of the European Journal of Workplace Innovation are designed to contribute to this exchange.

Today, the initiative comes from below

The most important thing we can learn from the New Deal for a 'Green New Deal' is the importance of mutually reinforcing state and societal action. What was important in the 1930s for enforcing minimum social standards is all the more important today.

As already mentioned, in 1933 ff. oppositional union leaders saw the New Deal 'as a golden opportunity to capitalise on government support' (Badger, 1989, p. 121). In other words, the government seized the initiative, important sections of the business elite opposed it, which was in turn met with massive strike movements by ever larger sections of the trade unions, and this led to even more determined government action, eventually resulting in groundbreaking social legislation.

It is more than obvious that this political dynamic was markedly different from the one we see today. Unlike in the 1930s, today the initiative comes from social actors and not from governments. The fact that in a number of countries trade unions have become part of social activities for a 'Green and Just Transition' should be seen as a major step forward. As the examples of trade union initiatives and of joint demands by environmental organisations and trade unions presented above show, things get moving, but we are at the very beginning of this process. Political pressure on governments can only develop from such activities. And if this bears fruit and governments become—or remain—active in environmental policy, this can influence the political climate and, in turn, encourage social movements to maintain or further intensify their pressure.

The example of Germany has shown that the political weight of trade unions is needed in the conflicts over political decisions on major 'building sites' that are crucial for the progress of the transformation process. At the same time, it is obvious that this political weight depends very much on how they are anchored locally with their demands. The more unions become drivers of transformation at company and regional level, the greater their ability to assert political demands and the greater their chances of being taken seriously as political actors. And vice versa: the greater the political standing of the unions in the public eye, the more convincingly they can mobilise at the workplace. Progress in each of these areas gives each other a tailwind.

First steps on this bumpy road have been taken at all these levels. After all, the transformation is a medium to long-term process with many uncertainties and great potential for conflict. And this transformation has only just begun.

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[10] For currently ongoing research on local and regional initiatives of trade unions and works councils see for example https://www.uni-due.de/iaq/projektinfo/transformationen.php.

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Adjusting to a greener world: radical changes or continuing adaptation for workers and firms in France?

Mathieu Hocquelet
Nathalie Moncel

Abstract

Starting from the hypothesis that the greening of production supposedly impacts three interconnected levels (employment systems, value chains and company strategies, occupations, skills, and work activities), the article provide insights resulting from mixed method research conducted by a Cereq team from 2020 to 2023. Firstly, analysis of statistical Cereq databases display two types of macro-level results: the distribution of young people across green and greening jobs is shaped by segmentation between low skilled and high skilled jobs; the scope and way environmental norms impact workers' activities depends on workplace organisations and management practices. Secondly, a three cases qualitative study in the construction; food retailing, solidarity economy sectors, underlines the importance of the relationship between companies and the market. This linkage remains a determining factor setting two greening trends at work: making profitable what is virtuous or making virtuous what is profitable, each organisation being able to be situated on a continuum from one to the other of these principles. Moreover, whereas environmental norms constrain workers to integrate new operating methods, the company surveys show how essential voluntary standards can be in orienting the trajectory of structures towards a more advanced and complex consideration of ecology in their activities, articulated with the health of the workers, their working conditions and the collective organisation of daily work.

Introduction

The "ecological" or "green" transition has become a key concept in current political debate, following that of "sustainable development" promoted by the Rio Summit of 1992 and "green growth" by the Rio + 20 summit.- The European Green New Deal published in August 2021 as well as the US Inflation Reduction Act underline the need to integrate environmental concerns into production, consumption and our ways of living. In this perspective, what types of radical changes in occupations and firms' organisation are to be expected? How will these changes impact workers' career and firms' practices, employment structures and work organisation, work routines and training provision?

The paper addresses these issues through the French case, using the concept of "greening" to highlight the ongoing processes that lead to integrate environmental concerns in public actions, firms' strategies and jobs practices (Mormont, 2013). Starting from an overview of how statistical data enables to catch the greening of employment in France, the paper thus displays results from firm's level analysis in specific activities to question the conditions for greening of work and skills. Organising work, reflexive feedback on activity, and an emphasis on the commons including health in the workplace appear to be salient features of organisations with a thorough and ethically coherent approach to greening. Using Cereq databases, the first part of the article sketches out how green occupations occur across youth employment trajectories, and secondly the impacts of environmental norms on workers' activities and training. The second part questions the conditions for the greening of work, focusing more specifically on the transformation of working practices.

Part 1 – Overview of concerns and measures for the greening of employment in France

There is now a consensus on the need for countries to embark on an "energy and ecological transition", and the impacts on employment and training policies were in France firstly addressed by environmental laws. Edited in 2015, the law on the energy transition for green growth marked a turning point in this direction by associating a set of national plans and schemes, including the Jobs and Skills Programming Plan (PPEC)[1]. Four years later, a report on the prefiguration of this PPEC was published, with the aim of examining " *the conditions under which employment, training and career development policies could be consistent with the objectives set by the energy and ecological transition* "[2] (p.6). The National Council for Ecological Transition (CNTE), a body for environmental social dialogue made up of colleges from the three chambers, the social partners and civil society, produced a report in 2020 entitled " Vision of a carbon-neutral France respectful of the living world in 2050 ", in which it is stated that the ecological transition is having a positive impact on job creation. The more recent "Climate and Resilience" law, adopted in August 2021, enlarged the concern for employment regulation and skills within a chapter entitled "Adapting employment to the

ecological transition" which promotes a change in the governance of employment at three levels: companies, sectors and regions

Finally, as part of a renewal of public planification, a General Secretariat for Ecological Planning (SGPE) was established in July 2022, under the Prime Minister's Office. In March 2024, this new institutional device has promoted a strategy for skills and employment that targets labour and skills needs to operate a green transition.

In relation to these successive public action activities, several data and analysis producers have developed measures at the global level to figure out transformations in the employment system. The first part of the paper review firstly reports about the volume of jobs to be created through the greening of economy; secondly the way green jobs are determined and measured, and finally original statistical data trying to catch on-going changes.

How can we measure the transformation of jobs and occupations in the context of the ecological transition?

Several forecast models of the effects on employment in France estimate that the number of jobs created will be fairly modest by 2030, ranging from 200,000 to 500,000 additional jobs and regarding the current 27 million of employment in France. Moreover, these forecasts depend on assumptions made about investment and financing of the transition.

Job losses would be concentrated in the transport sector (due to more low-carbon mobility), carbon-intensive industries and non-renewable energies. The impact on agriculture is the most debated, between slowing decline in employment and massive job creation, under the assumption of farming activities relocation.

These job volumes correspond to certain job profiles: those in the construction industry will increase the most (skilled workers in building industry, technicians and supervisors), as well as the maintenance workers and technicians in materials industries. Occupations in agriculture and forestry are also expected to gain as well as those in business services (financial service managers, accountants IT engineers). Conversely, the occupations considered the most polluting will see their share of employment in employment, such as car mechanics.

These figures for job creation and destruction linked to the green transition are highly hypothetical, depending on political decisions both at the European and national levels that are still subjects of debates and protestations (e.g. farmers' protest in the early 2024, debates over the banning of thermic motors expected for 2035). However, these reports draw attention to the impact of such transformations in production models. In the past, the effects of macroeconomic shocks, such as deindustrialisation in the early 21st century, have led to the devitalisation of the employment areas concerned and a deterioration of employment and wage conditions.

Another way of approaching current changes in employment systems is to identify green jobs. Acting in a typical way, the centralised French state has set a specific body to develop statistical categories related to green jobs. Set in 2010, the ONEMEV (national observatory of jobs and occupations in the green economy) is developing two approaches to the greening of employment. The first approach counts jobs in "eco-activities" (see definition box). In 2018, these accounted for nearly 1 million, full-time equivalent jobs, or 4% of total employment in France. This volume is growing, driven by the dynamism of ecoservices activities and the development of renewable energies.

Another approach to jobs in the green economy distinguishes between green jobs and greening jobs (see definition box). The two-level classification is less informative than the one developed by using the O*NET classification that connects each occupation to a specific and standardised list of tasks. Initially designed for the US, this classification suffers from many shortcomings when it was adapted to European datasets (Sofroniou, Anderson, 2021).

In 2019 in France, there was approximatively 140,000 green jobs (or 0.5% of total employment) and almost 3.8 million greening jobs (or 14% of jobs). The trend in these occupations is mixed, with a decrease in the volume of green jobs and a slight increase in greening occupations, the proportion of which remained unchanged between 2013 and 2018, while the volume of total employment rose by 1.2%.

Definitions

Eco-activities are activities that produce goods or services for the protection of the environment or the sustainable management of resources.

A green job is a job whose purpose and/or skills contribute to measuring, preventing, controlling and correcting negative impacts and damage to the environment (for example: natural area maintenance worker, forest ranger, technician in charge of water policing, waste collection centre worker, etc.).

A "greening" job is one whose purpose is not environmental, but which incorporates new "skill building blocks" to take significant and quantifiable account of the environmental dimension in the job itself (e.g. architect, thermal insulation installer, logistics manager, gardener, etc.).
Data from https://www.statistiques.developpement-durable.gouv.fr/emplois-et-metiers-de-leconomie-verte-synthese-des-connaissances-en-2022

Regardless of the approach adopted, the volume of jobs identified as supporting the transition to a greener economy are low. It is also worth highlighting the fragility of these measures, which take into account all the employees in a given category without distinction the environmental purposes of the occupations. By way of example, jobs in the building

industry are considered to be "greening" jobs, without being able to count the workers who act actually for energy efficiency in the sector.

In fact, the spread of the ecological transition within employment systems is a reality that is difficult to grasp by established categories.

Finally, changes in employment system in relation to greening economy could be captured by two ways to approach job renewal in firms: firstly, the way young people enter the labour market, and secondly the impact of environmental standards on work activities and continuous training.

Interviewing young people from all levels of qualification while they enter the labour market, the Cereq Generation Survey [1] provides insight about how the greening of jobs is making its mark on the careers of young people followed from 2010 to 2017.

Green and greening jobs are a little more common among new entrants into the labour market than for employees as a whole. Young people's green jobs display a polarisation between a high proportion of blue-collar workers on the one hand, and engineers and managers on the other. The first type of jobs is held predominantly by men who are often either non-graduates or with low education qualification. Young women are more represented in the second type of jobs and are often better qualified. Green and greening jobs offer stable careers for a third of the young people who have held this type of job, particularly graduates of environmental training courses in engineering and technical occupations.

Another typical pathway displays frequent moves between technician and blue-collar green jobs, particularly in waste treatment, and other types of jobs and periods of unemployment. Young people leaving environmental training courses are not specifically employed in green jobs, even though they are more present, particularly in the most highly qualified jobs. A strong link between training specialisation and the nature of the job appears to be limited to professions with expertise in a field related to environmental protection, forming the "internal green job market".

Other French research work recently established that green jobs have on average lower socio-economic security (Bachelot, Guergoat, 2023). However, this average result hides a strong heterogeneity of green jobs' quality, with clusters characterised with high job quality but also clusters with very low job quality on various dimensions. When all jobs are considered, green jobs also appear over-represented in clusters of lower job quality. Youth employment in green jobs thus is in line with the segmentation of green jobs.

Another Cereq survey carried out in 2019 addresses firms and workers' activities and training (see presentation box). The analysis of this dataset provides insights about the greening of

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[1] https://www.cereq.fr/enquetes-et-donnees/enquetes-sur-linsertion-professionnelle-des-jeunes-generation

work through the integration of environmental standards and the way it impacts on workers' activities and training.

> The training and employee trajectory surveys (dispositif d'enquêtes sur les formations et itinéraires des salariés / Defis2) is produced by Céreq. The purpose is to investigate the dynamics of employee training and firms' practices. This large-scale survey includes two stages: The company stage: a survey of 4,500 companies that are representative of private companies with three of more employees in all sectors of the economy (excluding agriculture), carried out in December 2015.
>
> The employees' strand: a panel of 16,00 individuals, who in December 2013 were employees of one of the responding companies in the company strand, regardless of the nature of their employment contract, are being tracked over a five-year period (from the autumn of 2015 to the autumn of 2019).

One in ten workers questioned in 2019 stated that their work activity had been modified by the introduction of environmental standards (waste management, pollution control...).

These workers are relatively more present in companies in the building industry and food retail sectors and in companies with more than 20 employees. However, the impact of environmental standards is more frequent in the extractive industries, energy, water, waste management, pollution control and food manufacturing sectors, where one worker out of three stated to be affected by the introduction of environmental standards. These workers are more frequently employed as skilled and highly skilled blue-collar and supervisory occupations in production, logistics or sales and technical sales.

Several dimensions of work organisation impact on the probability to be affected by environmental standards: teamwork; multi-skilling; collaborative training with colleagues outside of training sessions. At the same time, work situations dealing with environmental standards are more often located in working groups more conducive to exchanges and more governed by procedures and instructions.

On the other hand, companies interviewed in 2019 about the way they train the workforce stated to devote 16% of their training initiatives targeted to environmental standards. Most of these training courses are compulsory and frequently evaluated to lead to the award of a qualification, diploma or certificate.

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[2] https://www.cereq.fr/en/data-access-lifelong-learning-and-vocational-training-surveys-defis-cvts-base-reflet/defis-employee

This statistical analysis displays a form of "greening" of work and training, which is all the more frequent as the activities of workers and the managerial practices of companies prove to be favourable to skill enhancing. Whatever the sector of activity, the size of the company or the occupation level, organisational dimensions of work are crucial for the integration of environmental standards.

Statistical approaches provide few insights into work activities associated with these emerging and changing jobs. Numerous in-depth research on work activities has proved that skills are always contextual and evolving, that they relate both to individual and collective level, and are assessed by mechanisms such as job interviews. In fact, estimating the need for green skills, which are not green "by nature", means looking at production methods and value chains, what will be done in the second part of this paper.

Between a limited importance of green and greening jobs and a growing role of environmental standards in employees' activities and continuing training: getting back to work

Several research works carried out since the mid-2010s have studied in greater detail the nature of the transformations at work in green sectors, i.e. offshore wind energy, smart electricity grids or eco-construction (Drouilleau and Legardez 2020). These analyses have not revealed new occupations as such but highlighted different ways in which skills are being reconfigured.

While the notion of transition implicitly conveys a gradual, linear approach to change, or even orderly coordination, our research highlights the need to take work as the starting point for understanding these contrasting greening dynamics and their situated stakes. Mirroring this last decade of Céreq research, literature reviews emphasize the focus on highly skilled and specialized work. They invite greater attention to practices, rules, and orientations affecting workers in all types of occupations, including at the shopfloor level, as crucial to understanding the potential and impacts of sustainable transition in different industries, socio-technical systems, and industrial regimes (Moilanen & Alasoini, 2023; Coutrot & Nizzoli, 2023; Cukier et al., 2023). Additionally, the various ways ecological transition and decent work are articulated to form a "just transition," a framework developed by the labour movement, are explored. Unanimously, the literature highlights the need to consider a broader scope of workers while considering industrial characteristics; this is an area where humanities and social sciences research on work and sustainability is scarce. The social aspects of the sustainable transition have been little studied so far (Upham et al., 2020; Wittmayer et al., 2017).

Part 2. What does greening do to work? A Broader Public Action Approach to Greening Skills

The second part of the article questions the conditions for the greening of work, focusing more specifically on the transformation of working practices. From the nature of the transformations of work in green sectors and occupations to a broader perspective, we insist on the necessity for research to adopt a larger and dynamic scope, both in terms of industries, organisations, occupations and skills.

This perspective shift also implies a focus on work where concerns about employment in industries facing ecological transformations often tend, like its digital counterpart, to overshadow the transformations of everyday work, working conditions, and processes, the qualitative challenges posed by the greening dynamics, and the role of workers in related workplace innovations (Hocquelet, 2024).

As a contribution to bridge this blind spot, between 2020 and 2022, we investigated six companies in three industries (two companies from each industry), examining the actual transformations occurring in the workplace through a situated analysis of work practices. Subsequently, six monographs were documented based on a corpus of fifty interviews and a series of observations of work situations (about six hours per monograph).

Understanding the conditions for greening work in three industries

Through these monographs focusing on work analysis, we have sought to understand the realities of greening dynamics in various industries. The qualitative and inductive approach adopted focused on some of the central occupations in contrasting industries, which have not been identified as green or greening at first glance: food product sellers-producers in a small urban dairy and cheese store, multi-skilled salespeople in a national cooperative chain in food retail; construction site managers in one of the main French companies and rope access technicians working for one of its subcontractors in the construction industry; production workers who have reclaimed their plant from a multinational tea company and "multipurpose ecological workers" working in the field of professional training and integration in the SE sector.

Thus, by focusing on the main issues in key occupations, the six monographs emphasize companies' and industries' contexts and configurations, highlighting a plurality of greening mechanisms and dynamics. What then are the conditions for greening in these organisations? In what way is the renewal of industries linked to the ecological transition (repair, maintenance, recycling, etc.) a lever for the development of new trades and professional knowledge to be built? What resources have been mobilised and what obstacles have been encountered? Our monographs highlight several specific features that distinguish these organisations from the dominant industrial models and practices, especially in retail and construction industries, two oligopolistic industries in France, counting some of the biggest companies in the world. Here, we discuss and illustrate the main cross-cutting features

influencing, but also sometimes hindering, greening dynamics in the industries, organisations, and occupations surveyed.

Reframing work within a systemic vision of greening

Firstly, referring to the way in which the environment is framed (Lakoff, 2010) in the workplace and its effects on the field of possibilities, the monographs underline in most cases a systemic vision of greening. This dynamic appears to be driven above all by company professionals, not by the regulatory universe or the most widespread initiatives and labels in each industry, mostly considered insufficient, poorly enforced, and unequal by managers and workers surveyed. Supported by minority organisations in oligopolistic industries (retail, construction), this holistic approach to greening is put into practice both through commitment to prioritising and promoting local production, fair trade, organic farming, the respect of labour laws all along the supply chain, accounting transparency, hiring of permanent staff and promoting gender equity, refusal to use plastic bottled water while promoting glass deposit systems, synthetic flavours, colourants, and other additives, animal and human welfare, prioritising small producers and the development of fair trade and sustainable supply chains.

In turn, this consensus around the way ecology is framed at work in the organisations surveyed highlights the importance of voluntary standards in greening dynamics in the workplace and beyond. The role of voluntary standards has been underlined since the 1990s by international institutions such as the United Nations and the OECD as a way to complement national and supranational rules and regulations that are not sufficient. Indeed, if sectoral or cross-sectoral regulations push professionals to integrate new operating methods, the company surveys show how essential voluntary standards can be in orienting the trajectory of structures towards a more advanced and complex consideration of ecology in their activities. Whereas in the construction sector, the changes observed in the objectives pursued as a result of greening appear to be largely linked to exogenous factors, such as technological developments and the transformation of construction methods, the two monographs conducted in food retail underline their ambition to transform food retailing at two different scales and offer examples of local and global (national) ways to get off the industrial path taken by mass retailing and agro-industrial production for decades (including the end of European milk quotas in 2015), inherited from the still dominant commercial and agricultural sides of Fordism.

Both try to maintain a balance between their activist environmental orientation and a viable business model in the face of dominant generalist competition that rarely imposes such ethical standards, which often results in higher prices. Finally, the cooperative structures of the Social Economy (SE) we studied, two highly contrasting cases, explicitly aim at a virtuous project in terms of environment. The first, a tea factory under the cooperative and participatory association status, was born in 2014 from a plant previously owned by a multinational company, defending the reintroduction of natural flavourings. In this workplace, about forty cooperators are turning around a plant that once employed nearly 300 people.

The second cooperative structure, professional training and integration co-operative society of collective interest, considers ecology as its raison d'être. Both companies are characterised by democratic and horizontal governance; they try to articulate ecological and social issues such as working conditions, work organisation, and gender equality.

However, these strategic orientations can be partly hindered by dependence on the principals or prescribers who have in their power the financial survival of these structures and embody the path dependency of their industry. Indeed, the importance of the relationship between companies and the market clearly appears as a determining factor influencing the greening dynamics, bringing into play two greening trends: making profitable what is virtuous (minority cases studied here) or making virtuous what is profitable (Ceccere et al., 2014). Thus, companies are situated on a continuum ranging from one to the other of these principles, with constraints linked to dependence on the paths established by the sector's dominant players (supermarkets, agribusiness, construction).

Breaking away from industrial paths: re-organising work and advocating for new production-consumption paradigms

Using the contributions of Gorz on the question of autonomy and heteronomy of production (1988), and Béreni & Dubuisson-Quelier (2020) on the diversity of interactions between the activist and economic worlds, we display a first form of theorizing. From an industrial standpoint, the greening dynamics observed in workplaces depend on the structure's position on an axis ranging from activist commitment to compliance with market rules, intersecting another axis from autonomy to heteronomy, both specific to each industry. Fighting dependence on pathways, particularly the paths taken by major companies in each industry, which persist in adopted choices even if better alternatives exist, is one of the main practical obstacles.

If the dynamics between market greening and concrete ecologism constitute a first axis of tension, a second axis could be formed by the autonomy/heteronomy dyad in the sphere of production relations. According to Gorz, autonomy characterises a form of production in which the individual or group has control over the means of production, the work process, and the product, both in terms of design and quality (Gorz, 1988). Even if the means of execution are decided, Gorz underlines that work is heteronomous if its goals are determined by external wills. Discourses and representations reveal a tension between the autonomy and heteronomy of work, as these concepts, which are not mutually exclusive (autonomy is gained by negating heteronomy), frame action. Discourses and representations related to greening in the professional worlds investigated bear multiple translations of these concepts. Heteronomy thus appears in relation to professional hierarchies, which impose specialised positions in the division of labour, subordination in working relationships, and market constraints. Autonomy can be embodied in democratic organisational forms, oriented by a renormalisation of work from an emancipatory or ecological perspective.

	Heteronomy		
Economic Worlds	1. Strong roots in the economic worlds / strong heteronomy: Major influence on standards in terms of production conditions, adaptation to regulations, greening, and struggle to maintain a dominant position in the sector (e.g. construction and retail majors).	3. Strong roots in activist circles / strong heteronomy: Struggle from within in the face of greening and market greening (scaling up), performativity based on experimentation and links with local associations (e.g. national organic store cooperative).	**Activist Worlds**
	2. Strong anchorage in the economic worlds / strong autonomy: Market bifurcation, new sources of productivity, "green economy", subcontracting organisations linked to the diversification and greening of the activities of dominant groups within varied sectors (e.g. rope access technicians in construction).	4. Strong roots in activist circles / strong autonomy: Political bifurcations, experimentation, local roots (e.g. dairy and cheese store, SE organisations).	
	Autonomy		

Table 1: Four dynamics of greening at the crossroads of tensions between economic and activist worlds (M. Hocquelet / F. Séchaud, 2023)

Consequently, three businesses studied, two of which are cooperatives, are caught up in agri-food chains they wish to transform. Their greening dynamic and orientation require the involvement of all players, from producers to consumers, and a better understanding of their economic and environmental stakes. The activities developed within the framework of the professional training and integration SE structure by its employees and users (people

affiliated with "remobilisation" schemes and directed towards it by employment prescribers) respond partly to profitability or social order logics and partly to non-market or non-monetary logics, especially when they aim at particularly pronounced sustainable development objectives.

In the construction sector, the changes observed in objectives pursued due to greening appear largely linked to exogenous factors, such as the industry's long-standing regulatory framework, technological developments and the transformation of construction methods. This sector is emblematic of the importance given to the "upstream" (suppliers), whether they offer structural elements, low-carbon concrete, or more ecological treatment products. This aspect is less often considered than the "downstream aspect", such as waste treatment, which is partly outsourced to specialised companies in the two cases studied.

More room for deliberation, reflexivity on the meaning of work and workers' safety and health

At the organisational level, greening is linked to measures to protect workers' health, improve their working conditions, and give the collective more control over work organisation. The creation of deliberative spaces to question the activity, its aims, and how to organise work collectively, contributes effectively to this in-depth greening. As we've previously seen with SE organisations and the importance of voluntary standards, the role of deliberative spaces and times, and the desire for more democratic, horizontal governance appear intertwined and articulated with ecological and social issues such as work and employment conditions, work organisation, and gender equality.

The establishment of deliberative spaces and time slots that allow for the questioning of the activity and its goals contributes effectively to this increased greening (importance of reflexivity). In different production contexts, an articulation of the ecological dimension with that of workers' health, their working conditions, and the organisation of day-to-day work emerges transversally. In the case of the tea factory, the dynamics of greening work is linked to the search for a sustainable cooperative project based on its core values and a form of regulation of work through deliberation, distinct from managerial and hierarchical organisations. The democratic modes of governance and regulation in both structures, by encouraging time for deliberation on the work and employee participation in decision-making, support the integration of ecological concerns into their activities. As a result, employees' appreciation of the meaning of work has increased, though this has been nuanced by mixed trends in terms of job quality and working conditions.

Here, greening is diffused within the framework of collective organising of work, evolving daily because it is a process "in the making" whose effects are perhaps still somewhat evanescent to date. According to Bruère and Chardeyron (2013) the concept of "organising work' was initially proposed by de Terssac and considers the fact that the functioning of the organisation, including the work collective, is the result of individual regulations (Terssac & Lalande, 2002). Organising work allows us to group together, in the same category, a set of

organising activities. In our case, we can talk about ecologically led organising work, where the role of "professionals whose job it is—managers, executives, methodologists, equipment designers, supervisors, to name but a few—who are (usually) in charge of structuring the activity of others, and who therefore largely determine the characteristics that will define the work" is fading in favour of a greater focus on "the (collective) organising activities of all individuals, which are present in all types of professional activity: the work activity I deploy to carry out the tasks assigned to me, my strategies and operative compromises, will, at one and the same time, organise my work and that of others, within the same team or between interdependent teams, who will have to adapt" (Bruère & Chardeyron, Op.cit, p. 75).

Towards collective skills: organising a greening workplace while advocating for a greener industry

These organisational principles lead to the development and promotion of workers' organising skills, accompanied by reflexive feedback on their activities and consideration of the commons. These commons refer here to the collective use and management of resources by a community of workers, allowing them to move away from the binary alternative between private and public, by focusing more on equal access, sharing and decision-making than on ownership. More broadly, to green their activities and industries, professionals need to think increasingly globally and sensitively, while situating and modulating their specific contribution to the different systems of activity, production processes, sectors, and chains of action in which they participate, in terms of Life Cycle Thinking as seen in food-related cooperatives and beyond. This transformative way of framing work through the global impact of productive activity is mobilised individually and collectively in the organisation of day-to-day work, as well as in advocacy work with customers (e.g. introducing adults and children to traditional cheese-making methods during regular workshops) and stakeholders (e.g. open days to discover the local activist ecosystem) throughout the production, distribution, and consumption chain. This is in line with a more specific definition developed by Ludovic Ginelli and his colleagues (2020), who refer to the 'greening of practices' as any "cognitive and normative reframing exercise" aimed at bringing about an environmental shift in social norms and practices.

In the professional training and integration SE structure, recruitment is a gradual process, from volunteering to obtaining initial financing for a project personally supported and defended by the newcomer-contender, leading to an employment contract. The aim is to initiate candidates into its ecological project while keeping them out of the position of mere executioners. Additionally, skills (such as accounting and project writing) are pooled during regular training sessions so that each employee becomes a "Swiss Army knife" (as stated by the founder of the SE structure), enabling the team to respond to changing demands. In addition to tasks related to financing schemes (writing reports, delivering training courses, user support), each employee undertakes to maintain the workplace (courtyard, vegetable garden, henhouse) and offer workshops for staff and users, such as making objects using recovered or recycled materials, repairs, and urban agriculture. Therefore, employees

modulate and develop activities. Nevertheless, while the ecological aspects of production sometimes lead to a diversification of tasks, ways of working are not systematically transformed. The greening process, though still in its early stages, is already impacting some professional postures of the employees observed.

Whether driven by regulations or customer choice, this process changes the purposes of occupations and consequently some of their action processes, with waste management being the most emblematic example. In food retail organisations, multiskilled jobs flexibility is not driven by a strict Taylorist division of labour and just in time but by principles of "greening", prioritising workers' health, knowledge, know-how and getting the message across over productive efficiency (e.g. limiting working time in direct contact with customers, from counter service to checkout in order to preserve workers, the quality of customer relations and advocacy for a thorough greening). In the retail monographs, salespeople still aim to sell food products, guide, advise, and develop customer loyalty. However, the goals pursued by employees are significantly impacted by including their commercial actions within a systemic greening philosophy. At the heart of the professional goals are relatively original missions of raising customer awareness in ecological and environmental fields, with a dual activist and commercial dimension intended to be complementary.

However, ways of working are not systematically transformed. In some cases, considering the ecological aspects of production leads to a diversification of tasks without questioning the fundamentals of the division of labour. This is especially true in organisations dominating the market and subject to adopting an adaptative greening dynamic in the face of regulatory constraints. Besides, the "new skills" may also turn out to be old and/or collective skills that had been devalued or made invisible by profitability considerations and Taylorist division of work, returning to processes linked to proto-industrialisation aiming at craft work, as seen in the food trade, agri-food-related industries, and activities outsourced by major companies such as rope access technicians in the construction industry.

In the case of the tea factory, which seeks to maintain its production, the activity of machine operators on the production line seems to be changing little. Their ability to work on different machines is considered obvious but does not imply profound changes in ways of doing things, prescribed by the IFS Food standard required by the client-retailer. In this case, the activity is constrained by the need to deal with mass retailers to balance the economic model, whereas, according to workers, the meaning of work is reinforced in the activity dedicated to manufacturing the cooperative's specific tea brand. The fact that the 40 cooperators work in the same factory where they used to produce for a multinational company ten years ago has led them to become "Swiss Army knife" employees in practice, balancing specialisation (working on a machine) and versatility (developing the production line according to fluctuating orders).

Thus, greening does not always lead to changes in working methods. The close observation of professional practices and rules, also called "action processes," underlines that if the aims

of the activity (what guides and gives meaning to the goals pursued) and the tasks they consist of (what determines what needs to be done at any given time and how it should be distributed: actual tasks, work organisation) are undergoing major transformations, the ways of carrying them out in the organisations observed (the most efficient and effective ways of doing things according to the workers) doesn't necessarily change radically. However, monographed companies generally combine collective activities and individual tasks, which, due to their original and systemic ecological purpose, modify work for some or all of their employees.

This dynamism does not appear restricted to the organisations studied, mainly representing economic models dominated by market mechanisms, due to their systemic impact on most organisations, industries, and trades. These ecological dynamics of work profoundly change how employees work and interact with various entities and stakeholders. Consequently, whether considered from the perspective of sector-specific work greening or the adoption of activist greening practices, these dynamics appear to transform certain professional representations of employees concerning their work, the meaning given to it, and the purposes pursued through their activity. The examples and principles for greening work and workplaces are simultaneously translating work processes and developing the means to act on organisational, political, social, and environmental issues, establishing links between work in specific sectors and transformations at the individual and collective levels.

Conclusion: value chains, organisational configurations, dynamics and scope of greening

In view of our results, the analyses both underline the organisational and collective dimensions of greening and the importance of collective skills in these greening dynamics. To continue understanding the greening of jobs and skills would thus require studies and investigations to be directed, on the one hand, towards questions of organisation and the work environment, by widening the focus beyond the company to the production sectors and value chains, and on the other hand, towards skills useful for deliberation and organisational action by employees, opening up a shared meaning and purpose of the activity and its greening by workers' collectives. More broadly, organising work, reflexive individual and collective feedback on everyday activity, and an emphasis on the commons, including occupational health and the ability to organize, as well as advocating a systemic ecology appear to be the principal characteristics of organisations with an in-depth and ethically consistent (Coutrot & Perez, 2022) approach to greening.

To green their activities, professionals need to reason more and more systemically (chains of interrelations, causes, and consequences) and sensitively (impact of business on the environment, practical knowledge of natural raw materials) at the same time, situating and modulating their specific contribution in the different systems of activities, production processes, sectors, or chains of action in which they participate. Besides, in the different

productive contexts, an articulation of greening dynamics with the health of the workers, their working conditions, and the organisation of the latter has appeared.

In this context, how can the prospects observed in these three sectors move beyond niche production and consumption? This research questions the conditions for the most virtuous forms of greening to reach wider populations of workers and consumers, who are often, as in retail, the targets of the practices of dominant market actors, defining path dependency guided more by productivism and increased profits than by a transformative vision of their activities. The central role played by workers at a micro level underlines the importance of understanding the role of industrial relations and, more broadly, of workers' collectives in the greening of work.

Finally, we can turn the original question on its head, from asking: "what does ecology do to work?" to "what does the context of work—productive configuration and socio-industrial trajectory—do to/with ecology"? In other words, the "already there" or socio-technical systems can lead to strong structuring, path dependencies, and locks due to a high level of institutionalisation of technologies, policies, markets, and values that act as constraints in the face of any sudden or radical change in these same systems (Fuendschilling & Truffer, 2016; Geels, 2004 and 2011). Nevertheless, this research partly answers questions about the possible and existing connections between workers and transition at the micro level of industries, particularly the roles of workers as actors in transition, the different dynamics that characterise this relationship according to industrial contexts, and, in so doing, the possibilities of influencing the latter. It emphasises the crucial role of workers' practices in explaining path dependency (continued use of a product or practice based on historical preferences or usages, even in the face of available innovations and efficient alternatives) and invites further research into this question.

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A Just Transition? Green jobs, good jobs and labour market inclusivity in Scotland

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Abstract

Responding to the climate emergency, governments have pledged to deliver a net zero future. Delivery requires more green jobs and a just transition of good jobs and labour market inclusivity. The problem is that there is no agreed methodology for classifying green jobs. The paper reports the findings from analysis of Scotland, applying the GreenSOC – an adaptation of the green occupation's classification of the US Bureau of Labor Statistics and O*NET. The analysis uses the UK Labour Force Survey and web-scraped job vacancy data to assess the extent and demand for green jobs as well as the pay and gender composition of these jobs. The findings are mixed. First, there are few new green jobs but a strong greening of existing jobs. Second, while green jobs offer higher wages, they tend to be dominated by male workers. These findings suggest that the employment benefits of the transition to net zero are less inclusive than anticipated and that policy and practice need to adjust. Offering recommendations, the paper provides improved definitional and empirical understanding of green jobs as well as offering insights into how green jobs might be made more inclusive.

Introduction

Responding to the climate emergency, there is an international policy consensus on the need to deliver a net zero economy. This economy requires more green jobs and, additionally, a 'just transition' of good jobs and labour market inclusivity (EU 2023; HM Government 2021; ILO 2023; OECD 2021; UN 2021). Focusing on Scotland, this paper empirically assesses the delivery of these policy aspirations. The Scottish Government has an ambitious target of net zero carbon emissions by 2045 and a 75% reduction by 2030. Its just transition agenda, and ongoing commitment to improving job quality through what it terms 'Fair Work' (Scottish Government 2021a), aims to help deliver 'a fairer, greener future for all' (Scottish Government 2021b). The research was commissioned by Skills Development Scotland (SDS),[i] an agency of the Scottish Government in the context of the Scottish Government (2021b) recognising that a just transition will involve an adaptation of workers skills and working practices and need to meet employer demand, while contributing to tackling inequality in Scotland.

The starting position for the paper is recognition that there is no internationally agreed methodology for classifying green jobs, which makes it difficult to assess if either a net zero economy or just transition is being delivered (Abrahamsson et al. 2023; OECD 2023; ONS 2021). However, there is an emerging consensus on the utility of measurement work undertaken through the US Bureau of Labor Statistics and O*NET (Dierdorff et al. 2009; see also Sofroniou and Anderson 2021). Drawing on but adapting this work, our analysis uses a newly developed classification of green jobs that we call the 'GreenSOC'.

Whilst policy parlance refers to 'green jobs' – see, for example, the UK's Green Jobs Task Force (2021) and the EU's Green Deal (EC 2019) – analytically, a job is an occupation within an industry. As a consequence, we examine these green jobs through occupational and industry classifications. Our subsequent classification of green occupations allows the capture of new green jobs and the impact of the net zero transition on other existing jobs. As such it aligns with the ILO's (2023) point that change has to occur across all jobs and sectors if a net zero economy is to be achieved and sustained.

The paper is structured as follows. The next section discusses the policy push for a net zero economy and, with it, a just transition. The outline covers international policy positions as well as those within Scotland. It also highlights the definitional debates about measuring green jobs. The following section outlines the GreenSOC methodology as well as the data sources for the analysis. The next section presents the findings, first on the extent of green jobs and then demand for them. It then focuses on the just transition and good jobs and the inclusiveness of these jobs. The conclusion summarises the findings, reflects on progress to achieving a net zero economy with a just transition and makes recommendations for further policy development. The paper provides improved methodological and empirical understanding of green jobs as well as offering insights into how green jobs might be turned to be more inclusive.

Background

There is an international policy consensus that a transition to a net zero economy is needed to help tackle climate change (EC 2019; ILO 2023; OECD 2023; Renner et al. 2008;). This transition will create more new green jobs as well as impact existing jobs (Consoli et al. 2016; Gagliardi et al. 2016; IRENA 2016; Knudsen et al. 2023; Poschen and Renner 2015). Climate change policy, however, offers more than green jobs growth. What makes the transition to net zero distinct from other economic transitions is that it is not market driven but policy driven, intended to deliver a 'just transition'. Two policy aspirations are salient within this just transition. First that 'no-one is left behind' in the transition to a net zero economy, which means being 'inclusive' in two ways: supporting workers de-jobbed by the phasing out of fossil fuels and providing better labour market inclusion for marginalised workers, particularly female workers (ILO 2023; also OECD 2023; UN 2021). Second, the new green jobs will be 'decent jobs' or 'good jobs', at least as indicated by pay (Renner et al. 2008).

Within the UK, these policy aspirations are reflected in Scotland. Scotland has a government-sponsored Climate Emergency Action Plan (CESAP) also centred on creating more green jobs (Skills Development Scotland 2020). As part of its national strategy for delivering economic prosperity, the Scottish Government (2022) identifies five policy programmes, one of which is intended to 'generat[e] new, well-paid jobs from a just transition to net zero'. Paralleling these policy aspirations is another to improve job quality through the encouragement of 'fair work' in Scotland which includes pay (Scottish Government 2021a). Echoing the ILO, for the Scottish Government the just transition is thus one that is 'fair and leaves no one behind' (Scottish Government 2021b: 5).

A key challenge in measuring progress to a net zero economy is that there is no internationally agreed definition of a green job (ONS 2021). Indeed, even within the EU, different agencies of the European Commission interpret green jobs differently (Urban et al. 2023). The absence of a commonly accepted definition leads to widely varying green job estimates (OECD 2012).

Definitional approaches generally fall into one of two main camps (Sofroniou and Anderson 2021). The first is a 'purist' approach, with green jobs narrowly defined in terms of their 'green credentials' (Dierdorff et al. 2009) – that is, jobs in sectors that 'contribute substantially to preserving or restoring environmental quality' (Renner et al. 2008: 39) and are typically located in the energy/renewables industries (Sofroniou and Anderson 2021). The second is an 'inclusive' approach that envelopes the wider impact of the greening on jobs and includes but extends beyond sectors directly focused on environmental preservation and restoration (Dierdorff et al. 2009; OECD 2012).

It is recognised that a consistent approach to defining green jobs is needed (Cedefop and OECD 2015). Most policy emphasis and, as a consequence, measurement, has focused on jobs based on the purist approach, for example the EU's Environmental Goods and Services Sector classification (Eurostat 2016; see also Renner et al. 2008; Hogarth 2012). At the same time, there is recognition within policy that the whole of the economy and so all jobs in all sectors need to change if net zero is to be achieved and sustained (ILO 2023; Green Jobs Task Force 2021). These two positions suggest what needs to be included in the development of a consistent approach to measuring green jobs.

Reflecting this recognition, the classification of green occupations of the US Department of Labor's O*NET (Occupational Information Network)ii (Dierdorff et al. 2009) is gaining traction amongst researchers and policymakers internationally, including within Europe (e.g. Consoli et al. 2019; Green Jobs Taskforce 2021; Valero et al. 2021; Cedefop 2023). This green occupational taxonomy, using the US O*NET-SOC 2006, distinguishes three types of green jobs: first, New & Emerging Occupations, sometimes called 'pure' green jobs, which are completely novel or emerging in the transition to a green economy; second, Enhanced Skills Occupations which capture changing skills requirements in some existing jobs; and, third, Increased Demand Occupations resulting from green economic activities increasing employment demand for some existing jobs. Including net zero transition unaffected non-green, what are sometimes called 'brown' jobs, there is then four job types. We use this occupational classification as the starting point for measuring the extent and demand for green jobs and assessing if these jobs are delivering a just transition in Scotland.

Research design

In drawing on the O*NET approach to classify green occupations (Dierdorff et al. 2009), there are challenges applying it to Scotland and anywhere else outwith the US (Sofroniou and Anderson 2021). First, O*NET is focused on occupations based in the US (Christoph et al. 2020) but tasks can vary for the same occupation in different countries due to differing regulatory regimes and training and education systems (Richard et al. 2012). Second, there is a need to adapt the O*NET classification to the UK Standard Occupational (SOC), which covers Scotland. The SOC is updated every ten years. There is a crosswalk between the O*NET and SOC 2010 (the old version of the SOC) but no crosswalk from O*NET to SOC 2020 at the time of the study. To address these challenges, we used the crosswalk between the US O*NET-SOC and the UK SOC2010iii and then the crosswalk between the SOC2020 and the SOC2010 to identify the green occupations at the four-digit level of SOC2020. The researchers then manually examined the occupational list. A further examination was conducted by Skills Development Scotland and business stakeholders in order to finalise the list of green occupations at 4-digit level of SOC. The final list of green occupations was discussed and agreed with the SDS and the researchers. The use of external practitioner input plus data triangulation amongst the researchers is used in other attempts to create new occupational classifications, for example the UK's graduate occupational classification (GradSOC) (Elias and Purcell 2013).

In addition to this adaption to the UK/Scottish labour market, two other adaptations are needed. First more explicit inclusion needs to be made of knowledge within occupations. The current O*NET categorisation of green occupations rightly makes explicit reference to the skills of those occupations. However, all occupations comprise tasks underpinned by skills and knowledge and both O*NET and SOC outline these skills and knowledge. The knowledge component needs to be made explicit in order not to underplay changes occurring to some jobs as a result of the transition to net zero – that is, the greening of the skills and knowledge within existing jobs. Second, whilst data gathering for O*NET in the US is well-resourced compared to similar classification systems in the UK and elsewhere, its classification update can still be limited. Every year, some but not all occupations are reviewed (Handel 2017). Dierdorff's mapping was conducted in 2009. Given the intensified policy

push to address climate change since the 2015 Paris Agreement[iv] and its encouragement of new green jobs, there is a danger that the classification might be outdated. There is a need therefore for the classification to be supported by more timeous data collection (Christoph et al. 2020). Capturing 'real time' change would be helpful and web-scraped job vacancy data offers this opportunity (Cardenas Rubio and Warhurst 2022).

This triple adaption provides a new 'GreenSOC' that is more inclusive, more responsive and more sensitive to non-US, in this case Scottish, labour markets. It also means that the analysis can extend beyond the jobs in industries that directly contribute to net zero to other industries and jobs that indirectly support this aim.

Beyond the general adaptions, to distinguish 'pure green' New & Emerging Occupations in Scotland, we drew on the Scottish Climate Emergency Skills Action Plan 2020-2025 (CESAP) (SDS 2020). Using a sector-based approach, CESAP highlights the areas of economic activity deemed to be key to meeting net zero carbon emissions targets in Scotland. These areas involve energy production, waste and resource efficiency etc. However, the CESAP does not map these activities areas onto a standard industrial classification such as the Standard Industrial Classification (SIC) 2007 used in most of the official labour markets statistics in the UK. The lack of mapping makes it difficult to estimate the share of people working in companies that are key to delivering the net-zero target in Scotland. With additional input from SDS, we therefore mapped the CESAP sectors to SIC codes. We also ran a text mining exercise using the SIC2007 descriptors to identify green sectors that may not have been identified previously, for example we identified some SIC codes related to transport and waste treatment.

To assess if green jobs are good jobs, the UK now has a standard measure of job quality. However, data to support the measures is still being developed (see ONS 2022). In the interim, and included in the standard measure of job quality, we use pay as an indicator of job quality, with higher wages often used as an indicator of good jobs (see, for example, Goos and Manning 2007). As a measure of a just transition that is socially inclusive, we use gender, doing so for two reasons. First, because the fossil fuel oil and gas industries generally and within Scotland are overwhelming dominated by male workers (IRENA 2019). The shift away from these industries to a net zero economy ought therefore to be accompanied by a gender shift in employment (Cohn and Duncanson 2023; ILO 2015). Second, as part of the UN's Sustainable Development Goals 5, closing the gender gap in employment is deemed to be important (Azcona et al. 2023).

The analysis uses UK Labour Force Survey (LFS) data and web-scraped job vacancy data to assess the extent and demand respectively for green jobs in the Scottish labour market as well as the pay of these jobs and the gender of workers employed in them. The LFS is conducted quarterly by the UK's Office for National Statistics with our analysis covering the period 2014 to 2021. UK focused web-scraped job vacancy data has been collected by the Warwick Institute for Employment Research since 2019 and covers the period from then to 2022. It helps address the time-lag limitations of O*NET.

Findings

The findings first focus on the extent of and then demand for green jobs in Scotland. Findings related to the just transition are then presented, focusing first on whether green jobs are good jobs as indicated by pay and then these jobs' inclusiveness proxied by female employment.

The extent of green jobs

Using LFS data this section examines the extent of green jobs in Scotland. In 2021 there were 2.5m jobs in Scotland. The full range of green job types – and non-green or brown jobs – as a percentage of total employment in Scotland are shown below in Figure 1. New & Emerging green jobs account for just 4.3% of all jobs in Scotland. This figure is low. However, the findings suggest a strong greening of existing jobs: just over a quarter of jobs (25.7%) are Enhanced Skills & Knowledge jobs. Almost one-tenth (9.9%) are Increased Demand jobs. Most jobs in Scotland (60.1%) remain unaffected 'brown jobs', not falling into any of the three green job categories.

Some caution needs to be exercised with the figure for New & Emerging green jobs. Using the SOC2020 4-digit level, current LFS data does not provide sufficient detail of the specific economic activity of many of these jobs. For example, Mechanical Engineers are classified as a New & Emerging green job as they work on both new products and processes focused on renewable energy or energy efficiency. Including all Mechanical Engineers in this category is possibly an overestimate as not all Mechanical Engineers will focus on these products and processes; some remain focused on non-green products and processes. As a consequence, the 109,645 (or 4.3% of total employment) New & Emerging green jobs, and indeed all green job figures presented here, should be regarded as the maximum of the estimate driven by current data limitations.

Figure 1: All green occupational categories plus non-green occupations in Scotland
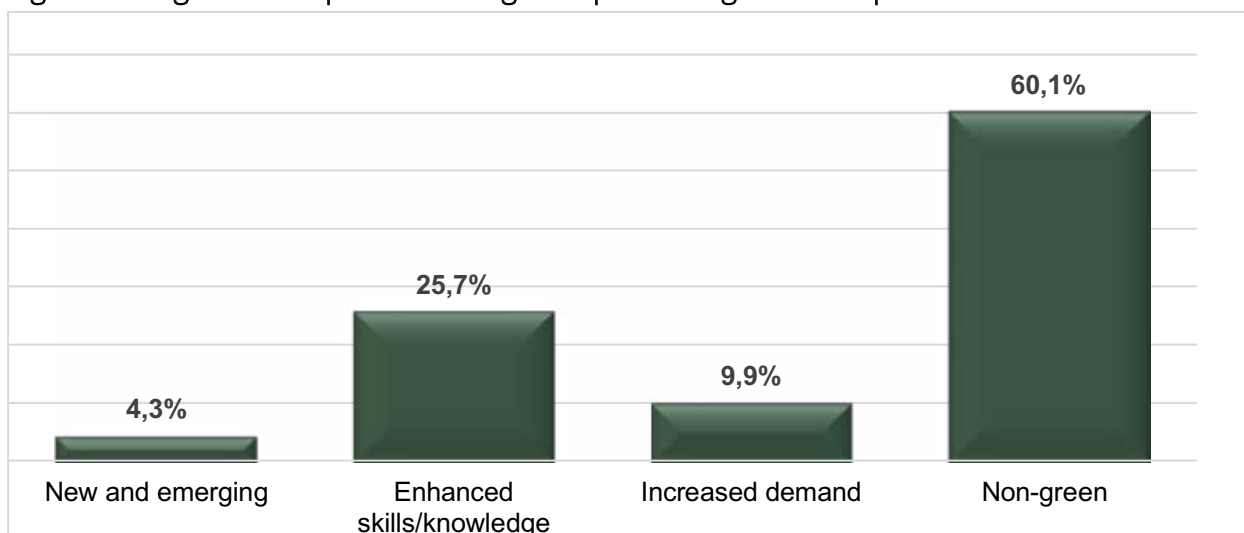
It is useful to disaggregate the percentage share of green jobs in Scotland by Major Occupational Group (UK SOC2020), see Figure 2 below. Professional occupations have the highest proportion of

green jobs by occupational group (32.1%), followed by Skilled trades occupations (19.6%). Caring, leisure and other service occupations have the lowest proportion of green jobs (0.1%).

Figure 2: Green jobs in Scotland by SOC2020 Major Occupational Group
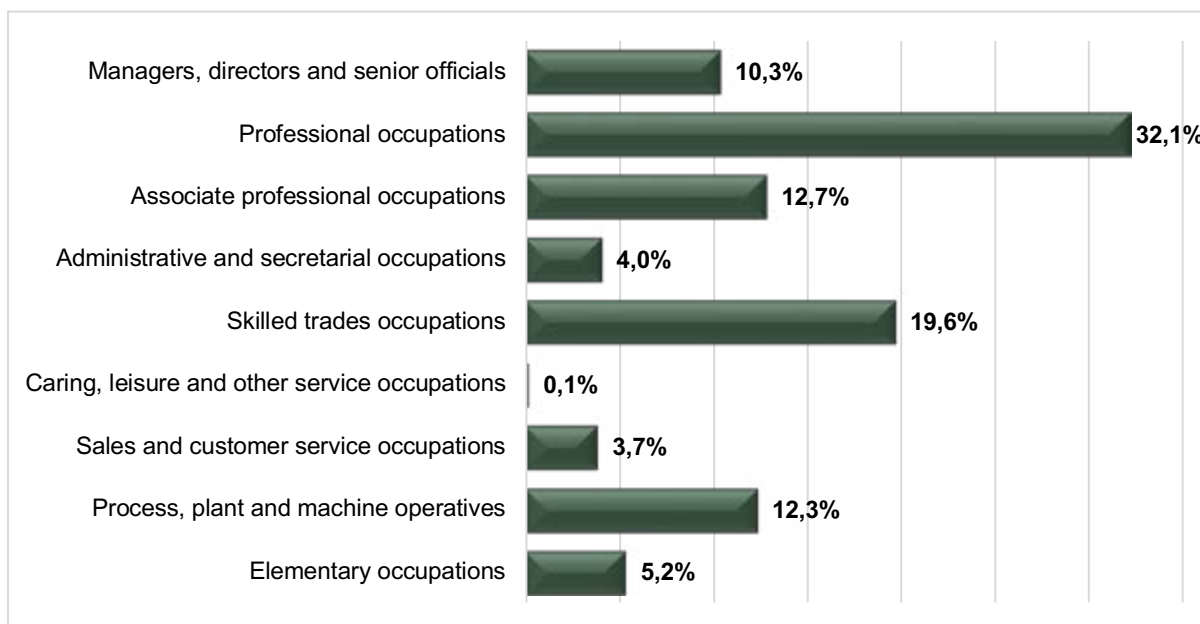
Moreover, there are clear differences in each green job category. Professional occupations have the highest proportion (43.2%) of New & Emerging green jobs and Associate professional occupations have the second highest (20.4%). Moreover, New & Emerging green jobs are concentrated exclusively in five of the nine UK Major Occupational Groups: Professional occupations; Associate professional occupations; Administrative and secretarial occupations; Skilled trades occupations; and Process, plant and machine operatives. Similarly, Professional occupations have the highest proportion of Enhanced Skills & Knowledge jobs (42.7%) and Skilled trades occupations have the second highest proportion (19.2%). Most Enhanced Skills & Knowledge green jobs (97.1%) are located in four Major Occupational Groups: Professional occupations; Managers, directors and senior officials' occupations; Skilled trades occupation; and Associate professional occupations. By contrast, over half of Increased Demand green jobs comprise Process, plant and machine operatives (29.3%) and Skilled trades occupations (27.1%). Professional occupations are notably absent in the Increased Demand category.

Demand for green jobs

Given that green jobs are a relatively new development within the labour market, analysis of web-scraped job vacancy data offers insights into 'real time' change. In particular, it helps identify any changing employer demand for green jobs covering the three categories.

Job vacancy data over 2019 to 2022 signals a post-Covid labour market recovery in Scotland. Figure 3 below highlights the low of 6189 vacancies in April 2020 as the pandemic took hold to the recovery of 22,140 job vacancies in January 2022.

Figure 3: Job vacancy numbers in Scotland, February 2019 to January 2022
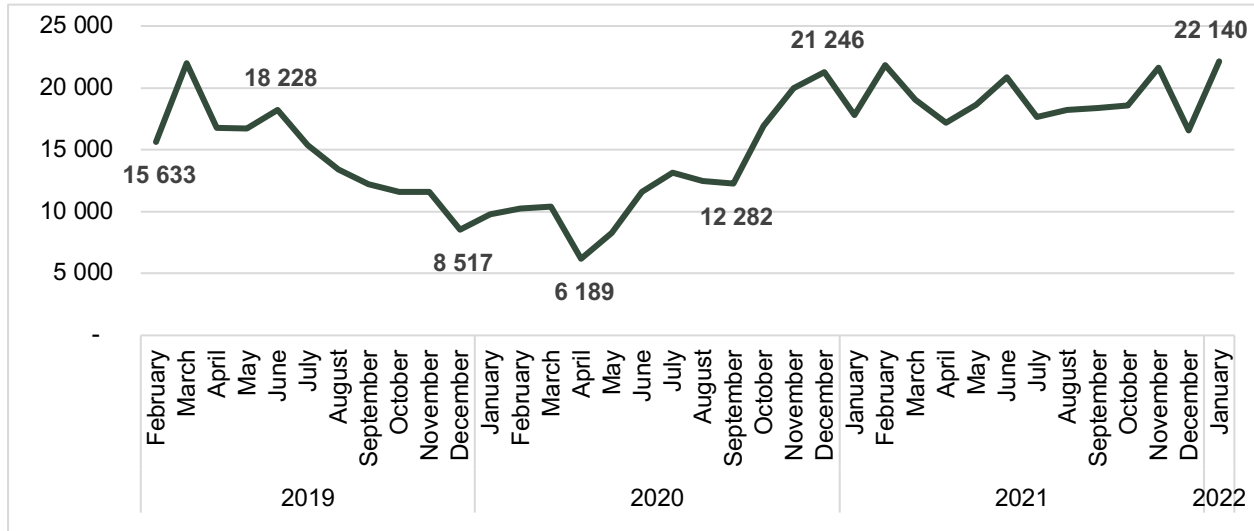
Analysis of job vacancy data reveals that green job vacancies as a proportion of all job vacancies in Scotland is consistent with LFS data on green jobs as a proportion of total employment. Just 39.9% of all job vacancies are green jobs across the three categories. Vacancy data also uncovered new job titles that do not even feature in the recently completed SOC2020, such as a 'net zero engineer'.

Vacancy data also mirrors LFS data in terms of variation in the relative proportion of jobs by green job category, see Figure 4 below. However, there are some differences: there is a slight decrease in the proportion of Enhanced Skills & Knowledge jobs and a slight increase in the proportion of Increased Demand jobs.

Figure 4: Proportion of green job vacancies in Scotland by category, February 2019 to January
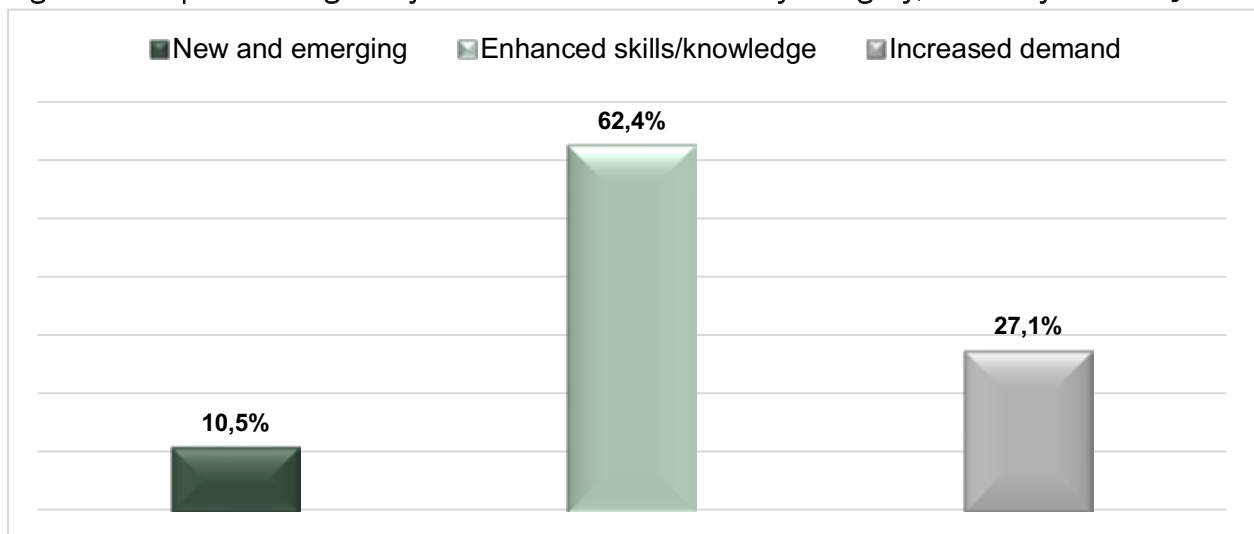
2022

It is important to note that the overall number of job vacancies increased over the period (see Figure 3 above). Thus, in terms of actual job vacancy numbers, there was an increase in all three green job categories. By Major Occupational Group, Professional occupations account for most of the New & Emerging job vacancies (47.1%). Professional occupations account for over half (55.7%) of all Enhanced Skills & Knowledge job vacancies. Elementary occupations have the highest proportion of Increased Demand job vacancies (41.8%), followed by Sales and customer service occupations (23.2%).

The quality of green jobs

In this section we use pay as the main proxy for job quality to assess whether green jobs are good or not compared to non-green jobs. We recognise that advertised pay rates might differ from actual pay received but that it is difficult to control for the possible variance. The vacancy data reveals that median advertised wages are higher in green jobs than in non-green jobs in Scotland (£29,673 vs £23,837). Within the three green jobs categories, median wages are highest, but only slightly higher, in Enhanced Skills & Knowledge jobs and lowest in Increased Demand jobs, see Figure 5 below.

Figure 5: Green job vacancies in Scotland by category and median wages

| New and emerging | Enhanced skills/knowledge | Increased demand |
| £32 500 | £33 452 | £20 800 |
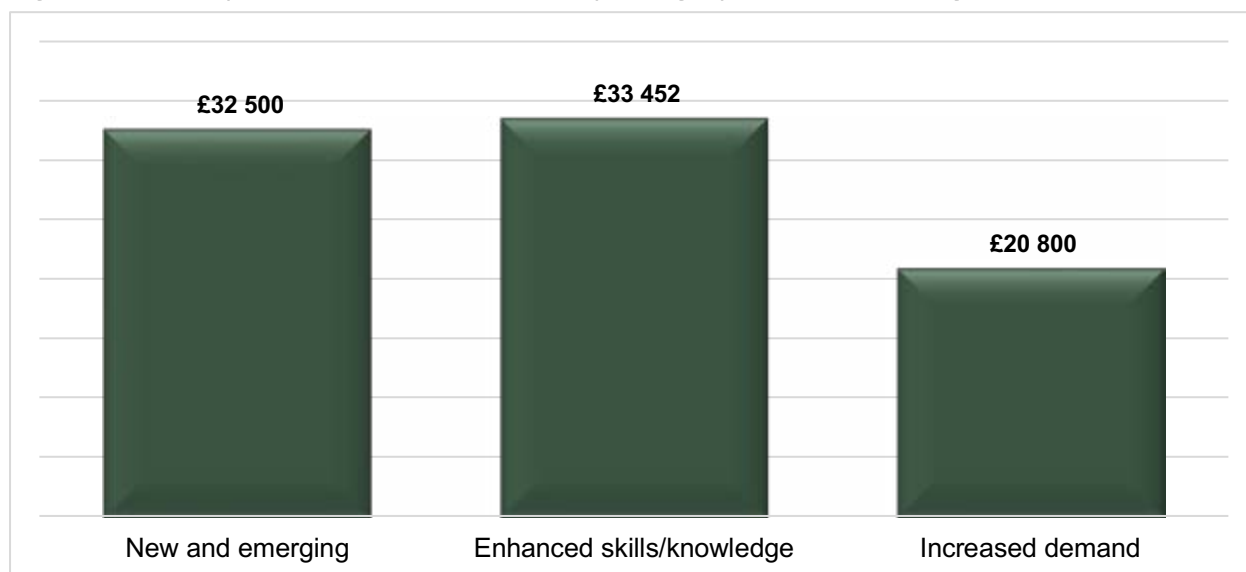
Moreover, wage trends over the period 2019 to 2022 point to contrasting pay trajectories for New & Emerging jobs and Enhanced Skills & Knowledge jobs (an upwards trend) versus Increased Demand jobs and non-green jobs (a downwards trend).

These findings reflect the types of occupations that are most prevalent in each of the three green jobs categories and the typical skills that characterise these occupations. Within the SOC there is a hierarchy of occupational types called 'groups', and occupational groups higher up the hierarchy are associated with higher skills, as proxied by qualifications, and so higher pay typically.[v] The findings on pay reflect this hierarchy, with a prevalence of Professional occupations and Associate professional occupations in New & Emerging green jobs, and a prevalence of Professional

occupations and Skilled trades occupations in Enhanced Skills & Knowledge jobs – see Figure 1 above. By contrast there are no Professional occasions in the Increased demand jobs, which have instead a prevalence for Skilled trades occupations but even more Process, plant and machine operatives.

Gender and green jobs

Delivering a just transition to net zero requires a clear focus on issues of inclusiveness, particularly in terms of gender. In this respect women are markedly under-represented in the three categories of green jobs in Scotland, see Figure 6 below. Green jobs disproportionately involve men (i.e. 27.8% women vs 72.2% men).

Figure 6: Green jobs by gender in Scotland
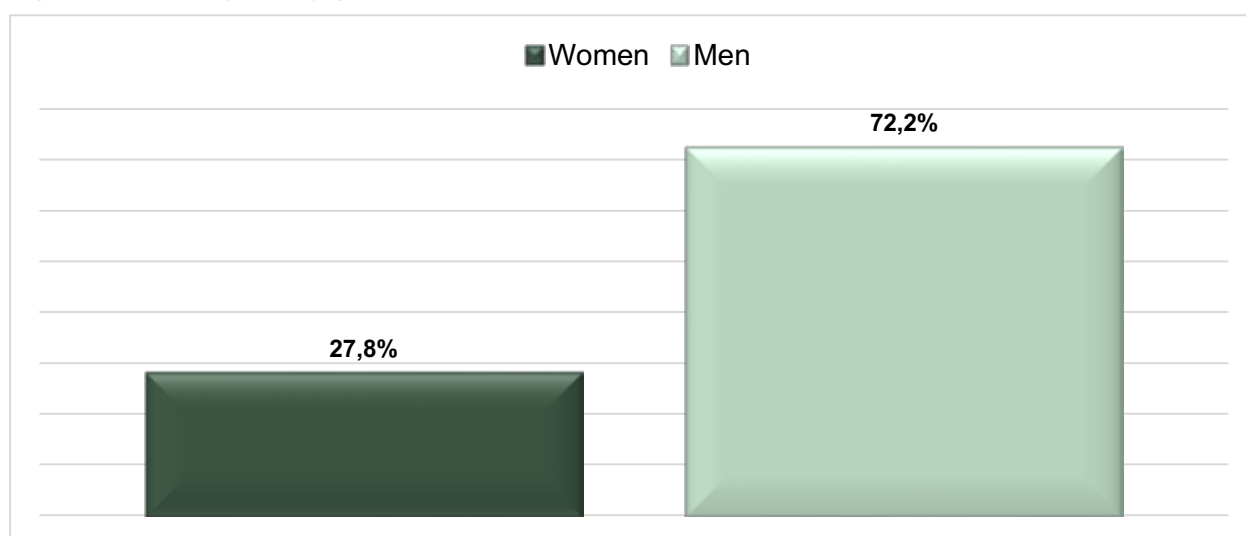
Although there are clearly far fewer women than men working in green jobs, it is useful to look at differences in the relative distribution of women and men by green job category (see Figure 7 below).

Figure 7: Relative distribution of women and men in Scotland by green job category
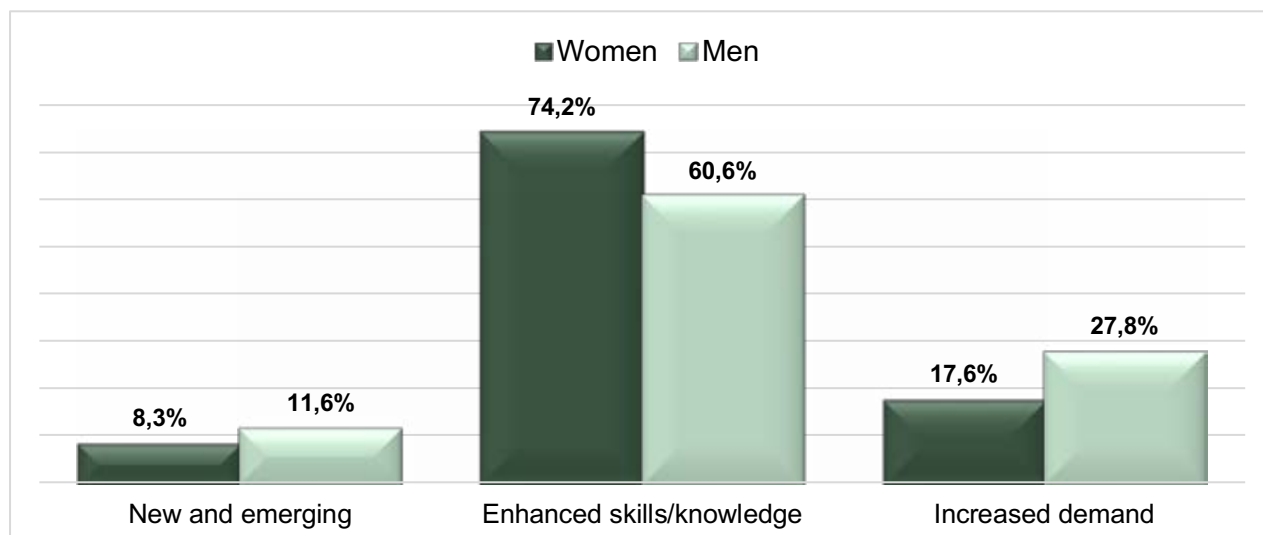
Of women working in green jobs, around three quarters are in Enhanced Skills & Knowledge jobs (74.2% vs 60.6% men). It is interesting that it is in New & Emerging jobs that the relative concentration of women and men has the narrowest gender gap (8.3% women vs 11.6% men) despite the fact that engineering occupations tend to dominate this green jobs category. Thus, while these jobs tend to be good jobs as measured by pay, they also tend to be exclusory in terms of who is currently accessing them.

Discussion and Conclusion

One of the key challenges in pursuing a net zero economy with a just transition has been the lack of consensus about what constitutes a green job. Without knowing what a green job is, it is difficult to measure progress in creating those jobs, their quality and who works in them. As such, it is important to develop and use a consistent approach to defining green jobs (Cedefop and OECD 2015). To address this unmet need we developed a new GreenSOC adapted from work by the US Bureau of Labor Statistics and O*NET (Dierdorff et al. (2009) that is gaining international acceptance. Our adaptations enable this work to be applicable beyond the US. This GreenSOC has three categories of occupations which capture, firstly, new, pure green jobs, secondly, existing jobs that are greening and, thirdly, existing jobs more in demand because of the transition to new zero. We used this GreenSOC to analyse green jobs in Scotland but suggest that it and its methodology be given serious consideration for wider adoption.

Framed by the GreenSOC, we then used data from the UK LFS plus our own web-scraped Scottish job vacancy data to analyse green jobs in Scotland. Despite the policy imperatives internationally and a climate emergency plan in Scotland, our findings reveal that most jobs in Scotland remain non-green or brown jobs, neither contributing directly or indirectly to nor affected by the net zero transition. As for the extent of and demand for green jobs specifically in Scotland, the empirical findings are mixed. On the one hand, there are few new 'pure' green jobs currently. On the other hand, there is clear evidence of a strong greening of existing jobs. Demand for green jobs is rising slightly, though again mainly for greening jobs. These findings show that a greening of jobs is occurring in Scotland through qualitative changes to existing jobs driven by green activities and technologies. Whether the new job titles revealed in the vacancy data merely reflect the greening of job labels (greenwashing) or signal more substantive changes to the content of jobs is not sufficiently clear, but this development further shows that it is possible for non-green jobs to change. As such, change is clearly happening that supports a greening of jobs across the economy, though not the change anticipated in current policy, with its emphasis on pure green jobs (e.g. Renner et al. 2008). In terms of a just transition and the quality of green jobs in Scotland, the data shows that green jobs generally offer higher wages than non-green jobs because green jobs are higher skilled professional, associate professional and skilled trades occupations. Moreover, the green jobs pay premium seems to be widening. However, in terms of inclusiveness, women are markedly under-represented in green jobs in Scotland, with green jobs employing mainly male workers. Overall, these findings

suggest that the transition to 'pure' green jobs is still limited and that while good jobs exist, the employment benefits of the transition to net zero are, so far, less inclusive than anticipated and that policy and practice need to adjust. Moreover, these findings for Scotland as a whole in terms of the proportion of green jobs and their pay and gender composition are replicated at regional level within both Scotland England – see for example Cardenas Rubio et al. (2023) and Dickinson et al. (2022) respectively.

At present, government policy internationally assumes that there will be a rise in green jobs and that these jobs will be good and inclusive, part of a just transient to a net zero future (EU 2023; HM Government 2021; ILO 2023; OECD 2021; UN 2021). These assumptions need to be tempered. Our findings for Scotland and other parts of the UK suggest that the extent and demand for pure green jobs is limited so far and that while those jobs that do exist offer higher pay, which as a marker of job quality suggests that they are good jobs, these jobs are exclusive in the sense that they tend to employ male workers. To help realise a net zero economy, stimulating employer demand for 'pure' New & Emerging green jobs will be needed. There are a number of ways in which this demand stimulation might occur: through, for example, green investment, state/regional-level regulation and incentive schemes (Cedefop 2012; Rodrik 2014) and firm-level 'eco-innovation' (Gagliardi et al. 2016). Developing an ecosystem approach to workforce development and planning that specifies the key actors and their roles, responsibilities, resources and relationships would be helpful, if a complex (Warhurst and Findlay, 2012; Anderson, 2010). Supporting the greening of existing jobs might be less challenging. Given that it is incremental changes to these jobs' skills and knowledge, one way of encouraging this greening will be through training that delivers upskilling and reskilling using micro-credentials (see Karanovic et al. 2022) rather than create new degrees or apprenticeships. Whilst it requires modification rather than reconfiguration of skills systems, past evidence suggests that this provision runs the danger of 'capture' by education and training providers unless embedded within well-functioning ecosystems (Buchanan et al. 2017). There are already initiatives to provide of such micro-credentials, for example by Una Europa. This alliance of 11 European universities offers a Micro-credential in Sustainability that is intended to be a supplement to a degree.[vi]

If a just transition for all is to be delivered, the current empirical shortfall in inclusiveness needs to be recognised and prioritised in policy (see also ILO 2023). Widening participation needs to be built into ecosystem planning (Knudsen et al. 2023), with our findings showing that there is a particular need for 'gender-transformative' planning (Kwauk and Casey 2022; see also ILO 2019; Sofroniou and Anderson 2021). In both cases – stimulating new green jobs and supporting the greening of existing jobs – there will be a need to ensure that female workers, as well as other marginalised groups, are able to benefit equitably from the transition to a net zero economy. Doing so will require inclusive training, upskilling and reskilling programmes (Kuersteiner and Ordal 2023; ILO 2019; SDS 2020). This mainstreaming of gender is evident already in Spain where, in 2020, a Just Transition Strategy was adopted that aims to ensure policies to promote green jobs enable women to take advantage of the opportunities provided by the transition (ILO 2022).

That green jobs seem to be better quality jobs is a welcome finding and concurs with the findings of other research (Consoli et al. 2016). What is needed now is monitoring and the public reporting by

the European Commission and national governments of the quality of green jobs. This task is currently hampered by the lack of an internationally agreed measure of job quality and so what might constitute a good job. In our analysis we used pay but there are other dimensions of job quality that feature in research and policy internationally (Warhurst et al. 2022), including in Scotland (Scottish Government 2021a). What is needed is an international standard measure of job quality against which green jobs can be assessed. A standard measure has been developed and adopted for the UK (see ONS, 2022) and is championed for the European Union by IndustriAll (2024). These measures have seven dimensions: pay and benefits; terms of employment; nature of work; social support; worker voice and representation; work-life balance; health, safety and psychosocial wellbeing. In addition, if the inclusiveness of the net zero transition is to be evaluated and similarly reported, there is a need to develop a set of performance metrics for an inclusive labour market. These metrics ought to include the female employment gap as well as similar gaps for other marginalised groups previously highlighted by the European Commission for example as in need of support: older and younger, migrant and low-skilled workers (EC 2010). These metrics should also be able to capture transitions of workers from employment in sunset fossil fuel dependent sectors to the sunrise sectors related to the environment sector/s as well as capture the rate of greening in existing occupations. Taken together, these metrics might form what might be called a Climate Change Labour Market Index.

The implementation of these suggestions would be more effective if part of a new integrated policy development. Policy silos are rarely effective. Climate change policy needs to envelop not only economic policy but incorporate education and training, employment and social policies. Only with these policies' integration will green jobs help deliver a just transition that addresses climate change. While we have provided improved definitional and empirical understanding of green jobs in Scotland, the Scottish findings offer not just empirical insights in the extent, demand and quality of green jobs and who works in them, they also offer theoretical insights into how a just transition might be achieved through green jobs.

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Safe and Healthy Green Jobs – Challenges and Opportunities

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Abstract

The green transition builds on a change to fossil-free energy and to a circular economy. In a European context, the major policy initiative is the Green Deal. While this transition needs to be rapid, gains and losses of jobs need to be considered. This may have profound positive and negative effects for different occupational groups as greening of the jobs may both eliminate current risks (e.g. associated with fossil fuels) and introduce new ones. This article provides examples of such risks to occupational safety and health. It also discusses employment conditions and worker bargaining power in relation to the twin digital and green transition. In order to reduce negative effects of the green transition on the health and safety of workers, we suggest that there is an urgent need to establish strategies for safe and healthy green jobs. We proceed to suggest steps towards such a Roadmap and also indicate some key knowledge gaps.

Keywords
Green Deal, green transition, creative destruction, occupational safety and health, circular economy, chemical health risks, twin transition, roadmap for safe and healthy green jobs

Introduction

In 2019, the European Commission initiated an ambitious Green Deal (European Commission 2019) to reorient EU policy toward a modern, competitive economy where economic growth has been decoupled from resource consumption. In essence, the Green Deal describes the transition from fossil fuels to fossil-free energy and to a circular economy with zero or much reduced waste. In order to reduce potential negative socio-economic impact of the Green Deal, there is also an element of "just transition" in EU policy making. However, forced rapid expansion of new industrial programmes may introduce new occupational health risks and exacerbate already existing ones, and further enhance the polarization in employment and working conditions within the workforce. In the following we describe opportunities and challenges of the green transition on jobs and on occupational safety and health, mainly from the European perspective.

The article starts with an overview of the occupational health and safety (OSH) risks specifically associated with transitioning to fossil-free energy and the circular economy, followed by a section on opportunities and challenges for a safe and healthy green transition in the context of other changes, e.g. the twin (green and digital) transition and a more unstable world with a battle for critical and strategic resources. We argue that worker bargaining power, the inclusion of worker health and safety, and of worker voice, are key for a just and sustainable green transition. This is followed by a historical reflection on the restructuring of the labour market in an economic developmental perspective, and forecasts on job losses and gains associated with the transition. The article ends by outlining potential steps in a Roadmap for Safe and Healthy Green Jobs and key knowledge gaps.

Greening - entry of new risks and exit of old ones?

We focus here on three areas where we foresee potential chemical and physical health risks in the working environment as a consequence of the Green Deal: the fossil fuel–free transition, new chemicals and processes, and the circular economy. The risks encompass both new risks and the return of old risks.

Fossil-fuel free transition

Globally, 12.7 million are employed in wind, solar photovoltaic, bioenergy, hydropower, geothermal, and other renewable energy jobs (IRENA and ILO, 2022). The number is expected to increase as we are transitioning from fossil fuel to fossil-free energy. For example, wind turbine service technician is the fastest growing occupation in the US (US Bureau of Labour Statistics, 2023). Installation and maintenance of wind turbines encompass manually demanding tasks associated with increased risks of musculoskeletal disorders of the upper extremities (Cooper et al., 2014; Velasco-Garrido et al., 2020), and accidents when working at

heights. During manufacture of windmill blades there is substantial risk of human exposure to epoxy-resins, skin sensitisation and contact dermatitis (Christiansen et al., 2024). Waste from windmill blades is accumulating and how they should be recycled with little environmental impact is yet unclear.

Workers involved in the production of cadmium/arsenic-based photovoltaic modules may be routinely or accidentally exposed to cadmium- or arsenic-containing inorganic compounds (Bakhyi et al., 2014; Spinazzè et al., 2015). At the same time, there is an increased risk of accidents and exposure to magnetic and electric fields (Bakhyi et al., 2014).

Renewable liquid fuels are being developed for road transport, shipping and aviation. Biodiesel is already on the market and is one of the few renewable fuels that has been evaluated for toxicity; *in vitro* and *in vivo* studies have provided evidence for oxidative stress, genotoxicity, and inflammation, in some cases stronger effects have been observed than for fossil diesel (Selley et al., 2019; Møller et al., 2020). Liquid fuels include synthetic e-fuels (from captured CO_2), isoparaffin, and lignin, biofuels, carbon-free gas fuels such as ammonia and hydrogen, and fuel cells, but less is known about exposure and health risks. For example, ammonia is irritating and causes acute effects when used for other purposes, thus more knowledge is needed about exposure and health risks when it is used as a fuel.

New types of batteries are being developed, the most prominent example is lithium-ion-batteries that apart from lithium also contain other toxic metals and organic chemicals including PFAS (Rensmo et al., 2023). However, producing and handling may impose occupational risks, including fires (Perttula et al., 2023). One example comes from the recent effort to rapidly establish a lithium-ion battery factory in Sweden, where chemical leaks at the workplace repeatedly have been reported (The Guardian, 2024). Further efforts aim to develop new, sustainable batteries with a long life to store energy from wind power or solar energy (Amici et al., 2022).

New chemicals, materials, and processes

The green transition requires development of new materials for plastics, carbon capture and storage (CSS), catalysts, industrial uses, and other emerging applications. Ideally, this should be performed according to safe and sustainable by design criteria for chemicals and materials (European Commission, 2022). However, like with the fossil-free fuels, the potential risks associated with these materials and the processes of producing and using them remain understudied.

Examples of new materials include nanocellulose for manufacturing stronger and more fire-resistant plastics (Oliaei et al., 2022), lignin as a bitumen extender in the production of asphalt mixtures (Pérez et al., 2019), and graphene for multiple purposes. Nanocellulose can be tailored to be superabsorbent, rendering it suitable for use in diapers, for example. Also,

graphene is a very strong material that can be added to concrete, improving its performance and crucially reducing the need for cement, a very energy-intensive product. However, whether the benefits of graphene outweigh the problems remains unclear (Collins, 2022).

One CCS process is mineral carbonation, in which CO_2 reacts with calcium or magnesium silicates in rocks to form calcium or magnesium carbonates. These carbonates can be used as building materials or stored. A disadvantage of this technology is that it requires a lot of mining to produce the minerals. Another process for CCS uses amines, but this technique could produce carcinogenic nitrosamines in the working environment (Gentry et al., 2014). Furthermore, new research (Fu et al., 2022) has shown the possibility of low-cost alternatives, e.g. cellulose foam, infused with zeolites with selective CO_2-capturing properties. Trapped CO_2 may be used to produce new chemicals from renewable raw materials.

For most of these new chemicals and processes, the health effects in workers remain unknown. Health risks from these exposures may be acute (e.g. give acute airway respiratory symptoms) but also become clinically manifest decades after onset of exposure, as cancer or lung fibrosis. For example, nanocellulose is made of fibres similar to asbestos, and the zeolites used in industrial applications have shown lung toxicity (Yu et al., 2021). Graphene and nanocellulose have been reported to cause lung toxicity in vitro and in animal studies and some studies have shown lung fibrosis (Brand et al., 2022; Fadeel et al., 2019; Kong et al., 2024). The often rapid changes in new "green" chemicals warrant follow-up studies in humans, and with a particular focus on long term impact.

Circular economy - recycling

The circular economy is tightly linked to the green transition since the latter leads to new and rapidly increasing demands for critical raw materials, of which the majority are metals, which we currently import and now should be recycled. Although municipalities and industries in many countries recycle some waste, completely closing the circle requires radical changes to how production and consumption are organised, and massive increases in recycling capacity with consequences for the working environment. For example, from 2000 to 2019, the number of people employed in the Swedish private-sector waste and recycling industry increased by 80% from 8200 to 14700 registered workers (SCB, 2021), and the industry is expected to grow further.

The recycling work ranges from manual to highly automated closed systems. In e-waste recycling for example, the recycling stage includes manual disassembly, sorting, and size reduction by crushing and grinding. Thereafter, the various fractions are processed further or are disposed of by incineration or in landfills. All of these processes have the potential to cause hazardous exposure to workers. Moreover, the complex nature of the waste, particularly e-waste, makes it difficult to define exposures (Bakhiyi et al., 2018). Therefore, the

safety of workers in this expanding field requires additional research to define risks and devise effective mitigation strategies.

Elevated levels of lead, mercury, copper, and cobalt in the work environment have been detected in facilities for sorting and recycling different waste streams; moreover, elevated levels of mercury and lead in the blood have been found among people who recycle metal goods and batteries (Poole and Basu, 2017). Brominated compounds and other flame retardants have also been found in the air during recycling of e-waste (Guo et al., 2015; Cai et al., 2020). Studies have measured workers' exposure in the metal recycling industry; fewer have investigated the resulting health effects. Impaired lung function and pulmonary, gastrointestinal, eye, and skin symptoms have been found in workers sorting and recycling e-waste and plastics (Poole and Basu, 2017). It should be noted that also reuse, another of the cornerstones of the circular economy may also lead to exposure to old contaminants among workers handling used materials, but this is even less studied than exposure during recycling.

Potential challenges in proactive health and safety management

Initiatives for a green transition and sustainable production and consumption have the potential for new exposures from novel fuel types, high exposure to new toxic substances (e.g., nanocellulose, graphene, critical raw materials), or 'old' toxicants in new settings and other exposures of concern, such as asbestos, PCB, arsenic and dust (EU-OSHA, 2021; HSE, 2013; Chevenal et al., 2017). As stated in EU's strategic plan for 2021–2027 (EU, 2021), when implementation has begun on several initiatives under the Green Deal and EU chemicals strategy for sustainability, the current limit values of certain hazardous substances used in existing and emerging sectors need to be reviewed.

Gaining knowledge about risks is only a first step towards protecting workers' health; implementing safe working practices requires knowledge transfer to managers and employees at the workplaces. As stated by Guy Ryder, director general of International Labour Organisation (ILO), the qualitative employment dimension of the just transition process needs to be addressed from the understanding that a "green job" is not by definition a decent job; green jobs will be made "decent" not by default, but by design (ILO, 2017). Hence, it is important to identify knowledge gaps, opportunities, and barriers for a safe and sustainable work environment throughout the green transition.

We are facing a major transition to get from today's circularity to the target of 100%. This challenge also presents an opportunity when designing industrial processes to proactively include work environment–related aspects, such as safe handling and minimized exposure also when materials are changing over time.

The green transition and occupational safety and health in the context of bargaining power

The European Commission increasingly refers to the 'twin transition' to describe the concurrent processes of decarbonizing economies (green transition) and advancing digital technologies (digital transition). The intention is that these two megatrends will reinforce each other, ultimately contributing to sustainable growth, just employment conditions, and improved worker well-being (Muench et al., 2022). While the health and safety risks described above seriously challenge the intentions and goals of the 'twin transition' and Just Transition, research shows that green investments increase the probability of decentralised agreements due to the reskilling and upskilling required to transform brown jobs to green jobs – and could thus have positive effects on working conditions and bargaining power (Damiani et al., 2024).

The labour environmentalism literature includes several positive examples of union action to include environmental issues in negotiations and other activities. One is how works councils and/or health and safety committees in the chemical sector have expanded their functions to include environment- or climate related questions in Belgium, France, Germany and Italy (Markey and McIvor, 2019). Another example is how trade unions have facilitated environmental skills development in Denmark, France, Germany and Romania (Markey and McIvor, 2019).

One area where the digital and green transitions meet is the on-going processes of electrification, automation and digitalisation of the transport sector, which is anticipated to contribute to decarbonization and meeting the goals set in the Paris Agreement (Gong et al., 2023). Electrification has reported positive effects on the work environment of professional drivers in the form of quieter environments and less harmful gases, but also battery charging that can be experienced as stressful as it disrupts the working day (Gong et al., 2023). Thanks to digitalisation and automation, many professional drivers today have driver assistance systems that help them in their work and increase traffic safety. Downsides of these systems include potential safety risks when instructions from tablets distract the attention of drivers from the traffic (Gong et al., 2023) or the potential stress of being monitored (Nurski and Hoffman, 2022). Although the purpose of data generated by systems and sensors to a large extent relates to safety and "green" goals, it can also be used as performance data. This possibility enhances the power of the employer, who will be able to track the driving of the employee in detail. That is why trade unions increasingly address monitoring and the potential power imbalances it may lead to, demanding the right to privacy and for more transparency of collected data (DeStefano and Taes, 2023).

One aspect that could challenge the power of trade unions, and thus their ability to stand up for workers' rights to a safe and healthy work environment, is the polarization of the workforce. It has long been argued that the digitalization of the production cycle leads to a drop in jobs with a high degree of routinization and an overall increase in non-routine low-skilled work and high-skilled work (Autor, 2010). If the on-going reskilling and upskilling of employees in the green transition, e.g. in green steel production or electric car manufacturing,

will lead to polarisation is yet to be seen. However, it is a potential threat to the ability of unions to act because they traditionally build their power resources on solidarity between workers in a profession or industry (Refslund and Arnholz, 2022). Questions that arise include whether the unions will be able to generate cohesion within a polarized workforce and how to entice low-skilled workers with non-standard employment contracts to engage at all. Research from carbon-intensive economies shows that trade unions sometimes resist, and other times support the green transition, relying on strategic actions, aimed at maintaining or expanding their power resources. This strategic positioning allows unions to either become agents of change or defenders of the status quo, depending on what best serves their interests in a given context (Stevis et al., 2020; Kalt, 2022).

One example of trade union responses is the construction sector, which significantly impacts climate change. The climate strategy of the EU, which aims for carbon-neutrality by 2050, requires workers to have higher qualifications, engage in technical precision, work effectively within interdisciplinary teams, and adopt a holistic approach to construction. This shift is driving a major overhaul of vocational education and training systems and employment. The response of construction unions to this varies significantly across countries, influenced by national contexts, policy implementation, and the unions' own positions and power. For example, whereas trade unions in Denmark and Germany, align with EU strategies, unions in Italy are less involved in shaping or implementing EU policies. Overall, union engagement with the green transition in the construction sector is limited due to a decline in union membership and power, subcontracting to small firms and the use of migrant labor, which further weaken union influence (Clarke and Sahin-Dikmen, 2020).

Adjacent to the green transition of traditional industries, there are parallel developments of "the green economy" with effects on the work environment, such as carbon offsetting, eco-tourism and actions for increased biodiversity. In the Global South, foreign aid tied to "green" goals has changed economic activities, leading to an increase in casual labour models, including informal work and short-term subcontracts such as carbon counters, species identifiers, GIS mappers and tree planters (Neimark et al., 2020) with minimal access to social security and coverage of OSH regulations.

In the Global North, one of the hallmarks of the twin transition is the "platformization" of work, which can be classified into two broad categories: online platform work (tasks performed online, e.g. software development or translation) and on-location work (tasks carried out in person in e.g. transportation and delivery). Digital labour platforms provide a variety of services in the "green sector", such as green last-mile operators using electric vehicles and bikes and compete with businesses in "traditional" sectors with green arguments. Whereas the traditional sectors typically offer formal employment contracts, based on an employer and employee relationship specifying OSH rights and responsibilities, the intermediary role of digital labour platforms and their business practices shape the employment and working conditions of platform workers in which the status of workers can be ambiguous and likewise OSH rights and responsibilities.

Restructuring the labour market – gains and losses

Economic development means that employment in some sectors and firms expands but also that employment in other sectors and firms declines. It is easy to find many examples of such development in history; a "creative destruction". An economist important for the analysis of this type of development is Joseph Schumpeter. Schumpeter's theory of economic development was presented for the first time in *Theorie der wirtschaftichen Entwicklung* in 1911. The book came in a second revised edition in 1926 and was after further processing in 1934 published in English as *The Theory of Economic Development*.

Schumpeter's starting point is a community in a stationary equilibrium. He names this condition the economic cycle (the circular flow). In the economic cycle, the economic activities are only repetitive. The same goods are manufactured period after period. For each individual company, costs and revenues are equal and they are not making any profit. Schumpeter defines economic development as such changes in the economy that are not forced on the economy from the outside but come from in it. With this definition, Schumpeter excludes changes caused by war, natural disasters and population growth. Economic development consists of spontaneous and non-continuous processes changes in the production functions, changes that lead away from the equilibrium. A firm is combining different factors of production. Economic development is the implementation of new combinations, which Schumpeter called innovations. An innovation can be: 1) the introduction of a new product, 2) the introduction of a new production method, 3) the discovery of a new market, 4) the conquest of a new source for raw material or semi-finished products or 5) the reorganization of an industry. An innovation and an invention are not the same thing. An innovation can be the exploitation of an invention but is not itself the invention. The production factors that are required to be carried out the innovations must be taken from their previous employment in that economy. As a rule, this happens by granting the innovator credit, a credit that is usually financed through banks. The credit expansion means that prices are raised, and that space is thus prepared for the new business.

The person who implements an innovation is called an entrepreneur. A business owner who only administers a company is not counted as an entrepreneur. Being an entrepreneur is not a special profession and business owners do not belong to a special class. On the other hand, enterprises that function lead to positions within a social class for the successful entrepreneur and his family. There are always many innovations that are theoretically possible. The importance of carrying out an innovation lies partly in calculating the consequences of something unknown, partly in the extra energy needed to do something that is right outside the daily routine work, partly in the community's disapproval of someone who does something new. Schumpeter names three motives that drive a person to overcome these obstacles and become an entrepreneur: 1) the desire to found an industrial dynasty, 2) the desire to compete with others, and 3) the joy of getting things sorted out. When the entrepreneur has made the innovation, the entrepreneur receives a profit until other

companies have had time to transfer resources to the same business. A new equilibrium then arises with a higher production value and another composition of the production. The effects are larger if they influence sectors employing many. There are many studies regarding creative destruction analyzing Schumpeter's theory of the changes of the economy. See for example Aghion et al. (2019) and Nicolas (2003).

Changes in the composition of production and employment could not only be initiated by innovations as in Schumpeter's theory but also initiated by policy changes as a green policy and of course also by wars and conflicts influencing international trade.

Creative destruction is in most cases favorable for some in the economy but not for all. Some lose their jobs at the same time as others get new jobs. Those losing jobs may need help to find new jobs, for example by training or education. See Acemoglu and Johnson (2023) for a study on how the development of economies in the last centuries have had different effects for different groups, often very negative effects for some groups at the same time as positive effects for other groups. This is the case also with "green policies". While such policies may eliminate some work environment problems, they may also introduce new ones. That is why it is important to study the effects of green policies regarding the work environment. It would be of value to compare with studies of the creative destruction of the development of AI. See for example Uctu et al. (2024).

Global scenarios for 2030 on job creation and job destruction from the energy transition and circular economy presented by ILO (2019) indicate substantial effects. For the circular economy job destruction is estimated at 71 million (59 million males) and job growth at 78 million (54 million males), out of which 49 million are expected to be able to reallocate within occupation with appropriate reskilling and upskilling, while 22 million will have to be reskilled into new occupations. The estimated labour market effect of the energy transition was less, an estimated potential loss of 7 million jobs but at the same time growth of 25 million jobs. The major changes in both losses and growth were foreseen within medium-skilled occupations, and smaller changes in low-skilled (net loss) and high-skilled (net gain) ones. The occupations with the main anticipated growth were for the energy transition Building and related trade workers and Labourers in mining, construction, manufacturing and transport, and for the circular economy Sales workers and Metal, machinery and related trades workers. These are occupations with varying degrees of current occupational hazards and non-standard employment which could easily be worsened unless worker rights and occupational health and safety are properly considered.

Towards a Roadmap for Safe and Healthy Green Jobs

We have in the above indicated several occupational health and safety challenges and opportunities associated with the green transition. Foresight scenarios developed by the European Agency for Safety and Health at Work (EU-OSHA) indicate that the future is largely

conditional to the extent to which OSH and worker rights are considered in the process (EU-OSHA, 2021; EU-OSHA, 2023). EU-OSHA concludes that failure to properly accommodate these aspects is likely to both impede the transition and increase social tension. The best scenario describes a fully circular economy, in which dangerous and polluting jobs have disappeared, and upskilling and reskilling has permitted workers to fill new and safe jobs. The worst scenario describes how the transition has stagnated amid economic and environmental crises and heightened social tensions. Intermediate alternatives include a carbon neutral/circular economy with worker safety issues or increasing regional divides.

Suggestions from EU-OSHA include (EU-OSHA, 2023):
- Raising awareness (e.g. through events and seminars disseminating relevant research findings)
- Protecting the marginalised, i. e. regarding the transition as an opportunity to improve the situation, and to escalate safety training and reskilling.
- OSH aspects should be integrated in decision-making, and result in evidence and foresight-based policies (e.g. as in the updated Directive and exposure limit for asbestos described below; European Commission, 2023), and OSH in public procurement standards.
- A capable OSH knowledge network will be needed generating, managing and delivering relevant information.

The green transition is, and needs to be, rapid (Whitmee et al., 2023). One of the main challenges is insufficient awareness of hazards linked to dangerous substances, such as novel chemicals, critical raw materials, recycling of materials containing asbestos, PCBs, or arsenic or the use of new technology to organize work. Insufficient risk awareness is often combined with weak bargaining power among the exposed workers and insufficient OSH-infrastructure in for example manual recycling and the construction sector.

In sectors that rely to a large extent on public procurement, one way forward can be to include health and safety requirements in the tenders.

Another way forward can be to improve existing knowledge about health and safety effects of the green transition by monitoring exposure levels, number exposed and the health impact in these expanding sectors, to assess the risk to individual workers as well as the overall disease burden. It is likely that differences between countries and regions may be substantial, depending on variation in the predominant new energy sources and type of recycling, as well as company size. Furthermore, close collaboration between toxicologists and those developing the new techniques may support safety by design and identify urgent knowledge gaps, for example regarding toxicological data for critical raw materials.

Yet another way forward is to match regulatory efforts to the green transition. This entails shortening the delays between emerging new evidence of risks and changes of occupational exposure limit values and stepping up compliance monitoring of regulations - especially in

sectors which are immature in handling hazards. An example of a forward-looking new EU-policy is the revised Asbestos directive (European Commission, 2023), which includes a 50-fold reduction of the current occupational exposure limit values aligned with updated health risk assessments of health effects, and obligations for different stakeholders to ensure that no unprotected exposure occurs. A stated rationale for these measures is the "green transition and the implementation of the European Green Deal, including, in particular, the Renovation Wave for Europe (…) the goal of which is to decarbonise buildings, tackle energy poverty and boost the Union's sovereignty by means of energy efficiency".

Lastly, EU-OSHA stresses the importance of enabling safe and healthy work environments for all workers, including the most vulnerable ones. One way forward in this endeavour is to strengthen worker representation in sectors affected by the green transition; another is the establishment of knowledge networks in the same sectors. For this purpose, institutional support to trade unions and other organisations representing the voice of workers is important – especially in sectors affected by the green transition with low levels of power resources due to low affiliation rates and collective bargaining coverage. Examples of such support can be to establish knowledge networks, encourage the inclusion of green aspects in collective bargaining and the systematic OSH management, and to inform and engage health and safety representatives in aspects related to safety and health aspects of the green transition.

Closing knowledge gaps for Safe and Healthy Green Jobs

This article has discussed how the green transition will have profound effects on available jobs, working conditions and occupational exposures. We argue that these jobs, in order to be safe, need surveillance that monitors the change as well as basic research on the health, toxicity and safety risks of new forms of work organisation, materials and techniques.

One research gap that needs to be filled is how the transition to fossil fuel–free energy will affect the work environment, for example new types of batteries and renewable fuels, that are still in the development phase. It is important to monitor which of them will be scaled up for large-scale production. Another research gap is how new technologies, including potentially toxic novel chemicals and critical raw materials, will affect humans. Schulte et al. (2024) recently suggested five OSH criteria to demonstrate responsible development of emerging technologies, each with a need for both a societal and business enterprise response.

Another knowledge gap is the one related to being new on the job. Being new is generally associated with an increased risk of accidents, and there is good reason to believe that safety risks (including unprotected exposure to hazardous substances) increase in new industries where safety procedures may lag behind. There is thus a need to map needs for reskilling and upskilling, including safety training in the industries providing the new green jobs.

Yet another knowledge gap is related to re-use and recycling. We know that this sector has the potential to introduce or substantially increase exposure to highly hazardous substances in e.g. construction materials and electronics, but we do not know if these exposures will become widespread. Furthermore, we need to know the exposure levels to assess the risks. Also in this case, monitoring and surveillance are needed as a basis for raising awareness and ensuring adequate protective measures and access to OSH expertise.

Finally, we suggest that the bargaining power and voice of workers are assessed in the context of employment conditions and occupational safety and health in jobs affected by the green transition. Social dialogue between the employers' and workers' organisations is always important, including labour unions with sufficient strength to protect the interest of their members. We suggest that this is particularly relevant in the context of job destruction and job creation in the green transition.

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Working Life in the Circular Economy: Taking Stock and Moving Forward

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Abstract

The circular economy (CE) has for long been an important strategy for sustainable development, promoting resource efficiency through reduction, reuse, and recycle. There is also a growing expectation that the CE may provide new jobs. However, working life dimensions of the CE are often treated separately from environmental and economic concerns. This is unfortunate given the impact that a transition to CE may have on salient issues in working life, including on job security, skills needed, occupational health and safety management (OHSM) and the cooperation between social partners. The lack of integration of environmental, economic and social concerns in CE also risks impeding goal achievement in several policy areas.

The present review article synthesises the existing scientific knowledge on a sustainable working life in the transformation towards a CE, and based upon the synthesis, critically explores the knowledge needs in relation to CE and working life: barriers and enablers; labour market changes; OHSM; skills requirements; the role for social partners; and policy challenges. A total of 2487 peer reviewed journal articles were identified, with 27 articles included in the review.

Future research should focus on creating and upscaling circular business models that promote transparency, collaboration, and value creation across supply chains, developing educational programs for stakeholders and the workforce. More research is required to evaluate existing policies, design effective policy frameworks, promote circular business models, and addressing employment opportunities and job security. Studies should also investigate how social partners can contribute to working life in the CE and identify necessary processes and agreements.

Keywords
Circular economy, Circular business model, Working Life, Policy, Training, Thematic analysis

Introduction

The quest for a circular economy (CE) is since at least two decades increasingly important in strategies and measures for sustainable development (Geissdoerfer et al., 2017; Ghisellini et al., 2016; Prieto-Sandoval et al., 2018). Instead of a linear production value-chain, the CE promotes resource efficiency through reduce, reuse, and recycle, thereby improving sustainability conditions, including climate mitigation (Allwood 2014).

The greening of the economy, including CE, has in recent years increasingly been seen as an opportunity to also enhance competitiveness and overall economic development (Loorbach, 2007; Loorbach & Wijsman, 2013). This double objective is reflected in the EU policy arena, including elements for circularity in the European Green Deal (EC, 2019), and the policy proposals following the 2020 Circular Economy Action Plan (EC, 2020, 2022). This also includes expectations for increasing employment (Bjerkesjö, 2021), not least for people far from the labour market (Brizga, 2022). However, in policy making, social concerns are often treated separately from environmental and economic ones, including working life conditions (Inigo & Blok, 2019; Jaeger-Erben et al., 2021; Mies & Gold, 2021; Padilla-Rivera et al., 2020; Schröder, 2020).

There are indications that this separation is the case also in the research context (Bjerkesjö, 2021). This is unfortunate since a transition to a CE may significantly affect e.g., the labour market (Aguilar-Hernandez et al., 2021), job security (Casano, 2019), skills requirements (Borms et al., 2023; Burger et al., 2019), occupational health and safety management (OHSM) (Galatti & Baruque-Ramos, 2022), and the cooperation between social partners (Bjerkesjö, 2021). Moreover, the transitions to green jobs represent complex processes, in CE involving a shift from linear models and value chains to network-based circular models. Therefore, the expansion of the CE requires new business models, markets and technologies. The lack of integration of environmental, economic and social concerns in the CE risks reproducing various goal conflicts and prevents the formulation of policies that foster goal synergies. Thus, there is a need to take stock of the current knowledge of working life in the CE and what is needed to promote sustainable development.

The present review article aims to i) synthesise the existing scientific knowledge on sustainable working life in the transition towards a CE, and based upon this, ii) explore the knowledge needs in relation to CE and working life concerns. To the best of our knowledge, no similar review has been published.

We delimit the review to two sectors: textiles and construction. These sectors are central from working life as well as environmental and economic perspectives, and due to high levels of greenhouse gas emissions and a potential for circular employment (Almasi et al., 2018; Leal Filho et al., 2019) they are targets for policy development that would benefit from a solid knowledge base. The exploration is limited to literature and circumstances that concern OECD countries, to facilitate a comparison across countries. The challenges and concerns

linked to working life in the CE lead us to focus the exploration on the following six themes: barriers and enablers; labour market changes; OHSM; skills requirements; the role for social partners; and policy challenges.

The synthesis is based on a review that began with 2487 peer reviewed journal articles identified in an extensive literature search in the Scopus database. The reviewed literature is organised around the referred themes.

Material and Methods

The review was conducted in line with the five steps of a systematic review proposed by Denyer and Tranfield (2009), namely: formulation of questions (see above), location of studies, selection and evaluation of studies, analysis and synthesis, and presentation of results. In order to retrieve relevant articles, a search string for the database Scopus was developed step by step, comprising alternate terms for circularity, plus varying concepts expressing working life parameters, plus phrases limiting the findings to the two focused sectors, all combined with a set of specifications concerning subject areas, year span and types of publication, as follows:

TITLE-ABS-KEY (circular* OR re-us* OR recycl*) AND TITLE-ABS-KEY (training* OR vocation* OR education* OR skill* OR employment OR job* OR labor OR labour OR "occupational health" OR "occupational safety" OR "health and safety" OR "value creat*" OR "value capt*" OR esg OR polic* OR "business model*" OR "gender*" OR "trade union*" OR "job security" OR "secure employment" OR "just transition") AND TITLE-ABS-KEY (construction* OR building* OR textil* OR cloth*)

We restricted the search to the six subject areas of engineering, environmental sciences, social sciences, business, management and accounting, multidisciplinary, as well as to final articles, reviews or chapters in English language, published in journals from 2009 up to the date for the search, September 26, 2023. Applying this search string resulted in 2487 articles. These were all scanned by one of the authors on title level for general relevance and OECD connection to increase relevance. In case of uncertainty of whether to include an article or not, abstracts were read. This selection resulted in 687 articles, of which one of the authors identified 41 articles based upon abstracts that convincingly showed that the article to a significant degree address the research aims. The 41 articles were then divided into four groups, one for each author to review fully and to describe systematically in a shared excel file (see below). As part of that process, a further 14 articles were deselected, resulting in the 27 articles reviewed here. The authors then explored the selected articles with a focus on content, focused area, methods, outcomes, proposed solutions, key terms used, research gaps identified and other aspects worth noticing.

Results

The results are presented below according to five of the themes in focus, since there were no articles addressing social partners' roles.

Barriers and enablers

Ten articles (Coscieme et al., 2022; Cruz Rios et al., 2021; Cuc et al., 2015; Harala et al., 2023; Illankoon & Vithanage, 2023; Kazancoglu et al., 2020; Shooshtarian et al., 2022; Singh et al., 2019; Wiebe et al., 2023) address barriers and enablers to circular business activities, focusing on the design of circular business models, involving innovation, novel assessment and information sharing methods, and tools for upscaling.

Traditional business models follow linear value chains, whereas circular business models operate within value networks and industry ecosystems (Singh et al., 2019). However, there is a scarcity of studies offering comprehensive insights into the entire value network. Moreover, the few studies that exist frequently neglect the holistic perspective integrating an overarching business model perspective with considerations of technology, skills, materials, and regulations as well as design, materials, manufacturing, distribution, reverse logistics, collection, sorting, and recycling (Kazancoglu et al., 2020). For example, Osobajo et al. (2022) find that CE research in the construction industry shows extensive focus on resource use and waste management. There are limited investigations in other areas of construction such as supply chain integration, building designs, policy, energy efficiency, land use, offsite manufacturing, whole life costing, risk, cost reduction, cost management, and health and safety management. Cruz Rios et al. (2021) discuss the most frequently mentioned barriers in the US, e.g., cost and schedule constraints, lack of clarity on what CE entails, existing regulations and codes that hinder reuse and repair, the belief that Design for Demolition compromises building durability and resiliency, conflicting goals between pre-engineered structures and future reuse, and the widespread use of nondurable building components.

Both technological and social innovation are essential for transformation to a CE, including its impact on working life. For instance, Illankoon and Vithanage (2023) highlight the importance of modern techniques, such as digitalization of the construction sector (including Building Information Modelling, virtual reality, digital twins, and offsite manufacturing), for optimizing material use, reducing greenhouse gas emissions, and minimizing waste. Digitalization can also facilitate collaboration and information sharing activities, which are crucial enablers for reuse (Harala et al., 2023).

The evolution of circular business models and their associated value networks has been studied in Finland and Sweden, focusing on the construction industry (Harala et al., 2023). The study concludes that industry ecosystem renewal towards circularity requires changes in roles, interactions, and perceptions to enable benefits across micro, meso, and macro levels, potentially leading to the emergence of new skills and jobs. Another example is provided by

(Shooshtarian et al., 2022), investigating value networks for recycled construction and demolition waste products, identifying both barriers and enablers for expansion. Moreover, the need for social innovations is emphasized, stretching beyond the mere traditional technological innovations (Coscieme et al., 2022).

Measurement and assessment of efficiency is also outlined in connection to circular businesses, such as thorough Life Cycle Assessments (LCAs) for textile end-of-life stages, highlighting a lack of research on clothing's environmental impacts. Research advocates for broader LCAs, suggesting a shift towards assessing reuse and recycling effectiveness in construction waste management facilities (Cuc et al., 2015). Transparency is a critical aspect connected to measurement and assessment, highlighting barriers to circularity stemming from the necessity of transparency and information sharing (Kazancoglu et al., 2020). In line with this, Wiebe et al. (2023) delve into the triple bottom line across five value chains, emphasizing the significance of transparency in generating multiple values. They interpret the social dimension through the lens of equity, particularly measured by employment opportunities, shedding light on the interconnectedness of economic, social, and environmental factors in value creation. Making new types of value creation and value capturing transparent is central. Initiatives such as textile repair, resource sharing, and product lifespan extension (value creation) not only align with a sustainable value proposition but also contribute to activities that enhance resource sustainability (value capture). This comprehensive approach addresses environmental concerns, ensures transparency in social values, and generates employment opportunities and understanding of equitable access to resources (Wiebe et al., 2023).

Moreover, for circular business models to come through, there is a need to achieve a comprehensive understanding of the upscaling of business models and the upcycling practices in value networks (Singh et al., 2019). In line with this, scholars underscore the current lack of practical tools available to facilitate the transition from linear to circular business models, highlighting the urgent need for the development of such tools to support the implementation of circular practices (Coscieme et al., 2022).

Labour market changes

Seven studies (Cuc et al., 2015; Econie & Dougherty, 2019; Gregson et al., 2016; Harala et al., 2023; Repp et al., 2021; Ross et al., 2023; Wiebe et al., 2023) offer insights into social aspects on how CE practices can influence employment dynamics, spanning from improved work satisfaction to alterations in employment trends and unsecure employment.

Circular practices have shown to enhance work satisfaction as employees are able to work in a more sustainable manner. This is beneficial for companies as it results in more engaged workers, ultimately boosting efficiency (Harala et al., 2023).

The transition from a linear to a circular economy is often viewed as a means to generate positive social impacts by increasing employment through labour-intensive activities such as reuse and recycling (Cuc et al., 2015). However, this shift can also result in reduced employment opportunities in low-income countries, in which primary production is predominantly situated. This is particularly the case in sectors like textiles. For example, Repp et al. (2021) note that a focus on CE within the EU could reduce employment in low- to upper-middle-income countries outside the EU while increasing domestic employment. This employment dynamic should be a key consideration when designing CE and environmental policies. Balancing these employment changes is crucial in global supply chains.

Similarly, Wiebe et al. (2023) demonstrate that transitioning from linear to more circular business models (repair, share, use longer) leads to increased domestic employment in Norway but may also result in decreased imports, potentially leading to lower emissions and also lower employment globally. For both textiles and construction, most of the new jobs will be low to medium-skilled (Wiebe et al. (2023). Ross et al. (2023) use an input output model for Germany that also considers second-order changes from a 15-percent decrease in intermediates-use in the construction industry. They conclude that an increase in jobs in the construction industry is accompanied by a fall in prices in the raw materials industry, which leads to increased exports when exchange rates fall.

CE may also enforce unsecure employment. Gregson et al. (2016) point out that recycling work in the EU relies heavily on migrant labour, which may be associated with issues related to work-life balance, racial disparities, gender stereotypes, and power imbalances. It is important to note that the study does not offer specific solutions but aims to raise awareness for policy discussions on these pressing issues. Similarly, Econie and Dougherty (2019) find that in the US, recycling workers are tightly controlled and have weak employment relations. Employment dynamics as an aspect of working life outline a critical part of circular business models, which need to be integrated with environmental and economic aspects in the CE.

Occupational health and safety management

Seven studies (Colmenero Fonseca et al., 2023; Cook et al., 2022; Delp et al., 2013; Engkvist et al., 2016; Harala et al., 2023; Powell et al., 2015; Vasconcelos & Junior, 2015) show how CE exposes worker to risks that have been eliminated from current linear production value changes or are unknown to employers, requiring improved OHSM programs, training and digital tools.

Health and safety issues might be the most significant and dominant barrier (Colmenero Fonseca et al., 2023) to achieve sustainable management of construction waste. A scoping review by Cook et al. (2022) addresses the risks to occupational and public health due to construction and demolition waste management, identifying risks due to exposure to accidents, asbestos, particulate matter, pesticides, damp and mould from wood products, dust from gypsum and flame-retardants during different variants of circularity, following the

waste hierarchy. They argue that, due to the informal character and the lack of unionization, most businesses in this industry underreport such risks and lack risk management capacity. Due to weak enforcement of legislation, this is particularly the case in low-income countries. Powell et al. (2015) provide complementary knowledge through an experimental study in which samples were taken from ten landfills across Georgia, USA, where construction and demolition waste had been discarded. The study focuses on asbestos-containing material and lead-based paint. Generally, they find that the US federal regulatory schemes for these materials are effective to limit indiscriminate disposal at landfills. The methods used can be replicated to other hazardous materials dumped at landfills, the authors conclude.

The lack of training could potentially contribute to the risks associated with accidents in the application of circular solutions. Vasconcelos and Junior (2015) report from fieldwork that analyses the causes of fatal accidents involving the use of mobile crushing equipment for recycling construction materials. Possible causes of these accidents included design flaws in the mobile crushing equipment, insufficient guidance from the manufacturers regarding bridge usage, inappropriate operating procedures, and a lack of training within the management team. To address these issues, corrective and preventive measures are proposed, with a specific focus on improving the design of the products involved in the accidents.

An internship occupational health training program in the US (Delp et al., 2013) address recycling jobs, whereas Engkvist et al. (2016) report from an intervention program to redesign Swedish recycling centres to improve occupational health and safety. Furthermore, digitalization is essential not only from a CE perspective but also for supporting workplace safety and ensuring the safety of reused materials (Harala et al., 2023). Occupational health and safety outlines one of the central components of working life, which is also a critical part of circular business models.

Skills requirements

Ten studies (Coscieme et al., 2022; Gillott et al., 2022; Illankoon & Vithanage, 2023; Katerusha, 2021; Kazancoglu et al., 2020; Mayer, 2020; Orsini & Marrone, 2019; Park & Tucker, 2017; Schumacher & Forster, 2022; Singh et al., 2019) show that lack of and insufficient knowledge, skills, training, education are among the most prominent factors impeding the growth of CE, specifically regarding working life aspects and integration of such aspects into circular business models.

In both the construction and textile sectors, lack of knowledge and insufficient skills, along with the need for training, are often referred to as significant barriers. Circular solutions, particularly in the textile industry, are often considered labour-intensive, especially in collection, sorting, and repairing processes (Kazancoglu et al., 2020). This labour-intensive nature can be a barrier to CE adoption, as it can reduce production efficiency, increase product prices, and extend the launching time to market (Kazancoglu et al., 2020).

Construction companies should prioritize investments in training programs to enhance the digital skills of their workforce and embrace digital technological applications in construction projects (Illankoon & Vithanage, 2023)

In the textile sector, areas requiring further attention include training in technical and business-management skills, and quality testing Coscieme et al. (2022); (Kazancoglu et al., 2020). Design knowledge hubs or similar knowledge sharing platforms have the potential to enhance the visibility of innovators in sustainable fashion, facilitating learning and sharing of successful approaches and practices for the CE. Similarly, Singh et al. (2019) identify key challenges and success factors related to upcycling in the textile industry in the UK. Among the challenges identified, lack of adequate resources is a crucial issue, including skilled labour. Conversely, success factors include the availability of critical resources, such as skilled personnel for upcycling designers and makers, as well as financial support for skill development and suitable work environments. To address the skills gap, Singh et al. (2019) suggest enhancing educational capacities and technical expertise in educational institutions and creating platforms for knowledge exchange, possibly through specialized organizations or collaboration opportunities with businesses.

In the construction sector, similar challenges related to knowledge and skilled workers are encountered. For example, Orsini and Marrone (2019) highlight the lack of skills for strategies like "use of natural resources" and "proper application methods during construction to minimize waste and enhance performance". Gillott et al. (2022) propose reviewing undergraduate civil and structural engineering courses to promote design for reuse and enhance the appraisal of existing structures. Training on the use of recycled concrete is also emphasized for Germany and Switzerland by Katerusha (2021).

Studies show a need to review and change existing educational programs to enhance awareness and knowledge among stakeholders. Park and Tucker (2017) explore institutional barriers to facilitate reuse in the Australian construction sector and identify a lack of awareness and knowledge among stakeholders. To overcome these barriers, sector-wide education and training programs are proposed to enhance awareness and knowledge of construction waste management, including the relationship between initial investment and lifecycle costs, as well as the benefits of reusing materials. Additionally, the study emphasizes the need for improved communication between architects and contractors. Similarly, Schumacher and Forster (2022) propose the review of undergraduate civil and structural engineering courses as a strategy to enhance the assessment of existing structures and encourage the adoption of design for adaptive reuse practices in the construction sector.

Mayer (2020) address the training issue with a well-defined program and certification tailored for construction professionals, emphasizing the importance of specialized training across the value chain and among different stakeholders. For instance, to enhance the reuse of building materials, construction workers need training that emphasizes assembly with future disassembly in mind. Disassembly workers need strategies for efficient dismantling. Reuse

retailers require training in areas such as procurement, storage, and the effective sales of reclaimed components. Similarly, reassembly workers need to acquire the necessary skills to construct reclaimed components under varying conditions. These targeted training efforts are crucial for overcoming barriers and promoting the implementation of CE solutions that integrate working life aspects with environmental and economic sustainability aspects.

Policy challenges

Nine papers (Colmenero Fonseca et al., 2023; Coscieme et al., 2022; Gillott et al., 2022; Illankoon & Vithanage, 2023; Katerusha, 2021; Kazancoglu et al., 2020; Schumacher & Forster, 2022; Shooshtarian et al., 2022; Wiebe et al., 2023) suggest policy development to support the transformation to CE and to strengthen the social sustainability in those businesses.

Coscieme et al. (2022) propose a framework that integrates key components for system transformation into a tool to analyze circular business models in a systemic context, supported by designed policy and consumer behavior-change strategies and initiatives across the life cycle. Schumacher and Forster (2022) suggest a broad set of clear recommendations, from collaboration and labelling to policy and education. Colmenero Fonseca et al. (2023) list various policy points for improving circularity, including C&D waste management, and increasing export fees. Likewise, Illankoon and Vithanage (2023) suggest the need for regulatory bodies and construction businesses to step in to promote circularity in construction. Katerusha (2021) finds that a mix of instruments is required to address the factors that inhibit increased recycling and the use of secondary building materials (see also Kazancoglu et al., 2020). Shooshtarian et al. (2022) also suggest government policies, such as preventing illegal dumping, defining waste clearly, implementing well-designed landfill levies, setting targets for the use of recycled products, and promoting consistency among public organizations in valuing and using recycled products.

Wiebe et al. (2023) use modelling to explore how increased textile repair, share and long use, as well as building materials reuse, repurpose and recycle point towards increased employment. The results are useful for identifying both potentially stranded jobs and job opportunities, of which the latter may be stimulated by e.g., stricter waste sorting requirements, tax system reform, and market and design regulations, including for product longevity. In a more specific study, focusing on so-called vertical extension of buildings, by adding new stories, Gillott et al. (2022) describe barriers and enablers for such adaptation and reuse of technically embedded carbon. Based on interviews, they find that, in the U.K., planning requirements and biased VAT schemes constitute barriers, which after reform could be turned into enablers. Besides the need for improving engineering education, however, no policy-related proposals for the social and working life-dimensions are presented in the article. Finally, Gregson et al. (2016) explore what they call the "dirty" side of the recycling coin, showing that resource recovery still requires manual labour, often from secondary labour markets dependent on migrant workers, which is hardly considered in policy and clean and green waste related rhetoric. Again though, no clear policy proposals are discussed.

Discussion

We have reviewed literature on CE and working life concerns, revealing a significant gap where research fails to integrate environmental and economic aspirations with the social dimensions effectively. In the following, we first highlight the limitations of the study, followed by a discussion on the practical implications and, finally, topics identified for further research.

Limitations

The selection of terms in the search string played a critical role in determining the pool of articles considered for analysis. This process involved a delicate balancing act: on the one hand, it aimed to retrieve a manageable number of articles, while on the other, it aimed to prevent the inadvertent exclusion of relevant studies. We consider the final selection providing sufficient material, except for the topics of social partners roles, in relation to the aims of the study. However, it is important to acknowledge that alternative search terms and selection filters could have yielded a somewhat different set of articles for review. Furthermore, there is a possibility that some pertinent search terms were overlooked altogether.

Practical and policy implications

The transition to a CE impacts working life by creating new jobs, particularly in reuse and recycling, but also introduces challenges such as job insecurity and health risks. This necessitates workplace innovation, collaboration between social partners, and government engagement. A significant barrier to CE adoption is the lack of knowledge and skills. Industries must develop targeted training programs to equip workers with the necessary skills for circular practices, including technical and business-management skills, and quality testing. Companies need to innovate, collaborate, and adopt digital tools to optimize material use and ensure safety. Effective CE practices rely on transparency and information sharing to build trust and ensure efficient reuse and recycling of materials. Collaboration across value networks is crucial to overcome barriers and create synergies.

To secure a just transition in the CE there is a need to ensure job quality and security, addressing skills gaps through training, and improving occupational health and safety. Effective policy frameworks are needed to support the transition to a CE, including incentives for circular business models, OHSM regulations, and support for job creation. Education and training programs must be updated to include CE principles. Social partners should collaborate to ensure just transition for all workers. Policymakers need to develop integrated policies that address environmental, economic, and social dimensions to support a sustainable and inclusive CE.

Identified research needs

Based on the reviewed articles, we identify six areas of future research inquiries. First, there is a need for research addressing the promotion of CE jobs through sustainable business models and the provision of necessary skills. This includes the development, scalability, and implementation of effective circular business models that foster transparency, collaboration, and value creation across supply chains. Additionally, research ought to target the development of educational programs and training initiatives to address knowledge and skills gaps among stakeholders in various sectors, thereby helping to overcome barriers and facilitating a successful implementation of circular economy solutions.

Second, research is needed on technical solutions and processes for developing sustainable jobs in the CE. This includes integrating digital technologies to optimize material use, reduce greenhouse gas emissions, minimize waste, improve workplace safety, and promote safe material reuse. Technological innovations and digitalization are crucial for enhancing the CE by improving resource efficiency, mitigating environmental problems, fostering collaboration, and sharing information, while also minimizing workplace safety risks and improve the safety of reused or recycled materials. Further research is required to accelerate the practical application of digital technologies, integrate education into training programs and enhance workforce digitalization skills through various means.

Third, while some policy recommendations have been given for promoting consideration of the work-life dimension of CE, more research is needed to evaluate the effectiveness of existing policies, regulatory frameworks, and incentives in driving the transition to a CE, and for overcoming identified barriers. Research is needed on the design of effective policy frameworks, promoting circular business models across different sectors, considering factors like collaboration, labelling, and taxation, while also addressing social dimensions such as employment opportunities, job security and OHSM. In line with this, further studies are needed on measures guiding the transition. The new Corporate Social Reporting Directive (CSRD) has the potential to generate fresh insights into measuring social dimensions such as employee relations, human rights, community engagement, product responsibility, anti-corruption initiatives, and board diversity. However, further empirical studies are needed to explore its practical application and impact.

Fourth, studies are also needed on how social partners along companies' value chains may contribute to working life in the CE and what processes and agreements that would be needed, as this aspect was entirely absent from the findings. Inclusivity and equality are important aspects to explore in this context.

Fifth, further research examining multiple sectors and countries beyond those in the OECD is also valuable; we see a severe shortage of such studies.

Finally, studies are warranted on how to conceptualize and theorize the work-life aspects within the CE, further integrating economic, environmental and working life dimensions. We observe a noticeable gap in success stories showcasing the practical implementation of socially inclusive circular economy (CE) initiatives. This highlights the need for further empirical research to address this deficiency.

Conclusion

The present literature review has focused on five themes in two sectors. As stated, additional research is needed to take on additional perspectives, and in-depth studies are needed in other sectors as well, to address sector-specific aspects. We still argue though, that some of our findings are relevant also for other industries. For example, developing circular business models for remanufacturing and recycling vehicle components would be important in the automotive industry, and repair and refurbishment could create new jobs in the electronics industry, but in both cases, new practices and policies are needed to ensure fair working conditions and management of health and safety risks. Similarly, reducing food waste and recycling organic waste could create new jobs also in the food and beverage industry but would require targeted training programs. Thus, the practical implications observed in the construction and textiles sectors could be valuable beyond these industries in order to create new job opportunities, improve working conditions, and address health and safety risks through practices such as remanufacturing, recycling, and waste reduction.

In closing, we conclude that it is high time to give a much stronger attention to working life issues in the rapidly expanding CE, in practice and policy, but also in research. Compared to many other aspects of the CE, such as associated climate challenges and opportunities, the various working life dimensions have so far received way too little interest.

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Development Practices Supporting Resilient and Sustainable Production – Exploring Greenfield Projects

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Abstract

The green transition necessitates manufacturing companies to address climate change and incorporate sustainable and resilient solutions into their production. The best opportunity to achieve such solutions in production is during development, especially in greenfield projects with fewer constraints from existing production solutions. So far, the knowledge of how to achieve this is limited. Therefore, this paper aims to elaborate on how manufacturing companies can attain sustainable and resilient production. The focus is on development practices in greenfield projects and their relation to active ownership, collaboration and learning, potentially supporting the lasting impact of change initiatives. The paper builds on results from a multiple case study, including three greenfield production development projects. A research design, involving 22 semi-structured interviews and four workshops, was applied. An analytical framework was developed to support the analysis, including active ownership, collaboration and learning. In total, 21 different development practices were identified and categorised into active ownership, collaboration, and learning. The paper contributes a new perspective on production development. As an alternative to the traditional planning-and-control perspective, a learning perspective on production development was applied, which is increasingly required for production development processes addressing new domains, such as the green transition.

Keywords

resilient production, sustainable production, production system, production development, green transition, workplace innovation

Introduction

Climate change and environmental degradation pose existential threats not only to the European Union but also to the global community. Considering the significance, the European Commission has introduced a series of policy initiatives. The European growth strategy, known as the 'Green Deal,' serves as a roadmap with the ambitious goal of transforming Europe into a climate-neutral continent by 2050 (EC, 2019). The overall objective is to detach economic growth from environmental degradation. The associated Industrial strategy, which emphasises endeavors to establish modern, resource-efficient, and sustainable industries, as well as the transition to a circular economy, underscores the pivotal role of the manufacturing industry in meeting the objectives of the 'Green Deal' (EC, 2021). In addition, adopting a human-centric perspective, where technology serves people, in combination with resilience and sustainability, is advocated for the future manufacturing industry (Breque et al., 2021). The green transition, in combination with the high pace of change and increasing complexity, challenges the manufacturing industry, and conditions for resilient and sustainable production need to be created.

The emergence of concepts such as sustainable production is driven by the intention to accelerate positive change and contribute to a more favorable world for future generations (Garetti & Taisch, 2012). To support the green transition, the production system must be considered across its complete life cycle — from the initial planning and design phase to its eventual phase-out (Johansson et al., 2019; Scharmer et al., 2023). So far, there is a lack of guidance that indicates relevant actions to achieve sustainable and resilient production (Scharmer et al., 2023). Studies focusing on production have been overshadowed in handling the environmental issue (Sarkis & Zhu, 2018). Furthermore, the number of conceptual studies on sustainable production still dominates in numbers compared to empirical studies (Jasti et al., 2022). Among the existing studies, a majority deal with brownfield development, which is the situation when an existing production system is refined or reorganised (Bellgran & Säfsten, 2010). However, during the development of new facilities in greenfield projects, there is a unique opportunity to rethink previous solutions and take larger leaps (Nåfors, 2021).

To be able to live and act in resource-efficient and sustainable economies, development projects must foster lasting impact in organisations (Svensson & Brulin, 2014). Until now, research on how the development of resilient and sustainable production can be enabled and supported is limited. As indicated above, current development practices, here defined as the activities, methods, and tools employed to design, improve, and innovate production systems, need to be revisited and potentially refined. The purpose of this paper is to elaborate on how manufacturing companies can attain sustainable and resilient production. The focus is on development practices and their relation to active ownership, collaboration and learning, potentially supporting a lasting impact of change initiatives. To fulfil this purpose, two research questions were formulated:

1. What development practices may support the development of sustainable and resilient production?

2. How can active ownership, collaboration and learning enable and support relevant development practices during the production development process?

The paper builds on results from three empirical studies of development projects involving different types of production systems.

Production development and organisational change

Understanding development and change is complex and necessitates contextual understanding and an interdisciplinary approach (van de Ven & Poole, 1995). To address the research questions in this paper, theories related to production development and organisational change is presented below.

Production development

Production development involves creating effective production processes and development of production capability (Bellgran & Säfsten, 2010). Production development implies that needs are converted into relevant physical and organisational solutions (Cochran & Rauch, 2020). The most significant opportunity to achieve sustainable and resilient production is during the early phases of the production development process (Bellgran & Säfsten, 2010). In the same way as cost, most of the impact on sustainability and resilience is decided in the early phases of the development process (Ulrich et al., 2020). Production development is often considered to be part of the product realisation process, including both product and production development (Bellgran & Säfsten, 2010; Ulrich et al., 2020).

A production system is expected to support multiple generations of products; therefore, a long-term perspective is essential during the development process. However, in general there is a lack of long-term thinking regarding the development of production systems, even though the life cycle of the production system often surpasses that of a product (Boldt, 2023; Bruch & Bellgran, 2014). The product lifecycle and the lifecycle of the corresponding production system converge during the product's production phase, see Figure 1, and a challenge is the coordination between the product and the production system, which has become even more pressing in the strive for sustainability (EC, 2021; EFFRA, 2019).
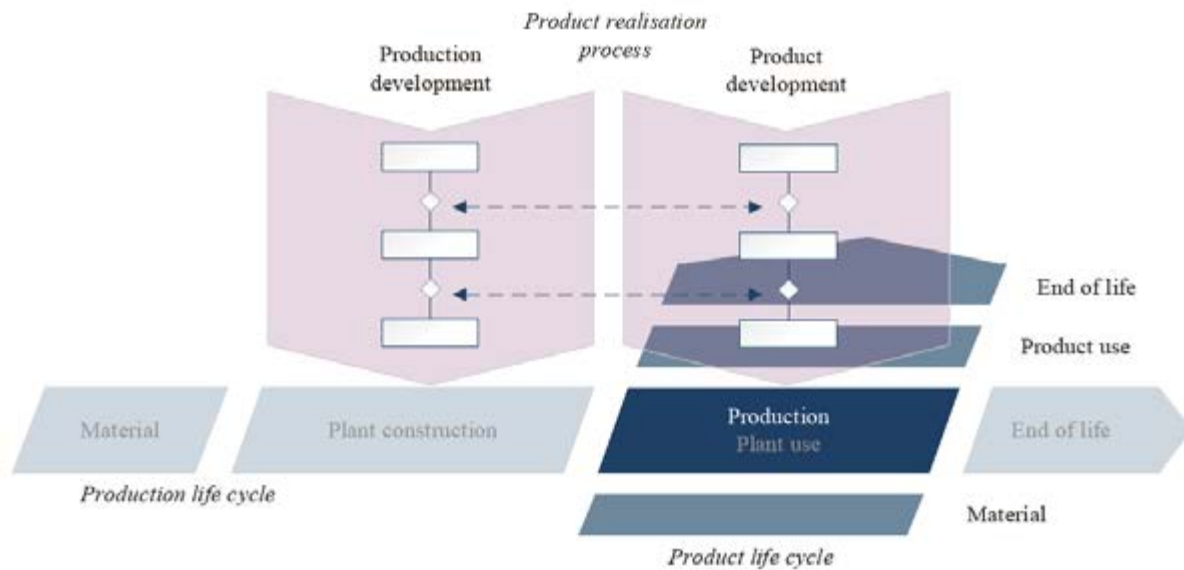
Figure 1. The intersection between product and production development (based on Vielhaber and Stoffels (2014) and Boldt (2023)).

Production development can involve the development of existing production plants (brownfield development) or establishing entirely new production facilities (greenfield development) (Nåfors, 2021). With a greenfield project, there is an opportunity to build right from scratch since the existing production system imposes fewer constraints (Bellgran & Säfsten, 2010). However, the development of production systems requires that many influencing factors are considered simultaneously. Furthermore, conditions may change over time due to the rapid pace of change, market demands, technology development, societal challenges, etc., impacting the sustainability dimensions but also requiring the capability of the manufacturing company to continually adapt and remain viable within uncertain environments, i.e., to be resilient.

Sustainable production

The urgency to act on climate change has encouraged manufacturing companies to take sustainability and circular principles into consideration when developing their production (Sarkis & Zhu, 2018; Skärin et al., 2022). Sustainable production strives to preserve resources while simultaneously promoting economic growth and improving human well-being. Definitions of sustainable production (Veleva & Ellenbecker, 2001) and sustainable manufacturing (Garetti & Taisch, 2012) commonly include the three dimensions of sustainability, social, environmental and economic, representing sustainable development (Purvis et al., 2019). Sustainable production implies that a life-cycle perspective is applied to a production system, from initial planning and design to the phase-out (Bruch & Bellgran, 2014; Stoffels & Vielhaber, 2016).

Resilient production

Resilience refers to the ability to recover quickly or easily from or resist being affected by disturbances of any kind (Oxford, 2023). It is a multidimensional concept with application across diverse fields (Essuman et al., 2020; Marchese et al., 2018; Negri et al., 2021). In the

context of Industry 5.0, resilience refers to increased robustness in industrial production, strength against disruptions, and the capability to provide and sustain critical infrastructure during crises (Breque et al., 2021).

The system should possess the ability to respond, learn, monitor and foresee potential critical events (Hollnagel, 2010), such as disturbances, problems, disruptions, and uncertainties – both planned and unplanned – that might influence the production system (Fjällström et al., 2009). Key to resilient production is the ability to adjust its functioning prior to, during, or following up on such events, where essential system abilities include knowing what to do, what to look for, what to expect, and finally the ability to learn from experience (Hollnagel, 2010). However, it is challenging to achieve resilience due to the complexity, which requires a system perspective on the production system to include aspects related to human, technology and organisation (Säfsten et al., 2023).

Production development from an organisational change perspective

A common way to approach production development is to suggest prescriptive production development models, often following a stage-gate logic (Bellgran & Säfsten, 2010). However, a challenge is the reluctance among manufacturing companies to use these development models to support production development (Boldt, 2023; Salim, 2021). The green transition necessitates manufacturing companies to adapt to sustainability challenges and incorporate relevant practices into their operations. Greenfield projects and the transition to sustainable and resilient production imply an organisational change. Therefore, an alternative approach may be to consider production development from an organisational change perspective.

Supporting organisational change initiatives

To succeed with such organisational changes, awareness of factors that can positively influence the outcome is essential (Errida & Lotfi, 2021). The area of organisational change is vast, and several models for organisational change exist (Galli, 2018). Beneath the different models, there are two underlying beliefs: a) change can be planned and managed through understanding a predefined set of steps, and b) change is an emergent, organic process that is not possible to manage in detail (Hallencreutz & Turner, 2011). The first belief (a) can be described as a structured approach, transferring individuals and organisations to a desired future state from a current state. The second belief (b) reflects an understanding of change as an ongoing learning process rather than a pre-defined series of steps (ibid). A distinction between planning-and-control models and process-and-learning models can be made (Elg et al., 2015). The former assumes that changes follow a set of predefined stages in a stable and predictable context, whereas the latter emphasizes on reflective practice and learning (Brulin & Svensson, 2012). The two approaches are not mutually exclusive; rather, both can be true at the same time.

According to Parry et al. (2013), organisational change, seen as a chaotic and complex process, can be managed continuously as it progresses. This involves interventions and

actions tailored to the project's current stage and state, providing ongoing adjustments to steer it towards a successful outcome. Da Ros et al. (2023) review highlights the necessity for change models to adapt to increasing complexity and uncertainties. Consequently, this demands a deeper understanding and consideration of organisational and human aspects in development and implementation processes.

It is essential that organisational change initiatives not just become temporary frenzy but instead lead to desirable effects in the organisations, lasting beyond a time-limited project (Svensson & Brulin, 2014). To succeed with this, three factors are relevant to consider: 1) active ownership, 2) collaboration, and 3) learning (Brulin & Svensson, 2012; Elg et al., 2015). These factors are interconnected and reflect a process-and-learning approach to change that is considered necessary in dynamic environments when previous knowledge or methods are limited (Brulin & Svensson, 2012). By addressing these factors during a development project, lasting and desirable effects can potentially be achieved, beyond the project (ibid).

The first factor, active ownership, ensures that the right conditions for the change process in terms of resources, governance, and attention, as well as means to take care of the results, are in place (Brulin & Svensson, 2012). Previous studies stress the involvement of top management, as changes are connected to organisational strategies, visions and goals (By, 2005). Leadership support involves enhancing skills and encouraging engagement and accountability for performance among actors in a change process (Bamford-Wade & Moss, 2010). As change initiatives strongly affect working conditions, a holistic understanding is needed that considers different actor's needs and interests (Docherty et al., 2008). Thus, change initiatives needs to be understood from the perspectives of working conditions providing both new opportunities, but also new prerequisites (Abrahamsson, 2022; Dhondt et al., 2023). Communication and transparency during change processes are regarded as important to enhance the understanding of different interests and set light on potentially contradictory demands (Svensson & Brulin, 2014).

The second factor, collaboration, is crucial for joint knowledge creation. Manufacturing companies need a variety of new capabilities to reduce their sustainability impacts, ranging from a more profound knowledge of materials usage to a rich understanding of social behaviour (De los Rios & Charnley, 2017). These capabilities rest upon cross-disciplinary competencies and collaboration. For example, intra-organisational collaboration involves cooperation between different organisational functions, and inter-organisational collaboration involves cooperation between different organisations. Collaboration in different forms is also crucial for achieving common goals (Boonstra, 2023). As the pace of change and development increases, it is regarded as increasingly important to achieve innovative collaborations among stakeholders that enhance flexibility and efficiency and consider aspects concerning socially sustainable work (Hasle, 2014).

The third factor, learning, is essential for workplace innovation, change, and new ways of thinking and acting. There are limitations in traditional linear approaches to change

implementation due to new development areas and the lack of possibilities to rely on previous knowledge or known methods (Elg et al., 2015). In work situations requiring rethinking and developing new approaches, a form of developmental learning occurs when individuals or groups experiment or test alternative ways of acting (Ellström, 2010). Such forms of learning are essential for organisations to increase their capability to handle or capture new or unexpected situations, problems, or challenges (Ellström, 2001). Aspects such as leadership, trustful relationships, communication and accessibility to relevant documentation impact on how an individual's learning can be transformed into organisational learning (Lundqvist, 2023; Wallo et al., 2013).

Analytical framework

To overcome the limitations of prescriptive stage-gate models, focusing on development practices may be a viable approach to support the creation of resilient and sustainable production systems. Development practices embrace the entire production development process, from planning to implementation and continuous improvement, with the aim of supporting efficiency, quality, sustainability, resilience and other requirements in the resulting production system. To achieve effects beyond a development project, the development practices may be connected to active ownership, collaboration and learning (Svensson & Brulin, 2014). With this as a starting point, an analytical framework for the purpose of this paper was developed, see Figure 2.
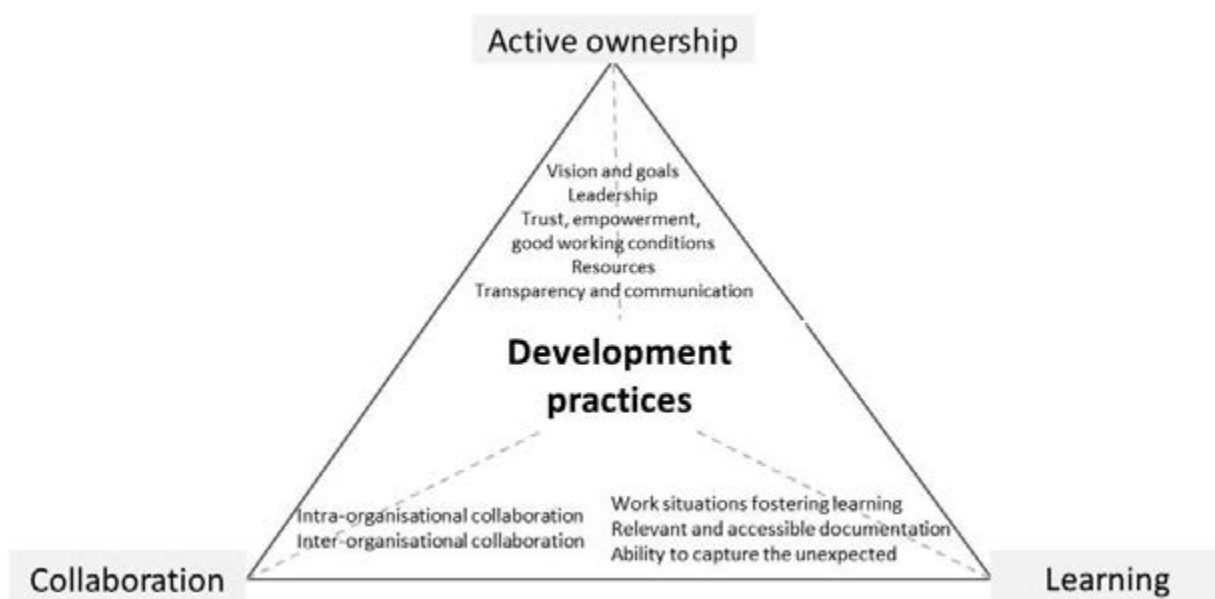
Figure 2. An analytical framework to support elaboration on development practices and their relation to active ownership, collaboration and learning (inspired by Svensson & Brulin, 2014 and Harlin, 2024).

Method and material

The results presented in this paper have been developed within an interactive research project focusing on the development of resilient and sustainable production (Säfsten et al., 2023). Interactive research implies that practitioners and researchers collaborate during all phases, from initiation to closure of a research project (Ellström et al., 2020; Svensson et al., 2015). For this paper, empirical data from three case studies have been included. The unit of analysis was development projects (Yin, 2018) carried out in three different organisations, see Table 1. The objective and the length/time frame of the studied development projects varied, as further described below. From here on, the studied development projects and involved companies are denoted as *Joint building* (Company Assistance), *Future bread production* (Company Generation), and *School kitchen* (Company Project Management); see Table 1. All three projects were classified as greenfield development, i.e., new facilities were planned. All companies had existing production facilities, which, to varied degrees, affected the new production system. Case Joint building and case Future bread production represent the industrial/private sector, and Case School kitchen the municipality/public sector. The development projects represented the development of different production systems.

Company alias	Description	Studied development project (project time)
Assistance	A manufacturing company with approximately 220 employees (year 2023), part of a large investment group. One production plant in Sweden	Joint building (2017-2024)
Generations	A family-owned food production company with approximately 260 employees (year 2023). Two geographically separated production plants in Sweden.	Future bread production (2020-ongoing)
Project Management	An industrial consultant company with four employees (year 2023), part of a group. Supporting organisations in different sectors with construction project management.	School kitchen (2021-2023)

Table 1. Industrial settings and studied production development projects

Data was collected through interviews and result workshops, see Table 2 for an overview. The interviews were semi-structured, and an interview guide was developed and anchored by the contact person at each company. The interview guide included questions about the respondents' background, roles, and experiences, as well as their understanding of sustainability and resilience in the context of production development. It also included in-depth questions about how the company worked on production development in general, and questions about the studied development project. Furthermore, questions capturing successful and hindering practices for the development of sustainable production systems were included. As was question about critical events and measures to manage these, in order to capture aspects related to resilience.

In each case, key persons were selected as respondents. In the case Joint building and Future bread production, the respondents were project managers, sub-project managers, production engineers, production managers, sustainability directors, and representatives from human resources, communication and IT departments. In the case of the School kitchen, several respondents were associated with the customer (a municipality) and the construction entrepreneurs. Therefore, the respondents included different functions and responsibilities, i.e., a school principal, a facility strategist, design manager, architect, and an installation specialist (electricity and security). The interviews were recorded and transcribed verbatim.

Workshops are an important element in interactive research (Berglund et al., 2020; Ellström et al., 2020). During the result workshops, the attendants were primarily the respondents in each company. However, both in case Future bread production and School kitchen additional persons participated. Notes were taken during the workshops. During the workshops, experiences were shared, and new insights were gained among the participants. The result workshops created an arena for discussion between academia and industry concerning a specific topic and, thereby, also an arena for learning. All interviews and workshops were carried out via the digital platform Teams.

Case study	Interviews	Result workshop
Joint building	Seven initial interviews, between 35 and 60 minutes.	On two occasions, there were a total of seven unique attendants (all respondents).
Future bread production	Eight initial interviews, between 32 and 80 minutes (Feb-May 2023). Four follow-up interviews, between 28 and 55 minutes (May 2024).	On two occasions (Dec 2022, Feb 2023), in total eight unique attendants (seven of the respondents and one additional person).
School kitchen	Seven interviews, between 31 and 90 minutes (January-June 2022). One interview involved two respondents.	On one occasion (Feb 2023), in total seven attendants (five of the respondents and two additional persons).

Table 2. Case study details

On an overall level, the analysis of the qualitative data followed the structured process suggested by Miles et al. (2019), involving data condensation, data display, and drawing and verifying conclusions. The analysis started with within-case analysis, and the results were presented and discussed at each company.

For this paper, the data was revisited, and a two-step analysis was conducted. The first step involved identifying development practices in each case. This process was guided by the questions posed regarding successful and hindering practices for the development of sustainable and resilient production systems. Quotes were used to illustrate how the development practices appeared in the data for each case. To ensure the confidentiality of

the participants involved, all quotes are provided without specific references to the roles of the respondents. During the second step of the analysis, the theoretically derived analytical framework was used, and thereby, it was possible to interpret the empirical results through a theoretical lens. Two researchers independently carried out the analysis, i.e., researcher triangulation, which strengthens the validity of the results (Yin, 2018).

Results

In this section, each case is described in detail. Initially, the context and the studied production development project are introduced. The described development practises are presented, followed by the measures taken to manage potential critical events.

Case Joint building

Company Assistance was co-locating activities from four different facilities into one new joint building. In addition, activity-based workplaces were planned for in the new facility. The purpose was to become an attractive employer and showcase a modern facility. A strong focus was on aspects related to social sustainability. One goal of the project and of the co-location was to create "one Company Assistance". Through the co-location of R&D, production, sales, and all other functions in the company, an innovation hub was envisioned, which was expected to secure the company's economic survival. Another goal was to create a best practice example of an accessible workplace. Accessibility and inclusion were described as part of the company´s DNA: "…in terms of accessibility, we really believe in this, being inclusive is part of the whole company DNA." Both economic and environmental sustainability were also important, although thinking economically was described as natural. The environmental requirements of the new building were ambitious, adapting to the LEED (Leadership in Energy and Environmental Design) gold certification.

To manage the co-location, two closely connected development projects were formed: a real estate project focusing on planning and building the facility, and a relocation and change project focusing on planning and implementing the co-location. In this study, the focus was on the relocation and change project. An informal project start was described in 2017, and the planned end date was September 2024. A formal project manager was assigned in 2021. A part-time consultant was assigned to support the project team with the real estate part of the project. An overall steering group was assigned, and a local steering group was formed to support the project manager. For each of the areas to be relocated, e.g., R&D and production, sub-project managers were assigned.

Good preparatory work was described as key to succeeding with the project – to understand what to do and how to do it, and to prepare people for change. During the project, a strong focus was on change management to get everyone on board. Another perceived success factor was the support from well-resourced owners with a strong commitment to

sustainability, who stood behind both Company Assistance and the construction company responsible for the building.

Development practices

Management involvement was perceived as essential for raising awareness of sustainability issues within the organisation. Through the involvement of key persons in the project team, it was perceived that the possibility of finding and using sustainable solutions increased: "... the key people who have been a little higher up, and then linked to the steering group and such, who are also very driven in bringing out sustainability issues and finding solutions and not making compromises."

The cross-functional integration was mentioned as important for the possibility of finding sustainable solutions. Not having a holistic view, integrating relevant perspectives and functions could have long-lasting consequences "... it's like the old saying – as an engineering designer, you can design in more problems than a production technician can eliminate in a lifetime, just in one morning."

During the development phase of the project, the operationalisation of goals was mentioned as challenging. In the case of Joint building, with a strong focus on social sustainability, operationalisation of their accessibility goal was perceived as challenging. However, it also gave an opportunity for the involved partners to learn. As one example, some of the accessibility adaptations were perceived as challenging by the construction company, but at the same time, it gave them a learning opportunity: "At the same time, they may also be tempted to learn more, because this may be in their interest to also gain knowledge about". The operationalisation of goals also gave rise to a conflict of interest. Some of the suggested solutions that were better from a sustainability perspective were not possible to realise due to the time frame of the project or due to economic reasons.

In the assembly plant, the emphasis was on layout planning and material flows: "We have worked a lot with layouts and flows and how that part should look". The ambition was to involve operators, and other employees close to production, aligned with their ordinary way of working in production development: "... they [production personnel] are not just here to screw or move things in the warehouse; they must also improve the processes they work in." When different automated production solutions were discussed, the importance of not limiting future development was mentioned. They were currently reluctant towards automation solutions, with the main argument: "... automated solutions may not be quite there yet, and we may not really want to buy into such a solution right now."

Measures for handling potential critical events

In the case of the Joint building several measures aimed at handling consequences from disturbances or potential threats were described. They had assigned a group to foresee potential critical events proactively. Experience from previous relocation projects in the company was part of the input. In production, the competent and flexible staff was described

as able to handle all possible variants. To avoid unnecessary challenges during the relocation project, a planned change of the business system was postponed until after the move to the new facilities. The entire project was driven by the vision to become an attractive employer for the future. They described a high ability to solve problems, especially in stressful situations: "… we are quite good at firefighting, to solve the problem." Although several preventive measures were employed, they described that their weak spot was to prevent critical events from appearing in the first place.

Case Future bread production

Company Generation was setting up a new production plant focusing on resource-efficient production, flexibility, scalability and sustainability for future competitiveness. By 2032, the goal was 100% circular production and fully automated production. The company's sustainability work was largely driven by the owners' high ambitions, where the focus was on circularity with minimal footprint.

The development project was initiated because of a fire where a newly built, but not yet inaugurated, production line burnt to the ground together with the rest of the facility. The development project's time frame was largely governed by the terms and conditions related to the insurance. The project start was in August 2020. While the project was ongoing, several external factors, such as raw material availability and customer behaviour, required adjustments to the project content. However, they perceived that their ability to adapt to surrounding changes was good: "… the world is so changeable, and the company is like an amoeba, changing all the time." In 2024, the project activities were partly transferred into daily work, and smaller and specific development initiatives were ongoing related to the overall goals initially formulated.

The project was divided into different stages, the first of which was to rebuild the burned-down plant. The second stage included forward-looking work to identify future product needs and optimise current production facilities, and the development project started at the beginning of 2022. Activities were divided into five subprojects, including (1) future offering, (2) building and construction, (3) process and machine, (4) IT/OT (Information and Operational Technology), and (5) organisation and future competence. The work was described as genuinely cross-disciplinary. The company had a holistic view of sustainability, including economic, environmental, and social aspects, which was reflected in the project team. A project model was applied to guide the work, including project directives, a steering group and clear project goals.

The focus of the study was on the second stage of the project. The overall goal, 100% circular production and fully automated production by 2032, aligned with the company's overall sustainability goal. Sustainability was described as part of the DNA of the company and thereby naturally included in all their activities. To succeed, sustainability was considered important to be part of the daily work, not something added on. The determination of the

owner family was described as an important prerequisite for successful progress in the project. Another success factor was the well-anchored goals, and the plan jointly formulated, together with performance indicators following up the progress. An innovative climate, being open to different scenarios, was emphasised as important for the development process.

Development practices

The value of a transparent process was emphasised in the case of Future bread production. It was perceived as essential that everyone understood the process and the decisions made. In addition, when designing a new system solution, the need for communication and synchronisation between subprojects was emphasised. To secure internal communication, both between sub-projects, but also in general, was key.

At Company Generation, sustainability was part of the daily work. However, a challenge to operationalise sustainability goals was brought forward, illustrated with this quote: "We should be 100% circular, yes okay, but what does that mean?". Related to the operationalisation of goals, there were some conflicts of interest. Some of the solutions that were better from a sustainability perspective were not possible to realise due to the time frame of the project or due to economic reasons.

During the development of production solutions, new ways of working were required. Due to organisational changes in Company Generation, relevant in-house competence was no longer available and therefore, collaboration with external engineering designers was required to design the required production solutions. In addition, challenging aspects related to manufacturing equipment were mentioned. They perceived that not all manufacturing equipment suppliers could deliver equipment that fulfilled their sustainability requirements, such as machines for packaging that functioned reliably with the modern plastic bags used by the company. Another challenge mentioned was to evaluate to what degree different system solutions contributed to the sustainability goals, and a need for some kind of decision support was requested.

Measures for handling potential critical events

The starting point for the case Future bread production was a major critical event, a fire. A new production line burnt to the ground with the rest of the facility and 75% of their production capacity was lost. This experience contributed to some production solutions developed in the studied development project. One key aspect during the project was to achieve redundancy – to reduce the dependency on specific equipment, production lines or individuals: "...we try to become less *individual-dependent* as well, but knowledge should be spread and preferably available as close to the operations as possible". The goal was that it should be possible to produce the top nine products at both their production facilities. This was also expected to contribute to the flexibility required to manage unpredictable customer behaviour and large demand variations. Another key aspect was security, striving for high-security awareness. As described by the respondents, they have built a capacity to manage crises. Despite the devastating event (the fire), their attitude was optimistic. For instance, they

tried to turn adversity into advantages. As one example, the fire gave media attention, which was perceived as valuable for the company.

Case School kitchen

Company Project Management was an industrial consultancy company that supported organisations across different sectors with construction project management. Their mission was to contribute to a sustainable society through systematic project improvement. The business idea was to systematically lead, design, and further develop sustainable projects, using expertise from all project phases.

The development project, i.e. the case School kitchen in a primary school, involved a major investment in a new school kitchen, fulfilling the sustainability goals of the municipality. The objectives were to increase the production capacity of daily meals (portions) and to create a suitable and improved dining environment for the pupils. The school kitchen dining environment was considered specifically important for pupils' well-being, performance and learning ability in their schoolwork.

The assignment was to transform the function of the existing kitchen from a 'receiving' kitchen to a full production kitchen to enhance meal production capabilities, addressing individuals' and customers' preferences and improving service quality. The new kitchen was to have the capacity to produce 750 portions daily on-site and additionally deliver 150 portions for external distribution, for example, to customers within elderly care in the municipality. Moreover, future utilisation of the school kitchen was discussed, including possibilities for use for public education activities. Thus, it was important to have an innovative climate in the development project, being open to different scenarios for the future production system, i.e. the new school kitchen.

A diverse project team was assigned to the development project and comprised engaged participants from different organisations. A project leader coordinated the entire development project and acted as a link to multiple stakeholders, for example, the municipal decision-makers, school administration, specialists, and community stakeholders (e.g. pupils). The project team collaborated closely with representatives from the municipality and controllers within different disciplines and included functions such as architects, engineers, production management specialists, and construction contractors.

The development project started in 2021 and was completed in August 2023. The starting point of the development project was a feasibility study conducted by the municipality. The feasibility study was the foundation for the municipal decision to develop the school kitchen. It involved evaluating the project's scope, financial implications, technical requirements, and potential impacts on the school's daily operations and community.

Development practices

During the planning of the development process, a common mindset and broad understanding among different stakeholders were mentioned as aspects affecting the possibility of achieving sustainable production in the forthcoming school kitchen. Specifically concerning environmental considerations and how to incorporate sustainability into the planning phase to ensure that the project aligned with broader environmental goals and long-term perspectives: "It is important to find long-term and functional solutions… but the long-term aspect can also be a bit problematic because there is so much, we don't know about future effects." To achieve this, early involvement and collaboration were described as key. In the case of the School kitchen, the importance of leadership guiding all involved parties with different interests and requirements towards a common goal (addressing sustainability aspects) was emphasised as important. It included joint analysis: "Having a serious discussion about what might happen."

The importance of the planning phase should not be underestimated, which became clear from the case School kitchen. Limitations in the pre-study, such as resource availability, conflicting requirements, and a lack of documentation, caused challenges later in the process. Case School kitchen, associated with the construction sector, described an immaturity in their industrial sector concerning standards for production development in general, and for sustainability aspects in specific, which affected the project. As described by the respondents, a standard work procedure and tools developed for the sector would be helpful.

It was perceived as important to choose solutions that were not limited to future needs and development beyond the actual requirements of the new school kitchen. To be able to develop sustainable production solutions, Company Project management perceived it as essential to inform and educate involved parties about relevant sustainability aspects: "It is important to understand why it is important, and how to optimise solutions for specific situations."

According to the respondents, the construction sector's interest in circular production solutions was still limited. In practice, the realisation of "re-use" solutions was perceived as challenging due to a lack of systematic ways of working with circular solutions. A specific challenge addressed was the design and implementation of temporary solutions ensuring safe and functional workplaces and a temporary school kitchen while advancing the new school kitchen: "…one might focus very much on what is to come, but how do we maintain sustainability during the period when the work is moving forward?". For example, ensuring continuity and safety of operations, efforts to reduce negative environmental impact that may arise from construction activities, and education and communication, including all parties that may be affected by the change.

Measures for handling potential critical events

The respondents expressed examples of several potential critical events that required consideration in the development project of the new School kitchen. One example was how

equipment problems in the kitchen would have impact of the kitchen operations and require alternative ways of working. It may lead to switching to paper plates when dishwashing machines break down. Such changes can temporarily alter the workflow and require a workplace design allowing adaptation. Another example of potential critical events was related to shortages in raw materials and transportation issues, necessitating adjustments in the workplace design to ensure possibilities to manage the logistics. Additionally, a critical event concerned the kitchen staff that applied work rotation between different school kitchens. Thus, the development project needed to consider how to ensure a flexible but standardised workplace. Another aspect was how the kitchen could be flexible and adapt to fluctuations in the number of produced meals and prerequisites for scaling up and down. Moreover, how to create possibilities to utilise the school kitchen for customers other than pupils, e.g., for education or public events.

Development practices supporting resilient and sustainable production

In this section, the development practices derived from the three cases are compiled.

Development practices

Development practices were defined as the activities, methods, and tools employed to design, improve, and innovate production systems. As a first step of the analysis, development practices applied to support the development of sustainable and resilient production were derived. The result of the analysis is presented in Table 3. Each development practice is supported by one or several illustrative quotes from the case studies, marked with a note indicating which case (1 represents case Joint building, 2 represents case Future bread production, and 3 represents case School kitchen).

Table 3. Empirically derived development practices from the three case studies

No.	Development practices	Illustrative quotes
#1	Leadership committed to sustainability	"... the key people who have been a little higher up, and then linked to the steering group and such, who are also very driven in bringing out sustainability issues and finding solutions and not making compromises." [1] "... the success factor for success is, of course, that this is a high priority point for management." [2]
#2	Engaging parties with strong commitment	"There is a huge commitment from all different parts... it's a privilege to be a part of this journey." [1] "We have ambitions that go beyond legal requirements." [3]
#3	Integrating sustainability as part of the daily work	"Sustainability as part of the ever-present, ever-present, no side project." [2]

No.	Development practices	Illustrative quotes
		"This understanding [concerning sustainability] is good to avoid being misled... so you can ask questions... at least have a discussion about it."[3]
#4	Clear sustainability goals	"The LEED Gold certification requires quite a lot more than if we were not to go down that track ..."[1] "... environmentally, it is these LEED standard requirements that will guide us in that we have high environmental goals."[1] "We have very strong sustainability goals that we share together with the property owner... not just environmental goals in the form of CO2-neutral property or energy-smart solutions, ... also, on mental and physical health... and world-class accessibility."[1] "It is important that goals are set, so that we have something to work on and that we are measured by that."[2] "... to keep it together, that we still have a common goal and a common plan going forward, which is the overall one for the company, which is well anchored, I think is a success factor."[2]
#5	Relevant competence	"... competence I can think too, this to know what you are looking for, knowing what parts to look at ..."[2]
#6	Considerations of market demands	"... the project team is as formed to cover as much of the business as possible to, from the impact of our consumers, to as well as delivery, completion of products and also beyond."[2]
#7	Create good work conditions	"... sustainable working methods, develop over time and not depend on one person."[1] "The important thing is to make it work well for people. It's not easy. No matter how experienced you are, it's always important to be careful and pay attention to details."[3]
#8	Transparent work process	"... to sort of create a process, to clarify it, that you understand both the process and the decisions."[2]
#9	Use of standards	Standard components: "Use products from the approved product database ..."[3] Standard equipment: "...we build lines so that you can run products on more than one line, to achieve redundancy if something happens..."[1] Standard work procedures: "... Then there is also the issue of the needs and perspectives of different people and stakeholders. That you may have a lack of demand and systems schedule for reuse and circular construction. We also talk very little bit about the immature construction industry that there is no particular industry standard."[3]
#10	Building trustful relationships	"Building relationships... you create trust and cooperation between each other... and educating each other"[3]
#11	Collaboration with system suppliers	"...maybe it's something that we also need to pursue together with one or more suppliers to get where we want to go in the long term."[2]

No.	Development practices	Illustrative quotes
		"Transition to external actors required new ways of working: … No in-house designers who can draw on these solutions, technical improvements and things like that …" [2]
#12	Collaboration between functions	"And it's like the old saying – as a designer, you can design in more problems than a production technician can eliminate in a lifetime, just in one morning." [1]
		"Local steering group: …represents all functions, plus finance, controlling and purchases because there are a lot of procurements we have to do. And then there's… project manager for the various relocation projects." [1]
		"Sustainability as part of the daily work, ever-present, no side project." [2]
		"… that we have worked together, the products of the future, it is not some sales organisation that has come up with something we are going to manufacture, but we have kind of worked together." [2]
		"… collaboration across departments in some way, to work less in these silos we have, but really embrace each other's knowledge even more." [2]
#13	Secure good conditions during development	"You might focus a lot on what is to come, but how do you maintain sustainability [in the temporary solution of the school kitchen] while working forward?" [3]
#14	Long-term perspective in selected solutions	"To build long-term sustainability for those who will manage the property and the operations …" [3]
		"It is important to find long-term and functional solutions… but it is precisely the long-term aspect that can be a bit problematic as well, because you do not know much about the effects that can come in the long run." [3]
		"We want to design the kitchen for flexibility and adaptability [in case of any disruptions or changes]." [3]
#15	Create preconditions for circular production solutions	"… but we have no way of storing old sinks and reinstalling them in 1.5 years. It does not work without a system." [3]
		"I become enthusiastic when we found solutions for reuse in the temporary dining hall, discovered that you can make money from reuse." [3]
#16	Provide opportunities for joint problem-solving	"We believe that collaboration between organisational boundaries is a foundation for creating creative ideas – that is, innovations […], you need to have your ear to the ground, you need to have the pulse of the market, you need to work smart in all kinds of support functions to get this culture of innovation." [1]
		"I can imagine that they are challenged about some of our social parts around the accessibility adaptations and such. At the same time, they may also be tempted to learn more …" [1]

No.	Development practices	Illustrative quotes
		"It is important to understand why it is important and how you can optimise solutions for specific situations." [3]
		"… and the idea is to be able to take experiences with you at all levels, in the project group and also us as contractors." [3]
#17	Updated and accessible documentation	"We have succeeded in this [development project], and we feel secure with the construction documents we have produced today, and it is approved by all different stakeholders." [3]
#18	Plan for the unplanned	"Unknown uncertainties always arise – leave some leeway in the timetable." [3]
		"There is a risk of boxing yourself in, considering possible changes in the future." [3]
#19	Creating an ability to handle critical events	"…. I actually think the company has a pretty good ability to handle both this and that" [1]
#20	Learning from other sectors	"Bringing the expertise from the construction side into the industry is quite interesting… I think there is a great exchange in both directions." [3]
		"They [public sectors] have tried to copy tools from industry to develop a production system for construction production… it has not permeated organisations; they have not managed to adapt tools suitable for our sector" [3]
#21	Operationalisation of goals	"We should be 100% circular, yes okay, but what does that mean?" [2]

[1]Case Joint building; [2]Case Future bread production; [3]Case School kitchen

Enabling and supporting development practices

The result from the second step of the analysis, to understand how active ownership, collaboration, and learning can enable and support the development practices during the development process in greenfield projects, is presented in Table 4. The derived development practices were categorised according to the aspects associated with the three factors of the analytical framework

Table 4. The relation between development practices and aspects of active ownership, collaboration and learning

Factor	Aspect	Development practices *)
Active ownership	Vision and goals	#1, #2, #3, #4, #6, #14, #21
	Leadership	#1, #3, #4, #6, #13, #18
	Trust, empowerment, good working conditions	#2, #5, #7, #10, #15
	Resources (e.g. technological, organisational)	#5, #9, #15
	Transparency and communication	#8, #17
Collaboration	Intra-organisational collaboration	#12, #16
	Inter-organisational collaboration	#11, #16, #20
Learning	Work situations fostering learning	#10, #16, #20
	Relevant and accessible documentation	#17
	Ability to capture the unexpected	#13, #14, #18, #19

*) Identified development practices in the three case studies, see Table 3:

#1. Leadership committed to sustainability	#12. Collaboration between functions
#2. Engaging parties with strong commitment	#13. Secure good conditions during development
#3. Integrating sustainability as part of the daily work	#14. Long-term perspective in selected solutions
#4. Clear sustainability goals	#15. Create preconditions for circular production solutions
#5. Relevant competence	#16. Provide opportunities for joint problem-solving
#6. Considerations of market demands	#17. Updated and accessible documentation
#7. Create good work conditions	#18. Plan for the unplanned
#8. Transparent work process	#19. Creating an ability to handle critical events
#9. Use of standards	#20. Learning from other sectors
#10. Building trustful relationships	#21. Operationalisation of goals
#11. Collaboration with system suppliers	

Discussion and conclusion

To support the development of resilient and sustainable production a multitude of aspects need to be considered. In this paper, three case studies lay the foundation for analysing development practices and their relation to active ownership, collaboration and learning. These factors are considered relevant, specifically in a dynamic environment, as they influence development and change initiatives and their outcomes in a long-term perspective (Brulin & Svensson, 2012; Elg et al., 2015), which is key in production development.

Sustainable and resilient production

The purpose of the paper was to elaborate on how manufacturing companies can attain sustainable and resilient production. Previous research has pointed out that circularity and sustainability discussions are often limited to a company's sustainability department (Ritzén & Sandström, 2017). However, the studied development projects indicate that sustainability has become a natural area to consider in manufacturing companies and integration of sustainability as part of the daily work was one of the derived development practices, see Table 3. From what we have seen in our studies, the two manufacturing companies have integrated sustainability as a natural area to consider, as previously done with other megatrends such as IT and quality (Lubin & Esty, 2010). The study in the municipality (School kitchen) demonstrated how aspects related to sustainability and resilience in practice were integrated into a greenfield project. Despite that, it was perceived that the industrial sector had more experience addressing these issues than municipalities. However, to succeed with organisational change, copy-paste is not advocated since comprehensive contextual understanding is essential (van de Ven & Poole, 1995). Thus, the ability to interpret and adapt overarching sustainability requirements to the own local organisation's context will be required.

The studied development projects focused on sustainability and circularity rather than on resilience. However, during the study's time frame, major external critical events challenged the manufacturing industry and other organisations. For example, the Covid-19 pandemic, lasting between January 2020 and March 2023, interrupted ordinary practice and called for new ways of working in the manufacturing industry (Ardolino et al., 2022; Kapoor et al., 2021). Another major event affecting the manufacturing industry was the Russian large-scale invasion of Ukraine in February 2022. This, together with some of the company's own experiences, such as a fire, has increased the awareness of the need for resilience in production. In the studied development projects, several actions were carried out to handle critical events, but also to prevent possible future critical events, aligned with the resilience strategies suggested by Hollnagel (2010).

Some of the solutions contributed to both sustainability and resilience. One example was the effort in case Future bread production to create redundancy in production, both among equipment and people. Redundancy enhances resilience by making systems more reliable, flexible, and capable of handling disruptions (Kamalahmadi et al., 2021). When managed properly, it can also contribute positively to sustainability by reducing waste, improving resource efficiency, enabling sustainable sourcing and more efficient lifecycle management of equipment. The relationship between resilience and sustainability has been extensively discussed in areas such as industrial ecology and environmental management (Fiksel, 2006; Marchese et al., 2018). Three main approaches can be found in the literature: 1. resilience as part of sustainability, 2. sustainability as part of resilience, and 3. resilience and sustainability as separate objectives lacking hierarchical structure (Marchese et al., 2018). In the manufacturing industry, close to production, the latter perspective seems dominant.

However, this study indicates that considerations of resilience and sustainability may be intertwined and need to be integrated in early design phases.

Enabling and supporting development practices

To enhance understanding of how to develop resilient and sustainable production systems, the approach was to identify and explore development practices, i.e., activities, methods, and tools, employed to design, improve, and innovate planned production systems. Depending on how these practices are managed, they may either support or hinder the development of production systems. As a result of the analysis, a total of 21 development practices were derived and categorised into active ownership, collaboration, and learning, according to the selected analytical framework. Development practices related to active ownership dominated, where aspects associated with vision and goal, leadership, trust, empowerment, and good working conditions were most common.

Some of the derived development practices were of a general character, not explicitly related to sustainability or resilience. Among these were, for example, the importance of management involvement, joint problem-solving, updated and relevant documentation, ability to identify and respond to critical events, transparent processes, and competence. Several of these more general practices, considered important for succeeding in development projects, have also been recognised as important in other development contexts (Svensson & Brulin, 2014).

There were also several development practices explicitly related to sustainability and resilience. First and foremost, a strategic priority and leadership commitment to sustainability was mentioned as key to success. This has also been pointed out in other studies. The implementation of the sustainable and circular manufacturing concept faces technical, organisational, and managerial challenges (Alayón et al., 2022; Sopjani et al., 2020). Involvement of top management is required, as is inclusion in the company's vision and strategy (Rashid et al., 2020; Schöggl et al., 2024). One potential way to create a common understanding and shared vision related to the implementation of sustainability is through common goals and joint performance indicators (Arekrans et al., 2023). Highlighted as important related to the implementation of sustainability goals is the hierarchical alignment between company vision and goals and the engineering practice (Arekrans et al., 2023).

Several development practices were related to collaboration, both intra- and inter-organisational collaboration. Previous studies have also emphasised that a lack of integration between different functions within the organisation and poor collaboration hinder the transition towards circular and sustainable solutions (Ritzén & Sandström, 2017; Sopjani et al., 2020). All three case studies addressed the importance of joint problem-solving, discussing potential solutions and their consequences for different actors. Collaboration during the development projects involved discussions about temporary solutions, ongoing operations, and the forthcoming future production system. Many times, it was perceived as

essential to collaborate with external systems and technology suppliers to learn and develop relevant solutions, something previously pointed out as key for small and medium-sized companies (Alayón et al., 2022). Numerous authors have investigated the integration of various organisational functions and emphasized its importance for sustainability (Ulrich et al., 2020). Previous studies offer valuable insights into the crucial role of collaboration in achieving sustainability goals and improving overall organisational performance (Jasti et al., 2022).

New problems occurred over time, and there was limited possibility of relying on previous experiences in the three studied development projects. The results showed that competence development was achieved by collaboration across traditional borders during the different development phases. Enhancing competence related to sustainability and resilience among functions and different actors was regarded as a cornerstone for achieving desired outcomes. Through high attention and awareness among the participants in the development projects, issues could be addressed in new ways. The development projects served as an arena for the co-creation of knowledge, enhancing competence development for actors, and beneficial both within and beyond the actual development project.

As noted by Brulin and Svensson (2012), a key challenge is maintaining development practices over time. They emphasise the importance of balancing active ownership, broad stakeholder collaboration and opportunities for continuous learning as key enablers for not only reaching short-term goals but also creating conditions for maintaining long-term effects. This aligns with the findings in this paper, particularly regarding the need for structured collaboration in the early planning and design phases. Operationalising these aspects in production development projects required active efforts among different functions within the production development team. For example, teams worked to develop innovative solutions and establish iterative feedback loops, which fostered continuous learning and supported the adaptability needed for sustainable outcomes.

The analytical framework applied in this paper originates from a model initially developed by Brulin and Svensson (2012) based on experiences from evaluations of large-scale research programmes (Brulin et al., 2012). The framework's broader applicability, as demonstrated in this paper, is supported by its use across diverse change and development contexts. For instance, the framework has been employed to study the conditions that foster sustained implementation of lean practices in the public sector (Lindskog, 2016). Additionally, it has been utilised to analyse industrial startups in organisations from both public and private sectors, rapidly implementing required work practices as an immediate response to the COVID-19 pandemic crisis (Harlin, 2024).

Throughout the case studies presented in this paper, development was characterised by uncertainties, a high degree of novelty, and interdependencies between actors to develop solutions. The analysis revealed that active ownership, collaboration, and learning were

essential during production development projects, supporting the planning, design, and implementation of solutions in greenfield projects.

Managing greenfield development and ongoing production

As a serendipity result of the three case studies, an expansion of the general production development process was suggested. Major changes in parallel with daily production required temporary solutions both in the case of the School kitchen and in the case of Future bread production. In the case Joint building focus was instead on minimising the downtime in production during the relocation, which required highly detailed and careful planning of each step. To emphasise the need to consider daily production, the activity of Designing temporary solutions was added to the generic development process, see Figure 3.

Development project

Prerequisites → Project planning - clarification of assignment → Designing system solutions (conceptual/ detailed) → Realisation of new or rebuilt production system → *Sustainable and resilient production*

Design temporary solutions (if needed)
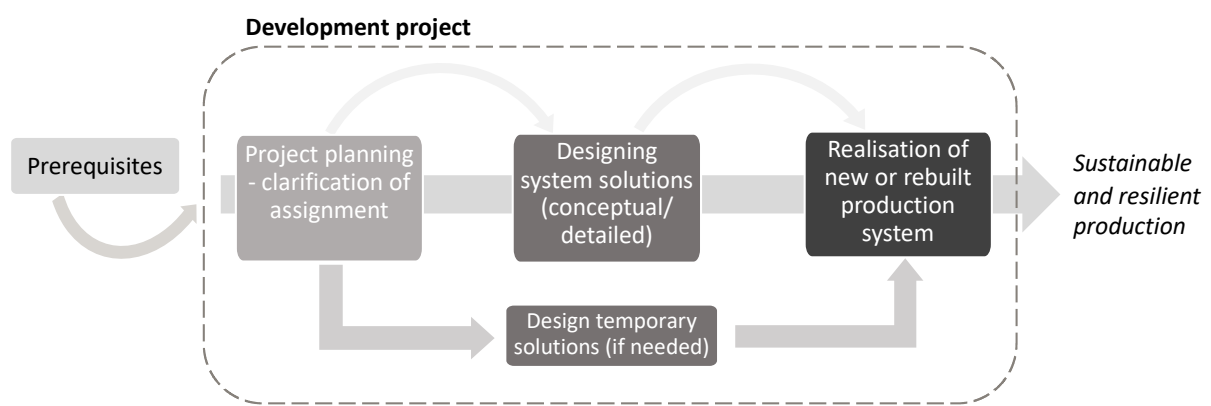
Figure 3. The production development process applied in the case School kitchen and in the case Future bread production.

According to the literature, greenfield development projects imply that current production systems have fewer constraints for realising potential solutions in comparison with more established production systems (Harlin & Berglund, 2021). However, our studies showed a continuous need during ongoing development projects to relate to their context/client and understand the constraints, especially since the development projects were carried out in parallel with already ongoing activities/production.

The case studies highlighted that greenfield projects were characterised by uncertainties and a lack of knowledge about how to develop solutions. Despite the high attention to sustainability, there was a notable lack of expertise in formulating the assignment and operationalising sustainability goals. Thus, contextual understanding and supportive leadership in the development projects were needed.

Theoretical and practical implications

The paper contributes a new perspective on production development, addressing the necessity of a learning perspective as an alternative to the traditional planning-and-control perspective. This perspective, illustrated with development practices derived from three cases and categorised as related to active ownership, collaboration and learning, is considered increasingly required for production development processes addressing new domains, such as the green transition.

Developing resilient and sustainable production is a complex task that demands a deep understanding of the prerequisites for sustainability and resilience, along with a comprehensive system perspective. A clear and well-anchored strategic goal among functions and organisations is required, as active ownership is a means to operationalise the goals. In addition, greenfield projects, in parallel with daily operations, require maintained operations during an ongoing development project, with a focus on the final goal of the development project and scenarios for the production system beyond the actual development project.

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Opportunities of workplace innovation in sustainability transitions: A mixed–methods analysis of environmental initiatives at the workplace

Fanni Moilanen
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Abstract

Although learning and innovation are key drivers of sustainability transitions, workplace innovation has gained little attention in the research area. Workplace innovation has potential to produce local change and development toward environmentally sustainable working life and society, since employees' ideas and initiatives can foster the adoption of environmentally sustainable work practices and processes both at the workplace and within work-related networks. The empirical analysis presents findings from a representative sample of Finnish employees collected in 2022, Climate change and work survey (n=1917), and analyses the results using a mixed methods approach. The quantitative analysis reports environmental workplace innovation and its associated factors. The qualitative analysis of the survey's open-ended questions assesses employees' experiences of the hindrances in the development and innovation at work on environmental topics. The results of a mixed-method analysis show both the enabling and hindering factors of environmental initiation. The discussion section further elaborates the findings with previous research. Workplace innovation provides a relevant means for tackling societal change processes of sustainability transitions on a local level of workplace, ranging from small-scale changes in working practices to the organizational or sectoral sustainability solution provision. However, the lack of environmental workplace innovation efforts in Finland indicates that there is a need to strengthen and support local development efforts on environmental questions.

Keywords: workplace innovation, employee-driven innovation, environmental innovation, green transition, sustainability transition, climate change

Introduction

Climate change and other environmental challenges including biodiversity loss and resource depletion are wicked problems that radically change and alter living conditions on Earth. Patterns of daily life and economy have developed without questioning the planetary limits (Rockström et al., 2023; Steffen et al., 2015). In response to these environmental sustainability challenges, both research and policy communities increasingly address the need for sustainability transitions (GSDR, 2023; Köhler et al., 2019). This systemic change aiming to turn the development of the society for an environmentally sustainable trajectory also impacts working life when jobs and production processes are turning low-carbon (Abrahamsson & Larsson, 2021).

Involvement of companies and different types of organizations is needed to solve global sustainability challenges (see e.g. Delbridge et al., 2024; Kozak et al., 2022). In addition, workers can by different means act themselves for the environment and initiate a more environmentally sustainable society through their work (see e.g. Houtbeckers & Taipale, 2017; Räthzel et al., 2021). Sometimes employees' are viewed as contributing to organizational action, such as corporate social responsibility measures (Onkila & Sarna, 2022), but opportunities of employee voice have been little explored in the context of distinguishing organizations' ways of contributing to societal change processes of sustainability (Delbridge et al., 2024). In the context of sustainability transitions, it has been presented that employees can act and take part to sustainable change (Moilanen & Alasoini, 2023; Süßbauer et al., 2019). This article elaborates employee participation in the context of workplace innovation research (Oeij et al., 2023; Oeij & Dhondt, 2017) as a mean to contribute to societal change processes of sustainability transitions, and sheds light on the benefits and opportunities of workplace innovation and development on environmental topics. Previous research provides evidence on how employee involvement in organization development can benefit its environmental improvements, such as climate change mitigation efforts (see e.g. Boiral, 2002; Markey et al., 2019; Süßbauer et al., 2019). Moreover, Wallo et al. (2024) suggest that employee-driven innovation is one driver in the green transition of industries. The potential of workplace innovation as a means for organizations' environmental work makes it relevant to explore how workplaces can act on environmental challenges and how workplace innovation could contribute to sustainability transitions. This article also proposes a mean for bridging different approaches to innovation research, as called by Pålshaugen (2015).

This paper answers the following research questions:

1. How could workplace innovation contribute to solving environmental sustainability challenges?
2. What individual and organizational factors enable and hinder environmental initiation at the workplace?

Section two reviews previous research discussing sustainability transitions, workplace innovation, and employee initiation and participation in workplace development on environmental topics. Section three presents the data and method of the study, namely the Climate change and work survey data. Section four presents the findings of this study, the results of regression analysis investigating factors associated with workplace environmental innovation, and qualitative results of the content analysis investigating the hindrances of environmental initiatives. The final section discusses the results in the light of previous research and elaborates the potential of workplace innovation to contribute to societal change of sustainability transitions.

2. How workplace innovations can contribute to sustainability transitions

2.1. Innovation in sustainability transitions literature

Sustainability transitions research has evolved to investigate global environmental problems (such as climate change, use of fossil fuels, and resource depletion) and their potential solutions. In sum, sustainability transitions refer to co-evolutionary and multi-actor processes of systemic change that are needed for turning into sustainable consumption and production patterns within planetary boundaries (Köhler et al., 2019). The development and adoption of innovation plays a significant role in the process of sustainability transitions, as innovations are seen as means to shift societal systems to a more sustainable layout (Kivimaa et al., 2021; Smith et al., 2010). In addition to research, sustainability transitions are increasingly discussed in policy domain as means to provide solutions pathways for challenges of environmental (and social) sustainability (EEA, 2019; GSDR, 2023).

In sustainability transitions research, pursuit toward a more environmentally sustainable society and gain of environmental improvements act as a motivation for innovation activities and their target (Susur & Karakaya, 2021). The focus of research is often on "environmental innovation", which are described as novelties with an environmental angle or aim (Van Den Bergh et al., 2011, p. 3). Innovation in transition research is often understood broadly, covering both technological and social innovations (Kivimaa et al., 2021). The environmentally oriented innovations are also discussed by Adams et al. (2016), who present "sustainability-oriented" innovations to cover both forms of innovation (social and technological), which can range from single and incremental initiatives to systemic solutions with a positive societal contribution. In this article, we refer to both social and technical innovations that contribute to environmental targets or aim for environmental improvements at the workplace as "environmental workplace innovation".

The change resulting due to transition is often a consequence of innovation adoption, as noted above (however, different change trajectories of sustainability transitions have been presented where the role of innovation is less significant (see e.g. Geels & Schot, 2007).

Transitions require changes and realignments in relations between actors, technologies, and rules (Fuenfschilling & Truffer, 2016). The rules coordinating actors, including values, practices, and structures, are viewed as hindrances of transitions, although they often receive less research attention in comparison to technological solutions (O'Brien, 2018). Innovations often fail with their transformative targets (Westley & Antadze, 2010), and their impacts can remain incremental, for instance due to misalignment between actors values and preferences (Smith & Raven, 2012). However, these incremental improvements are also needed to provide environmental improvements (Adams et al., 2016). Therefore, not all innovations of sustainability transitions are themselves radical or disruptive, but they can provide environmental improvements in their local context by incremental means.

Innovations are developed by different groups taking part in transitions. These include companies and governments, but also civil society organizations and citizens, who can contribute to transitions by co-creation and innovation in local initiatives (Avelino & Wittmayer, 2016; Huttunen et al., 2022). However, research on actors of sustainability transitions is having gaps in the field, including the potential of organizational change and participation in transitions (Upham et al., 2020) and elaboration on workers in transitions (Moilanen & Alasoini, 2023; Süßbauer et al., 2019). Since the focus of workplace innovation research is on the organization change and employee participation in the change process, it provides potential for exploration on how environmentally oriented change and development can take place at the workplace, and what forms of participation employees might have in that process. Analysing the environmentally oriented change at the workplace has potential in showing the variety of values, practices, and structures different members hold, and what type of challenges can result from their change.

2.2. How could workplace innovation target environmental sustainability?

Oeij & Dhondt (2017, p. 66) define workplace innovation as "... an integral set of participative mechanisms for interventions relating structural and cultural aspects of the organization and its people with the objective to simultaneously improve the conditions for the performance and quality of working life". As such, workplace innovation covers different forms of participation and inclusion of employees in organization decision-making and problem solving, which bring different types of improvements for the workplace. Often, employees are interested in the functioning of their work organizations and its future (Dow, 2003), and employees' knowledge and learning can be sources of innovation and development of work and work organization (Alasoini & Selander, 2023; Høyrup, 2012). Although workplace innovation has previously focused on improvements in economic performance and working life quality (Oeij & Dhondt, 2017), collaborative workplace practices have potential to provide environmental improvements. For instance, a survey shows that employees want to take part to the environmental work of their company (Polman, 2023), and their knowledge can provide information for environmental questions of the organization (Boiral, 2002; Süßbauer et al.,

2019). As a consequence, environmental workplace innovations have potential in providing new topics of intervention for the research and practice of workplace innovation.

Workplace innovations are social and collaborative process of learning and development (Kibowski et al., 2019; Totterdill, 2015). Learning can be both informal (group activities, working with clients or co-coworkers, or learning by working) or formal (classroom teaching or manuals) (Eraut 2004, p. 267). Previous literature in the field of sustainability transitions has investigated activities such as experimentation (Jalas et al., 2017) and co-creation (Itten et al., 2021), which are seen as means for innovating and learning in local context. Employees' ideas and knowledge can provide solutions for organizations' local environmental challenges (Boiral, 2002; CGIA, 2021; Süßbauer et al., 2019). For instance, employees' collaboration with customers and other stakeholders can provide insight for the organization on environmental sustainability improvements (Süßbauer et al., 2019), some of which management might be unaware of (CGIA, 2021). In addition, workplaces can increase employee participation by providing some employees "environmental champion" roles, who have responsibility in workplace mundane environmental issues (Hampton, 2018). However, the frequency of such environmental and collaborative workplace activities is less researched.

Workplace innovation has various benefits (Oeij & Dhondt, 2017; Totterdill, 2019), although the benefits of different types of innovations may not be straightforward (Mathieu & Boethius, 2021). Environmental initiation can provide improvements for both employees' working life quality and for the state of the environment. For instance, employee involvement in company climate action can increase employees organizational engagement (CGIA, 2021), and a survey by Kite Insight (2022) shows that employees feel motivated when they can do climate actions at the workplace. Past research shows practical examples on how participation and inclusion of employees, i.e. workplace innovations, can improve environmental sustainability of the workplace. Markey and colleagues (2019) found in their study conducted in multiple fields of economy that employees' involvement and participation was associated with greater variety of organizational carbon reduction behaviours, such as energy saving and introduction of new work practices. In addition, Boiral (2002) shows how environmental awareness training of the industrial sector workers resulted with them addressing potential pollution sources of the company more frequently, which resulted in organizational changes with environmental improvements. Moreover, Hampton (2018) has reviewed both the successes and challenges in the practical contributions of the labour unions in the UK, for instance their initiation on the environmental decision making at the workplace (related to energy production and commuting policies for example), and presentation of environmental questions into collective agreements. Due to applicability of employees' knowledge in organizations' environmental problem solving, workplace innovations have potential to provide environmental improvements in addition to previously researched benefits.

Employers' attitude toward workplace innovation and environmental improvements influences whether the workplace is engaged in environmental work and collaborative forms

of development. The role of management is critical on whether organization has environmental workplace innovations and encourages employees to initiate on environmental topics (Yuriev et al., 2022). Moreover, sectors of the economy are known to differ between their innovativeness (Beckman et al., 2023; Mathieu & Boethius, 2021). For instance, environmentally oriented organization provides more supporting conditions for employee-driven pro-environmental innovations (Yuriev et al., 2022). Therefore, management and the sector of the workplace may be associated with environmental workplace innovations. On the employee level, participation in workplace innovation efforts and learning are found to be more common among middle-aged employee groups, but according to Gallie (2018), there are no gender differences. Socio-economic factors also play a role, and higher education level is associated with higher innovation activities (Mathieu & Boethius, 2021). As such, participatory development activities may not be equally available for workers across sectors and different social groups.

Local sustainability initiatives have challenges in becoming adopted (Lam et al., 2020) and previous research has investigated their different hindrances and drivers in more detail. Regarding the hindrances, both colleagues and employers' lack of knowledge and scarcity of resources, among other thigs, have been viewed hampering employees' environmental initiation (Yuriev et al., 2018). As such, attitudes of other workplace members, particularly of the management, influence if environmental innovations become adopted in the workplace. In terms of the drivers, employee engagement in innovation process, easiness in use, opportunity to voice out opinions, and subjective norms are associated with innovation adoption (Parkhill et al., 2015; Putnik et al., 2019). Motivation and willingness to adopt the innovation are other important enablers (Hölsgens, 2021). As such, if workplaces are to change in response to environmental sustainability challenges and provide solutions, such as by introducing new and more sustainable ways of working, employee engagement is central in delivering the change efficiently. This is further strengthened if the management perceives the initiatives important and is willing to use resources on them.

In addition to local workplace environment, workplace innovations are always part of a larger system (Pålshaugen, 2015). Even though employees' environmental initiatives can be directed solely to their own or to shared working practices between colleagues (Moilanen & Alasoini, 2023), they may also connect individuals and organizations with interorganizational and systemic levels (Adams et al., 2016; Westley & Antadze, 2010). On a system level, workplace environmental innovations can be seen contributing to societal goal setting targeting sustainability transitions, such as EU carbon neutrality target 2050 or UN sustainable development goals (GSDR, 2023). However, the actors located in different levels may have differing values or be coordinating according to different systems (O'Brien, 2018). These differences and potentially following contradictions present challenges for workplace innovations in the workplace context as well as outside of it. This systemic dimension is illustrated for instance in the case of transitioning from element-based construction practices to more environmentally sustainable wood-based building practices in Sweden, which shows how scaling of an innovation requires cross-sectoral collaboration from

professionals working in different fields (Hemström et al., 2017). As such, environmental workplace innovation may confront challenges also outside the workplace.

The empirical part of this article moves to discuss in more detail the enabling conditions of environmental workplace innovations quantitatively and their hindering factors qualitatively.

3. Data & method

3.1. Survey data

We conducted the Climate change and work employee survey to measure the frequency of environmental innovative practices at the workplace and employee levels. The data collection took place in spring 2022 and was collected by Statistics Finland in collaboration with Finnish Institute of Occupational Health. The final response rate of the survey was 38,3 % (n=1917). The survey data includes items similar to workplace innovations (Kibowski et al., 2019), but on environmental topics, such as a question about co-creation of environmentally friendly work practices and presentation of ideas on climate change mitigation at the workplace. The survey method, its motivation and the development of the survey are presented elsewhere (Moilanen et al., 2024; Moilanen & Toikka, 2023). Table 1 presents the descriptive statistics of survey respondents.

The majority of the respondents were women, accounting for 53.6 percent of the total (see Table 1). Approximately 24 percent of the respondents were less than 35 years old, 35.9 percent were between 35 and 50 years old, and 40 percent were aged over 50. In terms of education, the most common level among respondents was EQF 2-4, while almost half represented EQF 6 or higher. About a third of the respondents worked in the fossil intensive sector, with a slightly smaller proportion employed in private services or healthcare. Additionally, 18.9 percent worked in research, education, and administration.

Table 1 Descriptive statistics of data.

		%
Gender	Women	53.6
	Men	44.6
	Other or not willing to disclose their gender	1.8
Age group	< 35	24.0
	35-50	35.9
	50+	40.1
Level of Education	No reported EQF	0.4
	EQF 2-4	45.1
	EQF 5	4.4
	EQF 6	23.4
	EQF 7	23.4
	EQF 8	3.3
Sector of work	Fossil intensive	33.0
	Private services	23.6
	Healthcare	24.5
	Research, Education, Administration	18.9

3.2 Survey measures used in the analysis

The dependent variable in our analysis is Environmental Workplace Innovation, a factor variable derived from five survey items related to climate change actions implemented in the workplace. These items assess whether: 1) climate-friendly practices have been developed in collaboration with the employer and employees, 2) there is a designated person or team responsible for promoting climate change or ecological sustainability at the workplace, 3) information on employees' skills in environmental and climate affairs has been gathered, 4) experiments or competitions on climate action have been organized, and 5) work practices have been adapted based on employees' suggestions to be more climate-friendly.

The independent variables in our study consist of Environmental Employee Initiation, Employer's Sustainable Attitude, and Sustainable Organization.

Environmental Employee Initiation was assessed using three questions, which were rated on a 5-item Likert scale. The questions focused on whether respondents had ideas for incorporating climate change mitigation or ecological sustainability into their work, had made changes to promote these initiatives, and had proposed environmental suggestions to their workplace. Responses of "I don't know" were excluded from the analysis.

Employer's Sustainable Attitude was measured through three questions concerning the importance placed on climate change mitigation by the employer, the willingness of the employer to allocate resources for this purpose, and the employer's willingness to intervene in practices that are harmful to the climate.

Sustainable Organization was evaluated using six questions related to climate change mitigation efforts within the workplace, including the organization's operational focus, changes in work practices, employee awareness, use of climate-friendly technologies, efficient use of raw materials, and the integration of climate change mitigation or ecologically sustainable products or services into the core business.

Additionally, the analysis incorporated respondent characteristics such as gender, age, education level, and sector of economy where they work as covariates.

For further details on the survey items, response scales, polychronic factor loadings, and factors used in the analysis, please refer to the Appendix.

3.3. Research method of quantitative analysis

Ordinary Least Squares Regression was used to investigate whether Environmental Employee Initiation, Employer's Sustainable Attitude, and Sustainable Organization are associated with Environmental Workplace Innovation among Finnish workplaces.

As posited in section 2, workplace innovations may be influenced by the employer's attitude towards such activities, the sector of work, and its environmental orientation. Three separate regression analyses were conducted. Model one was estimated using only Environmental Employee Initiation, Employer's Sustainable Attitude, and Sustainable Organization as independent variables. The second model included additional individual-level covariates such as sex, age, and level of education. The third model incorporated the sector of work as an additional covariate.

The absence of multicollinearity was analysed and confirmed by calculating the Variance Inflation Factor for each covariate.

3.4. Analytical framework of qualitative analysis

Workplace innovations are collaborative processes of learning and reflection (Kibowski et al., 2019), but quantitative analysis does not show details of these development processes. Consequently, a qualitative analysis was conducted to gain deeper insight on the workplace environmental development and innovation efforts.

The Climate change and work questionnaire form included an open-ended question to collect data on respondents' experiences of the development of work in topics related to climate change and ecological sustainability. The response guidance in the survey form encouraged to address the challenges and enablers in the development of work in these topics. The aim was to provide deeper insight into the workplace changes due to the green transition that the survey questions would not cover. Since most of the respondents described the challenges and not the enablers, the focus here is on the hindrances of environmental workplace development only. The open-ended responses consisted of 17 sheets of paper in total and they were analysed with inductive data-based coding with Atlas.ti-software. Data extractions are used as illustrations of workplace environmental innovation hindrances in the analysis section 4.2.

The inductive coding enabled to broadly capture the reasons the employees experienced hindering the workplace environmental development efforts. Earlier research of Westley & Antadze (2010) and O'Brien (2018) was utilized for categorizing the findings. The challenges articulated by the employees can be located into different levels (Westley & Antadze, 2010) and different social dimensions of work, namely values and practices (O'Brien, 2018). First, we categorized the hindrances discussing the lack of environmental workplace innovation (i.e. why there is no development efforts at the workplace on climate change or other environmental topics). Second, we grouped the hindrances of the workplace level, which relate to individual, interpersonal and organizational level reasons. The findings emphasize the benefits workplace innovation would provide for workplace development, since the results show that current development is not collaborative or participatory, which further hampers the change efforts. Third, the hindrances of workplace innovation can emerge beyond workplace, and these reasons are interorganizational and systemic, as illustrated by Westley & Antadze (2010). Although these hindrances were less discussed in the data, they show that even though novel environmental ways of working were shared between workplace members, they can still encounter barriers from external factors.

4. Results

4.1. Survey results

Table 2 presents the regression results from three models. Depending on the model, the number of respondents varies between 1,017 and 1,088. The adjusted R-squared value for the regression models is close to 0.40, indicating that approximately 40% of the variance in the dependent variable is explained by the independent variables included in the model.

Model 1 presents the estimates from the regression analysis using only Environmental Employee Initiation, Employer's Sustainable Attitude, and Sustainable Organization as independent variables. All the independent variables demonstrate statistically significant associations with Environmental Workplace Innovation, the dependent variable. The estimate for Environmental Employee Initiation is 0.08 (95% Confidence Interval: 0.06−0.10), while for the Employer's Sustainable Attitude, it is 0.07 (95% CI: 0.04−0.10). Notably, the estimate for Sustainable Organization is higher in magnitude at 0.14 (95% CI: 0.11−0.17).

Model 2 presents the estimates from the regression analysis using additional employee-level covariates, including female gender, age, and level of education. The estimates for Environmental Employee Initiation and Employer's Sustainable Attitude are consistent with Model 1, although slightly smaller in magnitude, at 0.07 (95% CI: 0.05−0.09) and 0.06 (95% CI: 0.03−0.09), respectively. In contrast, the estimate for Sustainable Organization is 0.16 (95% CI: 0.13−0.19), a bit higher in magnitude in comparison to Model 1. Additionally, the estimates for female gender and higher education levels (EQF 7 and 8) are positive and statistically significant.

Model 3 includes an additional covariate for the sector of business. Again, the estimates for Environmental Employee Initiation and Employer's Sustainable Attitude are consistent with both Models 1 and 2, although slightly smaller in magnitude, at 0.06 (95% CI: 0.04−0.08) and 0.06 (95% CI: 0.02−0.09), respectively. The estimate for Sustainable Organization is 0.17 (95% CI: 0.14−0.20). Furthermore, the estimates for female gender, higher education, and the research, education, and administration sector are positive and statistically significant.

In practical terms, the consistent estimates ranging from 0.06 to 0.08 for Environmental Employee Initiation mean that an increase of one point in the factor variable Environmental Employee Initiation adds between 0.06 and 0.08 points to the value of Environmental Workplace Innovation, depending on the model. Similarly, an additional one point in the factor variable Sustainable Organization adds between 0.14 to 0.17 points to the value of Environmental Workplace Innovation, depending on the model.

It is noteworthy that the inclusion of additional covariates does not significantly affect the adjusted R-squared; however, the estimates for Environmental Employee Initiation,

Employer's Sustainability, and Sustainable Organization remain consistent over different models.

Table 2. Ordinary Least Squares regression estimates with 95% confidence intervals.

	MODEL 1		MODEL 2		MODEL 3	
	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval
Constant	-0.50	-0.56−-0.44	-0.54	-0.62−-0.47	-0.54	-0.63−-0.47
Environmental Employee Initiation	0.08*	0.06−0.10	0.07*	0.05−0.09	0.06*	0.04−0.08
Employer's Sustainability Attitude	0.07*	0.04−0.10	0.06*	0.03−0.09	0.05*	0.02−0.09
Sustainable Organization	0.14*	0.11−0.17	0.16*	0.13−0.19	0.17*	0.14−0.20
Female			0.07*	0.04−0.10	0.06*	0.02−0.09
Age group, <35			REF		REF	
35-50			-0.03	-0.07−0.01	-0.03	-0.07−0.01
50+			-0.02	-0.07−0.02	-0.02	-0.07−0.02
Education, EQF 2-4 or lower			REF		REF	
EQF 5			-0.03	-0.10−0.05	-0.03	-0.11−0.05
EQF 6			0.03	-0.01−0.07	0.03	-0.01−0.07
EQF 7			0.07*	0.03−0.11	0.05*	0.01−0.09
EQF 8			0.13*	0.05−0.22	0.12*	0.03−0.22
Sector of Business, Fossil intensive					REF	
Private services					0.01	-0.03−0.06
Healthcare					0.03	-0.02−0.08

					0.06*	0.02−0.11
Research, Education, Administration						
	N=1,088		N=1,068		N=1,017	
	Adjusted R^2= 0.39		Adjusted R^2= 0.41		Adjusted R^2= 0.40	

Note 1. The dependent variable is Environmental Workplace Innovation. It is a polychronic factor variables with values from 0 to 1.11. The independent variables of interest were Environmental Employee Initiation, Employer's Sustainable Attitude, and Sustainable Organization. Gender, Age, Education and Sector of work were used as covariates. Statistically significant estimates are marked with an asterisk.

4.2. Results of open-ended survey questions

The findings shed light on the hindrances of there being no environmental workplace innovation in many organizations. Some respondents note that they haven't experienced any environmental improvements in the workplace. In many workplaces, awareness of climate change and other environmental topics has not resulted in shared development efforts.

At the employee level, a key reason is the lack of interest. Some respondents write that they are not interested in climate change or other environmental topics. Moreover, some respondents say that they don't have resources to reflect such topics at work. As such, some employees do not have the capacity or willingness to develop work toward a greener direction.

> The workload is often so huge that it is not possible for an employee to stop and think about ecological sustainability.

There is also a lack of interest in environmental innovations perceived among the employer or colleagues. Some respondents view their employer uninterested in climate change and related issues which prevent any improvements on topics. Moreover, the organizations are evaluated to pay attention only to those things that are mandatory or necessary to fulfil the basic functioning of the organization. In this context, considering the environment or climate is not essential. For these reasons, improvement and development by innovation in environmental topics is considered by some employees as unnecessary, or even harmful, to the maintenance of the core business.

In describing the challenges of green development of work, most respondents focused on the workplace level in their responses. Most of the respondents describe their colleagues as not engaging with sustainable practices, such as recycling, sorting, or eating vegetarian dishes. Moreover, colleagues might not follow the guidance provided on topic. The reasons for disengagement with green practices relate to values and attitudes, and some note that

changing the "old-established attitudes" is the most challenging part of workplace development.

The employee level challenges also relate to the materials and capabilities (un)available at work. For instance, lacking recycling units at the workplace prevents us from engaging with environmental practices. In addition, organizations are viewed to not providing enough training or guidance for the personnel to engage with them and get them into use. One informant points out that teaching of sustainable development is challenging due to lack of expertise on the topic. As a consequence, the new practices are not adopted by all members due to lacking capabilities, which results in the desired target to include environmental tasks at work only partially attained. Although novel environmental ways of working are introduced, their implementation is not provided enough resources at the workplace.

Some respondents say that they themselves, or their colleagues, engage with various environmental practices, such as planning or implementing tasks at work in such ways that they consider their potential environmental questions at the same time. However, these innovative environmental practices lack potential to provide change when they are not shared by all members of the workplace. For instance, one practical challenge may relate to the management, who is responsible of the overall management of the workplace, but whose lacking capabilities or interest on environmental topics hinder development of work in that dimension.

> It's difficult to have sustainability as part of activities of the municipality, when there is no personal interest in the management or capacities to develop affairs toward a sustainable direction.

Survey respondents also voiced challenges that relate to the inter-personal or organizational challenges. For instance, the way of introducing the new means of working in the organization is perceived to be challenging, since employees have not always been part of their development process. The introduced new ways of working might be experienced unfit for one's working practice. In addition, some respondents do not understand the expected environmental improvements the initiatives are said to attain, or they do not perceive them feasible. Consequently, adoption of these innovations in the workplace is a challenge if the new practices make work more complicated in comparison to older ways of working, or if their environmental benefits are seen questionable. As such, there is a need to improve the current means how work organizations introduce the change and improvements at the workplace on environmental topics. These findings highlight the benefits collaborative processes would provide, which currently are not utilized in many workplaces.

> Bans and guidance for single employees rarely lead to desired outcomes. They only raise the protest mood and decrease work ability, which increases indifference towards the climate.

The hindrances of workplace innovation may also be interorganizational. For instance, one respondent notes that their work on environmental sustainability in their office has not been adopted or acknowledged in other offices of the branch. As such, organizations in other branches of a larger parent company may develop and adopt green innovations at different phases than others. Moreover, some employees write about the challenges presented from the customers' side. For instance, customers might not want to move to an electronic and paperless service interface if they have become accustomed to have papers and persons, even though such shift would be a mean for the organization to become more low carbon.

Introduction of environmental work practices can also be dependent on the material artifacts outside the workplace. A couple of respondents note the challenge of using climate-friendly means of mobility at work due to less developed infrastructure for e-bikes and e-cars. Using low-carbon mobility is challenging if the services they are dependent on do not develop at the same time. That can result in slower or more complicated means of commuting. Moreover, the location of the workplace might be a barrier for low-carbon mobility. It is challenging to target greenhouse gas emissions cuts by low-carbon work mobility if the workplace premise is far and if it cannot be reached by public transport.

The hindrances in scaling up workplace innovation also touch upon actors beyond the workplace, including citizens and decision-makers, which highlights the potential systemic nature of environmental workplace innovation. For instance, it was noted that regulation may prevent the upscaling of products made of recycled material, and citizens' lack of knowledge can hinder the entrance of novel carbon sequestration methods in gardening work practices. Therefore, even though in some cases the workplace members would adopt new and innovative working practices, they may lack institutional acceptability from the rest of the system. As such, in some cases environmental innovations introduced at the workplace need to be accepted by other actors outside the workplace to make ways of working more environmentally sustainable.

5. Discussion and conclusions

The aim of the analysis was to investigate both the enabling and hindering factors of environmental workplace innovations. The results section investigated quantitatively the factors associated with environmental workplace innovation and qualitatively the hindrances preventing the environmental development efforts at the workplace. This section discusses the findings in the light of previous research.

Innovating, improving, and developing work on environmental topics (including climate change and resource efficiency for instance) is not present in many workplaces in Finland. Even though actions and initiatives to organize and produce sustainably is required from different types of organizations and companies (Delbridge et al., 2024; Kozak et al., 2022),

collaborative practices of environmental workplace innovations are not a mean applied in many organizations as a way of contributing to sustainability transitions.

For workplaces to successfully implement environmental workplace innovations, the quantitative analysis identifies the organizational characteristics associated with these activities. The employer's perceived sustainability attitude and sustainability of the organization are significantly associated with environmental workplace innovation. Management of the organization plays an important role in enabling employee participation, and this applies also in the context of environmental workplace innovation, as discussed elsewhere (see e.g. Yuriev et al., 2022). Employee participation is one mean to strengthen the overall environmental work in organizations (Boiral, 2002; Markey et al., 2019; Süßbauer et al., 2019), and this opportunity is acknowledged already among some of the environmentally oriented workplaces in Finland.

At the employee level, environmental employee initiation, involving one's own actions on climate change mitigation or ecological sustainability, is linked to the emergence of environmental workplace innovations. Additionally, higher education levels among employees are associated with increased levels of environmental workplace innovation, as well as employment on sector such as public administration, research, and education. Innovation-conducive jobs are often of better quality (Gallie, 2018), and since opportunities to participate to organization development are provided for expert professionals in the above mentioned fields, environmental workplace innovations potentially align with the participation of this group in other topics of workplace development. Regarding gender differences, the findings seem to illustrate that women would be more often involved in workplace environmental work, which contradicts earlier findings (Gallie, 2018). Environmental values and climate change worry might be a reason for gender differences (Moilanen et al., 2024), but this requires further research.

The qualitative results illustrate the multiple challenges environmental development and innovation efforts may confront at the workplace. Environmental development efforts at the workplace challenge the accustomed values and norms of the workplace members, as discussed by O'Brien (2018) for instance. Introducing even small-scale changes, such as sorting practices, can be challenging when employees do not view such activities necessary or important. Awareness raising, cultural change, as well as guidance and target setting from the management side are needed to further support the workplace change as a response to environmental challenges.

The qualitative findings indicate that much of the environmentally oriented change at the workplace level is not done in collaborative means. This can further strengthen employees' disengagement with new ways of working and raise resistance against change efforts, as discussed by Parkhill et al. (2015) for instance. Workplace innovations and joint development between workplace members could help facilitate change processes. Those participative mechanisms would allow presentation of different opinions and views, which can be further

discussed, and solutions proposed. Collaborative practices as well as personal motivation and norms support the adoption of innovations, as discussed in previous literature (Hölsgens, 2021; Putnik et al., 2019). If workplaces are to change their ways or working and producing more environmentally sustainable, as the policy agendas illustrate (EEA, 2019), shared dialogue and understanding of the changes and their target can ease their social acceptability.

The findings also show how environmental development efforts can take place in different phases between different workplace members and organizations. Some employees and workplaces try to make changes at work by engaging with different environmental actions, as presented in this study and also by Houtbeckers & Taipale (2017), for instance. However, there can be mismatches between some members embracing the new environmental practices whereas others, such as the management or members in other organizational branches, continue with the accustomed, less environmentally sustainable ways of working. This illustrates how targeting environmental improvements by changing ways of working might not be a shared idea between all members who are affected by them, or the new practices may lack their commitment. The hindrances of environmental innovations emerging from social relationships at work emphasize the reciprocal nature of change and innovation.

Social relationships between employees, co-workers, and customers have adjusted to particular means of working and collaborating in certain time and place, which are coordinated by shared values, practices, and norms (Fuenfschilling & Truffer, 2016; O'Brien, 2018). Environmental workplace innovations challenge these means of working, because norms and practices at work have evolved without acknowledging environmental problems or environmental questions. The processes of sustainability transitions are associated with struggles and conflicting values when sectors or communities are undergoing change (Avelino & Wittmayer, 2016), and this applies to change in the workplace. Adopting environmental sustainability as part of work through an environmental workplace innovation requires effort and willingness from all actors affected by it. This is crucial for environmental workplace innovations to achieve local sustainability shifts, as initiatives of single employees or workplaces are insufficient for affecting a systemic sustainability transformation.

In contrast to hindrances, the positive association with environmental workplace innovation, organizational sustainability, and employees' initiation highlight the systemic nature of sustainability transitions and the importance of a shared target to sustainability (Köhler et al., 2019). Environmental innovations are more frequent when the workplace conditions are aligned to support them, and these conditions are already found from some workplaces in Finland. However, it can be assumed that environmental workplace innovations could be developed elsewhere. An area of improvement is to enhance organizational and sectoral commitment to environmental sustainability through various means, as noted above. It is acknowledged that increasing workplace action in sustainability transitions requires the introduction of policy agendas which further articulate the activities for different types of

workplaces to contribute to sustainability transitions. Environmental workplace innovation could be one mean introduced in these agendas, as suggested elsewhere (Markey et al., 2019; Wallo et al., 2024), and current low activity can signal absent regulatory pressure. Policy agendas could articulate the benefits of environmental workplace innovations and aim for awareness raising especially in those organizations where there is no internal motivation among workplace leaders to engage with environmental sustainability.

Workplace innovation provides a lot of insight for the field of sustainability transitions on how to collaboratively and by different forms of workplace participation to engage with employees and try to improve fairness of change processes. In times of rapidly changing working life, being heard and engaged in the change processes provides a way to smoothen the transitions period (Abrahamsson & Larsson, 2021). Green transitions processes so far are viewed to lack opportunities for employees to participate and collaborate in Europe (Crespy & Munta, 2023), and our findings on the education level and sectoral differences raise a concern of just transitions, since opportunities to participate in organizations' environmental development are not provided across working population. Even though workplace innovations are viewed to bring benefits for workplaces, including both management and employees, they are not widespread.

Future research could take a closer look at the labour unions, including the environmental training they provide, climate champions they might train, and other formal employee representative bodies, and examine, how unions address environmental questions at the workplace. Past research has examined labour union actions in particular on climate change mitigation and provides important findings for future research (Hampton, 2018; Räthzel et al., 2021). In addition, workplace innovation is a mean to contribute to organization competences and resilience in times of change (Oeij et al., 2023), and the environmental challenges and the following transitions are expected to change working life in multiple ways. For now, many organizations are not engaged with environmental workplace innovations as a response to the effects of climate change or the green transition, and the results show how the measured actions are most common in sectors with quality jobs. This raises questions if environmental workplace innovations are only a new element of working life quality, and if they can be adopted in sectors most affected by the transition, such as the workplaces in the fossil intensive sectors. These questions require further research, especially since the results show that fossil intensive sectors are least engaged with the measured environmental workplace innovations. Future research could examine the role and significance of workplace innovation as part of organizations' overall responses to environmental challenges and their solutions, and whether employers' view employees' ideas useful in their responses to changes in the market and the environment. It is likely that old-established norms, practices, and structures maintaining stability between employers and employees influence if environmental questions are addressed together at the workplace.

In considering the levels of micro, meso, and macro, workplace environmental innovation has potential to generate change in all these levels. First, environmental targets or policy agendas,

such as sustainable development goals (GSDR, 2023), provide the target for environmental workplace innovations. On the meso levels of workplace or interorganizational relationships, collaborative practices of environmental workplace innovations bring together the workplace members, which enables to consider the potential differences in their values, practices and structures (O'Brien, 2018) and how the generation and adoption of workplace innovation may influence and change them. On a micro level, employees' ideas and initiatives contribute to the workplace environmental development. At the same time, the participatory development efforts support the adoption of workplace innovations when all influenced employees have been able to participate in the development process. The desired end result of the environmental workplace innovation is to provide environmental improvements, which align with environmental targets or policy agendas (such as greenhouse gas emission cuts or improvements in resource efficiency) and contribute to their attainment. However, it is important to note that environmental innovations do not always result with environmental improvements and their impact might be challenging to calculate (see e.g. Susur & Karakaya, 2021; Van Den Bergh et al., 2011). Assessing the environmental impact of workplace innovation is out of scope of this article but provides an important topic for future research attempts in the area.

There has been a call to explore employee participation in organizations' contributions to societal challenges (Delbridge et al., 2024; Upham et al., 2020), and this article presents that workplace innovation has potential in facilitating societal change processes, as presented by Oeij and colleagues (2023). The target of this article has been to explore the opportunities and benefits of workplace innovation in the context of climate change and other environmental crises and discuss the enablers and hindrances of such efforts. The findings indicate that at some workplaces, employees can participate and organization's members collectively initiate and present ideas on how to develop ways of working toward an environmentally sustainable direction. Environmental workplace innovation provides new questions for the workplace innovation literature. Future research could examine the potential impacts of environmental innovation for employee well-being, organizational engagement, or economic performance, which are often at the focus of workplace innovations literature (Oeij et al., 2023). Most importantly, more research is needed to better understand the potential and benefits in facilitating environmental change processes related to climate change mitigation, adaptation, or other environmental problems at the workplace by the means of workplace innovations.

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What does it take to make a workplace just and green? – Systemic human factors approach

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Abstract

Halting environmental degradation requires workplaces to undergo a profound shift towards ecologically sustainable work that challenges customary growth-oriented thinking and holds justice and the well-being of workers as a core value. Structures and practices of workplaces provide a critical link through which this transition could be achieved. However, there is a lack of clear and systemic definition and an easily applicable model to guide workplaces to become both just and green. In this paper, we aim to define the key characteristics of a just green workplace by using human factors/ergonomics (HF/E) as the underlying theoretical approach. Humans are positioned as the core component across all system levels. Thus, we posit that the HF/E approach can serve as a fundamental building block for just green workplaces. It helps shift the focus of the currently prevailing technology-, administration- and (de)growth-oriented green transition towards one that is more human-centric, contextually aware, as well as competence- and developmentally oriented. We apply a HF/E Tool to two case examples from different sectors to demonstrate the systemic, underlying factors of just green work at the individual, work, group, and organisational levels. Based on the findings, we present criteria and recommendations for a just green workplace. In addition, the value and development needs of the HF/E approach in fostering sustainability are discussed.

Introduction

Climate change, biodiversity loss, and resource scarcities are examples of environmental degradation that requires many workplaces to undergo a profound shift towards ecologically sustainable work that goes beyond short-term profit-making and holds justice as a core value (EU-OSHA, 2023; OECD, 2018). Structures, roles, and processes of workplaces offer a potential linkage by which such just green transition may be managed. However, in accelerating activities towards a rapid and large-scale societal just green transition, workplaces play very different roles. Some workplaces already consider themselves as 'green' and their core challenge may be to upscale from niche actor to serious competitor against established market actors. Others need to rethink their whole business model, and in cases like coal mining, they may face complicated issues of justice due to the inevitable downfall of their entire industry.

In practice, most workplaces face a double challenge of change and stability. First, rethinking and renewal is needed to change current work processes and products to become 'greener'. Second, workplaces need to maintain and support the safety and well-being of workers, to assure a just transition (SDGR, 2023; Thatcher, et al. 2018; Schulte et al., 2016). *A green transition* in workplaces is often interpreted as business or service innovations for degrowth (Smith & Sharicz, 2011), and an issue handled by applying environmental management systems to address industry-induced pollution (Zhu et al., 2013). However, to realize *a just green transition* in workplaces we need to define the key characteristics of implementing just and green work, and to understand the systemic nature of the underlying factors that contribute to the success of 'just greening of work'.

The definition of a green workplace is still not established and is vague, with many different characterisations aimed at adapting to and mitigating environmental change, as well as anticipating environmental policies or market demands (e.g., UN 2015; EC, 2019; EC 2020). In this paper, we highlight environmental and social sustainability and define a *'just and green workplace' (JGW)* as an organisation that focuses on ecological values (e.g. reducing harmful environmental impacts) while simultaneously addressing the social sustainability of workers (e.g. their sustainability competency as well as wellbeing and work continuity). (Raworth, 2017; EU, 2023; EU-OSHA, 2023; Bianchi et al. 2022). While the ESG (Environmental, Social, Governance) literature on corporate responsibility mostly focuses on large private firms, here we aim to cover all types of workplaces. In this paper, we also define work as (mainly) permanent and paid employment.

It is well known that a just green transition, with all the multilayered and multi-scale phenomena (e.g., climate change, biodiversity, employment, social security (e.g. Mechler et al., 2020), requires a systemic view to be appropriately addressed (Thatcher et al., 2018). However, in addressing many complex problems, there is a tendency to create an overall

view at an abstract or theoretical level, which does not serve well for implementing practical actions in workplaces (Teperi et al., 2023).

For example, this is an issue that includes broad frameworks such as a Corporate Social Responsibility Directive (CSRD) (EU, 2022; 2024), which push companies to embed sustainability targets into their management strategies and to report their sustainability efforts more clearly. Although CSRD provides a comprehensive overview of the necessary actions, it cannot ensure that strategies are implemented as effective practical actions. Another option is Industry 5.0 (EC, 2021), which, as an EU-level guideline, offers an overarching perspective on the actions needed for more sustainable and resilient operations. However, it is more focused on technological development and does not provide a broad view of greening actions in the workplace or for work communities as interactive systems. Both CSRD and Industry 5.0 offer sound reasoning for change but do not necessarily provide instrumental steps for operationalizing change in practice, which is the focus of this article.

Occupational safety and health (OSH) research provide knowledge on current threats posed by environmental changes, such as heat stress and extreme weather conditions caused by climate change, chemical risks related to agrochemicals, and UV radiation (ILO, 2024). However, OSH research is typically risk-based and tends to evaluate issues narrowly from one perspective at a time, most commonly from the perspective of natural sciences, such as physiological or physical aspects (Dekker, 2016; Leveson, 2020). In this study, we adopt a systemic, multidisciplinary view, including behavioural science (Assmuth & Lyytimäki, 2015; Teperi et al., 2023). We assess practical details necessary to achieve JGW solutions, considering the required competencies and developmental steps at the workplace.

Thus, in this study we apply the systemic, multidisciplinary Human Factors and Ergonomics (HF/E) (Wilson, 2014; IEA, 2024) approach to explore what a JGW might be like. By selecting HF/E as our view we aim to focus on the 'how', in order to realize the greening of work, instead of the 'what' of green work or 'what are risks or consequences of not greening work'. HF/E is operationalised using the HF Tool (Teperi, 2012), which has previously been shown to develop a mindset in people at work by improving safety awareness, competence, and practices in several industries through the implementation of a stepwise program (Teperi et al., 2015; 2017; 2023).

The HF Tool owes much to organisational and work psychology and system safety research, including themes such as resilience, adaptive capacity, organisational culture and learning, and management and leadership, to recognize contextual factors as specific themes. In this study, the HF Tool is used to describe how JGW can be realised, and which kind of contextual factors contribute at the individual, work, group, and organisational levels. The second aim is to reflect on the usability and development needs of the HF/E framework as operationalised through an HF Tool. Through the examination of JGW the study aims to contribute to wider

debates of the eco-welfare state and the eco-social contract that can also provide criteria for JGW (Hirvilammi et al., 2023).

As policies for JGW provide possibilities and demands for new ways of thinking and action, workplaces are places where creative destruction – possible tensions within green business and sustainability - are faced. The need for solving tensions puts pressure on workplaces to clarify their values, activities, and operations in a conscious and clear way. The core focus of this paper is concentrated on developed, Western countries, and especially Nordic countries. Although these countries have tackled essential targets for sustainable development such as water, sanitation, and training facilities (SDGR, 2023) their major risk is overconsumption of natural resources that pose a risk to breaching several planetary boundaries (World Economic Forum, 2023; Rockström et al., 2023). This highlights the need for immediate attention such as adapting to and mitigating climate change and avoiding overuse of natural resources. An essential cornerstone of implementing this is through the mechanisms of working life. Practically this begins with workplaces. The innovativeness of our paper lies, first, in presenting the theoretical and practical possibilities of HF/E as one approach to sustainability science; second, in helping workplaces take an active role in realising JGW; and third, in addressing the critical contributing factors for implementing JGW in practice. Furthermore, this paper represents the integration of behavioural, environmental, and engineering perspectives to achieve a comprehensive approach to the fair greening of work.

The aim of this study is to define the key characteristics of implementation for a just and green workplace (JGW); what it entails, and the actions that need to be undertaken.

Our specific research questions are:
1) Which factors facilitate or hinder the implementation of just greening activities of the workplace?
2) How does the HF Tool work in analyzing contributing factors of just greening of work?

What is a just and green workplace like? An overview to the legislation, guidelines and knowledge

Green work (or green jobs as a synonym) covers a wide range of different occupations in different sectors. Green jobs can be understood as contributing to the preservation or restoration of the environment. They can include jobs that help to protect ecosystems and biodiversity, or reduce consumption of energy and raw materials, or reduce waste and pollution (EU-OSHA, 2023; UNEP, 2008). Green is also seen as a spectrum, not as a binary category indicating that only a few skills are specific to green jobs, and many non-green jobs use similar skills to green jobs (Bowen et al. 2018; Bowen & Kuralbayeva, 2015). Green work may also be defined as actions that change workers' and management's work actions and their sustainability competency to be more sustainable (e.g. workplace practices and choices, the use and recycling of resources) (Ala-Laurinaho et al., 2023; Finnish panel for OSH, 2022).

These may, for example, include green HR practices in the workplace which defines green workplace design, sustainability education, OHS, green organisational design (e.g. incorporating circularity, only using renewable energy, greening the supply chains), and green workplace/equipment such as greening actions at work (Yong et al., 2020). Also, behaviours might extend beyond the working environment to the general living environment (e.g., encouraging public transport, encouraging recycling, changing diets, etc.) (e.g., Finnish Panel for OSH, 2022).

Just green work is an elusive concept that has been framed by international declarations and agreements, national legislation, sector-based standards, and voluntary guidelines as well as by research-based definitions (Bowen & Kuralbayeva, 2015). Different aspects of just green work can be highlighted or omitted by entrepreneurs, employees, or labour unions, and the dynamics of news and media, social media, and marketing which does not always help to build better public awareness of the concept. In this section, we aim to clarify the key categories that compose just green work.

Universal visions. In visions of the future that emphasise responsibility, people and people's well-being are placed at the centre of sustainable and responsible economic thinking (EC, 2021; UN, 2015: SDG8 for decent work, SDG3 for good health and wellbeing; EU, 2023). These seemingly inevitable European (e.g., EC, 2019; EC, 2012) and global development trends (SDGR, 2023; UN, 2015 for Agenda2030; ILO, 2016; 2017), combined with the rapid development of technologies such as wind and solar energy, green construction, and novel food products (EU-OSHA, 2013; Lorenz et al. 2024), open entirely new opportunities for workplaces – but also set targets for workplaces and their stakeholders (such as authorities and trade unions) to be implemented.

Mandatory legislation. The role of national states is crucial for JGW since states set and enforce laws and regulations that limit the power of private actors. More recently, international law has appeared as a response to the requirements of increasing globalisation and long production-consumption chains. The EC Conflicts Minerals Regulation (2017/821) is a concrete example combining environmental and social aspects in an international setting. However, most of the international management of sustainability comprises "soft law" type of agreements and treaties (e.g. UN Agenda 2030 and the Sustainable Development Goals).

OSH standards. Environmental management systems such as ISO 14000 provide an example of widely applied standards aimed at helping organisations to comply with legislation, which minimise the harmful environmental impacts and improve their performance. Requirements of just green work have been brought together by early sector-based initiatives such as the Responsible Care program in chemical industries (Gunningham, 1995) or more recent concepts such as sustainable mining (Renn et al., 2022), endorsed by extractive industries, both highlighting environmental and social responsibility as well as work safety. On a more general level, the concept of the "triple bottom line" emerged in the 1990s (Elkington, 1997)

to simultaneously emphasise economic, social, and ecological concerns. More recently, this has evolved towards more standardised forms of environmental, social, and governance (ESG) programmes and formalised sustainability reporting under the European Commission's 2023 Corporate Sustainability Reporting Directive (CSRD).

Marketing. Green marketing with different labels and claims aimed to convince customers about the environmental friendliness of a product or service have been widely used as a response to public worries about environmental threats such as chemical pollution, ozone depletion, biodiversity loss, or climate change. For example, various "organic" labels are used to advertise food. Likewise, labels such as "Fair Trade" are aimed to convince potential buyers about decent working conditions. Some of these labels are verified by independent parties while others are self-regulated and published without any external control. A critique of misleading marketing such as white-washing, greenwashing and, more recently, rainbow-washing or SDG-washing have been presented (Gatti et al., 2019; Todaro & Torelli, 2024). As a response, the European Parliament has introduced measures aimed at banning greenwashing and making durability information clearer and easily accessible to consumers. Perceived green washing by companies has also been shown to affect negatively on both employees' work performance (Li et al., 2022) and companies' financial performance (Walker & Wan, 2011).

Education and (vocational) training. Creating JGW requires a holistic approach to integrate various competencies to address complex socio-environmental challenges. EU's GreenComp framework defines sustainability competence in terms of four pillars: "embodying sustainability values", "embracing complexity in sustainability", "envisioning sustainable futures" and "acting for sustainability" (Bianchi et al., 2022). The idea of a sustainability competence framework is to foster European policy to promote learning on environmental sustainability. To attract people to develop JGW, sustainability education needs to be developed especially in the vocational sector as well as at workplaces. For example, Ratinen and Linnanen (2022) have developed a model of sustainability competence with an emphasis on systemic competence. On the other hand, research has shown that there are complex linkages between, for example, individuals' carbon footprint knowledge and their sustainability skills, which challenges sustainability education (Ratinen et al., 2023).

Organisational culture. Changes in production and work processes and industrial/service practices affect both work and employees (Xu et al., 2021). Corporate sustainability activities need to affect the core business efficiently to be successful (Baumgartner, 2009). Workplaces need to find feasible measures to integrate just green work into their policies, procedures, and practices in such a way that they are inherently embedded in everyday operations. For this, the aspects of just green work need to be part of the organisational culture and mindset of leaders and members of the organisation, aligning lessons learnt from organisational studies (Schein, 2010; Senge, 2006). Thus, just green work demands workers to have knowledge, sustainability competency to renew culture that is reflected as deeply rooted and espoused values and underlying assumptions, as well as ways of thinking, feeling and acting

(basic assumptions; Schein, 2010; unexamined rules by which people think feel and act; Hofstede et al., 2005).

Adaptation and innovation. The creeping crisis of environmental change requires adaptive measures and resilient performance, encompassing mitigation, adaptation, learning, and recovery skills (Nemeth & Hollnagel, 2022). Increasing demands for workplace learning and sustainability competence management may challenge worker well-being. Proactive, long-term support is essential for future-oriented well-being. (Collin et al., 2024). Innovativeness, the ability to think and act in new ways, is crucial. New thinking and action can be seen as something that is emergent but co-created in wide collaboration among a variety of actors and perspectives. (Sannino, 2010). Workplace innovation involves co-creational, participatory, and inclusive processes, becoming embedded as workplace practices. (EUWIN, 2024; Carayon, 2010). This emergent, co-created approach fosters collaboration among diverse actors and perspectives. Successful innovation reflects continued reflection, learning, and improvements in organisational understanding, leadership, employee management, work organisation, and deployment of new technologies. It involves building bridges between leadership knowledge, frontline employee knowledge, and system design expertise (Dul et al., 2012; Carayon, 2010).

Methods

Human factors as a systemic, solution-based approach

Humans are at the core of JGW across all system levels. Therefore, we explore JGW using a systemic approach from HF/E that aims to improve the safety, health, and efficiency of work systems, and recently also their sustainability (Richardson & Thatcher, 2024; Thatcher & Yeow, 2019). Extending the use of HF/E seems promising since the HF/E approach has already been shown to be useful in the design and development of work (Dul et al., 2012; Wilson, 2014). Applying HF/E has also shown promising results in helping organisations under crisis to move from mutual tensions to joint development of work and organizational structures (Teperi & Leppänen, 2011; for example, during a strike in aviation). Furthermore, when applied long-term and systematically, the use of the HF/E approach has helped to renew ways of action and thinking from mandatory elements in safety management systems in safety-critical industries to an improved and inherently emerging mindset for more human-oriented safety (Teperi et al., 2023).

We deem HF/E as a fundamental building block in JGW, as it is beneficial to redirect the attention of currently dominant technology, administration, and growth-oriented sustainability efforts towards a more human-centred, contextually aware, and competence- and development-focused approach. Prior research shows that applying a systemic, participative, and solution-based HF/E approach has helped workplaces to reshape their

mindset and innovate safety practices by improving the understanding of contextual factors behind every-day-operations (Teperi et al., 2015; 2017; 2023).

Despite the potential for innovative solutions that HF/E might offer for JGW, the science and practice of HF/E has not been extensively defined or practically applied in sustainability transitions (Thatcher et al., 2020; Richardson & Thatcher, 2024). As inherently systemic, HF/E offers an approach that recognises and elaborates on the systemic nature of sustainability challenges and sustainability competency in the world of work (SDGR, 2023).

In earlier research, the HF/E approach has shown to be a beneficial way to promote new thinking and practices, especially in safety-critical industries (Nemeth & Hollnagel, 2023). Safety thinking and practices have been improved by applying new, systemic, and human-oriented safety thinking (resilience) through the use of practical models and tools, such as the HF Tool (Teperi, 2012). The HF Tool has been implemented as part of real-world practices, including safety training, raising awareness, and incident reporting and analysis in organisations such as air traffic management, aviation maintenance, the nuclear industry, and rail transport (Teperi et al., 2015; 2017; 2023). Reforms in mandatory, technical-authoritarian legislation and guidelines have been necessary, as traditional safety practices have not adequately addressed the human-centric nature of performance, necessitating a rethinking of how to reduce incidents and injuries at work.

Earlier research has also shown that systemic thinking can promote sustainability (Ratinen et al., 2022) and that awareness and competencies are the focus of sustainability development (Ratinen & Linnanen, 2022). Furthermore, it is known, that the renewal of safety thinking (from technical and normative towards more systemic and human-oriented) develops in a step-wise-process that has time-based and spatial phases from raising awareness and improving competence towards renewal of safety and workplace practices (Teperi et al., 2023). Awareness and competence are the cornerstones without which the next development phases cannot evolve. Concrete actions for change are then needed. These pragmatic steps are the focus of this paper.

In this paper, we argue - aligning with earlier findings in safety research (Teperi et al., 2023) - that addressing sustainability transitions through the lens of HF/E can drive change. This process starts from strategic, organisational decision-making and progresses step by step throughout the workplace, enabling a solution-based and participative orientation to ensure commitment and motivation for true transformation towards JGW. By fostering transformative qualities among work organisations (including employees, supervisors, middle and top management, boards, safety and quality professionals, HR, and occupational health care services), they can accelerate their progress toward sustainable practices and outcomes.

HF Tool used for analyzing eco-usability observations

The steps for JGW do not evolve in a vacuum; rather, they need to be facilitated with a concrete model in workplaces, where the actual work is done. Therefore, in this study, we operationalise contributing factors for JGW by using an HF Tool (Teperi, 2012) to analyse findings of eco-usability observations conducted by two of the authors. The hybrid use of these two methods is described as follows.

The HF Tool provides holistic system coverage and addresses interactions among four system levels (inter- and intra-organisational, group, work, and individual levels), specifying items to describe each level in detail (for example, vigilance or well-being at the individual level; work atmosphere and communication at the group level; decision-making and use of resources at the organisational level). The HF Tool is used not only as a set of separate items but as a theoretical framework and practical tool to raise awareness, enhance understanding, and facilitate learning about the systemic reciprocal relations between and among the system levels and their practical representations (Teperi et al., 2023). A figure illustrating the HF Tool is presented (Figure 1).

The HF Tool aims to represent a new era in HF/E and OSH research (Teperi et al., 2023; Hamer et al., 2021) and has three main targets. Firstly, it fulfils the ideas of solution-based orientation and positive psychology (Seligman, 2011) to refocus scientific energy to understand and build factors that enable individuals and communities to flourish. This view is emergent in the new view of OSH research, recognising aspects that work well (Hollnagel, 2014) and seeing people as a presence of positive capacity (Dekker, 2016). Secondly, the HF Tool aims to represent a holistic, sociotechnical, and systemic approach to OSH, aligning Rasmussen's individual, work, group, and organisational levels of system safety (1997). Thirdly, the tool is used in a participative manner at all organisational levels, establishing the core idea of HF/E as art and practice (Wilson, 2014; Dul et al., 2012). The HF Tool has been designed and studied in safety-critical fields for the last 20 years. In practice, it has been used as a model in human-centred safety/OSH trainings, in incident investigation, risk assessments, and for incident reporting to analyse contributing and interrelating factors of sudden mishaps. The application of the HF Tool has already been studied and published in ATM (Teperi, 2012; Teperi et al., 2015), in the maritime industry (Teperi et al., 2017), and in the construction industry (Nykänen et al., 2020).

It is worth noticing that the HF Tool includes items that make the work 'just', i.e., to support health, safety, and well-being of the workplaces. It has not been earlier used for learning or analysing factors for green work. When using the HF Tool, it does not mean that all points presented in the model support JGW, but that the levels and items of the HF Tool may help to map contributing factors that can support and strengthen or weaken activities for a JGW. Figure 1.

Individual factors and actions
1. Competence, conceptual mastery of work
2. Situation awareness (perception, memory, decision making, response/execution
3. Working along norms and procedures
4. Understanding the whole/big picture
5. Preconditions, assurance and checking; assumptions
6. Underload, overload; coping of these
7. Vigilance, alertness, fatigue symptoms
8. Phase of life, anxiety, long term stress
9. Age; quality and quantity of work experience
10. Health, work ability
11. Motivation, attitudes
12. Emotional state and reactions, mood

Work characteristics
20. Quality and contents of work, work demands
21. Quantity of work, time pressure
22. Work distribution, work organisation
23. Technology, machines; usability and reliability
24. Procedures, regulations, norms; usability, validity
25. Possibilities to impact your own work
26. Feedback from work, professional esteem/appreciation
27. Possibility and ability to analyze and develop one's processes
28. Training: contents, effectiveness, possibilities to participate
29. Work hygiene factors, physical environment (noise, illumination, air condition, temperature, layout)

Mastering complex, dynamic and uncertain situations

Organisational factors
40. Management and leadership; structure, styles
41. Organisational/safety culture
42. Co-operation between different units and hierarchy levels (units, head office)
43. Mutual understanding of others' work
44. Decisions concerning resources, personnel, equipment
45. Change management
46. Co-operation with the partners; differences in way of actions
47. Support from head office

Group/team factors
30. Distributed knowledge of the work, shared mental model/situational awareness
31. Knowledge of every member is used
32. Misconceptions; misunderstanding; are they corrected
33. Structure and cohesion of the group (atmosphere, group dynamics, mutual support)
34. Communication in teams and between teams
35. Information flow (shift change)
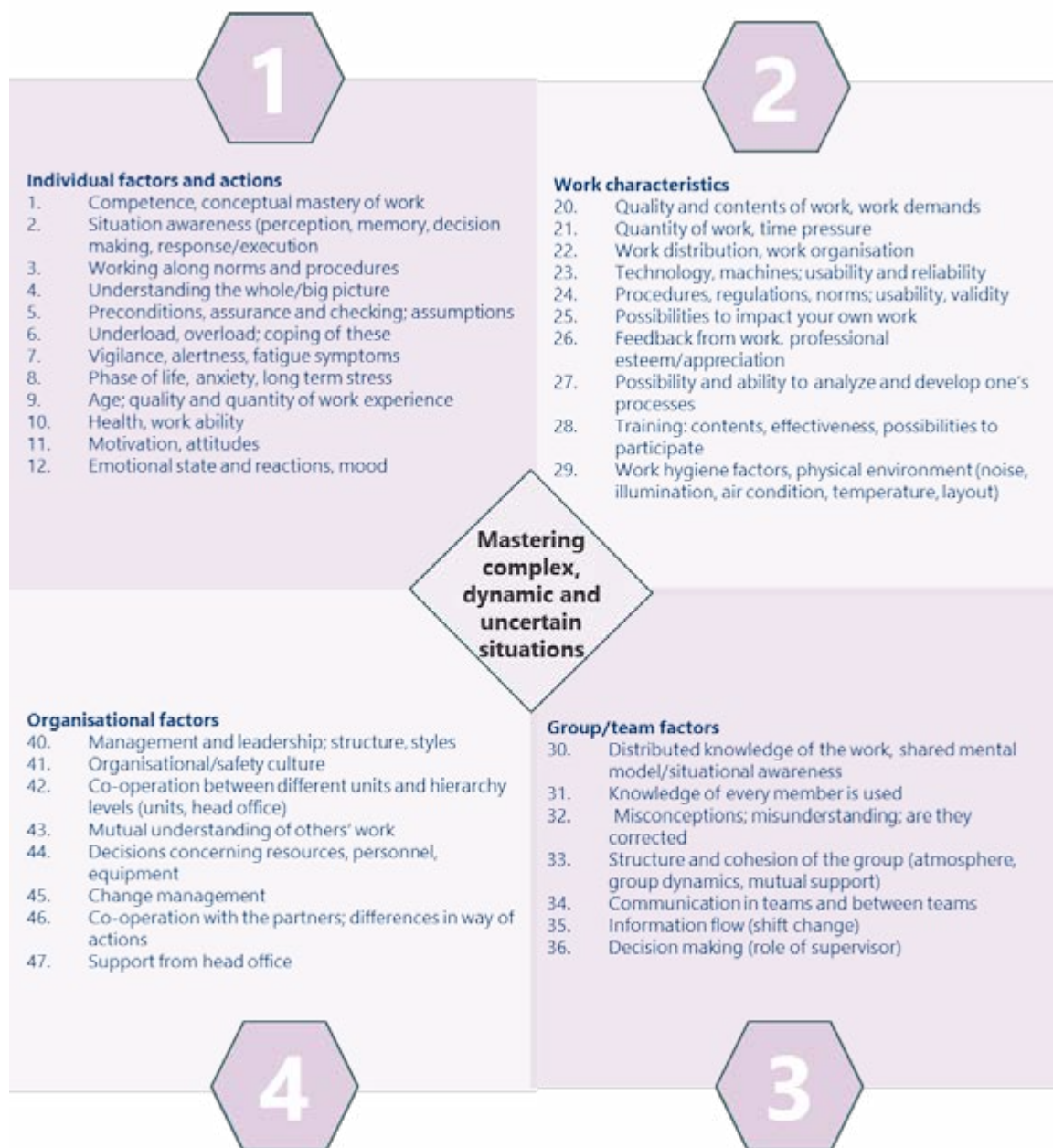36. Decision making (role of supervisor)

Figure 1. The HF Tool (Teperi, 2012)

To make the JGW more concrete and contextual, we conducted observations at two workplaces that represent different contexts, namely a school (public sector with an educational target), and a laundry (large private company with a wide client focus). During the observation of these workplaces, practical possibilities for workers to implement green actions were considered, and the special focus was on 'eco-usability' meaning the possibilities for the workers to work in a green way. The concept of eco-usability is a novel application, based on the framework of usability of buildings (e.g. Bittencourt et al., 2015). The method used in the observations in this study was an eco-usability walkthrough. Its' origin is in the usability walkthrough method that has been developed for assessing usability qualities of the

built and work environment (Babapour & Cobaleda Cordero 2022; Alexander 2006). It has been applied in the healthcare sector (Aalto et al., 2017; Haron et al., 2012) and in office buildings (Windlinger et al., 2016). In this study, we modified the basic usability framework to fit the aims of ecological sustainability and to support possibilities for 'greening the work'. Based on literature, we decided to use these five usability dimensions: safety, functionality, comfort, orientation, and interaction (Aalto et al, 2017). Using the environmental goals of the studied organisations, we added cross-cutting environmental sustainability zones (energy, water, recycling, logistics, and food choices) into the new framework that we called eco-usability. These environmental sustainability zones might vary with different organisations and sectors.

The method of an expert-driven eco-usability walkthrough included: an initial assessment of facilities and functions by experts, participatory eco-usability walkthrough in the facilities including recording and photographs, and visual summary and feedback based on observations, discussions, and special knowhow of the experts. Each observation round lasted two to three hours, during which two researchers walked through the facilities with study participants who were representatives from different user and occupational groups (e.g. management, facility maintenance, cleaning, employees). The number of study participants was five in both cases. At the end of the walkthrough, the study participants discussed their observations. Afterwards, researchers compiled a summary of the walkthrough results.

After two researchers (third and fourth author of this paper) had conducted the eco-usability observations, the collected data were discussed and reflected with the third researcher (the first author of this paper) who used HF/E approach as a perspective. Based on the discussions and aligning with the four levels of the HF Tool, the observation data were first classified into tables and split into findings concerning the individual, work, group, and organisational level actions for JGW (main rows, Table 1, Table 2). Furthermore, the tables were split to describe the starting point, currently applied actions at the school/laundry, experienced obstacles in JGW actions, and finally, the system-level solutions suggested by the researchers (four columns, Table 1, Table 2). Finally, the third researcher analysed each action for JGW (cells of the tables) by reflecting it through the lenses of the HF Tool items, using "+" and "-" marks to indicate which actions for JGW were regarded as positive, strengthening factors (+) or as negative, hindering factors (-) (Teperi, 2012).

After classifying the contributing factors of implementing JGW using the HF Tool, three researchers (two conducting the observations and one conducting the HF analysis) had discussions to evaluate the use and usefulness of the HF Tool in perceiving contributing factors and structures for JGW. These discussion findings are used to elaborate the results.

Results: Defining the characteristics of implementation for a just green workplace

Next, we aim to identify contributing factors that may facilitate and/or hinder the implementation of JGW, using the HF Tool. After this analysis, we will contemplate how the HF Tool works in analysing the contributing factors of just green work.

Factors facilitating or hindering the implementation of JGW

The school was selected as an example representing proactive measures for JGW, as they had already conducted greening activities (waste separation) when considering the impacts of climate change in their work.

Table 1. Case example: Waste separation at school; implemented actions, their obstacles and solutions (proactive measures for JGW)

Level I-IV	Starting point	Implemented actions at school	Obstacles	System-level solutions suggested by researchers (regarded as positive efforts)
Individual level				
	Motivated forerunners who want to recycle (+11)	Individuals led by example and encourage others so that everyone gets motivated to join the experiment in waste separation at work (+11, +26, +27)	Coping with the stress of daily work life and feelings of frustration (while others are not committed to recycling); how to stay motivated in the long run? (-8, -11, -12)	Directorate support, peer support for challenging emotions, joint experiment for waste separation, feedback loop between individuals, waste sorting system and support at the organisational level (+40, +25, +26, +23)
Work level				
	Lack of circular economy competence in the experiment team (-27, -28)	Developing competence for circular economy through multi-channel communication (+1, +34, +35)	Lack of circular economy competence in external operator's staff (-46)	Closer interaction and encounters between individuals from different occupational groups (+30, +31, +33)

	Non-functioning waste sorting facilities indoors (-23)	Waste reparation containers and instructions for separation at source indoors (+23)	Separated waste not transferred to waste station appropriately by external actors (-46)	Developing external actor's processes and equipment for waste logistics, closer interaction with external actor (+46)
	Poor winter maintenance of waste station surroundings creates slippery conditions outdoors (-29)	Quick fix: studded shoes for taking separated waste into the waste station in winter (+23)	Wearing the shoes harms the fluency of the work and does not fix the original challenge (-20, -22; core of the HF Tool)	Rebuilding waste station, agreement on maintenance measures (+44)
	Waste station does not support changing needs for waste separation (e.g. dimensioning of waste containers, ergonomics, lighting) (-29)	No actions implemented (not applicable item in the HF Tool)	Waste station does not support changing needs for waste separation (-29, -44)	Rebuilding waste station, agreement on maintenance measures (+40, +44, +45)
Group level				
	No systematic agreed approach for waste sorting in the classrooms (-30)	Waste sorting in some classrooms, waste sorting bags that are easy to transfer and easy to clean (+25, +29)	Lack of shared awareness and practices (-24, -30)	Systematic approach for labelling and colour coding of classroom waste bags for all classrooms (+23)
	No shared awareness how to act in the teacher breakroom regarding the waste sorting (-30, -35)	Shared awareness how to act in the teacher breakroom regarding the waste sorting (+30)	Shared awareness does not include all occupational groups or alternate staff (-30, -42, -43)	Orientation and engagement of all occupational individuals (+11) and groups and (+30, +40)
	No shared sustainability agency (no applicable HF Tool item)	Co-creation experiments as part of a project (+31, +32)	Lack of systematic agreed communication channels, practices and informal encounters between	Scheduled and regular (eco-usability) facilities walkthrough with representatives from different

			different occupational groups (-23, -24, -30, -33)	occupational groups; visual round-up from the walkthrough available to everyone (+43, +45)
Organisational level				
	Challenges in the communication with new external operator (-34, -46)	Giving corrective feedback to the cleaning company regarding problems with waste processes (+26, +27, -46)	Quality of cleaning operations does not support waste separation actions and the needs of the users of the premises (-46)	Re-examination of contract and quality criteria; regular interaction with all parties (+44, +45, +46)
	Organisational level actors who are motivated to drive greening of the school (+11, +40, +41)	Sustainable development strategy of the school is made (+40, +41, +44)	Lack of well-functioning channels of cooperation and development with key stakeholders (e.g. owners, waste management company, maintenance) (-27, -44, 46)	Social debate on local level; exploiting networks and social media; well-functioning channels of cooperation with key stakeholders (+44, +45)

The markings in the table (e.g., "motivated pioneers/forerunners who want to recycle (+11)" in the first cell of the Table 1. The text refers to the HF Tool items from 1 to 47 or to the core of the HF Tool and the +/- means whether the mentioned issue is a facilitating (+) and/or hindering (-) factor in the implementation of JGW. (see Figure 1 for details)

At the individual level, motivated individuals led by example and encouraged others to join the waste separation experiment at work. Coping with the stress of daily work life and feelings of frustration posed a challenge. Proposed solutions included directorate support, peer support for challenging emotions, joint waste separation experiments, and a feedback loop between individuals, waste sorting system, and support at the organisational level.

At the work level, challenges included a lack of circular economy competence, non-functioning waste sorting facilities indoors, and poor winter maintenance of waste station surroundings. Solutions proposed include developing competence for the circular economy through multi-channel communication, providing waste separation containers and instructions for separation at the source indoors, and implementing quick fixes such as studded shoes for taking separated waste into the waste station in winter. Additionally, rebuilding the waste station and reaching agreements on maintenance measures are suggested as solutions.

At the group level, challenges included the absence of a systematic agreed approach for waste sorting in the classrooms, lack of shared awareness and practices, and there was no shared sustainability agency. Proposed solutions included implementing a systematic approach for labelling and colour coding of classroom waste bags, creating shared awareness and practices for waste sorting in the teacher breakroom, and engaging in co-creation experiments. Scheduled and regular facilities walkthroughs with representatives from different occupational groups and the availability of a visual round-up from the walkthrough were suggested as corrective actions.

At the organisational level, challenges in communication with a new external operator, cleaning operations did not support waste separation actions and the needs of premises users, and lack of well-functioning channels of cooperation and development with key stakeholders were identified. Solutions suggested included giving corrective feedback to the cleaning company, re-examining contracts and quality criteria, creating a sustainable development strategy for the school, and engaging in social debate at the local level and exploiting networks and social media for establishing well-functioning channels of cooperation.

The laundry was selected as a next example to describe reactive measures for JGW because they had already faced challenges with heat conditions at work and had contacted external experts to help with the heat stress (changing thermal environment in a laundry). (Table 2)

Table 2. Case example: Adjusting to the changing thermal environment in a laundry; implemented actions, their obstacles and ways for solutions (reactive measures for JGW)

Level I-IV	Starting point	Implemented actions in a laundry	Obstacles	System level solutions suggested by researchers
Individual level				
	Excessive heat load (-7, -29)	Thermal breaks, individual fans (+23, +24)	No cool space available indoors for thermal breaks (-29)	Investment requirement to build a cool space (+44)
	Individuals spend their thermal breaks outdoors in the sun (-7)	Oral instructions in workstation meetings (+24)	Lack of understanding of the impacts of heat load on well-being at work (-41, -42, -43)	Orientation of employees, visual instructions at the workstations (+1, +3, +24, +28)
Work level				
	Thermal conditions	Thermal and air humidity level	No historical data or comprehensive	Systematic and comprehensive

monitored in real time pointwise indoors (+2)	monitoring in two-week measurements twice (winter and summer) (no applicable item in the HF Tool)	monitoring of thermal and air humidity levels indoors (no applicable item in the HF Tool)	monitoring system of thermal and air humidity conditions, to produce work environment data (+30, +43). Need for policy and management (+44)
Individuals spend their thermal breaks outdoors in the sun (-2, -7)	Initial plans by employees to create a cool and shady break area outdoors (+1, +2, +11, +25, +27)	Purchasing decision processes do not support this kind of employee initiatives (-40, -41, -44)	Need for organisation level solutions to enable employee agency (+40, +44, +45)
Group level			
No group for climate change co-creation (-25, -27)	Forming a new group with representatives from different levels of organisation to deal with climate related issues and ideas (+25, +27)	Group does not have comprehensive representation (e.g. property maintenance). Status of the group not established in the organisation (-31, -36, 43)	Need for organisation level solutions, support from top management and linking to company strategy (+40, +41, +42, +44, +45, +47)
The new group does not have agreed policies (-24)	Agreement on basic group policies that support group's agency (e.g. frequency and implementation of meetings) (-24, -44)	Lack of group's visibility and poor flow of information within the company (-35, -43)	Support from all levels of management (also top management), Updating internal communication policies and practices (+24, +40, +41, +42)
Organisational level			
Operating environment in constant change (e.g. increase in production, energy saving targets) that	Reacting to and solving single situations and changes (e.g. production machinery renewal, window foils) (-27, -45)	Needs for too costly investment to renew and optimise the whole ventilation system Need for changes in production facilities to adjust	Re-investments in production property (+44, +45)

	effect thermal conditions (core of the HF Tool; -45)		to increase in production (-44, -45)	

The markings in the table (e.g., "Individuals spend their thermal breaks outdoors in the sun (-7)" in the first cell of Table 2. The text refers to the HF Tool items from 1 to 47 or the core of the HF Tool. The +/- means whether the mentioned issue is a facilitating (+) and/or hindering (-) factor in the implementation of JGW. (see Figure 1 for details)

At the individual level, the excessive heat load was addressed with the implementation of thermal breaks and individual fans, but a lack of cool indoor space for the breaks posed an obstacle, which necessitated an investment in building a cool space. Additional challenges included individuals spending their thermal breaks outdoors in the sun, leading to an orientation of employees and visual instructions at the workstations as a potential solution.

At the work level, the monitoring of thermal conditions in real time indoors was implemented, but there was a lack of historical data or comprehensive monitoring of thermal and air humidity levels indoors. This obstacle called for a systematic and comprehensive monitoring system of thermal and air humidity conditions to produce work environment data, as well as the need for policy and management. There was also an obstacle related to the lack of support for employee initiatives, highlighting the need for organisational level solutions to enable employee agency.

At the group level, challenges included the absence of a group for climate change co-creation, lack of comprehensive representation in the newly formed group, and the absence of agreed policies. To address these issues, there was a need for organisation-level solutions, support from top management, and the establishment of basic group policies that support the group's agency.

Finally, at the organisational level, the operating environment was in constant change which had implications for thermal conditions, necessitating reactive measures and solutions. The need for costly investment to renew and optimise the whole ventilation system and to make changes in production facilities to adjust to an increase in production reflected the need for re-investments in production property.

The analysis of the eco-usability observations with the HF Tool showed that the currently conducted actions may be limited to the individual, work, and group levels. However, the final steps needed for successful implementation of JGW are mainly at the organisational level. For example, this includes building a strategy for JGW and establishing physical facilities and equipment for successful actions in green work, as well as collaborative learning and shared knowledge and awareness of the suggested actions for JGW such as recycling and coping with heat stress.

Evaluation of the HF Tool in analyzing contributing factors of just greening of work

The benefits of using the HF Tool were evident in identifying several key points, particularly the essential role of organisational factors, in implementing JGW. The HF Tool facilitated the mapping of a comprehensive view of contributing factors for the greening of work, enabling the perception and recognition of potential obstacles in future implementation of JGW actions. Additionally, the tool assisted in forming a mental model for JGW actions, understanding weak signals in the system that require short- and long-term actions, and visualising items to be addressed.

Several lessons were learned regarding missing items such as "no actions have been implemented," "no shared sustainability agency," or "weak relation to co-creation experiments" which would be valuable additions to the HF Tool. To better address social sustainability, OSH practices could be added to item 47, which currently only mentions HR and financial practices, to define all the relevant roles in actions for JGW. Additionally, physiological symptoms could be better described at the individual level as a new item, for example, number 13, to consider symptoms such as heat stress.

Currently, the HF Tool has only been used and applied in one organisation at a time and has not been tested in intra-organisational development processes in the context of JGW. Additionally, the original use of the HF Tool has been focused on safety-critical incidents, while sustainability transitions involve long-term processes with several slow changes in the functional environment. It may be beneficial to reformulate the core of the HF Tool ('mastering complex, dynamic, uncertain situations') to include "processes". Process orientation would help to direct attention both to short-term efficiency and long-term societal effectiveness. For example, there is potential to emphasise two aspects: resource efficiency (whether the workplace is using resources efficiently and reducing waste) and resource effectiveness (whether the workplace is using resources effectively to create value, e.g., in industrial ecology or to support the ongoing replenishment of resources).

In future, the HF Tool could be used not only in perceiving the current view, but also as a commitment tool for group discussions at work, for analysing 'just green' incidents or occurrences at work (e.g. which have been the obstacles, reasons and solutions for frustration), or following up the accurateness of solutions, or following up trends, motivating personnel and management for just greening of work. It could also serve as a proactive tool for planning JGW actions and revealing bottom-up ideas, ensuring joint commitment in implementing JGW actions at any workplace. Using specific indicators could help workplaces to proactively build a greener workplace. It would be worth testing whether the HF Tool helps to form these kinds of measurable indicators. The HF Tool could also be used to help workplaces to realise the accuracy of their green actions, which are the strengths and weaknesses of the system currently, and which are the ways forward. In this case, it does not

need to always be conducted as a walkthrough, as these inspections or collaborative audits could be incorporated as interviews or focus groups.

An interesting point is, who holds the "voice" of the environment in these engagements and data-gathering; is it employees, experts or managers? Or all these together? Using the HF Tool as a part of JGW activities probably serves as an intervention, as it forces the joint discussion and shared view for actions by several partners such as employees, management, HR, OHS representatives and OSH managers. Nevertheless, people with expertise in environmental issues may be necessary to include in the audit and solution processes.

Obviously, there can be obstacles to implementing the HF Tool, or any other tool, for JGW. Earlier barriers and hindrances have been found in aviation in the 2000's in Finland when old culture and structures hindered the fluent renewal of the culture; however, an organisational crisis with implementing new awareness, competence and tools and models helped to advance the organisational culture aspects. (Teperi 2012). This could probably be the case in those workplaces which are struggling with tensions and conflicts in fostering JGW.

Greening of work is like any other development action that just needs attention to human performance and their contextual factors: Do we help people to be green at workplaces, or are there too many obstacles? Do workplaces have enough stamina to continue, after encountering obstacles? Who leads the movement from actions - failed actions - obstacles – to solutions? Based on our findings, the HF/E approach is needed, to enable a a) holistic view, understanding systemic relations; b) solution-based, positive energy to proceed; and c) collaboration between several partners.

The most critical phase of the change is how to turn information from the HF Tool into an action plan for the organisation? After mapping the contributing factors of JGW the next steps need be building development phases in a systematic way. Aligning earlier study findings, successful implementation forms a spatially and temporally expanding performance that includes phases of raising awareness, building competence, developing and implementing sustainability practices to work and OSH practices and procedures, and fostering interorganisational collaboration (aligning Teperi et al., 2021; Teperi et al., 2023). It could be considered whether these phases could be similar when just greening the workplace. The HF Tool has earlier been found to be successful in facilitating these phases in the long term (follow up concerning 5 and 20 years of the use of the tool; Teperi et al., 2023). In this study we found that it could help in raising awareness and maybe it could work as a tool for sustainability competence, but further studies could show whether it has added value in implementing JGW, to instill them into the every-day-operations at work, as has been done earlier in ATM and railway (Teperi, 2012; Teperi et al 2023).

Discussion

In this paper, we aimed to define characteristics for implementing JGW. Workplaces pose a critical local linkage through which the globally targeted sustainability transformation can be applied (Rockström et al., 2023; SDGR, 2023). Each workplace needs to contribute by including environmental measures as core factors for just work. Thus, workplaces need frameworks, models and tools to map systemic, underlying factors of just green work to develop concrete steps for change. Our results indicate that linkage between green and just are reciprocal: greening of work (environmental sustainability) is not possible without social sustainability, ensuring that the workers are looked after, for example by including occupational health and safety. (EU-OSHA, 2023). Similarly, in the long term, just work is not possible without green actions ensuring sustained use of natural resources.

In this study, the HF Tool was used to uncover the facilitating and hindering factors for JGW, and to operationalise the potential of the HF/E approach in just greening of work. The facilitating factors were at individual, work, and group levels such as motivation and willingness to act on personnel and practical actions for recycling and managing the thermal conditions. The hindering factors of the JGW were how the systemic nature and concrete, interrelated levels and details of change could be identified at the selected workplaces. The applicable solutions may be produced only in such a way that workers themselves can be agents of the change as found earlier in work development research (Sannino, 2020).

As with any organisational change, the most crucial actions are from those at top and middle management level who determine whether socially and environmentally sustainable actions are supported in every-day-operations through joint commitment, to help workers to succeed in realising JGW in their daily actions (Schein, 2010; Flin, 2003). The other criteria for JGW – besides raising awareness and competence management – are instilling just and green practices into the every-day-operations of the workplace as well as to commit all organisational actors (including HR, OSH and other organisational structures) to form networks for solid and systematic implementation (Teperi et al., 2023)

There is a strong tradition in the Nordic countries for participatory approaches and for prevention when aiming to improve employee health, safety and well-being. Organisations typically struggle with designing and implementing such interventions (Waterson & Kolose, 2010; Teperi, 2012). Questions arise about how workplaces succeed in implementing actions for JGW, to improve work, human, and system performance through changing the way work is organised, designed and managed and how the value of these actions for the sustainable impact is evaluated. Skills and knowledge for how to develop, implement and evaluate interventions for JGW will be crucial in the future.

The transferability and applicability of these findings to the broader international context is still an open question. A lot depends on the ecological awareness of the workforce and management. In situations where they are mostly concerned about decent pay and decent

work conditions the "green" aspects of the work and workplace may get missed, unless they are introduced by the dedicated expert such as an HF/E practitioner or the people conducting the sustainability walkthrough. Also marginalised or exploited workers/groups (e.g., immigrants, indigenous groups) who don't always have full legal protection will be in vulnerable positions that need to be considered.

The innovativeness of our paper is in presenting the theoretical and practical potential of HF/E as one approach for sustainability science. Both sustainability science and HF/E hold a systemic view, are multi-disciplinary sciences, and encourage theory-to-practice as key principles (Wilson, 2014; Dul et al., 2012). The potential is already recognised (Richardson & Thatcher, 2024), but the connections have only recently been made. We see that HF/E findings presented in this paper may give practical value for bridging sustainability theory to enable JGW. The examples presented in this paper aim to represent a systematic approach to guide workplaces in setting proactive practices in a collaborative, systemic, and solution-focused way. Similarly, workplace innovation processes seek to engage all stakeholders in dialogue, by empowering high involvement practices and representative partnership structures at all levels of the organisation. (EUWIN, 2014)

When supporting or pushing employers and employees in the right direction, several stakeholders including trade unions (Stevis & Felli, 2015), authorities, clients and consumers have a role to play in actions for JGW. All these may have different power status, and interpretations and strategies in fostering JGW. This article focused on the application of the HF Tool in a single workplace at a time, but as is known, activities for a just green transition are systemic by nature (SDGR, 2023). To realize a just green transition in workplaces, comprehensive, systematic, and long-term intra- and inter-organizational development processes need to be conducted, as also found in safety research (Teperi et al., 2023; Waterson & Kolose, 2010). Thus, in the future, the use of the HF Tool could be expanded to map and facilitate intra- and inter-organizational processes, such as sharing awareness, best practices, and learning strategies among actors such as management, HR and safety and quality experts. Furthermore, the HF Tool could be used to improve communication within supply chains for just greening activities, if used by a dedicated expert who has competence in organizational development techniques and just greening activities at work.

Resilient performance of organisations is argued to be crucial (Nemeth & Hollnagel, 2022; Lyytimäki et al., 2023). Aligning this view, in addition to new understanding, employees and workplaces will be required to produce new kinds of capabilities and resilience (Nemeth & Hollnagel, 2022) in accordance with the requirements of the changing operating environment. It should be noted that not all kinds of resilience are desirable. In the future, activities, business, and lifestyles that are unsustainable for people and the environment must be reduced or eliminated. Several industries produce outcomes that are clearly against green transition (e.g. fossil fuel industry) (Lyytimäki et al., 2023). Unfettered economic growth is perhaps one of these unsustainable activities as has already been argued (Meadows et al.,1972; Meadows & Randers, 2012).

Sustainability competencies can be utilized for HF/E in JGW (Ratinen and Linnanen, 2022; Ratinen et al., 2023). Integrating these competencies into organisational practices and culture can help create workplaces that not only prioritise social and environmental justice but also foster collaboration, innovation, and resilience in the face of complex challenges. For example, systems thinking involves understanding the interconnectedness of various elements within a system and their dynamic interactions. Future-thinking involves anticipating and planning for future scenarios, trends, and uncertainties. In JGWs, workers as future-thinkers can help organisations envision and work towards more equitable and sustainable futures by reflecting on and aligning actions with core values such as equity, justice, and sustainability. Collaboration competence involves effectively working with others to achieve common goals. Workers in JGWs, are capable of addressing complex social and environmental challenges that require collective action. Action-oriented competence involves taking proactive steps to implement solutions and drive positive change. Action-oriented competence is crucial for translating values and aspirations into concrete actions and outcomes for making workplaces just and green (Ratinen et al., 2023).

As this study has presented only two cases, we offer some reflections on the broader learning derived from the study. HF/E could play a role in addressing greenwashing risks by providing guidance on implementing authentic JGW initiatives. The risks of different forms of greenwashing (Gatti et al. 2019; Todaro & Torelli 2024) need to be considered already when actions for JGW are planned. Basic starting points include full compliance with existing legislative frameworks and transparent and honest internal and external communication. Furthermore, willingness to implement real changes is needed, even when there are short-term commercial interests, technological difficulties, requirements for learning and unlearning, time pressures, and other factors that may limit acceptance of transitions to greener work. An important question of acceptance – falling outside of the focus of this study and our case study examples – is how to phase out unsustainable work or polluting jobs while facilitating just transitions for the workers involved in this work (Rosenbloom et al., 2020).

HF/E has long and systematically developed thinking and actions to enhance a just and fair culture at work by focusing on organizational factors and social processes (Waterson & Kolose, 2010; Dekker, 2016; Thatcher et al., 2018, 2020; Teperi et al., 2023). These HF/E principles could offer user-friendly tools for improving transparency and communication in workplaces, as well as enhancing accountability through better monitoring and reporting systems. Such systems have been found crucial for improving safety culture (Dekker, 2016). By making information about environmental practices clear and accessible, companies can accurately track, report and verify their environmental impact, thereby informing and educating both employees and customers and stakeholders in a trustworthy manner. Organisations are striving to achieve compatibility among multiple corporate responsibilities in their interactions with the environment and society. Merely reacting passively to external pressures does not integrate environmental and social responsibilities into the corporate

governance process, thereby creating a risk of widening gap between symbolic and substantial actions (Liu et al., 2023). HF/E could support the realisation of genuine actions more proactively and in a systemic, solution-based manner, which has been previously found beneficial in safety research (Teperi et al., 2023)

Conclusion

The current period presents a critical juncture for action, with workplaces serving as focal points for implementing globally required actions. However, the systemic view of practical actions has often been weak or narrowly focused on isolated short-term actions, posing risks to the relevance and efficiency of necessary measures. This paper demonstrated the application of HF/E through the operationalisation of an HF Tool, which was instrumental in identifying the contributing factors of JGW actions, particularly emphasising the significance of organisational factors, including management commitment and competence, in fostering collaborative, solution-based activities for JGW. While general level sustainability policies are important, the emphasis must be on enacting practical actions in workplaces. This paper highlights the need to consider what it takes to create a just and green workplace, showcasing how a systemic view, such as a collaborative, solution-based HF/E approach, can provide avenues for advancing procedures and practices for JGW.

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Challenges in Providing Industry with Skills for the Green Transition at the Right Pace

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Abstract

The manufacturing industry is undergoing a significant transformation, characterised by a green transition and rapid digitalisation. Technological advances have dominated Industry 4.0, whereas the transition to Industry 5.0 emphasises improving technology from a human-centric lens. This necessitates focusing on digital and green skills development to accelerate the green transition in industry. Within the context of Swedish higher vocational education (HVE), this paper aims to investigate HVE providers' experiences of challenges in providing industry with the skills needed for green transition. Interviews were conducted with 22 representatives of HVE providers collaborating with industry. The analysis is based on a model for analysing overlapping transitioning systems for development of skills for the green transition in industry.

The findings indicate that there was an imbalance in pace between HVE and industry caused by various challenges at three transitional levels. First, at the individual level, there was an imbalance between students', workers', and employers' perspectives on relevant training needs, skills, and engagement in the green transition. Secondly, at the company–HVE provider level, companies needed to keep pace with the programmes and courses offered by the HVE providers and recognise that workers on the shop floor needed to train and learn digital and green skills. Thirdly, the HVE system as a whole was unable to attract and recruit enough students to technical and industrial programmes, whereas the industrial sector did not have sufficient ability to identify emerging jobs which require digital and green skills to accelerate the green transition in industry.

Keywords: Green transition, digital and green skills, higher vocational education, Industry 5.0

Introduction

The manufacturing industry is going through a green transition alongside rapid digitalisation, necessitating strong measures to promote green technologies and innovative solutions in industrial production (Breque et al., 2021). The fourth industrial revolution, known as Industry 4.0 (I 4.0), has significantly impacted the industrial landscape, with emerging technologies like automation, robotics, and artificial intelligence (AI) (Oztemel & Gursev, 2020). While Industry 4.0 has mainly focused on technology advancements, the transition to Industry 5.0 (I 5.0) centres around improving technology through a human-centric lens (Breque et al., 2021; European Commission, 2022; Gupta, 2024). This underscores the critical role of human collaboration with technology in achieving sustainable production processes and accelerating the green transition in industry. Industry 5.0 embraces the twin transitions; emphasising that the digital and green transitions run parallelly and reinforce each other, meaning that digital technology and human skills can be leveraged as catalysts to drive the green transition (Muench et al., 2022; Wang et al., 2024). The green transition is forecasted to create new jobs and employment in sustainable industries such as renewable energy, waste management, and environmental conservation (Bednorz et al., 2022; Oeij et al, 2023). In existing jobs, the impact of the green transition could result in changed work content that will require enhanced skills which are expected to positively affect workers' work (Oeij et al., 2023). However, the concern is that everyone will not be able to benefit from these transition opportunities due to limited access to digital technologies and green innovations (Muench et al., 2022). Therefore, it is argued that it is important to ensure that the digital and green transitions are just and accessible to all (Muench et al., 2022) to mitigate negative employment effects (Sharpe & Martinez-Fernandez, 2021).

It is expected that emerging technologies and a greening approach will lead to unintended consequences that alter workers' work (Bednorz et al., 2022). The risk is that a polarisation may develop between high- and low-skilled green vocations, resulting in both winners and losers. 'Winners' will not only include workers in highly skilled vocations requiring technical and engineering knowledge. Many green vocations may become manual, which could also improve the job market for those with low qualifications (Popp et al., 2021) and for those who have lost their jobs in so-called 'brown industries' (ILO, 2011). There will also be losers—at least temporarily, as low-skilled workers who have more difficulties in taking up training or transitioning to new jobs are at risk (Vandeplas et al., 2022). To mitigate polarisation between workers in low- and high-skilled vocations, there is a consensus in research that transitioning to green jobs will require more extensive on-the-job training efforts in the workplace and more formal vocational education (Consoli et al., 2016).

While the industry's green transition is high on the policy agenda, it is still a quite new theme in vocational education research (Persson Thunqvist et al., 2023). It has been emphasised that vocational education must collaborate with industry to propel digital and green transitions, and vocational education providers have a key role to play in facilitating the provision of required digital and green skills (Persson Thunqvist et al., 2023). A critical problem, however, is that industrial companies' urgent need for digital and green skills does

not align with the vocational education system, as the system has difficulty keeping pace in a time of rapidly increasing green and digital technological advances (Rosenberg et al., 2018). These rapid advances will undoubtedly result in a need for new skills in industry, which is why the topic is at the top of the agenda for vocational education providers. In response to I 4.0 and the shift to I 5.0, vocational education providers have begun to find new ways of attracting students by collaborating with industry and addressing the need to reskill workers (Hong, 2023).

Within the context of Swedish higher vocational education, this paper aims to investigate higher vocational education providers' experiences of challenges in providing industry with the skills needed for the green transition. Although the green transition is prominent in the policy debate, its interpretation and application by different stakeholders remain unclear, and also the pace at which they must provide industry with skills for the green transition. These problems are the starting point of this article from the perspective of higher vocational education providers (henceforth referred to as 'HVE providers'). HVE providers are viewed from their role as contributors to the green transition in industry through education and training. This includes educating students—the workers of tomorrow—as well as training and upskilling workers currently employed in industry to develop the digital and green skills necessary for the green transition in industry.

The paper is organised into four additional sections. The following section outlines the theoretical framework which is based on Rosenberg and Ramsarup's (2020) model for analysing the green transition occurring in both industrial and educational systems, and at different levels within these systems. The next section describes the research method. The subsequent section presents the findings. The last section presents a discussion and thereafter some conclusions.

Theoretical framework

A model presented by Rosenberg and Ramsarup (2020) will be used in the analysis. This model provides a holistic perspective that facilitates the understanding of the complexity surrounding the green transition in industrial companies. This means that industry's green transition is not an isolated occurrence, but is mutually dependent upon, and overlaps with, other green transitions occurring simultaneously and across levels within a larger skill transformation system in which green skills and green jobs are developed (see Figure 1). This implies that the vocational education system itself must undergo a green transition to meet the needs of companies in their transition towards more green jobs (Rosenberg & Ramsarup, 2020). This requires coordination and collaboration between the green transition in industry and the green transition in the vocational education system to address current challenges.
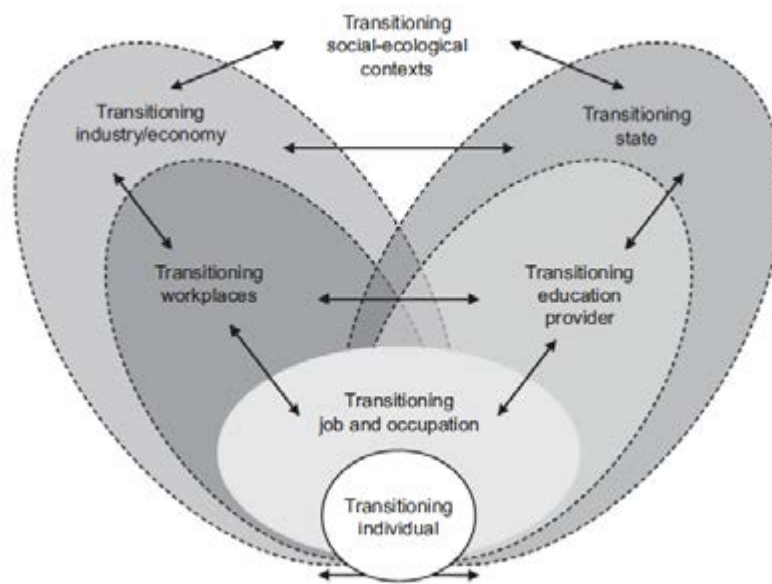
Figure 1. Rosenberg & Ramsarup's (2020, p. 11) model for analysing overlapping transitioning systems for developing green skills. The model is used with the authors' permission.

A criticism raised in the research is, however, that industry and workplaces' green transition and their increasing need for green skills are not aligned with the educational system, creating an imbalance or mismatch in the entire skill transformation ecosystem. While studies, albeit limited, indicate that one explanation for this mismatch is that the vocational education system is unprepared for the emerging demand for green skills development: both within existing vocations and emerging green vocations (Lotz-Sisitka & Ramsarup, 2020). The unpreparedness of the vocational education system can have several causes, but one explanation offered is that many green jobs are still emerging. Therefore, green jobs and tasks are not yet clearly defined or formulated in terms of green skill requirements. Furthermore, the transition from education to work complicates the skill transition, as workplace requirements for green jobs often are new or underdeveloped or even not yet known (Langthaler et al., 2021).

New, underdeveloped, or unknown workplace requirements implies that green jobs are not homogeneous; they vary across industrial branches, companies, and workplaces (ILO, 2011). Therefore, an increasing number of researchers have begun to classify green jobs on a continuum of greenness to demonstrate the variation and diversity of green jobs (Casano, 2019). Casano (2019) argues that the greenness of green jobs determines the type of education and training required, but apart from a few skill-specific exceptions, some green jobs do not differ significantly from non-green jobs. This indicates that most training can take place on-the-job, while other jobs which have a higher level of greenness and digital technology as those emerging alongside the green transition will require more extensive formal education. Formal education measures can be provided as short courses or training programmes on-site or online, but there must also be clear skill development pathways

between formal and informal learning arrangements for the education measures to feel relevant to workers in their daily work (Halvarsson Lundkvist & Gustavsson, 2018).

Other studies (Brown, 2015; ILO, 2011) classify green jobs into the qualifications needed to perform the job, which determines the type of green skills required. These studies divide vocations into the following: (1) existing vocations that will require few or no green skills; (2) transformation of existing vocations in industries that will require green skills; (3) new vocations in industries that will require existing technical skills along with green skills; and (4) emerging new vocations in new and expanding green industries that will require the development of green skills.

Therefore, it is difficult, if not impossible, to identify the need for training without first identifying the types of green jobs, and specifically the green skills workers require. Green jobs require different types of green skills, which has implications for the training efforts industry must undertake to upskill or perhaps reskill their employees to adjust production and work processes to the green transition (Pavlova & Singh, 2022). Despite a plethora of studies that have listed green skills, such as managing water and waste, recycling, conserving energy, and managing raw materials, as well as developing green technologies and solving problems, there is still ambiguity about what should be included, although it is argued that these skills are needed by industry and should be introduced into education (Ibrahim et al., 2020; Mohd Zubir et al., 2021; Nikolajenko-Skarbalė et al., 2021; Sern et al., 2018). A multitude of technical and generic skills have been identified as green skills, and what green skills have in common is that they add value to technical and generic skills by reducing their climate impact (Cledumas et al., 2020; Hamid et al., 2019). Apart from green skills there will be an increased demand for digital skills in the greening of industry. This is because digital solutions, such as automation, robotics, and AI are integral to the acceleration of a greener industry (Muench et al., 2022). There is a wide spectrum of digital skills ranging from basic computer proficiency and the use of technological devices; to aptitude in managing, understanding, and analysing information; to being able to use information proactively; and even expertise in AI, machine learning, and cybersecurity (Fraile et al., 2023; ILO, 2021).

Research context

The research context for this study is postsecondary education known as Higher Vocational Education (HVE). This educational form is publicly funded by the Swedish National Agency for Higher Vocational Education. The agency allocates funds to a range of providers such as municipalities and private companies, which run programmes and courses. Since 2018, HVE has annually expanded their possible intake of students (for description also see Ye et al., 2022) and reached 93,000 available placements in programmes at the beginning of 2023 (MYH, 2024). The programmes (1–2 years in duration) are adapted to the labour market's need for qualified employees, where employability is the main argument for receiving funding for these programmes. The key function of HVE programmes is to prepare students with the

necessary skills for vocations through a combination of theoretical studies and work-based training. HVE in Sweden can serve as an important alternative pathway for individuals seeking to upskill themselves in a vocation or reskill themselves for transition to a new vocation (Ye et al., 2022). Each HVE programme has a steering committee, where employers play a significant role in shaping the content of the programme, but also by providing work-based training. Together with HVE providers, employers bear the responsibility of ensuring that the training aligns with the skills required in working life. In addition to programmes, HVE providers offer shorter-length courses to employers tailored especially for employees to meet employers' specific upskilling and reskilling needs.

Method

Design and selection of participants

The present study is part of a larger research project focussing on skills that matter for workers in Industry 5.0. The article presents a sub-study within this project which employed a qualitative research design based on 20 interviews conducted from May to September 2023 with 22 representatives of HVE providers from different regions in Sweden. Of the 20 HVE providers, 13 were owned by one or more municipalities, 1 university, and 6 private educational companies. Eight of the interviewees were education leaders, meaning that they worked operatively and closely with companies to develop and run one or more HVE programme or courses, 8 were principals or department managers, and 6 interviewees had titles such as strategist, business developer, or were senior managers or owners of educational companies. All selected HVE providers offered programmes in technology and manufacturing. They all had experience collaborating with industrial companies ranging from small and medium-sized enterprises to large companies, in various manufacturing areas.

Data collection

The researchers contacted all 20 HVE providers via email, presented the study's aim, attached an informed consent form, and proposed interview times. If the HVE providers agreed to participate, they chose a time for the interview and provided informed consent by signing the form and returning it. On average, the interviews lasted 60 minutes and were carried out via an online platform but were audio-recorded with a digital recorder which was placed in front of the computer. All researchers carried out interviews, but often an interview was led by one of the researchers while another acted as a listener, asking additional questions as needed. The interview guideline was semi-structured around the following topics: how programmes and courses were adapted to the skills needs of manufacturing companies; the challenges for HVE providers and manufacturing companies in providing the skills needed for industry; skills transitions in manufacturing companies, skills that became less relevant and skills that emerged as a result of technological progress and green transition; the ways and forms in which HVE providers collaborated with representatives of manufacturing companies; the

image and spread of Industry 4.0 and 5.0, and the resulting consequences for future education. When interviewing, the guideline was used as a starting point, but the HVE providers were encouraged to speak freely about their experiences. All interviews were transcribed verbatim.

Data analysis

Data derived from the interviews underwent a thematic analysis inspired by Braun and Clarke (2006), which involved the following stages: identify, discern, and analyse recurring themes. An initial reading of the interview transcripts provided us with an overall picture of the challenges faced by HVE providers. After the reading, an inductively driven coding process was employed to identify recurring themes or patterns of meaning and to discern, categorise, analyse, and ultimately name the challenges identified. The analysis made it apparent that the interviewed HVE providers experienced that they operated under a multitude of challenges stemming from both higher vocational education and manufacturing companies. The challenges identified were divided into three main categories, related to the transitional levels presented in the model in Figure 1.

Findings

This section outlines the main findings of the HVE providers' experiences of challenges in providing the manufacturing industry with the skills needed for digital and green transitions.

Catering different student groups

The HVE providers faced challenges in providing manufacturing companies with skilled workers, both educating students, the workers of the future, and upskilling those already employed in companies with necessary digital and green skills. Therefore, they saw an urgent need to attract more students to technical and industrial education but also provide training to employed workers, in order to supply the industry with the necessary skills. To address this issue, the HVE providers were tasked with designing curricula that would furnish students with the requested skills sought by the labour market while remaining adaptable and responsive to the changing training needs in companies. In developing curricula, the HVE providers found it challenging to reach out to potential students and companies of all sizes, to understand the constantly evolving skills required of workers, which was paramount to be able to offer relevant and flexible programmes and courses.

Another challenge was to attract and cater to the needs of different student groups. The HVE providers emphasised that HVE students are relatively heterogeneous in terms of social background, motivations, life experiences, and motives for applying to and attending HVE, which the HVE providers believed influenced students' decisions to take specific courses, reskill themselves, and to possibly even change jobs. The providers were also required to develop different strategies for lifelong learning with specific skills demanded by employers.

This included guiding students in understanding employers' implicit requirements for social and individual skills that went beyond formal skill requirements for employment. A particular challenge was to increase capacity to broaden recruitment and promote so-called non-traditional vocational paths, especially regarding female students, given that women are still underrepresented in many industrial jobs. Another student group that needed special attention was workers who participated in shorter courses to improve their skills while continuing to work at their current jobs. The HVE providers emphasised that this type of training was dependent on workers' motivation to reskill and employers' willingness to allocate sufficient training time.

> Not everyone who studies in our programmes is unemployed or has nothing to do; many come directly from companies. In the latest round of production technicians, there were probably three or four who were on leave from their companies. This is because they have understood that: "Oh, this is going to be important," or "I need to move on," and they then educate themselves. So, I think that's how it works. Those who can influence change, like the CEO, production manager, and HR manager, understand the challenge in the green transition and in digitalisation. They don't hold off on sending their operators for training because they understand that it is necessary. (IP19)

Sometimes the HVE providers found it difficult to define students' future careers and vocational identities. This issue often arose when the specifics of various vocations were unclear or when new job titles were emerging in the industry. As a result, the HVE providers sometimes had to provide training for vocations not yet fully recognised, resulting in uncertainty about future job roles. They believed that local anchoring in companies of partially new vocational titles, especially in digital and green transitions, could create uncertainty among students as to what vocation they were training for. Even established vocations, such as production technician, were hard to define due to their broad and varied specialisations. The HVE providers recognised that new vocational roles could be perceived differently among students, ranging from practical industrial tasks to high-tech and AI-related duties.

An overall challenge for the HVE providers was to fill courses. Consequently, they could not deliver the skills that the industry demanded, often due to the low attractiveness of industrial jobs. The most common answer by the HVE providers as to why the industry was not considered attractive was that young people had a misguided image of the industry, rooted in notions of factory work as heavy and dirty. Some HVE providers emphasised that manufacturing companies should contribute more to changing this outdated image and develop marketing strategies for this. The HVE providers also had to deal with stereotypes suggesting industrial jobs were mainly for men, making it particularly difficult to recruit female students to technical and industrial programmes. However, they found that efforts towards green and sustainable development in courses could also be a potential strategy for attracting more women to industry by integrating technological development with sustainability and green innovations.

It is a tremendous opportunity, I would say, for the industry. Integrating technological development with sustainability development will increase equality in these technology-intensive and industrial jobs. (IP4)

These assumptions were also partly based on experiences or hopes among the HVE providers that female students were engaged in sustainability issues to a relatively high degree.

Broad, deep, and innovative education

A prominent challenge for the HVE providers was balancing breadth, depth, and long-term perspectives in technical and industrial programmes, while also being agile enough to quickly address urgent skill needs in companies, as they arise. The analysis shows that sustainability influenced HVE providers' development of programmes and courses. This was partly due to the requirement from the Swedish National Agency for Higher Vocational Education that the programmes and courses should be adapted to the goals outlined in Agenda 2030. The HVE providers revealed various ways of referring to and approaching these formal instructions, sometimes in the form of a mandatory element that had to be incorporated into curricula and courses, and other times as a more deliberate strategy to attract students and improve their learning. The latter was expressed in initiatives aimed at a specific industry or a certain technology such as wind power, solar panels, or green electricity. The HVE providers often tried to combine broad training with new technical skills, which was a challenging endeavour. For instance, they developed innovative titles for their programmes and courses to signal the breadth, but at the same time, employed specific phrases to attract students with the uniqueness of the programmes and courses they were offering, such as 'Automation and digitalisation engineer' and 'Automation and robot engineer within Industry 4.0':

The title is 'Automation and robot engineer within Industry 4.0' to include the whole name, so with that education we want the students to have a good platform to stand on, we don't want to direct them too narrowly. Even though it could be narrow in some operator educations, we want them to be able to pick the parts they find fun, under the umbrella of automation and robots. So that they can come out and be technicians, they can come out and be automation engineers, it depends a little on their level of ambition. (IP11)

With the development of programmes and courses towards new technology and sustainability, more challenges followed. The rapid pace of technological development required the purchase of expensive machinery and equipment for adequate vocational training. However, it was sometimes not possible to invest in new machines for the HVE providers due to financial constraints, especially for short courses. Finding educators with expertise in new technology and sustainability for courses was also a major challenge, as these courses were at the technological forefront. They also had to consider that some companies were unable to take advantage of cutting-edge technology courses due to

outdated equipment, which meant that the HVE providers also had to keep older equipment on hand. Demands and expectations from companies to rapidly train personnel could entail provisional solutions that were less well-founded. A strategy among the HVE providers was to have a basic concept for a certain type of course and supplement it with training modules that enabled flexibility. The challenge was to act swiftly in providing the courses to employers. Aside from conveying employers' requests for more courses that reskilled workers in digital and green skills, the HVE providers also considered the perspectives of students regarding how the programmes and courses could prepare them for a future vocation.

According to the HVE providers, assigning a few course credits in sustainability could facilitate getting an application for funding approved. One dilemma was, however, that if the integration of new technology and sustainability into courses was only perceived as decorative, rather than substantial, in nature. This was particularly the case when a few credits related to eco-friendly technology were added into a course without substantial changes.

> We've included a sustainability course, a specific sustainability course, in that programme that we didn't have before, and tweaked it a bit to make the credits align more explicitly. (IP26)

In the interviews, different approaches to the climate crisis emerged in the discussion of education focused on green transition. While several HVE providers passionately advocated for climate-smart developments in programmes and courses adapted to industry, it was also noted that some mentioned climate issues more casually, as a trend of the time.

Green transition as investment, duty, and marketing

Industry 5.0 and its focus on the digital and green transitions is very recent, or even still in the development and maturation stage in Swedish manufacturing companies. The HVE providers emphasised that the companies' challenges also became their problems. At a societal and organisational level, the primary challenge for companies was to ensure demand for skills and to increase industry's attractiveness. The HVE providers stated that many companies reported difficulties finding skilled workers. Significant numbers of retirements occurred at the same time that too few young people were attracted to industrial work. Companies demanded programmes and courses that were unique to their needs and students with skills that could directly enter production and fill companies' skill gaps. For example, the need for skills in energy and electricity emerged as particularly critical issues, as there was a significant shortage of expertise in these areas, ranging from electricians to electrical engineers. The issue of inadequate competence supply was also discussed by the HVE providers, as a technological transition required reskilling and upskilling staff on a large scale.

When providing education and allocating students to small businesses, the HVE providers had to consider their financial circumstances. They believed that if smaller companies did not adapt their operations to the green transition, small companies could risk not accessing

suitable courses or losing skilled labour to other companies. Among larger companies, more skills were needed to adjust to the climate crisis, entailing some form of green transition, considered necessary to remain profitable and survive competition. The HVE providers' experiences were that large companies often relied on their own in-house training, while expressing that the educational system did not deliver what skills they needed.

> Time and again, they express disappointment with the educational system for not delivering what they need without being actively involved themselves. Because, in a way, it's about selling and storytelling, making those people, especially young people, curious and eager to be part of their organisation. But I feel they [the companies] have failed miserably at this. It's like expecting someone else to fix it. (IP3)

The intense competition among manufacturing companies for labour, particularly in shortage occupations, also indicated a shift in the balance of power between companies and workers. The HVE providers had noted that when there was a high demand for labour, workers could make greater demands of their employers, but also that students had a wide range of employers and offerings to choose from. This involved not only salary, but also various values such as healthy workplaces, self-fulfilment, and flexible work hours. The HVE providers' experiences were that companies' motives for investing in green transition within production could coincide with external expectations and demands and therefore be seen as a duty but also as part of marketing and self-presentation. Motives could be to invest in the green transition to appear credible to customers and to build up a company's brand, but also, in a broader sense, to demonstrate responsibility based on interest in the climate. Challenges faced by companies could also be seen by the HVE providers in the context of the structural transformation of industry jobs following the movement towards Industry 4.0 and Industry 5.0. The HVE providers emphasised that this transformation required increased awareness among companies that workers had to develop many new digital and green skills. Some HVE providers saw a significant challenge for companies due to a radical shift in which the technological focus had to be balanced more with a social and just transition perspective on workers' jobs on the shop floor in companies. In the future, some HVE providers believed that automation, digitalisation, and artificial intelligence would eliminate many industrial jobs. Other jobs like operators would be transformed and have a broad theoretical foundation, while the need of craft skills would remain strong. At the same time, new occupations were expected to emerge. In response to industry's green transition and digitalisation, the HVE providers mentioned innovative programmes and courses in the making. It was programmes and courses for which funds were sought that dealt with new occupational titles that were not yet known, and whose educational content could sometimes be difficult to determine.

Discussion

The insights gathered from the interviews with the HVE providers unanimously convey that a green transition and rapid digitalisation are regarded as essential for Swedish manufacturing companies. In the transitioning process, the nature of work changes, and students (future workers) and current workers must develop digital and green skills to keep up to date with new technologies and green innovations. This will entail a massive demand for relevant skills within various industries. At the same time, there is uncertainty among HVE providers and companies about what type of programmes and courses would be most relevant for the industry to be able to address present and future skills needs. Additionally, our findings indicate that companies may find it difficult to determine which type of training suits the short and long-term skills requirements that will enable their green transition.

The multi-layered model (Rosenberg & Ramsarup, 2020) presented in Figure 1 serves as an analytical lens to further approach and discern challenges within the overlapping transitioning systems that exist in a larger skill transformation ecosystem aimed at providing industry with appropriate skills for the green transition. The findings illustrate that the green transitioning underway at different levels (Figure 1) is clearly not keeping the same pace and the green transition can thus be seen as unbalanced (Rosenberg & Ramsarup, 2020). The imbalance or difference in pace between the HVE system and industry can be caused by various challenges that manifest themselves differently within the two systems and at different levels.

The transitioning individuals

The HVE providers faced the challenge of managing two distinct groups, students (tomorrows worker) and workers, on parallel training pathways. This required different strategies, adding complexity to the training process. On the one hand, they had to attract and train students in technical and industrial programmes and courses. On the other hand, they provided training to workers based on the employer's terms and circumstances. The training aimed to enhance individuals' chances of gaining a stronger position in the labour market, as well as facilitating the transition to new tasks and jobs for those already employed in industry. This means that the training must be relevant not only for current job roles but also for future ones that may arise in response to the green transition (Casano, 2019).

By offering alternative training paths, the HVE providers demonstrated a high level of awareness about the value digital and green skills could bring for students and workers. However, the HVE providers believed that the success of the green transition at the individual level was largely dependent on the motives and driving forces behind individuals' decisions to take a course or to reskill and possibly even to change jobs. This means that individual willingness and motivation were crucial conditions in the green transition. Nevertheless, the findings showed that the HVE providers' experiences of sometimes unclear skill requirements made it challenging for them to decide which skills individuals should acquire to meet the needs of industry. While some training paths had clear requirements for digital and green

skills, others might not be as clear, because technological advances were driving the emergence of new jobs (Brown, 2015; ILO, 2011). Due to this, the HVE providers faced difficulties in keeping pace in providing training to students and workers for new job titles and roles that were not yet fully developed. Such rapid change required continuous adaptation to industry and flexibility from the HVE providers to navigate these challenges and contribute to the green transition.

Transitioning at company and educational level

The transitioning at company and educational level necessitated delivery of tailored programmes and courses to adapt to evolving job roles and tasks in workplaces and companies. In these tailored offerings, the HVE providers faced pressure to incorporate sustainable and technological solutions. These solutions were pivotal in facilitating the industry's shift toward digitisation and green transition, and in equipping workers with the skills required for change in companies. Notably, digitised and green jobs and skills were not progressing uniformly across all companies. Small, medium, and large companies differed in their requirements for skill development. Therefore, the HVE providers recognised the need to adopt to individual company specific skill development needs. Consequently, when developing programmes and courses, they had to consider the specific conditions of each workplace and company to ensure the transition to digital and green practices.

While HVE providers played a critical role in providing courses adapted to digital and green transitions, they were not the only players who needed to keep pace with the skills needed in industry. According to the HVE providers, companies faced challenges keeping up with evolving skill requirements. The HVE providers experienced that companies needed to recognise that workers on the shop floor had to be prepared to learn and train in a range of digital and green skills that would be required as the green transition accelerated (Oeij et al., 2023). This meant that companies had difficulties keeping pace with the programmes and courses offered by the HVE providers. For example, there could be a mismatch between innovative courses with high-tech and green foci offered by HVE providers, and the skills needed by companies. Due to outdated machinery and insufficient adaptation to the green transition, some companies were unable to benefit from innovative courses offered by the HVE providers.

As the companies had difficulty anticipating skill needs and requesting tailored courses, the HVE providers often found themselves in reactive mode, swiftly training workers when urgent skill development was necessary in companies. Therefore, the HVE providers believed that companies would benefit from adopting a more proactive stance, anticipating skill needs aligned with digital and green trends. This implies that it is not only the HVE providers' responsibility to pick up the pace. To do so they needed help from companies that are searching for skilled workers or looking for opportunities to reskill or maybe upskill their workers, which suggests that both parties need to take on collaborative responsibilities in their green transitions.

Transitioning at industry and HVE system level

The findings indicated that the green transition of the HVE system was not keeping pace with the green transition taking place in industry (Rosenberg & Ramsarup, 2020). The discrepancy was partly due to the HVE system being unable to attract and recruit enough students to technical and industrial programmes, while industry did not have sufficient ability to identify and demand digital and green skills, as many jobs were emerging or not yet recognised. Manufacturing companies struggled to find skilled workers, especially as the number of retirements increased and young people show less interest in industrial work.

As the findings show, the green transition of industry was not an isolated phenomenon but was mutually dependent on the green transition in the HVE system. There was no doubt among the HVE providers that uncertain forecasts about the industry's future high-tech and green skill needs had to be balanced with the current skill needs relevant to the changing nature of industrial work. Intense labour competition between companies could shift the balance of power between workers and employers. As a result, workers could demand more from employers, considering factors beyond salary, like workplace conditions and flexibility. Technological foci had to be balanced with social and just transition perspectives. Additionally, external expectations influenced their decision to invest in digital and green measures to enhance credibility, branding, and climate responsibility. Automation, digitalisation, and AI can eliminate many industrial jobs. Technology megatrends like automation, digitalisation, and robotisation can obscure the fact that many industrial vocations are in short supply.

Conclusion

The article contributes to the ongoing debate about the high demand for digital and green skills among manufacturing companies to accelerate the green transition in industry. It highlights the complexity of this transition by stressing the need for collaborative efforts between stakeholders within overlapping transitioning systems, all part of a larger skill transformation ecosystem, to provide the industry with the necessary skills for the green transition. However, as the findings show, there is a need to understand the reasons for the imbalance or differences in pace between industry and the HVE system, in general, and from a holistic approach. As demonstrated, a holistic approach can take the form of an ecosystem for skill transformation which enables a multidimensional analysis of industry's green transition, where stakeholders are interconnected and co-create knowledge about industry's digital and green jobs and the skills they require. Training and skill-enhancing efforts can become a catalyst for shaping occupations, jobs, and skills, and driving high-tech and green innovations. The way companies engage with HVE providers and other stakeholders in a skill transformation ecosystem can be important for the green transition in the workplace. Despite this, the green transition is still relatively underexplored in the workplace, and more knowledge is needed about workers' everyday learning and work during the green transition in industry. As part of the green transition, students (tomorrow's workers) play an important

role in ensuring digital and green skills. Therefore, companies can benefit from inviting students to contribute to the development of knowledge around the green transition.

However, knowledge about how a skill transformation ecosystem for green transition could be designed is limited. Therefore, further research is needed to develop knowledge that can provide insights into factors contributing to a 'successful' skill transformation ecosystem. This can include an understanding of the specific skills required of industrial workers in the green transition, best practices for stakeholder collaboration, and enablers and barriers within the skill transformation ecosystem. The results of such research could guide policymakers, HVE providers, and industry management by providing valuable insights into collaborative practices that help to create a more cohesive and responsive skill transformation ecosystem. This, in turn, could facilitate a smoother and more effective green transition, and the leverage of advanced technologies to drive the green transition. Ultimately, the research could contribute to the development of policy and educational and training programmes that are better adapted to industry's skills needs in the shift to Industry 5.0.

As with all studies, this study is not without limitations. A limitation is that our findings is based solely on the challenges faced by HVE providers. Incorporating the perspectives of industry representatives (managers and workers), students, and policymakers could have provided a richer understanding of different stakeholders' experiences of collaboration within the skill transformation ecosystem and their challenges in transitioning to a green transition in Industry 5.0.

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Identifying the potential for green jobs and associated skills needs: Methodological concepts applied to the South African coal mining industry

Eureta Rosenberg

Abstract

The idea of green growth holds much promise but also much uncertainty. It is hard to predict what new jobs might emerge, what new skills will be needed, and just how to achieve a transition that is socially inclusive and economically feasible, while shifting entire systems towards greater environmental sustainability. How should organisations respond, so as to benefit from and contribute to green growth? Based on research to identify environmental skills needed in the South African mining industry, and other sectors, this paper proposes a number of methodological innovations. One is to expand the standard value chain analysis, by using a critical realist methodology that also looks for absences: value that should be there but is currently destroyed or untapped. An example is the restoration of mined land, a form of regenerative economy with the potential to reduce value destruction and create new social, economic and ecological value. Identifying such leverage points can show up the possibility of new or re-configured jobs in the transitions to more sustainable development, in this case a transition away from coal. Another innovation involves the identification of the associated skills requirements. More than technical skills are needed, but just what do so-called 'soft skills' entail, and how can they be developed? The paper concludes with tools to apply at organisational level for green skills needs analysis, using a framework of technical, relational and transformational competencies, in support of the quest for green growth in senescent or at-risk value chains.

Keywords: sustainable development, value chain analysis, leverage points, mine restoration, relational and transformational competencies

Introduction

> "The future is often viewed through the mirror of the past. This can be risky, if past trends are allowed to influence or even determine what is considered a realistic strategy. This is particularly true if such factors are part, or even the main drivers, of the present problems. If we look at the problem of non-sustainability, such factors could be today's use of fossil fuels, today's accounting systems for economic performance (GNP), today's traffic systems, and today's public knowledge about environmental issues. If those factors are allowed to be the main determinants of what is taken to be relevant and realistic in the planning process, the strategy is likely to transfer the problems that are due to these factors into the future." (Holmberg & Robèrt, 2000, p.6)

The idea of green growth holds much promise: to slow and where possible reverse the damage caused to ecosystems by economic activity, in order to sustain natural resources like clean water and fertile soils that in turn sustain all life on the planet; *and* to re-configure economic activity so as to benefit those currently excluded (Stern, 2007); that is, sustainable development (Knudsen et al., 2023; Raworth, 2017). In the process, work opportunities could also be created. The International Labour Organisation (ILO, 2023) estimates that if Europe was to meet the targets of the New Green Deal and become carbon neutral by 2050 it would translate into approximately 2.5 million additional jobs in the European Union by 2030. A Global Commission on the Future of Work (ILO, 2019) reported that implementing the Paris Climate Agenda could lead to global job losses of around 6 million but also job gains of 24 million.

However, the idea of green growth also holds much uncertainty, particularly for work-based skills planning: Where can companies expect such green growth, and how will it happen? Will new policies actually be implemented? Who will invest? Companies may be unaware of global developments or unsure as to whether they should commit, while entire industries may be resistant. Such uncertainties stem from the complex nature of sustainability challenges (Holmberg & Robèrt, 2000) and the nature of sustainable development policies, which are often contested, ambiguous, contradictory, or inconsistently implemented (Chipkin et al., 2018; Death, 2014; Fakir, 2017; PAGE, 2016).

The unpredictable nature of the policy landscape presents a challenge for predicting what new green jobs will materialise and what skills will be needed (McLean, 2018). Skills needs analyses are in some contexts also hamstrung by the dearth of available data (Mwaura & Glover, 2021) and when conventional research instruments are applied in the face of all this uncertainty, the findings can be inconclusive or fail to drive transformation, as the opening lines, quoting Holmberg and Robèrt (2000), suggest.

Based on research to identify green skills needs in the South African mining industry (Rosenberg et al., 2015), as well as other sectors, this paper proposes methodological innovations for approaching skills planning in the face of such unpredictability. These include an extended industry value chain analysis that expands the classic concept of a 'chain' to

recognizing the weblike nature of value creation in industry, and through a dialectical critical realist lens also identifies absences: value that could be there but is currently untapped. Identifying leverage points for change (Meadows, 1999) can show up the possibility of new or re-configured jobs to compensate for job losses occurring in transitions to cleaner, 'greener' economic activity, even when this demand might still be latent, that is, not yet evident in the labour market.

The second proposed innovation involves the identification of the associated skills and skilling, upskilling and re-skilling needs, using a framework of technical, relational and transformational competencies (PAGE, 2016). The paper expands on this competency framework, and shares tools for organisational level skills needs analysis, in support of the quest for green growth and sustainable development.

The research from which these conceptual-analytical tools emerged, includes a programme of green skills demand studies conducted over more than a decade. The core of these studies involved a partnership between three South African universities, several government departments and industry partners including Sector Education and Training Authorities (SETAs). Starting in 2015, these studies explored value chains and associated skills needs in the mining industry (Rosenberg et al., 2015), the chemical (Jenkin et al., 2016), petrochemical (Ward et al., 2017) and agricultural (Cobban & Visser, 2017) sectors, as well as government procurement (Ward et al., 2016), and a cross-sectoral green economy learning needs analysis (PAGE, 2016). More recent studies involving land restoration (Human, 2020) and value chain innovations (Royle, 2023) were also included in the analysis. These studies were all conducted in South Africa, but the findings may apply in other contexts as well.

While the meta-analysis for emerging concepts included all these studies, the discussion will for illustrative purposes focus on the coal mining industry and in particular on mine restoration.

Literature Review – Context and Theoretical Roots

In 2015 the South African Mining Qualifications Authority (MQA) commissioned a study to determine environmental skills needs and learning opportunities in the coal mining sector in South Africa (Rosenberg et al., 2015). To design the study, the researchers drew on methodological insights from earlier research. This included a study to produce a skills strategy for biodiversity research and conservation (SANBI, 2010) which found that a holistic systems perspective on skills planning was needed; for example, skills interventions focusing on individuals were not effective unless attention was also given to workplace conditions. This perspective is well captured in the 'nested systems' diagram (Rosenberg & Ramsarup, 2020). Research into learning pathways and transition into green jobs (Lotz-Sisitka and Ramsarup, 2011) was also influential. These studies were in turn informed by research into sustainability transitioning, including the multi-level perspective on change developed by

Rotman and Loorbach (2009) and Geels & Kemp (2012). Rotman and Loorbach introduced a relational approach to studying change in complex systems, which also emerged as an important focus in the South African studies.

Perhaps the most influential theoretical influence on the South African 'green skills' studies was dialectic critical realism (Bhaskar, 1993) which led the researchers to approach skills contexts as a layered or laminated totality, with the interconnections and influences within and between the layers being vitally important (Rosenberg, 2020a). This is a key distinction from multi-level skills research methodology outlined by the ILO (2016, 2019, 2023). It is not only necessary to collect data and analyse it at multiple levels, but it is also necessary to analyse the connections between layers, or for that matter the absences, or connections that should be there, but are not. This intention to not only describe what is (as in a positivist, empiricist study) but also on 'what could be, and should be, but is not', was guided by the transformational dimension of dialectical critical realism (Bhaskar, 1993), which, similarly to Engeström's (2014) transformative development work approach, guides researchers to probe contradictions and absences as leverage points for learning and change.

During the MQA study (Rosenberg et al., 2015) on skills for mining, a number of contradictions were found to characterise the South African mining industry. A mining expert (Digby, 2014) summarised the sector as being at a crossroads with an uncertain future. Once the backbone of a thriving economy, South African mining had been losing its global market share (Baxter, 2016), plagued by declining productivity and increasing energy costs. By 2015 the industry had been operating at a net loss and shedding jobs. Coal mining in particular was being challenged by environmental drivers. The South African Coal Road Map Initiative (SACRMI, 2013) predicted further stagnation and job losses, with coal deposits becoming more inaccessible, coal mining becoming more expensive, alternative energy sources like solar and wind becoming more competitive, and water shortages. The industry has been water intensive as coal is washed before being burned in coal-fired power stations, which in turn also use large volumes of water to generate electricity, a growing concern in a country at risk of crippling water shortages due to climate change. Following the 17th Conference of the Parties, COP17, which was held in South Africa, a Green Economy Accord (EDD, 2011) was struck between industry, labour, government and civil society, committing South Africa to a clean, environmentally sustainable growth path that would reduce the use of coal and other fossil fuels, but at the same time create new jobs. Civil society argued that South Africa could and should develop one million climate jobs (AIDC, 2011). The transition would have to be well thought-through. Energy and sustainability experts (Eberhard, 2011; Eberhard et. al, 2014; Fakir, 2017) published energy transitions studies that outlined the complexities, including the 'locked-in' nature of the minerals-energy complex in South Africa. Currently the coal value chain is at the heart of the just energy transition debates in South Africa (Montmasson-Clair, 2023).

The situation is to some extent representative of the rest of the world, in the sense that South Africa experiences strong external and some internal pressures to reduce its reliance on coal;

there is an espoused commitment by the government to decarbonise the economy; but there are also significant drivers for the status quo to remain. It is perhaps most similar to Australia, where coal has been a backbone of the economy with the mining industry taking pride in its world leader status, and where there have been political divides on the extent to which the country will phase out coal. These were reflected in significantly different commitments by consecutive governments, between 2015 and 2022, to the Intended Nationally Determined Contributes required by the Paris Convention (Weldegiorgio, 2025). In Germany, by contrast, there has been a more consistent commitment to an energy transition (*Energiewende*) that enjoyed decadal, multi governmental support (Cheung, Davies & Bassen, 2019).

In South Africa, the sustainability context around 2015 was dynamic but largely uncoordinated, with the transition towards green growth more of an intention than a coherent programme of action. Skills planning needed a new approach. South African universities, with national government and international partners like UNITAR (United Nations Institute for Training and Research) had some success with a multi-method national study to determine Green Economy Learning Needs (PAGE, 2016). This study produced a framework for competencies that stretched beyond the technical, to make 'soft skills' more visible and producible, by conceptualising them as 'relational' and 'transformational'. The technical-relational-transformational competency model (PAGE, 2016; Rosenberg et al., 2018) drew on a systematic review of sustainability competencies by Wiek et al. (2011) as well as Otto Scharmer's (2009) transformational leadership model.

This paper shares what has been ascertained in the 2015 study regarding skills and competencies needed to shift the coal mining industry towards sustainable development. These findings will be followed by a discussion which will also refer to findings from more recent studies, thus providing an update on an earlier analysis of the 2015 study (Rosenberg, 2020b).

Methodology: Meta-Review of Selected Studies

This paper provides two sets of findings, based on two methodological processes which are both outlined here. Firstly, the conceptual findings in the paper, regarding the merit of the emerging conceptual-analytic tools for green skills studies, are based on the author's meta-review of a selection of green skills studies undertaken in South Africa from 2015 - 2023 (Table 1). The intention of this review is not to compare one methodological approach with others and there is therefore no attempt to be comprehensive in reviewing all green skills studies undertaken in South Africa or internationally. The aim is to explore whether certain analytical tools have merit, and the selection in Table 1 is therefore intentionally restricted to those studies in which the author has close knowledge of the study design and outcomes.

This small-scale meta-review is a version of a theory mining review (Okoli (2015) and informed by the understanding that theory is proposed by identifying key concepts and postulating the relationships between them (Sayer, 2010), which is the purpose of Table 1.

Secondly, the paper also shares empirical findings, to illustrate the identified concepts and demonstrate their proposed merit. Although the methodology of the study on coal mining is the subject of this paper, since some of that study's findings are also reported here, its methodology will also be summarised here. It is a laminated methodology, with a mixed method approach, and in the case of the green skills for coal mining study (MQA, 2015), the main methods and data sources were:

- Document analysis (iterative macro-level and meso-level analysis of relevant Acts, policies, policy guidelines and sector strategies)
- Site visit at the micro-level (workplace) to a coal mine
- In-person interviews and email consultations with mine employees, mine management and various mining and environmental experts,
- Audit of available courses and learning programmes based on a review of university websites and email engagements for clarification.

Table 1 lists the studies, showing the conceptual-analytic tools identified as useful; and the relationships between the concepts that emerged in the studies. While the emphasis in the discussion will be on coal mining, the other studies listed and reviewed served as 'test cases' to further test and refine the methodology for green skills determination. As noted in the Literature Review, the MQA (2015) study was already informed by the developing methodology explored in previous studies, some of which will also be referred to in the discussion.

Table 1: Concepts and relationships identified through theory mining

Study	Concepts That Proved Useful	Relationships Between Concepts Identified
Report on Green Skills research for the Mining Qualifications Authority (Rosenberg et al., 2015)	Extended value chain - value network or value web	Absences in the value network / web (non-circularity) due to historical factors - notably rehabilitation, compliance, waste management are missing
	Multifactorial driver analysis (qualitative) with history added (PHESTLE)	Historical considerations explain current contradictions in skills needs data
	Contestation in skills needs; conflicted job demands	Absences in the identification of skills needs; contradictory data

	Skills needs extend beyond technical know-how, to relational and transformational	Rehabilitation not possible under current social conditions and governance arrangements
	Skills needs extend beyond technical know-how, to relational and transformational	'Lock-ins' in the energy-minerals complex and historical economic practices
Green skills in the South African surface coatings sector: A focus on paint (Jenkin et al., 2016)	Multifactorial analysis (qualitative) with history added (PHESTLE)	Meso - and micro-level interactions
	Cross-occupational work tasks	Employee groups need to work across organisational divisions and occupational levels on sustainability tasks
Green Skills for Climate Smart Agriculture: A Case Study of Poultry, Winter Grains and Deciduous Fruit Value Chains in the Western Cape (Cobban, Visser, et al., 2017)	Multifactorial analysis (qualitative and quantitative) with history added (PHESTLE)	Meso - and micro-level interactions
	Innovation occurs in niches, but policy is mostly at industrial scale	Contradiction: small scale circularity and innovation towards local, organic production and waste reduction, whilst policy and training foregrounds (counter-productive) industrial scales
Occupationally directed skills development for green public supply chain management (Ward et al., 2016)	Multifactorial (quantitative) driver analysis	Strategic leverage points to green or sustainable public procurement can be quantified, while taking social, employment, cost savings and environmental benefits into account
Green Economy Learning Needs Assessment South Africa (PAGE, 2016)	Overlapping technical, relational and transformational competencies Transdisciplinary and distributed competence	Unstructured and networked nature of developing 'new skills'
Developing social indicators for the evaluation of natural resource management	Technical, relational and transformational competencies	Meso - and micro-level interactions

programmes using a capability approach in the Eastern Cape, South Africa (Human, 2020)		
Social Learning and Regenerative Sustainability: Unlocking value created in sustainability projects in higher education (Royle, 2023)	Technical, relational and transformational competencies	Unstructured and networked nature of developing 'new skills'

Analytical Tools and Associated Empirical Findings

Determining latent demand: The value of an expanded value chain analysis

In sectoral research it is standard practice to map an industry value chain (Herr & Muzira, 2009). In a document analysis of various industry publications, the typical presentation of the mining value chain was found to be:

Figure 1: Typical value chain representation for the coal mining industry

The MQA (2025) study showed however that, based on a macro-level analysis of international and national policies and Acts related to environmental management and the protection of water resources, as well as interviews with mining and sustainability experts, the typical conceptualisation of the coal value chain should be expanded: Before mining even starts, investment in exploration is needed, as well as research and development (R&D). To obtain what is termed in South Africa 'the social license to mine', companies must produce plans for local socio-economic development, but this is not included in the typical value chain. Neither is environmental management, nor a commitment to concomitant rehabilitation, remediation, reclamation and restoration at the point of mine closure, all of which are legal requirements. For coal mining this is a stark omission, because much of what is mined is not

saleable, and it is estimated that miners annually add more than 65 million tons of coal discards to the existing two billion tons of coal fines already deposited on the South African landscape. Despite this significant feature of coal mining, waste is not depicted in the value chain; an example of the externalisation of environmental costs (Raworth, 2017). Neither is the regulatory function, nor the financing and insurance that allows mining to proceed. In order to identify environmental skills needs, the simple linear value chain needed to be expanded to trace the full web of functions that are all needed to create value for the industry, including R&D, financing, insurance, corporate governance and sustainability reporting, regulation, prospecting, mining, processing, logistics, procurement, beneficiation, and waste management, as well as local development and human resource development. Education and training, including worker training in Occupational Health, Safety and Environment, emerged as scarce skills in the 2015 study.

For skills studies, the tasks that create the value in the chain (or web) must be mapped in some detail, together with the skills (occupational roles and associated competencies). In the MQA study the mapping of the value web was started with document analysis but also required interviews and site-based observations, to identify what occupations are or should be involved, what tasks they entail, and the specific competencies (knowledge, values, capabilities) needed for these tasks. 'Skills' is the term used in this paper for these occupations and associated competencies.

Through the extended value web analysis, the study found that green skills needed in coal mining, include:

- design innovation for safer and less damaging mining practices
- design innovation for cost-effective, water-efficient mining and beneficiation and dry processing
- management of discards and spoils
- remediation and reclamation science
- resource economics to determine rehabilitation and reclamation costs and benefits
- sustainability reporting (at head office level)
- procurement of environmentally sustainable goods and services (at the mine)
- environmental management (on site)
- occupational health, safety and environment officers (on site)
- environmental compliance enforcement (in government) and
- environmental regulation (e.g. issuing of mining and water licenses),
- among others.

With such a large number of green skills needs identified, an analytic tool was needed to identify which skills were the most important, so as to guide training and training programme development and resourcing.

In this case a quantitative approach was not feasible; there was limited available data about activities across the vast value web and it was unrealistic to generate this. More importantly, there was some contestation about what skills were actually needed. Government reported that there was adequate investment in remediation science, whereas universities reported they were under-resourced. The Department of Mineral Resources and Energy (DMRE) reported that it had enough, well qualified staff to process mining applications, but an environmental agency reported that the staff with this role were not up to the task. It took an interview with a former employee to ascertain that while well qualified graduates had the task of vetting mine applications, it was a difficult job because there was pressure to approve applications quickly, but also pressure to mitigate against pollution and protect scarce water resources. This micro-level data led back to the macro-level analysis of policies, to find that the occupational task was made difficult by conflicting policies: the Minerals and Beneficiation Act, which encourages mining, and both the National Environmental Management Act and the National Water Act, which demand environmental protection. This suggested that among employees, navigating this dual mandate successfully requires more than technical competence.

Before elaborating on this finding, it is important to note that data was needed at the level of macro-economic and national and international policies; at the meso-level of industry specific policies and practices; and at the micro-level of actual workplaces, be these the mine or the regulatory office. Moreover, the analysis of this data needed an iterative relational analysis across the levels. This analytic process resonated with our chosen methodological framework that was not only multi-level but *laminated* (Bhaskar, 1993) and iterative (Rosenberg, 2020a).

A conceptual framework for analysing competencies needed

A few occupations identified as important environmental skills for coal mining will be mapped here to demonstrate the competencies needed.

First, consider the already mentioned 'conflicted graduate' who has to process license applications under time pressure. High levels of technical knowledge are needed, not only of the use of the application system, but also of the relevant laws, policies and guidelines that should be applied, and the technical content behind them, e.g. regarding water management, solid waste, air pollution, environmental and human health, the role of mining in the national and regional economies, and more. Some of this knowledge would be developed as part of an Environmental Science degree; some would be developed on the job (e.g. the online application system used by the DMRE). But it is clear that individual licensing officers were unlikely to have *all* the necessary technical knowledge, and as in other complex sustainability related occupations (PAGE, 2016), they may need to draw on other internal or external experts. They also need to engage with the applicants, and they may need to report to senior management that the task is challenging and warranted additional support.

These required competencies, the so-called 'soft skills', can be described as 'relational' (PAGE, 2016). One could further argue that transformational competencies are also needed: by the managers of the licensing officers, to develop new work systems and processes that would shield staff from external pressures; and higher up in the system among policy makers, to address the policy ambivalences.

Another occupation that was reported to be associated with almost intolerable pressure in the workplace is the compliance officer, who is employed by the DMRE to do inspections on the mines. As she arrives on site, she finds her fellow graduates, employed by the mining industry, working with tight production targets and unwilling to collaborate with her to monitor environmental compliance. The reception she receives is also affected by the fact that while she has the same qualifications as the mine environmental managers, she earns less. It takes a particular relational skills set on top of high levels of technical competence and commitment, to see this job through. The DMRE reported high levels of turnover in the position, implying that not many are willing to do this work, leading to scarcity. It confirms an observation in SANBI (2010) that investing in skills is not enough; workplace conditions are also important. These workplace conditions are created by Human Relations and other corporate management occupations, which therefore also need good relational and transformational competencies, and also need to be included in value web analyses, if the intention is transformation.

Another occupation that needs technical, relational and transformational competencies is the project manager tasked with mine closure. The closing of a mine is a tension-filled time and space often characterised by violent reactions from employees and neighbouring communities whose livelihoods are now in jeopardy. In the context of gold mining, Secombe (2014) reported this as one of the reasons why mine closures are often rushed or incomplete. The project manager needs competencies that range from the technical ability to organise and oversee the operation of earth moving equipment, to the relational competence to engage disgruntled employees; the entire operation also needs to envisage alternative development options.

Mine rehabilitation can immediately provide value in the form of jobs but also restore some value to the area for future use. The standard practice in South Africa is however *not* to fully rehabilitate and reclaim coal mines. Mines are either sold, un-closed, to a new owner who nominally takes on the rehabilitation responsibility, or simply abandoned (Liefferink, 2016). To shift this practice, resource economists and others are needed to innovate in the value chain so as to find resources to pay for rehabilitation. The Green Economy Learning Assessment South Africa (PAGE, 2016) found "making the case" for government and corporates to invest in environmental protection, to be one of the top seven competencies needed for transitioning to a green economy (PAGE, 2018). In the case of enforcing and financing mine restoration, the technical, relational and transformational competencies required include resource economics and innovation in accounting systems. Blignaut et al.

(2013) argue for a change in accounting practices; 'natural accounting' where investment in the restoration of land and water as assets, are counted as positives on the balance sheet, rather than deducted as costs.

For these more complex tasks at the leverage points towards more sustainable development, no single individual can hold the necessary competencies - teams are needed, or put differently, distributed competencies.

In addition to determining skills demand, the MQA study (Rosenberg et al., 2015) also conducted an audit of courses offered by education providers to meet the demand, and possible gaps. In keeping with the study's iterative, laminated approach, the provider audit was conducted throughout the second half of the study and informed by the findings regarding skills needed, as they emerged. As the researchers realised that it took more than technical competencies to process a mining license, or project manage mine closure, they started looking in the provider audit for programmes that develop relational and transformational competencies alongside or in relation to, more technical skills. These turned out to be upskilling and reskilling programmes for mid-career professionals, who had identified these competency needs in their own experience in the workplace.

While other studies (e.g. Ramsarup, 2017) showed that extensionists, engineers and other professionals working in the cross-disciplinary sustainability space had few if any clearly laid out learning pathways, the mining sector is quite structured and so are associated training opportunities. Thus, there were undergraduate programmes in mine rehabilitation (e.g. at the University of Venda), and sustainability courses at postgraduate level for mining professionals (e.g. at Wits University). The latter programme focused on strategic leadership for mid-career professionals and made use of expertise from a variety of fields, case study analyses, interactive and deliberative learning activities. Such programmes were reported to be (human) resource intensive. Overall, education providers reported their programmes to be sought-after but under-resourced, and the number and size of programmes available to learners was found to be very limited compared to the need.

Discussion

Analytic Concepts Applied to Mine Restoration

To illustrate the application of the above two analytic tools for green skills demand and supply studies, consider how a company or industry may determine the skills needed for the restoration and rehabilitation of mined areas in South Africa.

Given the complexity of the systems within which skills need arise, the analysis would be laminated (systemic and relational). One laminated layer would involve a macro-analysis, looking at global and national trends, policies and legislation that might shape the demand for rehabilitation skills. This is a standard practice in skills studies (ILO, 2016; UNEP, 2008), but the analysis deepens at the point of considering interactions between factors, both within and between the layers, and history. For example, in this case, the South African Constitution and associated legislation (such as the National Water Act and the National Environmental Management Act) aim to ensure citizens a healthy environment free of pollution; with principles including Polluter Pays and Precautionary Principle. The Mining and Minerals Act states that the right to mine is dependent on the owner undertaking to close the mine on completion of operations and rehabilitate the land; rehabilitation should also occur concurrently with operations while mining is still active. In combination with the National Water Act and the National Environmental Management Act, this means taking all reasonable precautions to prevent pollution. Given the stipulations of the mining license, reasonable precautions include rehabilitation and restoration, both concurrent and at the end of operations. On the basis of this set of regulations, mine rehabilitation would be one of the most in-demand job opportunities in the country.

In the MAQ (2015) study, mine executives agreed that concurrent rehabilitation is best practice; however, this does not seem to be applied in practice. The Centre for Environmental Justice reported the existence of 6,000 abandoned and derelict coal mines. Thus, the potential for employment creation and environmental restoration remains untapped, because mining companies do not rehabilitate the sites they leave behind (Liefferink, 2016). Employment will only be unlocked if a mechanism is found to disrupt this 'lock-in' (Fakir, 2017). Looking at both macro-level current trends and historical lock-ins as well as interactions between them is important for skills needs predictions, but clearly not sufficient.

At the meso-level one would look at the industry itself, as shaped by global and national but also regional trends. The South African coal mining industry has been described as at the heart of the country's Just Transitions challenges (Montmasson-Clair, 2023). The coal value chain has been analysed for employment vulnerabilities by Makgetla et al. (2019) who found that more mines are likely to close due to the reduced demand for energy in a stagnant economy that has previously obtained virtually all its electricity from coal. Reiterating the commitment of the 2011 Green Economy Accord, which pledged support for climate change commitments to reduce greenhouse gas emissions on a green, low-carbon and labour-

intensive development path (EDD, 2011), the South African president in 2020 launched a National Climate Change Adaptation Strategy with a commitment to

> "… a new, inclusive economy that creates employment and fosters sustainable growth. An important aspect of this new economy is that it must be able to withstand the effects of climate change. A climate-resilient economy is necessary to protect jobs, ensure the sustainability of our industries, preserve our natural resources and ensure food security" (Ramaphosa, 2020)

But *will* coal-fired power stations and coal mining be phased out in the foreseeable future? Why, given the availability of cleaner alternatives which are now more cost-efficient than coal, has this not yet happened? The skills analyst needs to consider that there are counter-pressures from various sources (Fakir, 2017; Chipkin, et al., 2018). As is the case in the United States and Australia (Weldegiorgio, 2025), South Africa's coal mining is regionally concentrated. In these regions, local economies are largely undiversified, and highly dependent on coal, both for direct and indirect employment (Montmasson-Clair, 2023). Coal workers are largely semi-skilled and unskilled, with a majority not completing high school, but better paid than similarly qualified workers in other sectors; they are also highly (74%) unionized and enjoy strong political backing (*ibid*).

Unlike in the case of consistently supported energy transitions such as Germany's *Energiewende* (Cheung, Davies & Bassen, 2019), the extent to which climate related agreements will affect South Africa's coal industry is therefore unclear. However, whether mines close or not, and workers lose jobs or not, the restoration of mined land remains a significant social and environmental concern, and it can generate jobs for thousands that are not yet employed. Montmasson-Clair (2023) makes the point that any just transition in South African starts from a current point of injustice, with Africans, in particular the poorest, producing a far smaller share of the worlds' greenhouse gas emissions, but bearing the brunt of climate crises like floods and droughts. He also confirms the importance of rehabilitation as part of transformative justice, noting the importance of structural reforms and paradigm shifts.

What is furthermore clear, is that if employment in mine rehabilitation and remediation is unlocked, the skills required will not only be technical. Technical skills will indeed be necessary, to clean up polluted water and soil; reclaim valuable minerals; restore soil fertility through a range of means. Technical skills are not limited to technical knowledge; they would include adaptive management, because, as a mine-based environmental manager shared in the MQA (2015) study, technical know-how needs to be applied in the workplace, and then further refined, as one needs to learn from the often unexpected or incomplete outcomes of restoration and other environmental management actions.

At the micro- or company level of the laminated skills analysis, perhaps through case studies of individual mine closures, one would note that in addition to technical competencies, relational or social competencies will also be vital for any company wishing to rehabilitate a

mine site, particularly at the point of closure, when there would be high levels of dissatisfaction among workers about-to-be retrenched, and neighbouring communities. To move into such a situation with rehabilitation teams, will require the ability to analyse context, politics, culture, gender relations and more. This may be the case even before mine closure. In one study involving soil and wetland rehabilitation (Human, 2020) it was found that rehabilitation work is allocated by local leaders to residents on a roving basis, involving an intricate mix of cultural norms (governed by a traditional authority system) as well as national (democratic) government procurement criteria. Here again the importance of a systemic vantage point and considering interactions, in this case between the meso- and micro-levels of the laminated systems affecting skills needs, is evident: Based simply on national or environmental priorities, skills for rehabilitation may be needed at the most degraded sites but in practice, they may be employed elsewhere, based on local considerations that exceed the technical. To mediate between these competing demands, project managers will need relational competencies.

The transformational skills to unlock a new practice of investment in mine rehabilitation has been outlined above. For these more complex tasks at the key leverage points towards more sustainable development, no single individual can hold the necessary competencies - teams are needed, or put differently, distributed competencies. In a study on the chemicals industry, Jenkin et al (2018) termed these 'occupational teams', and a paper reflecting on the Green Economy Learning Assessment for South Africa (Rosenberg et al., 2018) elaborated on the distributed nature of sustainability competencies in other contexts, too.

Undertaking the hypothetical 'skills for restoration' study would be a worthwhile exercise, because several studies including Liefferink (2016) and Maia et al. (2011) have shown that there is a demand for restoration of degraded land and the rehabilitation of mine contaminated ecosystems and that restoration and other natural resource management activities can create as many, or more, jobs than any other sector, including energy, or mining itself.

But what about the individual workplace? Geels and Kemp (2012) argued that it is from micro contexts (niches) that sustainability transitions will spring, and this has also been the experience in South Africa. This might mean that individual workplaces will have sustainability skills needs that are best determined at their own level, with the bigger picture in mind. The tools in the Appendix 1 (Tables 2 and 3) have been designed in the PAGE (2016) study and can be used by individual companies and organisations, but also by 'teams' with members from more than one workplace, who may need to work together on, for example, environmental impact assessments, cleaning up spills in rivers that span several management contexts, and so on, to determine skills needs in those specific contexts. The tools are simple, but have significant features, the first of which is this recognition of the need to skill a team, rather than only one individual. The second important feature is that reference to relational and transformational skills are built into the template, to remind employers, employees, planners and providers, of the need for more than technical skills. The tool

should ideally be used with a guide on what the different types of competencies might entail (definitions such as those developed in PAGE, 2016) as well as an audit of existing providers and the types of learning opportunities they offer. Attention is needed to whether the learning opportunity is likely to build the type of competency needed in the particular context. For example, sending an individual licensing officer on a short course to enhance her technical skills on the online application system might not be as effective as sending an entire team on a short course where a learning network can be activated, to also learn from and build a community of practice with others in similar challenging situations.

Comparison with international contexts

How does this range of competency requirements compare to other contexts, internationally? A study for the Minerals Council of Australia (MCA, 2019) is informative. Focusing on the impact of technology, but also sustainability requirements, it predicts that the industry's skills demand will be for a great increase in non-routine, cognitive tasks, and some increase in non-route manual tasks. Routine cognitive tasks will decline, and so will routine manual tasks, due to digitalisation and automation. The study further reflects that the technology transformation will create a demand for technical skills like systems evaluation and systems analysis, but also skills like "active listening", "active learning", "judgement and decision making" (MCA, 2019:18) - what in the framing of this study, we could call relational and transformational competencies. The similarity to the South African findings is striking, even when comparing the impact of technology transitions, with the impact of sustainability transitions.

A key similarity between coal mining in South African and coal mining in Australia is in the level of uncertainty with regards to the socio-political commitment to phasing out coal. The laminated (systemic and relational) methodology for skills determination may be particularly suitable for such uncertain contexts, and the MCA (2019:8) report also recommend "iterative review, feedback and testing" to be incorporated in the development of a skills roadmap for Australian coal mining. The methodology discussed here may be less needed in contexts of greater certainty, with fewer regional differences in terms of the reliance on a coal economy, and/or a more stable policy context, e.g. in Germany's consistently implemented socio-technological plan for an energy transition (Cheung, Davies & Bassen, 2019). However, uncertainty is to a greater or lesser extent a feature of most work contexts today; as the MCA (2019:3) puts it: "We face a future of work with more unknowns than knowns". This finding may be echoed by other authors in this Special Issue reflecting on the challenges experienced by vocational education providers, to respond to industry needs that are not easy to pin down in relation to transitions at different levels (Gustavsson, Halvarsson Lundkvist and Thunqvist, 2025).

Conclusions

In summary, a theory mining analysis of a series of green skills studies undertaken in South Africa since 2015 has shown that a critical realist laminated methodology is useful for identifying latent jobs and latent skills needs. By looking for what is there, but also for value that could and should be there but is not, in the expanded value chain of coal mining, through the interplay between macro, meso and micro level findings, the researchers determined that a range of skills are needed, from innovation in mining design and financing, through to remediation and restoration, environmental governance, and the technical, relational and transformational competencies to achieve the sustainable development goals, particularly in the context of an industry as challenging as coal mining.

The rehabilitation of mined land is a regenerative economic activity in which value that is either destroyed, or untapped, is potentially recreated. To achieve this potential, technical skills needed include mine water remediation, soil and wetland restoration and rehabilitation. Some of these skills already exist, as do relevant courses and research programmes, albeit under-resourced. Technical and transformational skills are needed to reconfigure accounting practices in order to finance rehabilitation and the associated jobs, as well as skilling and reskilling of retrenched workers. Again, more than technical skills are needed, to start and sustain rehabilitation initiatives, in contested and uncertain socio-political contexts. The range of competencies needed to innovate towards greater environmental sustainability in coal mining will be distributed across groups, as has been found to be the case elsewhere. In the contexts of high potential but also high levels of unpredictability, employers and skills planners can determine context specific requirements through tools that look for skills needs in groups, rather than individuals, and plan accordingly. It would seem that these findings are also applicable in other contexts navigating the changing nature of work, with high levels of uncertainty, in transitions towards environmental sustainability.

APPENDIX: Tools for Workplace Level Green Skills Planning

At each leverage point for change towards sustainability or green growth, ask the following questions in the team/ unit/ department:

	In relation to the tasks in the first column, and our competencies...		
What are ...	**What are the strengths in our team?**	**What are our competency gaps?**	**How can we improve our competency mix and levels?**
The technical task(s)?			
The people related task(s)?			
The transformational task(s)? (What change do we want and why?)			
Hint: Use the tasks and competencies discussed in the Green Economy Learning Assessment (PAGE, 2016) to guide you in completing these columns			Hint: Use the next table and a database of available sustainability courses for this column

Table 2. Tool for Localised Learning Needs Assessment (PAGE, 2016)

Learning options	Is good for:	Not good for:	Good in combi-nation with:	Possible providers, places, resources, people: *Hint: Start with a database of available courses, explore further*	Decision
Enroll for a long course (degree, certificate)					
Attend a short course or workshop					
Online course					
Conference					
Informal networks					
Professional association					
Monitoring or coaching					
On the job learning					
Brown bag lunches					
Reading, guided or sharing					
Own action research					

Table 3. Green Economy Learning Options Decision Making Tool (adapted from PAGE, 2016)

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Discussion Forum

The job quality side of climate change

Agnes Parent Thirion and Jorge Cabrita
Eurofound

Climate change is having a profound and transformative impact on the way we live and work. These impacts are direct, through the great shifts in temperatures and weather patterns which are being growingly felt across the globe, and indirect, through the measures and policies that are being deployed in order to tackle it. The Council recommendation on ensuring a fair transition towards climate neutrality confirm the endorsement of EU Member States towards "*the imperatives of a just transition of the workforce and the creation of decent work and job quality*", which have been established in the United Nation's Sustainable Development Goals and the Paris Agreement. This idea motivated Eurofound in a recent report, "the Job quality side of climate change" to investigate how climate change impacts job quality through a literature review, the consultation of its European network of correspondents and some statistical analysis of the European Working Conditions Telephone Survey of 2021.

The article will first set the scene by describing job quality, and its main components, depicting the relationship between Green House Gas emissions (GHG) and the employment levels by sector of economic activity. The latter can suggest priorities for decarbonisation. Changes in jobs =also occur as result of greening which is the process through which occupations adapt the content of their tasks to climate change with a significant impact on changes in the work performed and job quality in these occupations. It will then explore how job quality is expected to change due to climate change risks, and as a result of the greening of tasks and occupations. It will finally consider climate change as a possible driver to reinventing work, by changing the work processes involved in the current extraction, production, distribution and consumption systems which would also impact on the job quality of workers.

Setting the scene

In order to evaluate the impact of climate change on job quality, it is important to introduce job quality is, employment and greenhouse emissions to assess the contributions of economic activities to emissions and the greening of tasks, the transformation of occupations due to greening.

Job quality

For more than a decade, Eurofound has been working with its tripartite stakeholders and the research community on the measurement, definition and operationalisation of job quality (Eurofound 2012, 2017, 2022).

The rationale for measuring job quality and capturing job quality dimensions, at the level of the job is that this is the level of the contract between an employee and its employer. There is a legitimacy of public authorities to intervene in case of externalities.

Job quality is made of these characteristics of work and employment that have a proven causal relationship, positive or negative, with health and well-being as evidenced by high quality epidemiologic studies (for example Niedhammer et Al. 2022, Costa et al, 2010).

Positive and Negative refers to the fact that workers while carrying their job, are exposed to "job demands" and "job resources". Job demands are job attributes that require an effort and increase a worker's risk of poorer health and well-being. Job resources are attributes that support workers, doing so in three ways: by reducing job demands and their physiological and psychological costs; by helping workers achieve their work goals; and by fostering personal growth. This conceptualisation is in line with the job demands–resources model proposed by Bakker and Demerouti (2008).

Job quality is multidimensional: one way of organising all these characteristics of work and employment is to consider different dimensions or domains. Eurofound has been organising its monitoring of job quality around 7 indices: earnings, prospects, working time quality, skill use and discretion, social environment, physical environment and work intensity (Eurofound, 2012 and 2017).

It is the combination of negative and positive attributes that determines how good a job is. For instance, if a worker experiences very intense work, having the autonomy to decide how to do it may reduce the adverse impact on them. By capturing job quality at individual level, these compensating and interacting effects can be measured most effectively. A job is described as 'strained' when the number of demands exceeds the number of resources and 'resourced' when the number of resources exceeds the number of demands. Workers in strained jobs are at risk of poorer health and well-being, not only in the short term but also in the medium and long term.

Employment and greenhouse emissions

The European Green Deal launched by the European Commission in 2020, reflects the European Union's commitment to make the region climate neutral by 2050. In order to achieve such goal, the "Fit for 55" set of legislation has been adopted with a view to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

Eurostat Statistics for the European Green Deal clearly show that the volume of emissions of greenhouse gases (GHG) per employed person has been declining in the EU, at least, since 2010. This results, on the one hand, from decreasing GHG emissions and, on the other hand, from increasing employment in the EU. In 2020, there were 13.6 tonnes of GHG emissions by every employed person in the EU, the lowest value on record and 4.4 tonnes less than in 2010 (Eurostat, 2022). However, despite this positive and auspicious outlook, not all sectors of activity produce the same amount of GHG emissions nor employ similar shares of people.

Figure 1 – Cumulative GHG emissions and employment by economic sector of activity. EU27, 2022 (%)
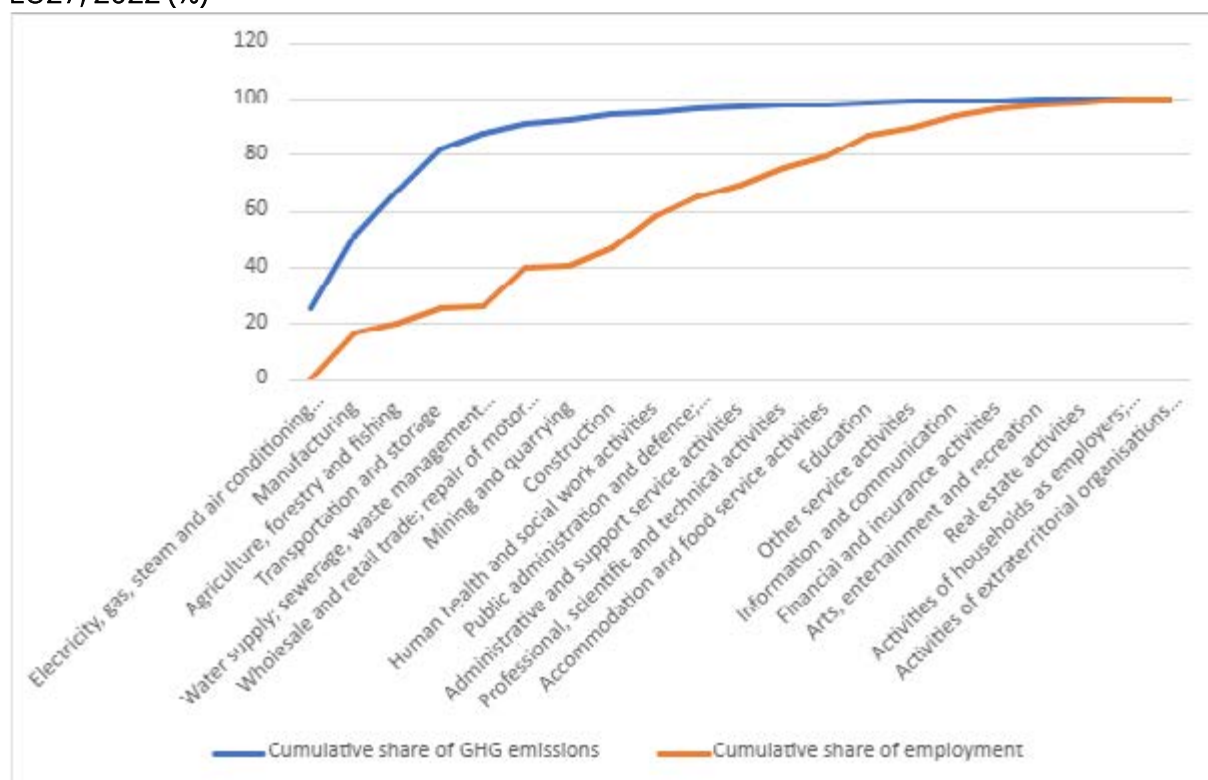
Note: the blue line shows the cumulative share of total GHG emission by sector from the left to the right; the orange line shows the cumulative share of employment.
Source: Eurostat, European Union Labour Force Survey, employed population over 15 years old (lfsa_egan2) and air emissions accounts, greenhouse gases (env_ac_ainah_r2).

The figure ranks broad economic activity sectors by their share of total GHG emissions in 2022, from the sector with most GHG emissions on the left, to the least emitting sector on the right-hand-side. The graph shows that the sector with the largest share of GHG emissions in 2022 – electricity, gas, steam and air conditioning – accounts for 26% of emissions but less than 1% of the total employment in the EU. Overall, the largest emitters of GHGs in the EU account for a relatively small proportion of the total employment in the region: the sectors to the left of (and including) water supply and waste management produce 88% of the EU's total GHG emissions but employ only 27% of the EU workforce. If this criterion is used to assess the size of workers likely impacted by climate policies, it is not necessarily very large. An

important use of this figure is to identify main industries to restructure as we aim to decarbonize.

Climate change and the greening of tasks

One possible perspective to investigate the impact of climate change on job quality is through the greening of work tasks and occupations. According to Dierdoff et al. "the greening of occupations refers to the extent to which green economy activities and technologies increase the demand for existing occupations, shape the work and worker requirements needed for occupational performance, or generate unique work and worker requirements."

By using this perspective, we can assert that the green transition is likely to impact occupations in three possible ways. It will lead to the development of new occupations, some of which do not even exist yet (for example, green policy planners, renewable energy engineers). In many cases, it will transform existing occupations, requiring different and new skills to be learned and developed (for example, construction managers, electrical engineering technicians, meteorologists). Finally, some existing occupations are needed to 'make and build' the transition (for example, crop and vegetable growers, carpenters, fitters, welders, insulation workers, electrical engineers), leading to increased demand for these occupations, but without significant transformation of their skill sets. Other occupations will be less impacted or not impacted at all by the green transition; tasks will not change per se although job content may be informed by the transition (for example, occupations in the education or health sectors).

According to EWCTS 2021 data, more than 50% of the workers employed in agriculture, mining, water supply and sewerage waste management, construction, transportation, electricity and gas supply, manufacturing, and extraterritorial organisations and bodies are in occupations which are likely to be impacted by greening.

Why should job quality be an essential ingredient of conversation on the adaptation of companies and work to climate change?

Let's now turn to examining what current evidence tells us about the association between job quality and climate change. First, we will examine the issue of climate change risks and their impact on job quality, then estimate the job quality of jobs according to greening, turn to those sectors that are at the intersection of different climate change influences and illustrate with two examples.

Climate change risks at work, an increase in exposure in risks which can also impact on other dimensions of job quality

Environmental degradation is associated with changes in the working environment, including exposure to heat and air pollution, ultraviolet (UV) radiation, increase in the frequency and intensity of extreme weather events, and communicable vector-borne diseases and expanded vector habitats. It is also associated with changes that impact on natural resources in the work environment (Schulte and Chun, 2009; Adam-Poupart et al, 2013; Schulte et al, 2016).

Climate change also leads to an increase in psychosocial risks, for example linked to fear of employment loss and increased insecurity. Job insecurity can arise as a result of climate degradation, when the yields of agricultural products decline; as a result of adaptation policies, when there is pressure to close certain industries (such as coal mining); or as a result of mitigation policies, as new skills are needed to work in the same industry.
Emerging occupations and industries also come with specific occupational risks and job quality profiles: in some cases, "known" risks are combined in new industries and work situations in novel ways; in other cases, new or unknown risks may emerge.

Working outside and working in the emergency services increase exposure to climate change risks. The exposure of workers in these occupations and work situations will be higher than that of the general population as their job is to face these situations. Certain industries and occupations, such as agriculture, construction, energy, municipal services, tourism and healthcare, are more impacted by climate change and climate policies than others. Some groups of workers are more exposed than others, such as men, migrant workers and low-wage workers.

While exposure to some climate change risks such as heat, UV radiation is highest for workers in certain specific occupations and work situations, exposure to extreme weather events will impact on all workers concentrated in the area; it can also impact on companies and industries whose value chain production depends on companies located in the area where the extreme weather events occurred.

Research has found that workers in occupations vulnerable to heat have poorer job quality and working conditions due to rising heat levels (Schulte, P. A. and Chun, H. (2009)). Heat exposure makes performing work activities more strenuous and difficult: it increases physical discomfort, reduces manual dexterity and affects cognitive performance, visual motor capacities, short-term memory and vigilance It alters workers' emotional state (leading to irritability or anger) and can aggravate tensions within an organisation or with the public, and it is therefore ultimately likely to increase psychosocial risks at work (Anses, 2018).

Practices on adaptation to regular and strong exposure to climate risks can lead to different answers that have different impact on job quality:

There are different ways that a climate change risk can impact job quality. for example,

> In order to prevent work under extreme hot temperatures, companies may decide to adapt the timing of work; as a result exposure to high temperatures will decrease but work in the evenings, or in the morning (times where the temperature is less hot) will increase, resulting in an increase in a working time job demand. This is also likely to impact more negatively women who remain more engaged in caring work particularly of children and might have to decide between caring for their children or going to work at these early and late time of the day where social services may not be available.

> Another example found in the report shows how a technical solution to address work in high temperature may lead to positive benefits in overall job quality. The Dutch association of construction and infrastructure companies, advises its members to invest in on-site facilities, alternative construction methods and changing employee behaviour (Bouwend Nederland, 2022). Investing in on-site facilities may include providing good shelter, such as a construction tent. These can provide more workable days, which makes meeting work schedules more feasible. Choosing new construction methods can also make the construction process less dependent on weather conditions and less hazardous, for example, modular construction.

These examples show the importance of bringing in the job quality perspective and its multiple dimensions while adapting job situations to climate change to assess if and how this transformation can be supportive (or not) of job quality. The "bad news of increase exposure to risks in work due to climate" change could at least be partially offset by practices which integrate job quality in their design and assessment.

Climate change and the greening of tasks: job quality a key element to support the successful implementation of the green transition

The greening of tasks will impact job quality as a "process" and as a "result". The process of greening calls for significant deliberations on what changes are needed as well as on the provision of a significant volume of training to workers in order to support their adaptation and ability to perform in their new roles. This would constitute a higher risk for those workers in "enhanced green occupations." Furthermore, the reorganisation of occupations is likely to lead to changes in the way work is structured with further implications for job quality. The quality of the change process (from anticipation to planning) will influence the job quality of workers as their work requirements change (Westgaard, R. H., & Winkel, J. (2011). Two essential dimensions to consider are the quality of collective and individual employee involvement in the design and implementation of the restructuring and reorganisations plans, the scope and content of supportive actions in particular in relation to access to training. Special consideration needs to be given to the conditions of access to training as part of the job or not. When this is not the case, workers for example with high care duties are at risk of

being excluded due to lack of time. Additional consideration also needs to be given to workers in self-employed jobs calling for different policy mechanisms to support change in the desirable direction.

Greening also matters for job quality as the different groups of greening occupations have different job quality profiles with different specific job quality concerns.
When the current job quality in these occupations is estimated, the results show contrasting profiles amongst occupations.

Workers in increased demand occupations currently report higher than average exposure to job strain, which puts job holders at increased risk for their health and wellbeing. Workers in this group report higher exposure to job demands, in particular physical risks (such as handling or being in contact with infectious materials) and physical demands (such as, working in tiring or painful positions and doing repetitive movements), dependence (for the self-employed), intimidation and discrimination and job insecurity while at the same time they report weaker access to job resources, including task discretion and autonomy, organisational participation and workplace voice, intrinsic rewards (such as receiving recognition for their work, social support (by colleagues and managers) and opportunities for self-realisation.

As our societies embark on the process of decarbonisation, it is important to monitor if and how the jobs involved will be of good quality. What should we do if we want a green transition based on jobs and work environments of good quality? We should develop a preventive approach aimed at decreasing exposure to job demands and supporting access to more and better job resources, and closely monitor this approach throughout the transition.

This highlights the importance of supporting job quality to support the implementation of the green transition. Previous work of the European Commission (ESDE 23) have shown that most occupations experiencing persistent labour shortages had poorer job quality. This is a concern that we would need to anticipate. In this context, increased demand occupations are at most risk from a job quality perspective and deserve policy attention to improve working conditions in these jobs.

Figure 4: Job quality index, by greening occupational group, EU27 (%)

Source: EWCTS, 2021

Sectors under multiple climate change influences: an opportunity to improve job quality

By combining the various influences described in the first section of this article such as increase exposure to climate change risks in some sectors the proportion of GHG, the proportion of greening occupations in these sectors, one can identify sectors likely to experience the highest level of change.

These sectors are at the heart of the transformations linked to climate change.
We illustrate our point with two sectors, agriculture and energy.

Agriculture

This sector is responsible for about one fifth of all emissions.
It plays an essential role in satisfying the basic human need for food. It also contributes to ecosystem health. This is a sector characterised by more than half of the workers being self-employed. Self-employed workers have a different access to lifelong learning and to different labour standard rights and protections. Also, close to a fifth of workers are over 56-years-old and about two thirds of workers are male.

Agricultural workers are highly exposed to climate change hazards including financial insecurity as yields become less predictable and farmers may need to adapt their practices to the new environmental conditions. The quality of adaptation practices and the risks associated with maladaptive practices need to be considered. Maladaptive practices, such as the increased usage of chemical pesticides due to declining yields, could increase exposure to dangerous substances and impact the quality of the food produced.

According to the EWCTS 2021, about 80% of agricultural workers are working in occupations likely to be impacted by greening: 71% work in increased demand occupations; 7% in enhanced skills and 2% in new and emerging occupations.

In terms of job quality, agriculture is a sector in which the share of workers in strained jobs is larger than the EU average and most other sectors. According to the data of the European Working Conditions Telephone Survey 2021, overall, 40% of workers in agriculture, forestry and fisheries are in strained jobs, in which job demands surpass job resources. Workers in agriculture tend to be more exposed to physical risks, physical demands, unsocial work schedules and perceived job insecurity than the EU average. At the same time, in terms of job resources, workers in agriculture tend to present better than average opportunities for self-realisation but worse than average in terms of social support, task discretion and autonomy, and training and learning opportunities. From a working life perspective, while a comparatively large share of workers reports a high level of engagement, many report difficulty in making ends meet (51%), having their health and safety at risk because of work (46%), while more than half report physical and/or emotional exhaustion (53%) (Eurofound, 2024).

Energy

Although renewable and clean energy is meeting a growing share of Europe's energy needs, in 2022, the energy production sector (including the electricity, gas and steam supply) still accounted for 26% of the EU's total GHG emissions.

Like agriculture, energy is both part of the 'problem' and the solution for climate change as we depend on energy for most of our activities and production while quality of life depends on a reliable supply of energy at an affordable price. Many jobs are at risk in the fossil fuel industry, leading to the need to cater for and retrain workers involved.

In the case of extreme weather events and when the energy supply is down, industry, transport, services, cooking, heating, lighting, payment systems and access to the internet will all be negatively affected. Higher temperatures, humidity and dust deposits on insulators also increase the risk of systems failure.

According to the EWCTS, close to two thirds of the workforce in the energy sector are currently employed in occupations likely impacted by greening: 20% belong to new and emerging occupations, 23% to enhanced skills ones and 21% to increased demand.

Renewable and clean energy such as wind energy generation and solar energy generation come with specific combinations of old occupational risks but also new, less known risks. Furthermore, the production and supply of renewable energy sources are decentralised, and, as a result of that, new, smaller companies may enter the sector without always having the necessary work safety culture set-up.

In terms of job quality, according to the EWCTS, the energy sector fares better than the EU average, with 'only' 24% of its workers in strained jobs. In fact, the sector performs better than the EU average in all job demand dimensions, and especially in terms of physical risks and physical demands. The sector also fares relatively well in most job resource dimensions, only falling behind the EU average in terms of opportunities for self-realisation.

All these facts suggest the high relevance of job quality in supporting the transition of the agriculture and energy sectors. At the same time, it indicates different priorities for setting the appropriate job quality agenda in the different sectors.

Climate change influences on production processes and final products and services

This global and sectoral perspective should also be completed by evoking the actions of companies and organisations and their employees. There are many ways companies and organisations can engage. Companies and organisations may change their practices as they engage in "green workplace behaviours", which are 'scalable actions and behaviours that employees engage in that are linked with and contribute to or detract from environmental

sustainability' (Ones and Dilchert, 2012). They are diverse in their nature; examples of green behaviours contributing to environmental sustainability are shown in Table 5 (Francoeur et al, 2021).

Table 5: Categories of green workplace behaviours

Category	Behaviours
Conserving	Recycling, reusing, reducing use, repurposing
Avoiding harm	Preventing and reducing pollution, monitoring environmental impact, strengthening ecosystems
Transforming	Choosing responsible alternatives, changing how work is done, creating sustainable products and services, embracing innovation for sustainability
Influencing others	Educating and training for sustainability; encouraging and supporting others
Taking initiative	Initiating programmes and policies, lobbying and activism, putting environmental interests first

Source: *Francoeur et al, 2021*

Little evidence is available yet on the extent to which companies and organisations engage in such practices. First results from a Finnish survey (Moilanen and Toika 2023) suggest that most employees in Finland do not perceive the organisations in which they work as sustainable, and actions to hasten the transition to sustainability are scarce. Training on sustainability is not yet common and neither are collaborative climate actions.

These behaviours are likely to impact on job quality when they become part of the job tasks. For example, the introduction of such behaviours can be under the direct influence of employees or not. This suggests the more changes will happen in companies and other organisations in the next years, which would likely impact on the job quality of workers.

Conclusion

There are multiple ways by which climate change will impact job quality, directly and indirectly. Climate change will profoundly impact labour markets, as well as working conditions and job quality. However, current research evidence remains patchy and the implications, particularly for working conditions and job quality, are less researched and less well understood than is the case for other megatrends such as digitalisation and population ageing.

More research is needed, including concrete adaptation practices including maladaptive practices. The evaluation of practices should assess how the different dimensions of job quality are impacted, identify and measure the trade-offs between job quality dimensions as well as their impact on workers' wellbeing and the performance of companies and other organisations. This would support the dissemination of good practice.

The fact that those occupations that are likely to be impacted by greening of the economy through an increase in demand, which represent an important share of the whole workforce, have poor job quality calls for strong action towards the improvement of working conditions and job quality. Overall, the impact of climate change and the green transition in terms of job quality will be probably mixed – with the creation of both new and probably better-quality jobs and of increased demand jobs with inferior job quality. In addition, the other occupations likely impacted by the greening of the economy (new and emergent occupations, or requiring some re-skilling), may have a job quality similar or better than average but can still benefit from improvements in some dimensions. So it will be extremely important to monitor if and how the jobs involved will be of good quality.

This short overview of the influence of climate change, and the policies addressing it, on job quality identifies the strong benefits of bringing job quality into the conversations about climate change at work and in companies and other organisations. Such conversations are likely to be different according the various sectoral perspectives. Altogether, this pushes for a wider job quality improvement agenda that covers not only exposure to physical and psychosocial risks, but also other aspects such as the conditions of learning at the workplace, applying one's own knowledge and skills, or access to job resources.

As climate change will lead to changes in the work performed, the processes used, and the exposure to job demands and job resources available, there are many benefits in shaping policies and practices to changing climate change by mainstreaming job quality and integrating job quality concerns.

A better understanding of the implications of climate change on job quality calls for the development of new methodological and conceptual tools, or at least improvement of existing ones. It is important that working conditions surveys, for example, cover specific issues related to the impact of climate change and the extent to which workplaces address the challenges posed by climate change and measures put in place to address it. Companies cases studies and workers interviews can support the development of new indicators.

Numerous bottom up initiatives address these issues : how can we collect and analyses these practices to increase the speed of collective learning ? Let's advance in this journey to prepare a future that we want in our changed climate environment by having job quality at the top of our agenda. It is not a matter of just measuring how many jobs will be destroyed or created with the green deal. It is a matter of ensuring that all stakeholders are involved in the design, implementation and monitoring of the necessary change, from tasks at individual level, to work processes at the workplace, to infrastructure and supportive social policy at societal level. This means that in order to ensure a just transition, workers, their representative organisations, their families, and their communities are, more than heard, duly involved in the whole process. The Stakes are extremely high, time is short and collective intelligence and cooperation are key resources to advance.

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[1] Disclaimer: this article may not reflect the official position of Eurofound.

Green Skills and Justice

Richard Ennals

This paper is written from within a series of concurrent discourses and dialogues over the last 50 years, when I have been a researcher, research manager, writer and editor. This meant starting from a UK perspective of Skill and Justice, with the work of John Bellers, then moving to Scandinavia, and ending with a European synthesis and international systematisation, where we can regard our ongoing differences as a crucial resource for sustainable development.

Keywords: Action Research, Collaboration, Development Coalition, Dialogue, Differences, Justice, Skill, Systematisation, Transition

Introduction

Over the last 50 years I have moved between different disciplines and countries, at each stage reflecting, writing and publishing. I have had to engage with diverse partners and use the vocabulary and concepts of the specialist fields. My own focus throughout has been on people rather than technology, on collaboration rather than competition. I write and publish in order to explain myself to myself and to others.

John Bellers

The ideas, writings and practical work of John Bellers provide my overall framework. He was a late seventeenth century English Quaker economist, whose work preceded current discussion of "Industry 4.0" etc. by over 300 years. He was cited by both Adam Smith and Karl Marx. He emphasised the importance of Skill in 1695, argued the case for a European state in 1710, and proposed a National Health Service in 1714 (Bellers 1695, 1710, 1714). He opposed slavery and empire and located work in the context of the needs of society.

Bellers recognised the changes in society in his day and argued for just ways of handling transitions in working life, with a central role for work. His principles are applicable today in the context of economic and social turbulence. Bellers brings a British flavour, albeit with

publications from 1695 and 1710, and I take it as a point of departure for my own work over the last five decades with a series of international partners.

Bellers wrote before the Industrial Revolution, and developments which gave undue emphasis to market forces at the expense of what Smith called "Moral Sentiments" (Smith 1759). Together with Adam Smith and Karl Marx, Bellers provides a European perspective which has been unjustly neglected. In this paper I appeal to a European intellectual past in which the UK played a central role. The intervening centuries could be seen as based on mistaken capitalist views of the economy and society. We might want to present Bellers as an early pioneer of Workplace Innovation, with principles such as co-ownership, partnership, respect for skill, and commitment to social equality.

I began my working life in 1973, managing a cardboard recycling project in North London with John Bellers Ltd, employing people who were officially regarded as unemployable. They were treated with respect, earned a wage, and paid rent as tenants of the Peter Bedford Housing Association. I was engaged in Action Research fifty years ago.

Bellers founded a "College of Industry" in 1695 (Bellers 1695), which influenced Robert Owen in 1817 (Owen 1817). In 1710 Bellers published a constitution for a European Parliament (Bellers 1710), and in 1714 he advocated a national system of hospitals: the basis for a National Health Service (Bellers 1714). He was ahead of his time, with a concern for skill, Europe and just transition! We are addressing long-standing questions.

Advanced Information Technology in the UK

I undertook teacher training, became a teacher of history and social studies in the UK and Nigeria, and used computers in the classroom from 1978 (Ennals 1979, 1980, 1981). This led me to research on computers in education, using "Logic as a Computer Language for Children" (Kowalski 1979). I worked at Imperial College London from 1980 and launched collaborative projects around the world (Ennals 1983, 1985).

In 1983 I worked with SRI International on an international conference in Cambridge which was intended to lay foundations for a new research laboratory with intellectual leadership from SRI (Benson 1986). I decided that I preferred to work with European partners, and a Human-Centred approach to technology.

In 1984 I was managing research at Imperial College Department of Computing, building a programme of research and development with government and business partners, with a focus on a new generation of computing technology. This was in line with the Japanese Fifth Generation Computing Programme (Fuchi 1981), which was intended to develop applications for use by ordinary citizens. Innovation was to be driven primarily by a managed "technology

push" in computer science, rather than "industry pull". Companies and universities needed to learn to "collaborate or die". Many UK IT companies died.

In 1985 I managed part of the UK National Alvey Programme in Advanced Information Technology, with a focus on Intelligent Knowledge Based Systems (Oakley & Owens 1989). The programme was based on a report edited by John Alvey of the Post Office. I was responsible for designing and managing the UK Logic Programming Initiative, a set of eight projects which was part of a collaborative programme concerned with the hardware and software of Declarative Systems, central to the Japanese Fifth Generation agenda. Our work was linked with the ESPRIT programme of the European Union. This reflected the strong European collaborative context of our research in logic programming.

The programme was criticised by researchers in the tradition of socio-technical systems thinking. For example, a "large demonstrator project" concerned with the administration of welfare benefits was technology driven and had only limited trade union involvement. The leading UK company in the Alvey Programme was ICL, which is now owned by Fujitsu of Japan. The current crisis in the Post Office caused by Fujitsu Horizon software demonstrates how little has been learned: deficiencies in the software were covered up, and 900 postmasters were prosecuted for apparent fraud.

The technology which I was managing was sought by the US Department of Defense, as part of their 1983 Strategic Defense Initiative (SDI), which was intended to protect the USA and their allies from attack by Inter-Continental Ballistic Missiles. This application would directly threaten the research which I was managing in the UK. Having been advised by senior colleagues, I resigned my posts, and I campaigned against UK participation in SDI, speaking and writing (Ennals 1986). In 1986 I was a co-founder of the journal *AI &Society: Knowledge, Culture, Communication*. I went on to edit six special issues of the journal, which continues today.

The UK government closed down the Alvey Programme in 1987, and there was no follow-on programme. Evaluators from the Treasury concluded that the programme was not profitable: this could not be expected of a research programme!

UK Bad Practice Case Studies

Having resigned my government funded research management posts in December 1985, I was able to adopt a more critical position, and I worked with a series of international partners. I have identified several UK "bad practice cases" over the years and explored what could be learned from overseas experience (Ennals 1995). The UK government has consistently declared that it had nothing to learn from experience in Europe, thus paving the way for the 2016 Referendum in which a majority voted to leave the European Union.

Amid the general atmosphere of European consensus in papers for this special issue, I can see a case for outlining some details of policy approaches which are markedly different. I could regard the UK as a rich store of "bad practice cases". Here are some current examples.

The manufacture of steel is fundamental to a modern economy. On 19th January 2024 it was announced that Tata Steel (owned in India) will close their two blast furnaces at Port Talbot (Wales), at the cost of some 2800 jobs. They will build new electric arc furnaces to process scrap metal but will no longer have the capacity to make steel from iron ore. Instead, such steel will be imported from India: offshoring the carbon emissions. The sudden forced transition is thus neither green, circular nor just. The views of the trade unions have been disregarded. Unemployment at the steelworks and through the supply chain will be considerable. There is an absence of alternative local employment. The UK previously reduced carbon emissions by closing almost all coal mines and outsourcing most manufacturing to the Far East.

Tata also owns Jaguar Land Rover, building luxury cars. As part of their move to electric vehicles, they will need to build a new battery gigafactory. A previously planned gigafactory project in Blyth was recently abandoned due to lack of investment. Nissan in nearby Sunderland currently operates the only battery gigafactory. The former British owned UK automobile manufacturing sector has shrunk and depends on foreign ownership. Electric vehicles also have the problem of a very limited infrastructure to support recharging. Investment has been far behind targets. It is not clear that British EVs will be sustainable.

Following Brexit, the UK withdrew from the European Horizon Programme, thus losing vital funding for collaborative research involving universities and companies. When I recently reviewed collaborative human-centred manufacturing project proposals for Vinnova, I encountered creative plans for future green developments and just transitions. Rather than being European and collaborative, the UK places more emphasis on links with the USA, including in defence technologies.

Despite commitments made at COP26 and COP28, the UK is opening a major new coal mine in Cumbria and issuing new licenses for drilling for oil and gas in the North Sea. Deadlines for stages towards net zero are being relaxed by the present government.

This generally parlous situation helps to explain why, since leaving my roles as a research manager with the UK government in December 1985, I have worked with partners in Scandinavia and Europe, as well as in Africa and Asia. My autobiographical account in this paper highlights the presence of sustainable alternatives, with roles for active government and new development coalitions. I have hoped to encounter alternative approaches which could be applied in the UK and present them to an incoming government following the imminent General Election. I have explored contributions from the Quality tradition (Ainger, Kaura & Ennals 1995; Ennals 1995; Hutchins 2006, 2019, 2023).

Working Life Research in Scandinavia

From 1986 I moved my research base to Sweden, while retaining an academic base in Kingston, at Kingston College and then Kingston University. I worked with Bo Göranzon at the Royal Institute of Technology (KTH), who was interested in "What Computers cannot do" (Dreyfus 1972), and the role of "Tacit Knowledge" (Polanyi 2972). He led the Dialogue Seminar at the Royal Dramatic Theatre from 1986, and hosted the conference "Culture, Language and Artificial Intelligence" in Stockholm in 1988. His approach was based on reflections on Professional Skill, with case studies in "Practical Knowledge", resulting in a PhD programme "Skill and Technology", which was linked to a series of six books published by Springer (Göranzon & Josefson 1988; Göranzon & Florin 1990; Göranzon & Florin 1991; Göranzon & Florin 1992; Göranzon 1992; Göranzon 1995) This emphasis could be contrasted with the British focus on observed "Competence", in new initiatives in Vocational Qualifications. Göranzon applied his Dialogue Seminars approach through consultancy with Saab Combitech, and with Vattenfall nuclear power (Göranzon, Hammaren & Ennals 2006). His student Johan Berglund applied the approach to nuclear safety and studied the Fukushima nuclear disaster: his theme was "Formalisation and Skill" (Berglund 2016). Göranzon's colleague Björn Nelson at Linnaeus University applied the approach to education and training in the Swedish construction industry, with a project in which workplace supervisors became vocational trainers.

From 1988 I also worked with Björn Gustavsen, in Sweden and Norway, as well as across Europe. With an initial background as a lawyer, drafting the 1977 Norwegian Work Environment Act as an action research project (Gustavsen & Hunnius 1981), he was a leading thinker in organisational development, with a pattern of organising Dialogue Conferences. He presented a central concept of "development coalitions", in which disparate partners could collaborate to achieve common objectives. This provided a locomotive for regional development (Gustavsen, Hofmaier, Ekman Philips & Wikman 1996; Gustavsen, Colbjornsen & Pålshaugen 1997; Gustavsen, Finne & Oscarsson 2001; Fricke & Totterdill 2004; Gustavsen, Nyhan & Ennals 2007), and a series of Norwegian national programmes (Levin 2002), as well as European initiatives in Work Organisation (Ennals & Gustavsen 1999). From 1998 I was an editor of the journal *Concepts and Transformation* (later *International Journal of Action Research*), which was founded by Gustavsen together with the book series *Dialogues on Work and Innovation* (for example Greenwood 1999; Emery 1999). In the final months before his death in 2018 Gustavsen worked with the Norwegian Labour Market parties to develop a new collaborative programme based on addressing issues related to climate change.

In addition, from 1997, I worked at the Swedish National Institute for Working Life with the programme "Work Life 2000: Quality in Work", in which Sweden set out a distinctive perspective for future European collaborations in Working Life Research. I was rapporteur for a series of 64 specialist research workshops (Ennals 1999, 2000, 2001). There was a strong Swedish emphasis on workplace health, driven by a coherent occupational health research community (Karasek & Theorell 1990; Marmot 2004). There was kaleidoscopic coverage of working life research, but without the emergence of a single view of knowledge.

Specialist groups of researchers could participate in dialogues which provided a "patchwork quilt" representation of the field. I learned to speak and write in the various specialist languages, but without claiming personal practical expertise. Following "Work Life 2000", I worked on "Work Life and EU Enlargement", with the 10 EU applicant countries. Bengt Knave of the National Institute for Working Life, who led that programme, was also President of the International Commission on Occupational Health (ICOH), and we worked to address working life issues in developing countries (Elgstrand 2009).

In Norway from 2002, at the instigation of Björn Gustavsen, I worked with the PhD programme "Enterprise Development and Working Life" (EDWOR), based at NTNU, with quarterly week-long teaching sessions around Norway, as well as in Turkey and the USA. Our PhD students were also salaried researchers in a set of funded projects around Norway: we were building a research culture for the new generation. My students then continued as my research partners. Some, such as Trond Haga (Haga 2007), worked in the offshore oil and gas industry, and pursued research agendas related to energy policy. The Norwegian government was conscious of the need to prepare for economic development after the peak use of oil and gas, supporting a balanced programme of research through a network of research institutes. James Karlsen (Karlsen 2007) worked on territorial development, with a methodology based on Action Research (Karlsen and Larrea 2014). I have worked with Hans Christian Garmann Johnsen at the University of Agder (Johnsen & Ennals 2012; Johnsen 2014, 2223; Johnsen et al 2015, 2017, 2018).

In Finland I worked with Jorma Rantanen at the Finnish Institute of Occupational Health, during his period as President of ICOH, following Bengt Knave. I continued to serve as a rapporteur, with ICOH, WHO and ILO.

Collaborative Research with the European Commission

The European Commission supports programmes of collaborative research which are intended to develop partnership and dialogue between member states. They are organised by several different Directorates-General, with published programmes of work.

From my base at the Centre for Working Life Research at Kingston Business School, I engaged in several international collaborative research projects in the applications of Information Society Technologies, taking me into fields such as mobile technologies, employment and recruitment, remote aircraft maintenance, stress at work, and the health of older workers. What these various projects had in common was that they crossed conventional barriers between disciplines and areas of governmental responsibility, at national and European levels, and involved work from different perspectives. I was also involved in evaluating collaborative research proposals, advising funded projects and troubleshooting when problems arose.

A recurrent theme was the exploration of how technology could be applied, and the limits of those applications. Researchers came together with backgrounds in different philosophies of knowledge. This could result in thorny problems. Qualitative and quantitative research were brought together, highlighting areas of misunderstanding. Some researchers made unrealistic assumptions regarding ease of automatic translation between European languages when dealing with job titles and educational qualifications. Others were over-ambitious regarding the formalisation of tacit knowledge (Polanyi 1972). Projects were encouraged to produce final reports which dealt with "lessons learned". These could be the most important outcomes! Project officers faced the challenge of managing portfolios of projects which had been proposed and evaluated by others and did not necessarily comprise coherent programmes.

Workplace Innovation

From 1997 I also worked with Peter Totterdill and the UK Work Organisation Network (later Workplace Innovation Ltd and Workplace Innovation Europe), which built a collaborative framework in a country, the UK, which lacked the Scandinavian tradition of consensus. We brought together the "Social Partners" (trade unions and employer organisations) with a series of projects. There were strong links with EU partners, which have been sustained until the present day. We organised the conference on "Working Together" for the UK Presidency of the European Union in early 1998.

In 2013, the European Commission supported the establishment of the European Workplace Innovation Network (EUWIN). From 2015, the *European Journal of Workplace Innovation* (EJWI), of which I was an Editor and then Editor in Chief, added the support of an international journal, published at the University of Agder, Norway: free, open access and online. In 2016, the Brexit Referendum, in which the UK voted to leave the EU, prompted the formal relocation of Workplace Innovation Europe to Ireland, enabling European funding for international collaboration to continue. EUWIN achieved a sustainable existence through self-financing and took on an ongoing portfolio of collaborative projects. I was appointed Honorary Advisor.

A European Approach

This summary chronology provides the backdrop for the emergence of a distinctive European approach to work and innovation. There has been "no one best way", but common themes have included: a respect for Skill, a concern for Sustainability, and an emphasis on Social Justice, accompanying labour market developments with a central role for Social Partnership. These themes are central to the current European focus on "Green Skills" and a "Just Transition", which involves bridging the specialist fields which are covered by Directorates-General in the European Commission.

We have, for example, considered the health of older workers (Ennals & Salomon 2011), and encouraged the Workplace Innovation movement, which has gained in popularity in Europe and internationally (Totterdill 2015; Oeij et al 2017, 2023). Rather than adopting the narrow capitalist focus on "Industry 4.0", we have taken a Human-Centred approach (Brödner 1990; Ainger, Kaura & Ennals 1995), building a collaborative culture in which we "learn from differences". The current diversity of new initiatives can be labelled "Industry 5.0". We seek the empowerment of workers, a participative style of management, and the evolution of a culture of "Skill" (Göranzon et al 2006), rather than the imposition on others of Taylorist requirements for "Skills".

Current Research Issues

There are several ongoing research issues concerning "Green Skill and Just Transition", which are important for the UK and countries across Europe:

Should we simply focus on quantitative measures of Training and Skills, or look at Work Organisation and the role of Skill? How can we encourage Work-Based Learning? What is the changing role of CEDEFOP? (Gustavsen, Nyhan & Ennals 2007).

When we consider "Green" "Skills" or "Skill", should we focus on new approaches such as the "Circular Economy"? How can good practice be shared? What are the preconditions for success? (Abrahamsson & Ennals 2022)

How do European Commission Framework Programmes encourage and develop processes of Dialogue (Larsson 1997)? What are the roles of research partners and European Commission project officers? How can we encourage pre-competitive collaboration, involving universities, companies and institutions?

How should we better deal with issues at the interface between specialist discourses, such as "Stress at Work" (Karasek & Theorell 1990; Marmot 2004; Cooper 2005, Levi 2022)? How can this be problematic? What are the institutional obstacles in the different professions?

How should we address problems of health and safety at work (Ennals 1999, 2000, 2001; Abrahamsson & Ennals 2022)? What is the role of the European Commission and European institutions such as Eurofound and EU-OSHA (Abrahamsson & Ennals 2022)? How should responsibilities be divided between the European Union and member states?

In the context of rapid changes and transitions in working life, how can we address "Justice"? How does this relate to "European Social Dialogue"? Can we identify separate traditions and find ways of bringing them together, learning from our differences?

How should we draw on different European traditions in working life research? Can we tackle issues in the philosophy of knowledge (Wittgenstein 1922, 1953; Johnsen 2023)? For example, how can research based on medical model work alongside conventional social science research? Can social scientists learn from the medical model of clinical intervention (Toulmin 2001)?

What is the role of EUWIN as an enabling network structure in this emerging collaborative context? This article is intended for publication in EJWI, which works in close association with EUWIN.

Conclusion

I suggest that these questions have in common that they require engaged researchers, rather than a conventional scientific detachment. They also require some understanding of the history of recent centuries, from which current trends and debates have emerged. This includes a need to understand developments in other continents, such as Africa (Bam 2021), and Latin America (Freire 1968). Traditions in different continents can be bridged through systematisation (Streck 2012). Thus, for example, EJWI is published in Europe, but welcomes contributions from around the world.

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Discussion Forum

Green skills, Green Jobs, and the Green Eco–system. Where do we go?

Kenneth Abrahamsson
Frank Pot
Paul Preenen
Peter Totterdill

The global environmental, climate and biodiversity challenges require an urgent global response. The green transition and the move towards sustainability, including the transition to a climate-neutral economy, is triggering the need for a fundamental transformation of our society across a wide range of sectors. Europe must lead by example, by delivering on ambitious environmental, climate and biodiversity goals, enhancing growth, competitiveness, and quality job creation, while protecting the environment and ensuring a just transition to a more resource-efficient and circular economy.

<small>Source: EU Council conclusions on skills and competences for the green transition. March 7, 2023</small>

Where do we go from a policy perspective?

The struggle for a climate neutral economy is a fast-paced political, social and economic hurdle race with many both known and unknown obstacles. One major institutional change is that the new US administration under the leadership of president Donald Trump will abolish President Biden's policies to fundamentally reduce greenhouse emissions and deciding to leave Paris Agreement. Other obstacles are that many countries continue to use fossil-based energy system as coal and oil. The growing geopolitical tensions and the fact the old technology energy systems also tend to be a political currency. There are also signs of the green spirit in losing its energy by declining interest and market demand for electric cars.

Another challenge or threat is that there is no one-directed highway to a sustainable green economy. It is a broader and more complex process of change influencing politics, enterprises, public sector and the civil society. It is also a process where the concepts of just transition will be tested in reality. Who will carry increasing cost for working and living, to support more long-term oriented goals of societal changes from an ecological perspective? The green transition needs new patterns of workplace innovations, but it is not easy to anticipate which occupational risks and hazards that may appear when the production stress and time for delivery is being stepped up. Another problem is staff recruitment and

composition of working teams, when employees and hired personnel are coming from various backgrounds. It takes time to build and initiate and strengthen a community of practice in a context of high products demands and in combination with various levels of algorithmic management and work intensification.

There is no standard model for how the challenge of just transitions can be solved. The concept of just transitions is both broad and blurred, reflected in the phrase just transition with or without workers. Technological and organisational changes do not always go hand in hand. Major industrial and organisational transition actualise the need for skills development and formal education upgrading. Swedish government have launched a new model for transitionary upskilling offering paid educational level for eight months. This reform was part of a collective agreement between social partners on job security regulations.

More and more studies illuminate the crucial role of the local community, welfare institutions and systems of social security and public health. The move toward a climate neutral and de-carbonised economy is not just a matter for the labour market and job structures. It also has strong repercussions for the local society, and support from citizens and local interests. Shifting policies at European and global levels could both be drivers for change and major obstacles. The current policy tension between the European model for a climate neutral society with a far-reaching impact on various sectors, and the upcoming US policy on abolishing Biden's green policy mission and increase oil production, "drill, baby, drill" make the future pollical cohesion working climate change much more difficult, not to say impossible.

The challenge of boosting the capacity of electrification is not a one model quick fix. Installations of new plants on nuclear power is a time demanding and costly process. Wind power is an increasing field but is also meeting various obstacles and growing ethical tensions between environment, local groups and also how to make electricity available at sometimes a tripled capacity level for the industrial sector. It is a fundamental cross pressure between social, cultural, economic and technological goals. There will also be increasing global competition in the green transformation.

We are dealing with the future of work and societies with various concepts. Lehndorff compares the US New Deal initiated by President Roosevelt in the early 1930th with the EU Green Deal was proposed by the European Commission in June 2022 and was published in the EU's Official Journal in the end of 2024. Some years before that, The Global Deal was initiated by the Swedish Prime Minister Stefan Löfven in 2016 and developed in cooperation with the International Labour Organization (ILO) and the Organisation for Economic Co-operation and Development (OECD) as founding partners. And the EU takes a further step in talking about thew Clean Deal with the focus on the industrial sector; sustainable working conditions, sustainable production systems and sustainable, zero-carbon products.

The policy for the Green Deal is not an open highway for societal and labour market change. Hopefully, the green transformation will not be a Mean deal considering various forms of problems to be solved and also social, economic and political barriers, recently reflected by President Donald Trump's counter policies to climate change and the green transformation in the US. In times of reluctance, science denial and new anti-climate popular movements, the role of EU becomes more important.

The recent policy document **Europe's Choice** provides a broad overview of ways to a climate-neutral and sustainable and energy-smart solutions. One important clarification is to relate the concept of just transition to the European Pillar of Social Rights. Another important mission is to develop a **Quality of job roadmap**. Climate change and job quality is a relation and interface that needs to be subject to further analyses and policy development.

Europe's way of life depends on the protections and opportunities of our social model and our social market economy. This is why it is so important for the principles of the European Pillar of Social Rights to become a reality across our Union, respecting each country's social model. We need new impetus in areas where more progress is needed, and we will frame this work in a new **Action Plan on the Implementation of the European Pillar of Social Rights.**

It will include initiatives looking at how digitalisation is impacting the world of work, from AI management, to telework and the impact of an "always on" culture on people's mental health. New forms of work should not lead to fewer rights, and I will propose to introduce a right to disconnect.

People and their jobs must always remain at the heart of our social market economy even as our industries and economies change shape. We need to ensure a **just transition for all.** This is why I will put forward a **Quality Jobs Roadmap**, developed together with the social partners. It will support fair wages, good working conditions, training and fair job transitions for workers and self-employed people, notably by increasing collective bargaining coverage.

And we will significantly increase our **funding for a just transition** across the next long-term budget. This will be part of a renewed commitment to strengthening European social dialogue in a time of economic and social change. Together with European trade unions and employers, we will deliver a new **Pact for European Social Dialogue in early 2025**.

EUROPE'S CHOICE POLITICAL GUIDELINES FOR THE NEXT EUROPEAN COMMISSION 2024−2029 URSULA VON DER LEYEN CANDIDATE FOR THE EUROPEAN COMMISSION PRESIDENT

The ILO/UN resolution on Just transition that was taken summer 2023 underlines the role of the social partners in the green transition.

> *" Members should give special attention to respecting, promoting, and realizing freedom of association and collective bargaining as enabling rights, which are vital for social dialogue. Consultations, exchange of information and other forms of dialogue between social partners and with governments are also important for a just transition."*

The twin challenge of climate change and digitalisation in a post-covid society, also calls for new and innovative workplaces, horizontal and vertical mobility and skill development and investments in new education programmes. It is also a process that are in the hands of social partners, but also with support from governments and other actors.

Where do we go from an analytic and theoretical perspective?[1]

Green Transformation and Workplace Innovation

Peter Totterdill (WIE)

The achievement of corporate sustainability is likely to be strongly associated with companies in which employees across the workforce are fully aligned with strategic goals and in which employee involvement in continuous improvement and innovation is firmly recognised and valued.

Organisational distance between senior leaders and the wider workforce leads to lack of engagement and the misalignment of day-to-day practice with strategic goals, including sustainability. Workplace innovation emphasises flatter organisational structures and co-created leadership, through which front line employees can actively engage in the development and delivery of company strategy and thereby 'own' it. A good example highlighted during the San Sebastián Conference is that of Booth Welsh[2], where every employee is given the opportunity to contribute to the design and delivery of measures related to strategic goals based on "People, Planet and Profit".

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1 As part of the editorial work, I asked for comments by EJWI friends on the analytical focus of green jobs and workplace innovation, and received responses from Peter Totterdill, Paul Preenen and Frank Pot.
2 Totterdill, P. Exton, R. (2022) Workplace Innovation: Are we Serious? In: Abrahamsson, K. and Ennals, R. Sustainable Work in Europe: Concepts, Conditions, Challenges. Berlin: Peter Lang.

Likewise, workplace innovation plays a pivotal role in driving sustainability by embedding continuous improvement and employee-driven innovation in day-to-day practice, leading to greater employee involvement in the adoption of digital technologies whilst empowering individuals and teams to create and adopt eco-friendly solutions and the optimisation of existing processes.

We already know much about how to create workplace practices and cultures which empower workers to deliver organisational goals whilst also improving job quality. It is important to start with what we know, understanding workplace innovation as the catalyst for sustainable transformation by aligning organisational practices with environmental objectives, ensuring that growth, job quality and sustainability go hand in hand.

The concept of green jobs is problematic.

Frank Pot

The concept of green jobs suggests something good: architects who design green cities, engineers designing low carbon production processes, workers who discuss with their management how organisations and processes can become greener. But green jobs can also cover (very) bad jobs from a point of view of job quality or decent work. Workers installing solar panels on roofs rather often work not safely and/or have low wages. Workers in the recycling business (collect, sort, process) are exposed to dangerous substances and have often 3d jobs (dirty, dangerous, demanding/difficult).

Workers who must dismantle equipment, toys, etc. to recycle the components have heavy repetitive work with musculoskeletal problems and are exposed to hazardous substances. Workers in biomass may be exposed to microorganisms and endotoxins which may have the potential to affect health.

For green production processes and products special materials are necessary such as cobalt, cadmium and lithium. The mining of these materials is done under very bad working conditions, often also at the expense of local communities (water supply).
Concluding. When we practice or talk about green transition and/or green jobs we must pay attention to job quality and how to prevent precarious employment and segmentation (migrants doing the 3d-work) and leave no one behind.

The importance of social *in*trapreneurship for the twin transitions

Paul Preenen, TNO

Countries, regions, and organizations that are able to make both the green and digital transformation (twin transition) will likely emerge as the new leaders in the new (green)

economy. At a high level and from a top-down perspective this logically demands strong guiding policies, strategic investments, and bold leadership of politicians, policy makers and leaders.

From a bottom-up and intra-organizational perspective this requires the involvement and engagement of employees who are able and motivated to drive and integrate the two transitions. Social intrapreneurship, an emerging concept in practice and science, can play a significant role in driving these transformations bottom-up within organizations. Social intrapreneurship is defined as discretionary and informal employee-led process of identification and exploitation of entrepreneurial opportunities that address social or environmental challenges while contributing to the objectives of established organizations (Alt & Geradts, 2019).[3]

Social intrapreneurs are employees who act as change agents *within* an organization, driving innovative, purpose-driven projects that align business goals with social and environmental impact. Social intrapreneurs can bridge gaps between corporate sustainability goals and on-the-ground innovations by promoting sustainable practices and foster a culture of social responsibility and human centricity within organizations. These individuals could push for policies that prioritize green innovations while simultaneously addressing social concerns, such as job displacement or unequal access to training for new green technologies.

Social intrapreneurs focus on creating synergetic solutions that deliver both social value and business success. In the context of climate and digital change, this means leveraging digital tools and innovations to drive sustainable and social outcomes. For example, a social intrapreneur might promote the use of AI or big data to track and reduce carbon emissions, aligning environmental goals with organizational efficiency and profitability, while simultaneously safeguarding decent working conditions for employees.

In sum, social intrapreneurship can be a powerful tool for organizations facing the twin challenges of climate change and digital transformation. However, even though we can expect that social intrapreneurs can make things happen in many but not all organizational contexts, the question remains how we can optimally stimulate and facilitate social intrapreneurship in organizations.

Which organizational factors and practices drive social intrapreneurship? Future research should investigate this further by making the connection with Workplace Innovation theory. Which Workplace Innovation practices and organizational structures stimulate social intrapreneurship? Or alternatively, can social intrapreneurs enhance and implement Workplace Innovation in organizations to successfully guide the green and digital transformations in organizations?

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3 Alt, E., & Geradts, T. (2019, July). Social intrapreneurship: Unique challenges and opportunities for future research. In Academy of Management Proceedings (Vol. 2019, No. 1, p. 16643). Briarcliff Manor, NY 10510: Academy of Management.

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