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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