European Agency for Safety and Health at Work

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Priorities for occupational safety and health research in Europe: 2013-2020

European Agency for Safety and Health at Work

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Foreword

This report aims to update the European Agency for Safety and Health at Work working paper 'Priorities for occupational safety and health research in the EU-25' (EU-OSHA, 2005), first published in 2005, taking into account the latest developments in scientific knowledge in the field, changes in the world of work and recent trends that have an impact on occupational safety and health (OSH).

The present report does not provide an exhaustive list of research needs. The objective is to identify priorities for OSH research in the coming years in accordance with both the Europe 2020 strategy (European Commission, 2010a) and the Horizon 2020 programme (European Commission, 2011a) and their priorities and key objectives of 'smart, sustainable and inclusive growth' and 'excellent science — competitive industries — better society'.

It should also be noted that some OSH issues that are particularly important in terms of prevention or information dissemination are not dealt with here. The report focuses only on priorities for research linked to gaps of knowledge in the field of OSH.

The report is structured around four major themes:

- Demographic change — sustainable work for healthier and longer working lives.
- Globalisation and the changing world of work — OSH research contribution to sustainable and inclusive growth.
- OSH research for safe new technologies as a prerequisite for sustainable growth.
- Research into new or increasing occupational exposures for the benefit of a smart and sustainable economy.

This approach was chosen over a more technical OSH risk-centred presentation to emphasise the fact that OSH research can contribute to achieving the targets set by the Europe 2020 strategy. It also underlines the global economic, social and technological challenges that the European Union (EU) is facing and aims to show their impact on the world of work and, consequently, on OSH research priorities.

Healthy and safe working conditions are closely associated with the productivity and the performance of enterprises. As stated in a communication of the European Commission: 'High quality of work goes hand in hand with high employment participation. This is because the working environment plays a crucial role in enhancing the potential of the workforce and is a leading competitiveness factor. In order to innovate and to deliver promptly and efficiently, EU companies depend for their survival and expansion on a committed workforce, thriving in a high-quality working environment, with safe and healthy working conditions' (European Commission, 2010b). OSH research has a key role in ensuring safety, health and well-being at workplaces. It provides arguments and scientific evidence upon which efficient and sustainable policies and prevention measures have to be based (European Commission, 2007). It also delivers the evidence base for the development of practical methods and tools to be applied at the company level.

OSH research is needed for tackling the negative effects of globalisation on companies and their workers in the context of demographic change. A longer working life is an economic and social necessity: research can contribute to this aim by developing solutions that help workers remain healthy, engaged and willing to extend their careers.

New technologies have great potential in the development of a safer and greener economy, but the sustainability of their applications must be assured. New technologies are only sustainable if the potential health and safety risks can be brought under control. This requires identification and evaluation of risks and development of preventive solutions. In the context of economic crisis, it is particularly important for research resources to be properly allocated and efficiently used. OSH research prioritisation and better coordination between different institutes and research centres is necessary: setting joint priorities should be encouraged (European Commission, 2007).

The methodology used to draft the report is described in Chapter 4.

Executive summary

In June 2010 the European Council adopted the new 10-year Europe 2020 strategy for smart, sustainable and inclusive growth, a strategy for delivering high levels of employment, productivity and growth, and at the same time social cohesion[1]. The Strategy identifies the major challenges Europe faces – the demographic change, globalisation, and rising global competition for natural resources, putting pressure on the environment, the Strategy is proposing five measurable EU targets for 2020 that will steer the process: for employment; for research and innovation; for climate change and energy; for education; and for combating poverty. The key goals, set out in the Strategy are reflected in the 7 flagship initiatives, the Digital Agenda, and Agenda for new skills and jobs. All EU policies, instruments and legal acts, as well as financial instruments, should be mobilised to pursue the strategy's objectives. Mainstreaming priorities across policies is emphasized in many policy documents. The optimal achievement of objectives in some policy areas - including climate action, environment, consumer policy, health and fundamental rights - depends on the mainstreaming of priorities into a range of instruments in other policy areas[2]. These policy goals have a clear relevance for health and safety at work and related research.

Promoting good health is an integral part of the smart and inclusive growth objectives of Europe 2020. Keeping people healthy and active for longer has a positive impact on productivity and competitiveness[3]. Thus, health and safety at work and OSH research have a role to play in delivering smart, sustainable and inclusive growth.

Reaching the high-level goals of Horizon 2020 and the overall EU policies for the next decades will depend on the success of new enabler technologies such as those needed for the new energy policies, climate adaptation and future manufacturing. However, new technologies will succeed only if the benefits are clearly visible and the potential risks are regarded as acceptable by society. This requires identifying and addressing stakeholder and public expectations and responding to their concerns in order to build trust and confidence and to show that the new technologies are "well under control".[4] This in turn, requires identifying and assessing the health and safety risks associated with new technologies and integrating OSH aspects in the development of new technologies and processes, as well as strengthening risk communication / OSH communication.

Work is an economic activity and occupational injury and illness are also matters of economics. Understanding the role of economic factors in the etiology of workplace ill-health and the effects this has on the economic prospects for workers, enterprises, and society is crucial for policy development and to support decision making at enterprise and society levels.

The impact of any OSH research on workers' health and safety will depend on how research findings are translated into practical and accessible workplace solutions. It is paramount that OSH research is focused on the transfer and translation of scientific knowledge into practical, accessible workplace solutions and interventions. It is equally important to integrate OSH research in the development of new technologies and processes (prevention through design).

Risk communication, and OSH communication in general, are closely related to the transfer and dissemination of research results. Risk communication is particularly important in the context of new technologies where there are uncertainties regarding the potential risks. There is a need to strengthen **risk communication** research to identify efficient ways of delivering timely and appropriate information on OSH to various target audiences.

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[1] EU2020

[2] A Budget for Europe 2020 /* COM/2011/0500 final */
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0500:FIN:EN:HTML

[3] A Budget for Europe 2020 /* COM/2011/0500 final */
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0500:FIN:EN:HTML

[4] European Emerging Risk Radar (E2R2) Initiative: "Matching the technology challenges of 2020" European Parliament / Science and Technology Options
http://www.europarl.europa.eu/stoa/cms/cache/offonce/home/events/workshops/integ;jsessionid=4A9AAC6D54988A0292C1192038303A57

In order to find sustainable solutions to complex issues, it is necessary to build bridges between OSH research and other disciplines. In particular, the links between OSH and economic, general health and environmental issues have to be considered. Connecting OSH research closer to these and other relevant fields will help to mainstream OSH so that it will be considered when important decisions are made at societal and company level.

Demographic change

The European Union (EU)'s population is becoming older: the number of people aged 60 and over in the EU is now increasing by more than 2 million every year. The working population is also ageing, as the proportion of older workers in employment increases in comparison with the cohorts of younger workers. In the 27 Member States of the EU, the 55- to 64-year-old working-age population is expected to increase by about 16 % between 2010 and 2030. Policies that address the ageing of the population and its workforce focus on enabling older workers to remain active and productive for longer.

Given current policy directions, which are focused on preventing premature retirement and prolonging workforce participation, identifying the factors affecting retirement decisions becomes crucial. Research on the employability of older workers has identified that the low participation of older people in the labour market is the result of a combination of wage conditions, rigidity in workplace organisation, inadequate skills and competencies and poor health status, rather than the wish to retire early.

It is obvious that prolonging working careers strongly depends on the adaptation of workplaces and work organisation. Workplace accommodations are likely to benefit workers of all ages. Several studies acknowledge that more research is needed into how workplaces should be designed and work organised to meet the needs of older workers. Further research is also needed on the effects of specific workplace exposures on the trajectory of normal ageing. Workplace interventions targeted at older workers, including improving work organisation, training and workplace accommodations, deserve the highest level of attention.

Over the past 10 years female employment rates have increased throughout Europe (EU-27), from 57.9 % in 2001 to 62.3 % in 2011. As the Europe 2020 strategy envisages a 75 % total employment rate in the EU by 2020, involving more women is seen as one of the major factors in meeting this target. The goal of higher female employment underlines the need to more effectively address the health and safety issues that affect women.

Taking into account the different health and safety risks to which female and male workers are exposed at work; the different effects of those risks on men and women, in terms of exposure to hazardous substances; their impact on reproductive health; the physical demands of heavy work; the ergonomic design of workplaces; and the length of the working day, and also considering domestic duties (ILO, 2009), a more targeted gender-sensitive approach to research and prevention is needed. It is necessary to integrate the gender aspect into all work-related research topics.

Over the past decade, unprecedented levels of immigration both from third countries and within the EU-27 have substantially increased the proportion of EU-27 inhabitants who do not live in their native country. As most migrants are relatively young, they contribute to the size of the EU-27 labour force. In the future, the labour force will increasingly include people with a migration background. By 2060, close to one-third of the EU-27 workforce will be of foreign descent. These trends imply that additional efforts are needed to enable immigrants to integrate into their host society and contribute to the labour market by making full use of their potential.

In the coming years, more than previously, the labour market will be characterised by increasing diversity. As a consequence of the diversification of labour supply, there is an increasing need to engage with a more demographically diverse workforce (female, migrant, younger and older workers, and workers with disabilities). These demographic groups are disproportionally represented in precarious employment arrangements and non-standard working times. There is a lack of information and research on these groups of workers and the jobs they occupy. Monitoring and research of the changing scale and nature of the risks as the proportion of these groups in the workforce increases is therefore critical.

There is a considerable body of evidence showing that health has strong effects on labour market participation in general and the labour supply of older workers in particular. Ageing leads to an increase in the risk of developing disorders and diseases, and health issues are the most common reason for leaving the workforce before the statutory retirement age. Musculoskeletal disorders (MSDs) and the growing incidence of mental ill health are the primary diagnostic causes for disability retirement (OECD, 2010). Therefore, it is crucial to organise work and to design workplaces in such a way that the manifestation (or, at least, the aggravation) of these illnesses can be prevented and more employees are enabled to work until the regular retirement age.

Although there is growing evidence that, in addition to mechanical load, psychosocial risk factors play a role in the development of MSDs, more research is needed to clarify this influence in the context of multifactorial causation. More high-quality intervention studies are needed to evaluate the effectiveness of interventions that apply a multi-risk approach in order to promote evidence-based practice in the prevention of MSDs.

Although there is evidence that the prevalence of common health problems does increase with age because of the normal and inevitable ageing process, this does not necessarily hinder work performance and is not a valid reason to exclude an individual from the workforce. More research is needed into how workplaces need to be designed and work organised to meet the needs of people with chronic diseases and health conditions and to identify modifiable factors and possible interventions in order to prevent work disability and unnecessary job loss.

Too many workers leave the labour market permanently as a result of health problems or disability, and too few people with reduced work capacity manage to remain in employment. Spending on disability benefits has become a significant burden on public finances and hinders economic growth as it reduces effective labour supply. Although the main factors predicting disability are, to a large extent, known, there is only scattered information available from workplace intervention studies aimed at the prevention of disability in long-term settings. Irrespective of diagnosis-related issues, further research on the determinants of return-to-work outcomes, based on longitudinal data, is required. This research must take into account more thoroughly the complexity of processes related to the development of long-term sickness absence and disability, as well as successful reintegration after illness.

Globalisation and the changing world of work

In the past, globalisation has often been seen as a more or less economic process. Nowadays, it is increasingly perceived as a more comprehensive phenomenon that is shaped by a multitude of factors and events that are quickly changing our society. It has created more opportunities for economic development, but it has also intensified competition and increased economic pressure, resulting in companies restructuring and downsizing and business activities being outsourced and offshored. The consequences for workers include job insecurity and work intensification.

Restructuring — company reorganisation, closures, mergers and acquisitions, downsizing, outsourcing, relocation, etc. — is necessary if companies are to remain competitive. Restructuring is now becoming permanent and tends to occur in all Member States. In operation since 2002, the European Restructuring Monitor (ERM) recorded over 14,000 cases of large scale individual company or organisation restructuring from 2002 to mid-2012 (Eurofound 2012).

Already before the crisis restructuring had become a permanent structural component of the economy. In this difficult context of the economic crisis, anticipating, managing, limiting and cushioning job losses, however they are caused (from mass redundancies following the closure of large companies to sporadic lay-offs in SMEs and the termination of contracts of casual workers), is increasingly challenging. The issue of restructuring has been placed at the top of the political agenda of governments and social partners in the EU since the economic crisis began.

Data relating to health and restructuring are lacking and fragmented at both national and European levels. Collecting and evaluating data on workers' health in restructuring processes, including in SMEs, is important for assessing the real-life situation and planning future activities in this area.

There is empirical evidence of the negative health impact of restructuring both on the direct victims, that is those who lose their jobs, and on the survivors of restructuring. Given the evidence of the potentially negative health effects of restructuring, occupational health services should promote prevention and workplace health intervention before, during and after restructuring.

Globalisation, resulting in more competition, increased economic pressure and restructuring; the rapid spread of **information and communication technology** (ICT) and the Internet; and the shift from manufacturing to services have all affected the world of work: employment and working patterns have undergone significant change, resulting in increased exposure of workers to psychosocial hazards. In the context of organisational changes and of restructuring in particular, job insecurity and work intensification appear to be major OSH risk factors.

Globalisation and increasing competition have had a large impact on production methods and work organisation, resulting in a gradual transition from relatively standardised work organisation and working time patterns towards more complex and diversified structures. Over the past decade, the number of workers employed under atypical arrangements (fixed-term contracts, self-employed, temporary agency workers) has risen significantly, coupled with a relaxation of legislation governing dismissal in various countries. Studies on the OSH effects of precarious employment found a negative association with OSH and that the higher the instability of employment, the more it is associated with morbidity/mortality.

Globalisation is closely linked to the development of new technologies, in particular of ICT. The rapid spread of ICT and the Internet is changing the way in which companies organise production and also modifies working conditions and work organisation. ICT has contributed to the development of the 24/7 economy, which requires flexible work organisation, high flexibility in working hours and quasi-continuing availability. The growing use of computers and automated systems at work has also led to an increase in fixed body postures and physical inactivity at work. Physical inactivity is associated with increased health risks such as coronary heart disease, certain types of cancers and psychological disorders such as depression and anxiety.

Structural, organisational and technological changes in the work environment increase the pressure on work–life balance. Factors such as advances in ICT, information load, the need for speed in response, the importance attached to the quality of customer service and its implications for constant availability and the pace of change can be sources of pressure. Research is needed on the impact of new working patterns, different types of flexibility, and the implementation of new technologies (e.g. mobile ICT supported work) on work–life balance and health and well-being at work.

The ongoing shift towards a **service and knowledge-based economy** underlines the importance of the services sector. This sector provides an increasing number of high-skilled jobs, for example in ICT and marketing, but also provides an increasing number of low-skilled and low-wage jobs, often characterised by non-standard working conditions and unsociable working hours. Particularly in the education and health and social sectors, employees experience distressing working conditions with high emotional load and may be exposed to violence and harassment at work. The potential health hazards in the services sector include growing psychosocial pressures due to increased availability demand and frequent and new human contact. It is likely that this phenomenon will become more important as the services sector continues to grow.

Those affected by violence and harassment in the workplace tend to report higher levels of work-related ill health. Victims of violence and harassment experience depression, anxiety, nervousness, sleeping problems and concentration difficulties among others. Organisational consequences include absenteeism, accidents and impaired performance. Commonly accepted definitions and classifications, as well as systematic strategies, are needed to better assess the prevalence of work-related violence at the European level. There is a lack of intervention evaluation research in relation to harassment and violence at work; therefore, too little is known about the most effective measures of preventing harassment and violence at different levels.

Psychosocial and organisational risk factors such as high workloads, tight deadlines, long and/or non-standard working times (long hours, shift work, night work), precarious or isolated work — whether or not they are combined — are likely to contribute to the development of certain chronic disorders and diseases. The nature of many of the complex interactions between work-related psychosocial risk factors, risk behaviours and chronic diseases and health conditions, including occupational diseases and disorders, is not well studied or understood. A better understanding of the links between work-related psychosocial risk factors and morbidity and mortality is needed for the development of evidence-based policies and effective prevention strategies.

Traditionally, occupational health psychology has focused on risk factors in the workplace and their adverse health effects, and the vast majority of intervention research concerns the detection and management of occupational health problems rather than the reinforcement of positive aspects of work. The mechanisms that underlie employee ill health and malfunctioning, however, are not the same as those that constitute employee health and optimal functioning. Positive occupational health psychology advocates an integrated approach that balances positive and negative aspects of work and well-being. This positive approach in occupational health psychology research needs to be strengthened.

As new technologies and globalisation reduce the importance of economies of scale in many activities, and larger firms downsize and outsource more functions, the weight of SMEs in the economy is increasing. In 2008, two-thirds of the EU-27's non-financial business economy workforce was active in an SME.

The potential of small enterprises has been recognised and it is appreciated that employment and economic growth to a large extent depend on these enterprises. Both political and scientific interests in OSH in small enterprises have, therefore, grown considerably during the last decade.

In terms of OSH, small businesses present a challenge: they are difficult to regulate, as they are typically heterogeneous, geographically scattered, lack cohesive representation and have a short life cycle. The need to focus OSH research on small businesses is now recognised, but effective mechanisms to reach, assist and impact these companies continue to be a challenge. To date, most OSH research and interventions have been primarily focused on large companies.

In order to develop effective OSH strategies and policies targeted at small businesses, it is important to understand their organisational and cultural realities and to know their specific needs and motivations. Moreover, knowledge is needed on the specific success and obstacle factors in the different stages of the enterprise life cycle on one hand and during different economic cycles (growth, recession) on the other.

The quality of research on small and micro-enterprises needs to be improved. Innovative support schemes adapted to the realities and needs of small and micro-enterprises need to be developed, implemented and evaluated.

OSH and new technologies

OSH research has a key role in contributing to the development of safe, new technologies. A global shift towards a **greener and more sustainable economy** exposes workers to traditional OSH hazards; however, the new test is how to deal with the exposure to a combination of old risks within new settings and conditions. Means by which to transfer existing knowledge to new applications and working environments need to be identified. Furthermore, the current speed of expansion in green jobs will also lead to a skills gap and a reliance on a large number of inexperienced and/or underskilled workers who will be handling and interacting with new or unfamiliar technologies. As with any new and developing technology, workers in 'green jobs' will also be exposed to new hazards, which probably have not been previously identified. These 'green' challenges can be met only by developing safe working processes together with workplaces that fully exploit new processes and technologies.

The need to decrease greenhouse gas emissions by 2020 has contributed to the development of **renewable energy technologies** such as wind, solar and waste-to-energy applications. These new technologies are needed to be able to move towards a greener economy; however, their implementation brings about occupational exposure to biological agents, chemicals and new materials, generating potential health risks that have to be assessed and managed.

The need to find solutions to resolve environmental protection issues has encouraged and developed the industrialisation of waste treatment and large-scale waste disposal systems such as incineration and recycling. As raw materials such as rare elements are becoming scarcer and more valuable, their recovery and recycling by landfill mining may become economically viable. **Waste management and recycling** is one of the fastest growing green economy sectors in terms of employment. However, the OSH issues associated with them have not yet been adequately addressed. Workers are exposed to injuries, biological agents that are able to provoke infections, allergies or toxicity and dangerous chemicals (e.g. heavy metals, flame retardants, rare earth elements or nanomaterials) present especially in waste electrical and electronic equipment or associated with their treatment. The related health risks to these activities need to be identified, assessed, and brought under control.

The implementation of **information and communication technologies (ICT)** has the potential to change the nature of how work is carried out and affect the working environment. However, it is these **ICT-related changes in the world** of work rather than the technology itself that bring about not only great opportunities but also a certain number of health and safety risks.

Ambient intelligence (AMI) refers to the extension of the working or living environment with intelligent functions that adapt to the needs and tasks of the user. Ambient intelligence-based working assistance systems include head-mounted devices equipped with information displays and other vision-based or tactile systems. The possibilities of using AMI solutions for creating tailored support systems to adjust workplaces to changing abilities of older people or to the needs of people with disabilities need to be explored.

The rapid development of ICT has enabled the development of flexible work forms and virtualisation of the working environment (virtual offices, teleworking), which can contribute to well-being at work. The other side of the coin is that certain OSH risks related to IT-supported work, including mental workload, permanent accessibility and human–computer interactions, have increased. Research is needed to find prevention solutions to these issues. Furthermore, usage and usability of ICT should be studied to also take into account the specific needs of, for example, migrant workers or older and disabled workers. Research in cognitive ergonomics concerned with mental processes is necessary to ensure that OSH aspects are effectively integrated into the development of new technology applications.

Intelligent but complex new technology applications are increasingly used in the workplace. Safety and health aspects should be taken into account as early as possible during their development. Moreover, it should be noted that risks can emerge not only when these devices are used, but also during their entire life cycle. It is therefore important to consider in advance not only the environmental but also the potential occupational hazards related to these applications, from research and development to disposal and recycling (**prevention through design**). New modelling and simulation methods can be advantageously used for these purposes. Virtual and augmented reality applications are particularly useful when designing safe workplaces and should be further developed.

Smart and interactive materials have the potential to improve OSH. New high-performance materials based on, for example, nanotechnology applications may be used to improve the safety and performance of working clothes, personal protective equipment and so on. Moreover, new adaptive/wearable sensors monitoring workers' physiological parameters and environmental conditions can be integrated to give online information that helps in decision-making in difficult working environments. Their efficacy and functionality in prevention applications should be evaluated, particularly with regards to new hazards and changes in the working environment.

Use of new technologies brings about varied, potentially increasing risks regarding **exposure to EMFs**. Although most sources emitting EMFs can be considered harmless, some types of appliances, such as magnetic resonance imaging scanners and transmitting antennae, may expose workers to acute risks such as induced currents and elevated temperature. Owing to the extensive use of wireless communication devices, there has been growing concern over the possibility of adverse impacts on health, including carcinogenic effects, resulting from exposure to radiofrequency EMFs. The potential adverse health effects of long-term EMF exposure have not, been established as the results of research so far are contradictory and warrant further study. In order to evaluate the long-term effects of exposure to EMFs, there is a need to conduct a systematic evaluation of the number of workers exposed to EMFs and a characterisation of emitting sources. Furthermore, tools are needed for workplaces in order to assess the risks to particular groups of workers, such as persons with medical implants and pregnant women, as required in the EMF directive.

The number of applications generating intermediate-frequency fields is increasing as a result of increasing use of devices emitting in the range of 300 Hz to 100 kHz, examples of which include radiofrequency identification devices and antitheft devices operated in shops. Knowledge on their possible health effects is limited and they should be studied further. There is also a need to conduct research in order to evaluate the possible health effects of new frequencies, such as in the terahertz region, the utilisation of which is currently being developed for emerging applications.

Industrial biotechnology enables the development of promising energy-efficient, sustainable processes for producing food, chemicals and pharmaceuticals. These processes have the advantage of relying principally on low-energy, atmospheric pressure systems and use far fewer synthetic chemicals as raw materials than the equivalent chemical processes. The corresponding risks may therefore be diminished. The unknown OSH issues in industrial biotechnology are primarily related to exposure to biological agents, (micro-organisms and their components), which can be harmful to workers' health, provoking, for example, infections or allergies.

Increasing occupational exposure to chemical and biological agents

Innovations necessary to improve productivity and regain competitiveness according to the Europe 2020 strategy are likely to result in new challenges for OSH: new or increased exposure to biological and chemical agents, as well as mixed exposures. The burden of ill health at work is already heavy: 23 million people in the EU reported a work-related health problem in 2007. The majority of work-related fatalities are attributed to work-related diseases, almost half of which are due to exposure to hazardous substances at work. European statistics show that the number of fatal occupational accidents is decreasing, whereas the fatalities due to occupational diseases are increasing. Moreover, a growing number of allergies, asthma and illnesses related to sensitisation have been observed in workplaces. Their onset is associated with exposure to chemicals and biological agents present in the working environment.

Related to this trend, the use and safety of chemicals is becoming more challenging. The EU REACH regulation (EC 109/2006) intends to reply to this development: its registration process requires the industry to prove the safe use of chemicals. A revision, which aims to extend the REACH legislation to cover the risks of exposure to **carcinogenic, mutagenic, reprotoxic (CMR) and sensitising substances**, is currently under way. Exposure to these substances is not limited to the chemical industry; it also concerns waste management and recycling, as well as the development of 'greener' industrial products and processes.

Occupational cancers are one of the major causes of work-related fatalities. However, many are considered avoidable. A lack of exposure data is a shortcoming in connection with not only carcinogens but also substances that have mutagenic and reprotoxic effects, such as endocrine disruptors (EDCs). According to a recent study requested by the European Parliament's Committee on Employment and Social Affairs, 'the absence of adequate exposure data is the weakest link' in connection with EDCs. The report underlines that 'prevention very much depends on uncertainties about the effects of EDCs' while exposure data are missing to determine 'whether the observed health effects in humans are linked to EDCs'. The extent of exposure to CMR substances should be determined to gain a better knowledge of the factors leading to occupational cancers; comprehensive international data need to be collected. In parallel, biological monitoring of workers should be further developed as this will provide information on internal dose, as well as the toxic effects and individual susceptibility. A further fostering of biomonitoring necessitates the development of appropriate biomarkers.

The use of non-hazardous substitute substances is preferred to minimise exposure. This is not always possible, and therefore quantitative data on the potency of CMR and sensitising substances are needed, as well as improved and harmonised risk quantification methods.

The number of substances (e.g. epoxy resins or isocyanates) that are predicted to have sensitising effects and cause allergies is continually increasing. Currently, 20 % of the general population is sensitised to one or more substances. Allergic diseases have the potential to become chronic and reduce a person's ability to work. In order to minimise the risks when dealing with sensitising substances and to establish safe working routines, a more refined allergenic potency ranking needs to be developed for these substances. For those sensitising substances that cannot be substituted, reliable toxicological thresholds at which a sensitising effect is produced should be established. This would help to design more efficient prevention measures. Another current concern is the increasing sensitivity of the human body; factors leading to it should be identified.

The existence of reliable measurement methods is the first step towards reducing workplace exposure to CMRs and sensitising substances. As these substances can be harmful at extremely low concentrations, **analytical methods** should be further refined to be able to reliably detect and quantify trace amounts.

Nanomaterials possess unique chemical, physical and mechanical properties, and therefore are used in a variety of applications in different industrial branches, ranging from food and feed to transport. New sophisticated multicomponent or hybrid materials are being designed at an accelerated pace. Developing these innovative materials is an important driver for European competitiveness, but an increased use of nanomaterials also means that an increasing number of workers are potentially exposed at every stage of the material's life cycle, from research and development through production to disposal and waste treatment. The knowledge gap between the technological progress and nanosafety research is estimated to be 20 years, and it is likely to expand. This means that knowledge on new-generation nanomaterials in the work environment has to be rapidly increased. New toxicity testing methods and risk prediction tools have to be developed to be able to consider safety aspects from the product development phase onwards (safety by design).

Risk management of nanomaterials requires exposure assessment data, which in turn calls for **standardised measurement methods** to quantify and qualify (i.e. characterise chemically and physically) the nanoparticles present in the working environment. It is crucial to develop such methods to facilitate the development of risk management tools. To be able to compare measurement data globally, internationally harmonised measurement strategies should also be established.

There is evidence that some nanoscale particles are toxic; their toxicity being inversely proportional to their diameter. However, decisive scientific knowledge is still lacking. In this situation, a precautionary approach should be applied and pragmatic, easy-to-apply **exposure assessment** methods developed to estimate the related risks. Appropriate **risk management** approaches to design workplaces to make them as safe as possible could then be created. The final aim would be to validate and implement harmonised risk assessment and management at an international level.

Data on workplace exposure to nanomaterials are needed to develop exposure scenarios and models. As the measurement of nanoparticles is difficult and expensive, it is necessary to further develop information databases that could give a realistic overview of the occurrence of nanomaterials in the workplace and of the workforce exposed to them.

A parallel, complementary approach would be to develop and promote 'responsible' nanotechnology integrating health and safety considerations.

The way towards a greener and more resource-efficient economy may result in an increased exposure to **biological agents** (micro-organisms that may be able to provoke infection, allergy or toxicity). At the same time, globalisation, that is international trade and traffic, fosters the worldwide spread of old and new pathogens. The occupational health effects attributable to biological agents range from sensitising effects and allergic reactions to acute and chronic disease. They are still far from being fully understood.

Workplace exposure to biological agents can be direct or indirect as an unintended result of work processes. Direct exposure may occur during the use of micro-organisms in, for example, the food industry or research laboratories, whereas indirect exposure occurs during activities such as waste treatment, retrofitting and agricultural activities and in the healthcare sector where antimicrobial-resistant micro-organisms can pose a serious threat. Workers in the rapidly growing waste management and recycling industry face various health problems including pulmonary, skin and gastrointestinal problems owing to the exposure to bioaerosols that may contain not only micro-organisms but also endotoxins, sensitising substances and volatile organic compounds. They can also be present in biotechnology installations.

In order to be able to develop suitable risk management strategies, a further development of **detection and identification methods** for biological agents is needed to cover the whole spectrum of micro-organisms. This is particularly true for airborne viruses, which can be an occupational health risk for transport, public and health service workers (recent examples are severe acute respiratory syndrome (SARS) and avian influenza) and which are prone to spread quickly in a globalised world. Direct measuring techniques allowing for quick decisions are needed, and it is particularly important to develop and validate protective measures. To be able to understand the complex relationships between work-related **exposure to bioaerosols and observed health effects**, new investigation methods also need to be developed.

Mixed exposures are a reality in workplaces. In all working conditions workers are exposed, to varying extents, to different kinds of hazards (including chemical, physical and biological). Workplaces, technologies and work tasks are becoming ever more complex; knowledge of multifactorial exposure is not sufficient and should be developed.

In particular, workers are often exposed simultaneously to several chemicals used in or generated by industrial processes. Better exposure descriptions to such chemical mixtures are lacking. Their toxicology, mechanisms and modes of action should be studied and criteria should be defined to predict potentiation or synergy between different chemical agents.

1 The economic, societal and policy contexts

In June 2010 the European Council adopted the new 10-year *Europe 2020 Strategy for smart, sustainable and inclusive growth*[5], a strategy for delivering high levels of employment, productivity and growth, and at the same time social cohesion. The Strategy identifies the major challenges Europe faces – the demographic change, globalisation, and rising global competition for natural resources, putting pressure on the environment and proposes five measurable EU targets for 2020: for employment; for research and innovation; for climate change and energy; for education; and for combating poverty.

All EU policies, instruments and legal acts, as well as financial instruments, should be mobilised to pursue the strategy's objectives. Mainstreaming priorities across policies is emphasized in many policy documents. The optimal achievement of objectives in some policy areas - including climate action, environment, consumer policy, health and fundamental rights - depends on the *mainstreaming of priorities into a range of instruments in other policy areas*[6]. These policy goals and priorities also have a clear relevance for health and safety at work and related research.

One of the most striking evolutions is the *ageing of the population* in European countries. The number of people aged over 60 is currently increasing by about two million every year, twice as fast as it did before 2007. In the 27 member countries of the European Union, the 55–64 year old working age population is expected to expand by about 16% between 2010 and 2030. In many countries, older workers will then make up 30% or more of the total workforce. Many older workers are leaving the job market before the age at which they qualify for a pension, often because of health problems and especially because of work-related health problems. Policies which address the ageing of the population and the workforce focus on enabling older workers to remain active and productive for a longer proportion of their life span.

On the other hand, the workforce tends to diversify as more women enter the labour market and *globalisation-driven migration* brings new populations to Europe. The success of the strategy depends largely on the EU's ability to face up to the major demographic transformations of this coming decade and its capacity to use the strong potential of the two fastest growing segments in its population: older people and immigrants. According to Eurostat its Demography report from 2011, three policy areas appear crucial to boost economic growth and achieve greater social cohesion:

- The promotion of active ageing: older people possess valuable skills and experience. More opportunities for active ageing will allow them to continue to contribute to society, even after retirement.
- The integration of migrants and their descendants: this is crucial for Europe because migrants will make up an even larger share of Europe's labour force. The low employment rate of migrants is both socially and financially unaffordable.
- The reconciliation of paid work and family commitments: people with caring responsibilities still lack adequate support and suitable arrangements for combining their different responsibilities and exploiting their high level of skills and education on the labour market. Women are particularly affected because of the persistent gender–employment and pay gaps[7.]

In the upcoming EU Framework Programme for Research and Innovation 'Horizon 2020'[8] of the European Commission, 'Health, demographic change and wellbeing' is one of the areas on which future research funding will be focused. The challenges arising from demographic change are also

[5] COM(2010) 2020 final EUROPE 2020 A strategy for smart, sustainable and inclusive growth http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

[6] A Budget for Europe 2020 /* COM/2011/0500 final */ http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0500:FIN:EN:HTML

[7] EUROSTAT 2011, Demography report 2010 Older, more numerous and diverse Europeans ec.europa.eu/social/BlobServlet?docId=6824&langId=en

[8] European Commission 2011 Horizon 2020 - The Framework Programme for Research and Innovation http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020-documents

highlighted in the current Community OSH strategy[9]. The aim of strengthening and prolonging labour market participation in female, immigrant, young and older workers has far-reaching implications for occupational health and safety as it calls for increasing efforts to improve the design of workplaces and work tasks as well as the way in which work is organised.

Another aspect of population ageing is the demand for care and household services, which is expected to increase due to this important trend, combined with the expected decline of the number of potential carers within the family[10]. As care services and housework services have an important job-creation potential, the health and safety aspects of this work need to be assessed, especially because it affects primarily women, and to a greater extent women who are migrants.

In policy debates in many Member States, personal and household services are mentioned for example as a means of improving work-life balance. Better work-life balance could be achieved through increased externalization of domestic work as well as of child and elderly care. Accessible and affordable care services are also seen as an important precondition for increasing female participation in the labour market. Moving these services from the shadow to the formal economy will also contribute to the creation and growth of micro- and SMEs and given that many of these services are provided by self-employed persons and small and medium-sized undertakings.

The economic landscape in Europe has changed radically in recent years due to accelerating globalization. In the past globalisation has often been seen as a more or less economic process. Nowadays it is increasingly perceived as a more comprehensive phenomenon, which is shaped by a multitude of factors and events that are reshaping our society rapidly. It has created more opportunities for economic development but also intensified competition and increased economic pressure, resulting in restructuring, downsizing of companies, and outsourcing and offshoring of business activities.

The necessity of adapting to an increasingly globalised economy has also increased pressures on *flexibility in contractual and working time arrangements*. Since the 1980s, most industrial societies have experienced a market trend towards the diversification, decentralisation and individualisation of working time patterns, driven both by companies' needs for greater adaptability in order to meet market constrains and by large changes in the gender division of labour.

The European Commission is currently reviewing Directive 2003/88/EC, the Working Time Directive, by means of a two-stage consultation of the social partners at EU level and a detailed impact assessment. In December 2010, the Commission adopted a second-stage consultation paper asking workers' and employers' representatives for their views on possible changes to the Directive. The Commission also adopted a report on how the current working time rules are being implemented in the Member States and made available an independent study on the social and economic impact of the Directive[11]. As research suggests that long and unusual working hours increase the risk of psycho-vegetative health impairments both directly and indirectly, it is important to ensure that workers' health is not jeopardised.

The *shift from manufacturing economy to service and knowledge based economy* has been going on during several decades in Europe and in other highly industrialised countries[12]. This evolution has further increased the importance of a services sector which today accounts for about three-quarters of the gross domestic product (GDP) of the EU-27[13]. Workers in this sector are at higher risk of exposure to some hazards, such as harassment and third party violence and issues linked to working conditions and work organisation in this sector become thus more and more important, this has been recognised by the European Social Partners. In their *Framework agreement on harassment and*

[9] European Commission 2007, COM(2007) 62 final, Improving quality and productivity at work: Community strategy 2007-2012 on health and safety at work http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0062:FIN:en:PDF

[10] European Commission 2012 COMMISSION STAFF WORKING DOCUMENT on exploiting the employment potential of the personal and household services - Towards a job-rich recovery http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2012:0095:FIN:EN:PDF

[11] http://ec.europa.eu/social/main.jsp?catId=706&langId=en&intPageId=205

[12] R.Schettkat, L. Yocarini, 'The Shift to Services: A Review of the Literature', Discussion Paper No. 964, IZA - Institute for the Study of Labor, 2003, pp. 1-5. Available at: http://ftp.iza.org/dp964.pdf

[13] European Commission – Eurostat (2012). Economic sectors – Services. Retrieved 7 August 2012 from: http://ec.europa.eu/trade/creating-opportunities/economic-sectors/services/

violence at work[14], the European Social Partners recognize that harassment and violence can potentially affect any workplace and any worker, irrespective of the size of the company, field of activity or form of the employment contract or relationship. However, certain groups and sectors can be more at risk.

The EU2020 Strategy aim of inclusive growth means fostering a high-employment economy delivering economic, social and territorial cohesion. This is reflected in the Flagship Initiatives “An Agenda for new skills and jobs” and "European Platform against Poverty", focusing on employment, skills, quality of jobs and working conditions, as well as vulnerable groups and combating social exclusion and discrimination.

One of the four priorities identified in the “agenda for new skills and jobs” is *better job quality and working conditions*. The agenda emphasises that “there is no trade-off between quality and quantity of employment: high levels of job quality in the EU are associated with equally high labour productivity and employment participation. Working conditions and workers’ physical and mental health need to be taken into account to address the demands of today’s working careers, which are characterised by more transitions between more intense and demanding jobs and by new forms of work organisation.

Council Decision of 21 October 2010 on guidelines for the employment policies of the Member States calls the Member States to step up social dialogue and tackle labour market segmentation with measures addressing precarious employment, underemployment and undeclared work. The quality of jobs and employment conditions should be addressed. Member States should combat in-work poverty and promote occupational health and safety[15].

Promoting good health is an integral part of the smart and inclusive growth objectives of Europe 2020. In its Communication of 29 June 2011 ‘A budget for Europe 2020’ the Commission stressed that ‘promoting good health is an integral part of the smart and inclusive growth objectives for Europe 2020. Keeping people healthy and active for longer has a positive impact on productivity and competitiveness[16].

On 9 November 2011, the Commission adopted a legislative proposal for the 3rd multi-annual programme: Health for Growth (2014-2020) that strengthens and emphasises the *links between economic growth and a healthy population* to a greater extent than the previous programmes. Only a healthy population can achieve its full economic potential. The Programme points out health problems being one of the major causes of absenteeism from work and early retirement and emphasises that increasing the number of healthy life years is a prerequisite for reaching the employment target of 75% for 20-64 year-olds and avoiding early retirement due to illness. The overall aim of the occupational health, with a focus on the health of the working population, dovetails with that of public health. Improving the health of the working population contributes to improving the health of the whole population[17].

As Europe develops competence in public health, a new issue is coming to the forefront – *mental health.* The European Pact for Mental Health and Well-being launched in 2008 prioritised mental health by recognising the benefits of mental health for the European Union. The pact stresses that: ‘Employment is beneficial to physical and mental health. The mental health and well-being of the workforce is a key resource for productivity and innovation in the EU. The pace and nature of work is changing, leading to pressures on mental health and well-being. Action is needed to tackle the steady increase in work absenteeism and incapacity, and to utilise the unused potential for improving productivity that is linked to stress and mental disorders[18].’ The document also points out that the workplace plays a central role in the social inclusion of people with mental health problems.

[14] Framework agreement on harassment and violence at work http://ec.europa.eu/employment_social/dsw/public/actRetrieveText.do?id=8446

[15] COUNCIL DECISION of 21 October 2010 on guidelines for the employment policies of the Member States (2010/707/EU) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:308:0046:0051:EN:PDF

[16] A Budget for Europe 2020 /* COM/2011/0500 final */ http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0500:FIN:EN:HTML

[17] http://www.personneltoday.com/articles/01/05/2009/50412/occupational-health-and-public-health.htm

[18] European Commission, 2008, European Pact for Mental Health and Well-being http://ec.europa.eu/health/ph_determinants/life_style/mental/docs/pact_en.pdf

As new technologies and globalisation reduce the importance of economies of scale in many activities, and larger firms downsize and outsource more functions, *the weight of small and medium sized enterprises (SMEs) in the economy is increasing*. In 2008, two thirds of the EU-27's non-financial business economy workforce was active in an SME. The potential of small enterprises has been recognised and it is appreciated that employment and economic growth to a large extent depend on these enterprises. Both political and scientific interests in OSH in small enterprises have therefore grown considerably during the last decade. At the European level, the European Commission works on broad policy issues affecting entrepreneurship and SMEs, which is reflected in several policy documents, such as the Small Business Act for Europe (SBA)[19] and the ENTREPRENEURSHIP 2020 ACTION PLAN[20]. Many Member States have launched programmes to support small enterprises.

The current crisis which started in 2007 and seems to prolong its effects for several years to come has brought about growing unemployment and aggravating social problems which impact on all countries in EU-27, in particular the Euro area. The economic crisis has increased the pressure on companies for restructuring activities, and, 'more jobs have been exposed to competitive pressures and deteriorating working conditions. In many instances, new forms of work and a higher number of job transitions have not been accompanied with appropriate working conditions, increasing psychological stress and psychosocial disorders. This has social and economic costs and may undermine Europe's capacity to compete: unsafe, unhealthy work environments result in more claims for disability benefits and earlier exits from active life'[21]

The results of an ETUI report on job quality in the crisis point out that *the crisis seems to have affected different dimensions of job quality in different ways*. Overall, there is a decline in measured job quality and job quality levels in Europe remain highly diverse. There is a clear increase in the use of part-time and fixed-term contracts and/or in the extent to which workers reported that they were working in such jobs involuntarily. Moreover, the numbers of workers who are afraid to lose their job have increased markedly which are clear signs of the declining bargaining power of labour brought on by the crisis[22].

Considering in particular the role of OSH and with regard to the mid-term review of the European strategy 2007-2012 on health and safety at work, the European Parliament points out that savings caused by the economic crisis must not mean losing sight of health and safety at work and stresses that austerity budgets and cuts in social spending should not harm action to improve health and safety at work'[23].

The fast expansion of human economic activities on a worldwide scale puts an *increasing pressure on the Earth's limited natural resources* and the adjustment capacities of its ecological system. It will be necessary to raise the energy and material efficiencies of all human activities to entirely new levels within a relatively short period of time. The EU 2020 strategic goal of sustainable growth means building a resource efficient, sustainable and competitive economy and developing new processes and technologies, including green technologies to improve resource and energy efficiency. This means, however, that new and emerging risks may appear and have to be considered.

The *greening of the economy* presents a major opportunity to start new businesses and green technologies have a great potential for employment creation. Current available evidence in so called 'green jobs' and eco-industries appears to point to a potential for employment creation in this area. The overall employment in the so-called "eco-industries" as defined by Eurostat is estimated at 1-2% of total European employment. Job creation in these industries has been positive throughout the

[19] European Commission, 2008, A "Small Business Act" for Europe COM(2008) 394 final http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0394:FIN:EN:PDF

[20] European Commission 2013 ENTREPRENEURSHIP 2020 ACTION PLAN http://ec.europa.eu/enterprise/policies/sme/public-consultation/files/report-pub-cons-entr2020-ap_en.pdf

[21] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS An Agenda for new skills and jobs: A European contribution towards full employment http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0682:FIN:EN:PDF

[22] ETUI 2012 Job quality in the crisis - an update of the Job Quality Index (JQI)

[23] European Parliament, Motion for a European Parliament Resolution on the mid-term review of the European strategy 2007-2012 on health and safety at work, 2011. Available at: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A7-2011-0409+0+DOC+XML+V0//EN#title1

recession in comparison to many other sectors, even if investments have dropped, and is forecast to continue to be quite sound in future years. Average annual growth in employment in the eco-industries in 2000-2008 was 2.7%. Total numbers employed have grown from 2.4 million in 2000 and 3.0 million in 2008 and are forecast to reach 3.4 million in 2012. 'Green' construction, building insulation activities and consumer waste disposal are examples of sectors experiencing employment growth and meriting further investigation of possible problematic areas in terms of job quality, such as precarious forms of employment or health and safety issues[24]. It is therefore important that potential health and safety risks associated with green jobs are identified and taken into account when developing new technologies and processes.

The European Commission in its Communication "Preparing for our future: Developing a common strategy for key enabling technologies in the EU"[25] has identified key enabling technologies (KETs) that strengthen the EU's industrial and innovation capacity to address the societal challenges ahead. Advanced materials, nanotechnology, micro- and nano-electronics, biotechnology and photonics have been identified as priority areas for improving European industrial competitiveness. KETs are a key source of innovation. They provide the technology basis for a wide range of product applications, including those required for developing low carbon energy technologies, improving energy and resource efficiency, boosting the fight against climate change or allowing for healthy ageing.The Communication points out that public knowledge and understanding of key enabling technologies is often lacking. This can contribute to environmental or health and safety concerns about the development and use of high technologies. In order to ensure wide user acceptance and the prompt deployment of high-technologies, public understanding and knowledge of enabling technologies needs to be improved and any ethical, environmental, health and safety concerns anticipated, assessed and addressed at an early stage.

Recently there have been discussions about sustainable work or sustainable working life. From the human point of view, work is considered sustainable if people can execute the work tasks successfully without risking their health and if they can also find some satisfaction in what they are doing. But there are other aspects of sustainability. Work cannot be called sustainable unless the requirements of sustainability are met in all four key dimensions – environmental, economic, human and social – simultaneously. In the future, the issue of sustainable work may gain new importance in a society facing the challenges of a fast ageing population and the pressure to use natural resources more economically, protecting the environment, and at the same time ensuring that the activities remain profitable. The question is how to promote more sustainable ways of working in a balanced manner within the economic, human, social and ecological dimensions taking into account the specific challenges that arise in the different economic sectors and occupational fields[26].

[24] COMMISSION STAFF WORKING DOCUMENT 2012 Exploiting the employment potential of green growth ec.europa.eu/social/BlobServlet?docId=7621&langId=en

2 The economic dimension of occupational safety and health

According to the International Labour Organization (ILO), some 2 million people worldwide die every year from work-related accidents and diseases. An estimated 160 million people suffer from work-related diseases (WRDs) and there are an estimated 270 million fatal and non-fatal work-related accidents per year. The economic cost of these injuries and deaths are colossal at the individual, enterprise and societal levels (ILO, 2007), inhibiting economic growth and affecting the competitiveness of businesses.

In economic terms, the ILO has estimated that 4 % of the world's annual gross domestic product (GDP) is lost as a consequence of occupational diseases and accidents. The estimated economic impact of occupational injuries and diseases corresponds to a 2.6–3.8 % loss in gross national product (GNP) in the European Union (EU) (European Commission, 2007). Several countries have estimated the overall costs of work-related accidents and ill health to their national economies, as shown in some European Agency for Safety and Health at Work (EU-OSHA) publications (EU-OSHA, 1998, 2002). A national estimation from the UK tends to confirm these figures. In 2006, 30 million working days were lost in the UK to occupational ill health and injury, corresponding to an annual cost to society of GBP 30 billion, more than 3 % of GDP (HSE, 2012). While these estimates vary, partly because of different national recording criteria, there is broad agreement with the ILO's global estimate.

Evaluations of costs and benefits of occupational safety and health (OSH) have been undertaken since the 1950s, but the most important contributions regarding the economic dimension of OSH were made in the 1990s and at the beginning of the twenty-first century. However, providing estimates for the total costs to society of work-related accidents and ill health is not an easy task and the results depend heavily on the chosen methods, the cost categories and the data that are used. Employers face costly early retirements, loss of skilled staff, absenteeism and high insurance premiums as a result of work-related accidents and diseases. Furthermore, a considerable share of these costs falls upon social security systems and public finances. On average, Organisation for Economic Co-operation and Development (OECD) member countries spend 2.4 % of their GDP on incapacity-related benefits (OECD, 2006a).

The indirect costs in particular can be very significant and, although some are very hard to quantify, such as the loss of reputation after a poor safety record, they are certainly very real. Moreover, the best estimates may underestimate the true total costs because of the under-reporting of occupational accidents and the failure to recognise the work-related origins of certain diseases (Driscoll et al., 2005).

The Community Strategy 2007–2012 on Health and Safety at Work (European Commission, 2007) states that OSH plays a vital role in increasing the competitiveness and productivity of enterprises and contributing to the sustainability of social protection systems because it results in reduced costs of occupational accidents, incidents and diseases and enhances worker motivation.

However, at the company level OSH is often viewed not as a contributory factor to economic viability but as a constraint. This is particularly the case among small and medium-sized enterprises (SMEs) and micro-enterprises, which, in addition, are more vulnerable to OSH incidents than larger enterprises (see section 6.4 for issues related to SMEs and micro-enterprises). Perceptions of the connection between effective OSH and the resulting financial benefits could, and should be improved (EU-OSHA, 2009a).

In the EU-OSHA working paper on OSH research priorities it was stated that economic analysis remains focused mainly on the costs of registered occupational accidents and diseases (EU-OSHA, 2005). However, the cost estimates do not seem to have the desired impact because there is a lack of commonly agreed cost estimation methodologies and enterprises do not seem to be sufficiently interested in the economic aspects of OSH to take them into account in their **decision-making process**. Therefore, it has been suggested that research should focus in addition on the socioeconomic context in which OSH decision-making takes place and the factors that promote or hinder the consideration of OSH issues at the company level to better understand how best to **integrate OSH into the decision-making process**, optimise communication on the economic aspects of OSH and, finally, to **mainstream OSH** into the company's general management.

The impact of stress and violence on workers and the consequences at the organisational level are among the major OSH concerns. The cost of stress at work and the related mental health problems has been estimated in the EU-15 to be significant, at an average of 3–4 % of GNP, equivalent to EUR 265 billion annually (Levi, 2002). The cost of stress alone has been estimated in the EU-15 at EUR 20 billion annually (1999), in the order of 0.3 % of GDP (WHO, 2012b). In spite of intrinsic challenges and difficulties, further efforts should be made to evaluate the socioeconomic impact of occupational diseases, work-related stress and violence at work in order to have a more comprehensive understanding of their consequences. Approaches relying on both statistical data and expert knowledge might be helpful in establishing more robust estimates.

Priorities for research

- Strengthen research on the economic dimension of OSH, including the estimating of the socioeconomic costs of the consequences of poor or non OSH and analysis of costs and benefits of OSH prevention to support evidence-based policies and decision-making at society and enterprise levels.
- Develop further the methodologies to estimate the socioeconomic costs of occupational diseases, work-related stress and violence at work.
- Undertake studies on the effects of regulatory systems, employment relations, social security systems and other contextual factors at the society and enterprise interface in order to identify the ways in which to influence OSH decision-making at the company level.

3 Transversal issues

3.1 Mainstreaming OSH research in other research areas

To be able to find sustainable solutions to complex issues, it is necessary to build bridges between OSH research and other disciplines. In particular, the links between OSH and economic, general health and environmental issues have to be considered. Linking OSH research closer to these and other relevant fields will help to mainstream OSH so that it is considered when important decisions are made at societal and company level.

An example of mainstreaming is the need to integrate OSH with public health, as the work environment is rarely considered in public health research. The majority of people spend most of their lives at work. The work environment, both physical and organisational, may contribute to the development of ill health caused by exposure to workplace hazards. In addition, hazards in the work environment can undermine workers' ability to care for their health and contribute to the development of risk behaviours. It is essential to address the impact of work on health in the overall effort to protect the public's health and reduce preventable human suffering and healthcare costs. The integration of occupational health with mainstream public health is long overdue and is particularly important today as the EU seeks to address the challenges of the demographic change.

3.2 Translational research - transfer of research results to the workplace

OSH research plays a vital role in establishing the evidence base and creating and updating knowledge in the field. But the impact of any OSH research on workers' health and safety depends on how research findings are translated into practical and accessible workplace solutions and policy actions. The importance of research to inform practice and policies has been recognised. However, despite of the large number of research projects in OSH, a considerable part of this research is not transferred to potential users. The impact of research results on policies and on professional practices is not always satisfactory and is not always clear what works, in which context and for which type of decision-making.

In the recent years, more attention has been paid to knowledge translation and it has been appreciated as an integral part of OSH research (Zardo, P., Pryor, P. 2012, IRSST 2010). Research has been carried out to examine the broader determinants of research transfer and to study the factors which make the transfer of research results effective in this field (Laroche, E., Amara, N. 2011). This kind of research needs to be further developed to increase the impact of OSH research on policies and the application of knowledge in the workplaces.

3.3 Intervention research

Intervention research in OSH addresses the development, implementation, and evaluation of OSH interventions at all levels, including intervention programs, OSH policy interventions or any other OSH interventions at workplace level (e.g., OSH training, medical screening tests for occupational diseases, engineering solutions to reduce hazardous exposures). The goal of intervention research in OSH is to translate basic research knowledge into preventive action and benefits and to determine whether specific interventions work. Scientifically rigorous design and evaluation of workplace interventions is challenging because of the many different workplace settings and stakeholders that exist, the complexity of interventions and because workplaces are dynamic, changing constantly. The difficulties include: too short time-frame for follow-up, there is no control group, drop-outs in the control group, etc. As a result, the majority of OSH interventions are not evaluated using strict evidence-based research criteria. (WHO 2010, Goldenhar et 2001). It is widely recognised that there is a lack of good quality intervention research in OSH. There is an urgent need for studies that evaluate the feasibility, effectiveness, and costs and benefits of interventions at the workplace, in occupational health service settings, and at policy level (Viikari-Juntura E. 2007, LaMontagne, A. D. 2003)

Intervention research in the broader sense includes evaluation of the intervention process, development and implementation, intervention effectiveness research, and evaluation of the cost-effectiveness of the intervention. As the potential impact of an effective intervention depends in large part on the extent of its implementation in a larger scale, diffusion research should be part of intervention research (Goldenhar et 2001).

- There is a need for formal evaluation of OSH interventions at all levels, including process, effectiveness, feasibility, and cost-effectiveness evaluation, to justify and improve health and safety investments. The quality of OSH intervention research needs to be improved by developing the methodology, including process documentation and evaluation.
- There is a need to develop comprehensive intervention models and strategies where good working conditions and a high level of employee health and well-being are integrated into the efforts for increased productivity and quality (Kristensen 2005).

3.4 OSH communication and risk communication

Risk communication, and OSH communication in general, are closely related to the transfer and dissemination of research results. Risk communication is also a key component of effective risk management. Appropriate risk communication empowers non-experts, including various OSH stakeholders including workers, to make informed judgments and informed decisions[27]. The challenge is to provide the right information in the right way in order to allow changes in the receiver's belief, attitude or behavior related to risk issues. Risk communication is particularly important in the context of new technologies where there is uncertainty regarding the potential risks, such as nanotechnologies or electromagnetic fields. There is a need to strengthen **risk communication** research on the efficient ways to deliver timely and appropriate information on OSH to various target audiences and the most effective channels and message formats (BFR 2012, FDA 2012, WHO 2012, IAEA 2012).

The main priority areas for the research on risk communication and OSH communication in general include:

- Identifying and characterising stakeholder and target groups (e.g. in terms of risk perception and factors influencing it) to be able to define optimal message contents and formats. Focus on the groups that are difficult to reach, such as micro and small enterprises, self-employed, workers in temporary and precarious work, etc.
- Evaluating the effectiveness of different communication channels and media and adapting them to the specific characteristics and needs of different audiences
- Investigating the possibilities new technologies can offer to fit the communication to the attitudes and expectations of different audiences
- Identifying and investigating the influences and underlying mechanisms that are determinant for a sustainable adoption of prevention measures and innovations
- Further development of methodologies suitable for evaluating the effectiveness of communication in the specific context of occupational safety and health
- Development of risk communication strategies that can handle uncertainties surrounding possible hazards associated with new technologies or materials. For example, with regard to risks associated with nanotechnologies where knowledge of new emerging nanomaterial's will continue to lag behind their development and use.

3.5 Prevention through design

The 'prevention through design' concept can be described as addressing OSH issues in the design process to prevent or minimise work-related hazards and risks associated with the construction,

[27] http://www.wiedemannonline.com/blog/wp-content/materialien/ghent-lectures/Topic10.ppt.pdf

manufacture, use, maintenance and disposal of facilities, materials and equipment that is eliminating hazards at the design stage. Prevention through design is a concept applicable to all industry sectors and workplaces and particularly relevant in the development of new technologies, processes and materials. The concept should be promoted as a cost-effective means to prevent or reduce work related accidents and health problems, and enhance occupational safety and health.

4 Methodology

This report is based on desk research, expert consultation and input from a seminar organised jointly by Institut National de Recherche et de Sécurité (INRS) and EU-OSHA on 10–11 May 2012 in Paris, France.

Preliminary desk research resulted in a selection of key documents on OSH prepared by OSH networks such as the Partnership for European Research in Occupational Safety and Health (PEROSH) and NEW OSH ERA; national OSH research institutes; important non-European OSH institutes such as the National Institute for Occupational Safety and Health (NIOSH), the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) Canada, National Occupational Health and Safety Advisory Committee (NOHSAC) New-Zealand, World Health Organisation (WHO), and International Labour Organisation (ILO) , as well as various policy documents relevant to OSH. Global horizon-scanning and foresight reports that offer insights to predicted societal and technological changes were also selected.

In the next phase, the most important OSH research areas were identified and four main topics corresponding to the priority OSH research areas were selected: demographic change; globalisation and changing world of work; OSH research for safe new technologies; and research into new or increasing occupational exposures. They were defined taking into consideration the economic, societal and policy context, and the related challenges on the one hand, and the targets of the Europe 2020 strategy (European Commission, 2010a) and the Horizon 2020 programme (European Commission, 2011a) on the other hand.

Subsequent desk research and expert consultation identified between three and six of the most important topics within each thematic area. On this basis, a first draft of the report was prepared and sent to EU-OSHA national focal points and OSH research priorities seminar attendees for comment.

In the seminar, 16 presentations across five sessions were given on EU strategy on health and safety at work and OSH research needs; PEROSH and European Trade Union Confederation (ETUC) views regarding OSH research priorities; and specific aspects of the four main topics corresponding to the priority OSH research fields. Each session was followed by a general discussion. Input from seminar presentations and discussions and comments from national focal points, OSH experts and seminar attendees were used, together with further desk research, including recent documents, conferences and workshops on OSH, to prepare the second draft and the final version of the report. The seminar materials are available at http://osha.europa.eu/en/seminars.

The following key documents and websites were consulted (the list is not exhaustive):

- European Commission, EUROPE 2020: A strategy for smart, sustainable and inclusive growth (2010) and Horizon 2020 — The Framework Programme for Research and Innovation (2011);
- PEROSH, Sustainable workplaces of the future — European Research Challenges for occupational safety and health (2012);
- NEW OSH ERA, Complementarities, gaps and new opportunities in OSH-research on new and emerging risks (2007) and Foresight study on future challenges of OSH research
- EU-OSHA, Priorities for occupational safety and health research in the EU-25 (2005);
- Websites: European Commission; European Agency for Safety and Health at Work; Eurofound; networks, including NEW OSH ERA, Partnership for European Research in Occupational Safety and Health (PEROSH), European Foresight Monitoring Network, European Technology Platform on Industrial Safety, European Network of Safety and Health Professionals, European Network for Workplace Health Promotion; national OSH institutes in Europe, including National Institute for Occupational Safety and Health, Institut de recherche Robert-Sauvé en santé et en sécurité du travail; international organisations, including Organisation for Economic Co-operation and Development, International Labour Organization, World Health Organization; stakeholders, including Business Europe, European Trade Union Institute; and scientific databases, including Web of Knowledge of Thomson Reuters (Web of Science, Medline, Current Contents Connect, Journal Citation Reports).

5 Overview of research priorities

5.1 The economic dimension of occupational safety and health

- Strengthen research on the economic dimension of OSH, including the estimating of the socioeconomic costs of the consequences of poor or non OSH and analysis of costs and benefits of OSH prevention to support evidence-based policies and decision-making at society and enterprise levels.
- Develop further the methodologies to estimate the socioeconomic costs of occupational diseases, work-related stress and violence at work.
- Undertake studies on the effects of regulatory systems, employment relations, social security systems and other contextual factors at the society and enterprise interface in order to identify the ways in which to influence OSH decision-making at the company level.

5.2 Demographic change — sustainable work for healthier and longer working lives

Older workers

- Investigate the physiological, pathological and psychological effects of prolonged workplace exposures to physical, chemical, biological and psychosocial hazards on older workers and how these exposures affect the trajectory of normal ageing throughout the life span, and functional abilities and the occurrence of diseases later in life.
- Investigate the association of work, health, work ability and work motivation with work participation. Further research on the determinants of early withdrawal from the labour market is needed, with a specific focus on the age group 45-54, to support the development of efficient interventions.
- Conduct high-level intervention studies, including organisational, training and accommodation interventions, and evaluate their efficacy for older workers and the cost-effectiveness of such interventions.

Women at work and gender aspects in OSH research

- Improve OSH research, epidemiological methods, monitoring and prevention activities **by systematically including the gender dimension** in order to provide the evidence base for **gender impact assessments** of existing and future OSH directives, standard settings and compensation arrangements.
- Further scientific research on the effects of exposure to hazards associated with reproductive health problems (such as certain hazardous substances, physical work, noise, extreme temperature conditions, and occupational stress) on the male and female reproductive health, including fertility and sexuality at large.
- Research on women's reproductive health issues, such as menopause and menstruation disorders, including the occupational risks that can cause menstrual disorders, and the effects of menstrual or menopausal symptoms (including tiredness, stress and anxiety, headaches and migraines) on coping with work.
- Focus on specific female-dominated sectors and types of jobs in which women are over-represented, such as health care, education, retail, hospitality, personal and household services, and part-time and precarious jobs. The health and safety needs of domestic workers (who are predominantly female) should be a particular focus, especially as they currently fall outside the terms of existing EU legislation (European Parliament, 2011).

Migrant workers and other vulnerable groups

- Identify major challenges for OSH arising from an increasing proportion of workers with a migration background in the labour force and ways of improving their integration in the labour market to make full use of their potential.
- More research is needed on migrants and other vulnerable groups of workers and the jobs they occupy: as the proportion of these groups in the workforce is increasing, monitoring and research on the changing scale and nature of the associated risks is needed.

Health inequalities and work

- Develop strategies and interventions to reduce socioeconomic and gender-specific health inequalities at work. Direct measures to business activities and professions with the highest levels of exposure and strain and in which unhealthy lifestyles are common.

Major health problems

Work-related musculoskeletal disorders

- Clarify the interaction of combined physical and psychological factors in the development of MSDs.
- Develop and conduct high-quality multidimensional intervention studies combining technical, organisational and person-orientated measures and a participatory approach to prevent MSDs, and evaluate the efficacy and cost-effectiveness of such interventions.

Working with chronic diseases

- Research is needed on the effects of harmful workplace exposures on individual and population outcomes among older workers with existing chronic conditions, both during employment and after retirement, to facilitate evidence-based interventions and improve accommodations.
- Evaluate models of integrated and collaborative health management (including work design, work organisation, workplace health promotion and rehabilitation) for workers with chronic diseases and health conditions, including mental illness and disorders, to prevent work disability and unnecessary job losses. Interventions also need to address the psychosocial aspects of working with a chronic disease.

Early retirement versus prolonging working life — work disability prevention and return-to-work research

- Research practical and feasible ways of modifying the physical and psychosocial working conditions at both individual and company level to prevent work disability in long-term settings, targeting various industrial sectors and occupations where the risk of work disability is particularly high.
- Develop the methodology for designing and implementing complex, high-quality workplace interventions, aiming to reduce the duration of time off work and improve the sustainability of return-to-work (RTW) following long-term sick leave or work-related disability, using a tailored and multifaceted approach directed at various groups and settings and including process, effect and cost-effectiveness evaluations.
- Further studies are needed to better understand the individual, environmental and societal determinants of RTW outcomes and identify principles and solutions that are common across health conditions and work situations.
- Priority target groups for work disability prevention (WDP) and RTW are ageing workers with chronic health conditions at risk for early retirement; and temporary workers in unsecure, flexible

work arrangements without a job to return to after the disability occurred, which is a growing group of vulnerable workers representing 15–20 % of the workforce in the EU.

5.3 Globalisation and the changing world of work

Health management in restructuring

- Monitor the health effects of restructuring, including in SMEs: collect and evaluate data and evidence on the effects of restructuring on the health and well-being of workers.
- Conduct workplace health interventions aimed at providing psychosocial support to workers before, during and after restructuring processes to enable them to better cope with the transition and new demands placed on them during the transition while maintaining their health. Evaluate the efficacy and cost-effectiveness of interventions.

Changing organisations, new employment and work patterns and psychosocial risks

- Investigate the impact of new employment and working patterns, including different forms of flexibility, on health and safety at work, considering both, the potential psychosocial risks and the associated adverse health effects on the one hand and the opportunities they may provide for improving health and well-being at work to support evidence-based policies and practices at societal and company level.
- Focus on the health and safety aspects of precarious work in terms of access to occupational health care, health surveillance and traceability of occupational diseases, worker participation and access to training.
- Further research is needed on the determinants of work–life balance in a wider societal context, including societal values and systems. Investigate how new working patterns and different types of flexibility, as well as implementation of new technologies, affect work–life balance and, consequently, health and well-being at work and organisational performance, to provide the evidence-base for policy development and good practices at company level.
- Monitor and analyse the impact of the economic crisis on health and safety at work.

Violence and harassment at work

- Clarify the terms, definitions and classifications used in relation to different types of work-related violence and harassment. Commonly accepted, operational definitions of what constitutes workplace violence and harassment will be necessary to facilitate uniform collection of data. Standardised data collection using common definitions is essential to draw conclusions on effective prevention.
- More sector-orientated research is needed to clarify the influence of various situational and environmental factors of third-party violence or harassment in worker–client interaction in different workplace settings.
- Conduct high-quality interventions aimed at developing, testing and evaluating strategies to prevent harassment and violence in a variety of workplace settings and the negative consequences of such behaviours. Evaluate the process, efficacy and cost-effectiveness of the interventions.

Psychosocial risk factors, work-related stress, and chronic diseases and health conditions

- Investigate the complex interactions between work-related psychosocial and organisational risk factors, work-related stress, physical inactivity at work, risk behaviours and chronic diseases and health conditions to provide an evidence base for policy development and effective prevention strategies. Focus on groups particularly vulnerable to the adverse health effects of psychosocial risk factors at work.

- Develop interventions, programmes and strategies that merge traditional workplace health protection with workplace health promotion and address both work-related risks —organisational and psychosocial — and behavioural factors simultaneously. This logically includes a focus on both the work environment and individual choices and behaviours.

Well-being at work — a positive approach

- Reinforce the positive approach to occupational health psychology research, focusing on positive job characteristics and well-being, including work engagement, job resources, psychological capital, job crafting and positive spill-over.
- Explore further the relationships between workplace innovation, health and safety at work and company performance, and the possibility of improving health and well-being at work through workplace innovation.

OSH in small and micro-enterprises

- Further studies are needed on specific features of small and micro-enterprises, success and obstacle factors throughout the enterprise life cycle and in different economic contexts (growth, recession), and the key factors affecting OSH decision making in these entities.
- Improve the quality of research on small and micro-enterprises with an emphasis on the use of existing knowledge in new research and exchange of experience between researchers. Higher priority should be given to interdisciplinary studies and evaluation of the effect of the various interventions. Intervention research should cover the whole intervention process, from intermediaries through dissemination methods to preventative activities, evaluation of the efficacy and cost-effectiveness of the intervention.
- Develop, implement and evaluate innovative support schemes adapted to the realities and needs of small and micro-enterprises, including the self-employed, taking into account their special nature and combining different approaches (information, training, development of support networks or guidance from external OSH services and economic incentives). Develop cost-effective programmes that can be applied at a larger scale.
- Conduct further nationally comparable research to identify the key conditions that contribute to a ‘favourable’ environment by which levels of OSH management practice among smaller establishments (especially those with fewer than 100 employees) could be increased.

5.4 OSH research for safe new technologies

Occupational hazards in green technologies

- More “Prevention through Design” research is needed for the safe development of technologies, processes and substances during their conception and before their introduction into the market and taking into consideration their entire life-cycle in order to “design out” any potential hazards. Outcome of this research could be used to harmonise/standardise designs.
- Research is needed to evaluate traditional and new OSH risks found in different situations and combinations within green jobs. This would facilitate the transfer of existing OSH knowledge to green technologies, and the development of job specific risk assessment for green jobs, as well as identifying OSH training needs.
- In-depth analysis of methods is needed which can be used to identify current and future OSH skills needs at all levels within green jobs.

- Develop new toxicity research methods that support speed-to-market practices, and make it available quickly to apply to green technologies as they develop.
- More toxicological and epidemiological research is needed to assess health risks from occupational exposures to multiple substances and to new materials e.g. development of job-exposure matrices. This needs to be considered for the life cycle of new green technologies (cradle-to-cradle).
- Research is needed on occupational risks related to waste management in general, including collection, transport, and disposal and processing of waste and in particular on OSH risks of landfill mining, processing of bio-waste and waste to waste technologies. Investigate better exposure assessment (job hazard analysis) through improved research methodologies.
- The long-term health implications from exposure to biological agents in these new technologies needs to be studied e.g. risks from green construction materials, bio-energy or in waste management.

Information and communication technology: opportunities and risks in the working environment

- Explore the possibility of using AmI-based solutions for creating tailored support systems to adjust workplaces (ambient assisted working following the model of ambient assisted living), identifying the impact that usage and usability could have on older workers and on people with various skill levels, physiological states, and cognitive abilities.
- As more intelligent and more complex human-machine interfaces are being introduced into workplaces, research is required on their safe and effective use. This would include cognitive ergonomics and neuroergonomics studies for user-centred design of new ICT applications with particular focus on the needs of specific worker groups such as disabled, maintenance workers or migrant workers.
- Further research is needed on OSH relevant to (mobile) IT-supported work, such as mental workload, decision making, skilled performance, permanent accessibility, work-life balance and human computer interactions.

Risks regarding exposure to electromagnetic fields (EMFs)

- Systematic evaluation of the number of workers in Europe exposed to EMF as well as characterisation of the sources they are exposed to.
- Research is needed on the long-term health effects of occupational EMF exposures.
- Research is needed to identify better exposure assessments, which are crucial for the evaluation of exposure conditions of workers. A better understanding of real exposure is needed for: informing future experimental settings, designing more conclusive epidemiological studies and adequate risk assessment are key requirements of scientific studies on biological effects of EMFs.
- Research on assessing EMF exposure of workers at particular risk (e.g. persons with medical implants, pregnant workers) is needed.
- Development of accurate and reliable dosimetry and exposure assessment are key requirements of scientific studies on biological effects of electromagnetic fields.
- Exposure to IF fields such as such anti-theft devices or welding and their possible health effects should be studied as there are only a limited number of investigations into IF field exposures.
- Research on the exposure to ELF fields and their possible health effects is needed since the biological cause-effect relationship between ELF magnetic fields and disease causation is not understood.
- More research is needed on the health effect of static fields, including possible health effects from chronic short term exposure to several Teslas.

- Research into non-specific effects (cognitive and sensory functions, sleep disturbance etc.) of radio-frequency fields to gain a better understanding of mechanistic explanation.

Unknown risks of biotechnology

- In order to fill the gaps in knowledge, a better understanding of activities, associated hazards, (including biological, chemical and physical hazards and including production scale-up), and exposures is needed, for example OSH risks in production, processing and use of biofuels.
- Further toxicological and epidemiological research into topics such as occupational exposure to the biological agents being utilized in the biotechnological sector needs to be carried out.
- As a result of the increasing use of biotechnologies in the industrial sector, there is a need to develop tools for risk assessment and prevention measures. The development of medical surveillance programs are also needed for the collection and use of medical information, biological monitoring, medical screening, or other health data for developing strategies for the prevention of disease

5.5 New or increasing occupational exposure to chemical and biological agents

Carcinogenic, mutagenic, reprotoxic (CMR) and sensitising substances

General

- The need of alternative analytical methods for testing toxicology of chemical agents, e.g. detect minimal amounts of CMR and sensitising substances.
- Development of reliable tools for quantitative risk assessment that will generate better quantitative data for the potency / potential of carcinogenic, mutagenic and sensitising substances.
- Bio-metrology for occupational exposure – development of appropriate biomarkers: that will help to identify the nature and amount of chemical exposures in occupational situations and that will permit the prediction of the risk of disease in individuals and groups exposed (including "vulnerable" groups).
- Need for gender- specific research - most carcinogenic exposure studies have been generated from studies of men whilst reprotoxic studies focus on women. Few studies have estimated variability in exposure measurements based on gender, race, ethnicity, or related variables. Research methods are needed to evaluate for example occupation cancer among women and minorities that will allow determining if same external exposure may result in different internal doses
- The methodology and use of job exposure matrices should be further developed to identify exposure risks in the working environment.

CMR

- Need to develop existing knowledge on CMR effects by conducting research on health problems and their link to work (e.g. collection of exposure data). This will improve understanding of the relationship between occupational risk factors (including "hidden" CMR risk factors) and the incidence of occupational diseases
- Research is needed that will cover more occupational groups and involves long-term population studies e.g. should include service industry, vulnerable workers like young migrant females in maintenance work, organisational factors or lifestyle factors often influenced by the way work is organised.

- Validation and improvement of models for worker exposure assessment: measuring, modelling and risk assessment. These can be used to identify exposure reduction needs and methods, define exposure-response relationships in epidemiological studies, and demonstrate the effectiveness of interventions and engineering controls. Research and development of instruments and tools for workplace management of CMR substances.
- Research on the criteria or process for setting occupational exposure limit values for CMR substances Investigation is needed to develop a clear overview of occupational carcinogens and related work processes outside the scope of REACH. These substnaces/processes need to be addressed by research, monitoring and prevention so that the same level of protection is provided to workers.
- Reprotoxic studies in humans have mostly looked at effects closely related to the course of pregnancy, for example abortion, gestation length and birth weight. Additional research is needed in functional disorders related to e.g. the immune, cardiovascular and nervous systems.
- Additional research is needed to update reproductive and developmental toxicity databases which have limited information for many chemical exposures in the occupational setting.

Sensitisers

- Establish a more detailed system for an allergenic potency ranking resulting in different categories of sensitising substances.
- Identify factors leading to an increasing chemical sensitivity of the human subject.
- Establish scientifically sound and reliable toxicological thresholds that provide information on the “dose” of a substance that must be reached to produce a sensitising effect.

Endocrine disruptors

- Expand and strengthen knowledge of EDCs on occupational populations. Research is needed in exposure assessment strategies that will help pinpoint and identify unrecognised substances with EDC properties within workplaces. With current assessment methods the full spectrum of chemicals that potentially contribute to endocrine-related diseases is far from known.
- Establish new approaches to examine the effects of mixtures of EDCs on disease susceptibility, as examination of one EDC at a time is likely to underestimate the combined risk from simultaneous occupational exposure to multiple EDCs. Assessment of human health effects due to EDCs needs to include the effects of occupational exposure to chemical mixtures on a single disease as well as the effects of exposure to a single chemical on multiple diseases.
- Develop more specific and sensitive biomarkers for detecting endocrine-mediated effects in workers exposed to endocrine disruptors.
- Focus work on the occupational populations/subgroups that are most likely to be susceptible to endocrine disruptors EDCs.

Nanomaterials in an innovation-driven society

- Increase the knowledge on nanomaterials in occupational settings including new generation nanomaterials.
- Increase understanding of how chemical and physical modifications affect the properties of nanomaterials. Develop risk characterisation information to determine and classify nanomaterials based on physical or chemical properties.
- Understand generalisable characteristics of nanomaterials in relation to toxicity in biological systems

- Develop new toxicity testing methods and risk prediction tools to allow for safety aspects to be considered as early as in the product development phase (safety by design). Research will allow for ‘responsible’ nanotechnology which integrates health and safety considerations.
- Develop standardised measuring methods for both qualitative and quantitative measurement of nanoparticles to obtain reliable exposure data as a basis for exposure assessment as a basis for exposure assessment and risk management.
- Develop exposure assessment and risk management tools for the field that will help to understand and improve best workplace practices, processes, and environmental exposure controls.

Biological agents in a greener yet globalised economy

- Develop methods to investigate the relationship between occupational microbiological exposure and observed health effects. The precise role of microorganisms in the development and the aggravation of symptom is poorly understood.
- Need to develop dose-response relationship for most biological agents.
- The study of occupational biological risks is insufficiently developed; there is a need for research into metrology, epidemiology, appropriate measurement and assessment methods and prevention of risks.
- Develop accurate sampling and analytical methods for micro-organisms to identify the whole spectrum for example airborne microorganisms, allergens in bioaerosols, microbial fragment etc.
- Develop direct-measuring techniques for microbiological agents as a prerequisite for quick decisions on suitable workplace protective measures.
- Conduct further research on the evaluation of bioaerosol occurrence and their variability of exposure.
- Work on determining OEL values standardised analytical methods are still lacking.

Mixed exposures in complex workplace settings

Chemical and biological mixtures

- Investigate the toxicology and mechanisms of action of chemical/biological mixtures.
- Increase the knowledge of the rather limited number of chemicals for which there is quality information on mode of action. Develop more and improved exposure descriptions for chemical/biological mixtures (where, how often and to what extent).
- Develop robust and validated tools for the prediction of interactions.
- Increase knowledge of how exposure and/or effects change over time.
- Define criteria to predict potentiation/synergy of chemical mixtures.

Ototoxic substances

- Toxicity testing of new chemicals should be improved to properly evaluate their ototoxicity.
- Levels of simultaneous noise and specific chemicals exposures considered safe to the human auditory system should be identified.

6 Demographic change — sustainable work for healthier and longer working lives

Context

The EU's population is becoming older and more diverse. Population growth is maintained mainly by immigration. Today, Europe is the continent with the highest proportion of older people (65+), and the population will continue to age over the coming decades. The number of people aged 60 and over in the EU is now increasing by more than 2 million every year. The EUROPOP2008 projections prepared by Eurostat indicate that, by 2014, the working-age population (20–64 years) will start to shrink, as the large baby-boom cohorts born immediately after the Second World War enter their sixties and retire. In the 27 Member States of the EU, the 55- to 64-year-old working-age population is expected to increase by about 16 % between 2010 and 2030. By then, in many countries older workers will make up 30 % or more of the total workforce (Ilmarinen, 2012). Policies that address the ageing of the population and the workforce focus on enabling older workers to remain active and productive for longer.

At the same time, unprecedented levels of immigration both from third countries and within the EU-27 over the past decade have substantially increased the proportion of EU-27 inhabitants who do not live in their native country. EU-27 Member States are host to some 20 million non-EU nationals, and about 5 million non-nationals have acquired EU citizenship since 2001. As most migrants are relatively young, they contribute to the size of the EU-27 labour force. In the future, the labour force will increasingly include people with a migration background. By 2060, close to one-third of the EU-27's workforce will be of foreign descent (Eurostat, 2011a). These trends imply that additional efforts are needed to enable immigrants to integrate into their host society and contribute to the labour market by making full use of their potential.

The proportion of women in employment is also growing. There was a marked increase in the employment rates of women during the last decade — from 54.3 % in 2001 to 58.5 % in 2011.

In the coming years, more than before, the labour market will be characterised by increasing diversity.

In June 2010 the European Council adopted the new 10-year Europe 2020 Strategy for smart, sustainable and inclusive growth (European Commission, 2010a). The Strategy aims to increase the employment rate among the 20- to 64-year-old population to 75 % through greater labour market participation of older workers, as well as women and migrants. The success of the strategy depends largely on the EU's ability to face up to the major demographic challenges of the coming decade and its ability to make use of the strong potential of the two fastest growing segments of its population: older people and immigrants, as well as the potential of women.

According to the Eurostat demography report from 2011 (Eurostat, 2011a), three policy areas appear crucial to boost economic growth and achieve greater social cohesion:

- The promotion of active ageing: older people possess valuable skills and experience.
- The integration of migrants and their descendants: this is crucial for Europe because migrants will make up an even larger share of Europe's labour force.
- The reconciliation of paid work and family commitments: women are particularly affected

As a consequence of the diversification of the labour supply in the labour market, there is an increasing need to engage with a more demographically diverse workforce (female, migrant, younger and older workers and workers with disabilities). These demographic groups are disproportionally represented in precarious employment arrangements and non-standard working times. Women, older and younger workers, as well as migrant workers, tend to be concentrated in particular sectors and jobs often of a precarious nature. Their disadvantaged status in the labour market limits their bargaining power and makes them vulnerable to unsafe hazardous working conditions. There is a lack of information and research on these groups of workers and the jobs they occupy. Monitoring and research of the changing scale and nature of the risks as the proportion of these groups in the workforce is increasing is therefore critical.

6.1 Older workers

In 2025, 35 % of the workforce is expected to be over 50 years old. The health and safety of older workers is a growing issue at EU level and in Member States. Retaining the older population at work is becoming a crucial economic success factor. The EU 2020 Strategy emphasises that to achieve the goal of 75 % employment by 2020, the employment rate of workers aged 55–64 must increase substantially. Improving health and safety in workplaces is one of the main contributing factors to increasing the employment rate of workers aged 55–64.

Enabling an ‘active life in old age’ will become one of the major challenges in Europe and other highly industrialised world regions in future years. In order to meet this challenge, EU Member States need to develop and implement new solutions, policies and strategies, which in turn require comprehensive research activities. The ‘identification of factors that support prolongation of working life in good health and maintaining good productivity’ is considered one of the priority research areas by the Joint Programming Initiative (JPI) "More Years, Better Lives - The Potential and Challenges of Demographic Change". The initiative’s vision paper points out that OSH, if broadening its perspective from work as a risk factor for ill-health to work as a source of vitality and empowerment, could be regarded as a ‘sound investment’ (Joint Programming Initiative, 2011).

Much of the research literature on ageing and health focuses primarily on the health of people over 65 years old. Very little is known about the overall health (physical, psychological, social) of and age-related health changes among the older worker population (aged 40–65) (Robertson and Tracy, 1998). According to a recent report by Eurofound (2008a), dissatisfaction with working conditions peaks in the 45–54 age group and is higher in low-skilled occupations and mid-skilled manual occupations. In the 50–59 age group, self-evaluated health is particularly poor among mid-skilled manual workers and low-skilled workers. This suggests that research should focus on those aged between 45 and 54 years to identify work conditions and factors that would encourage their continued participation in the workforce. In terms of age, the key target group concerns workers approaching retirement age (45–54 years). It is important to monitor the working conditions of this group of workers to identify the determinants of the early exit from the labour market (Eurofound, 2008a).

The health of older workers is a concern, in particular the impact of age-related declines in health on productivity. The literature reveals that a major issue in terms of the ageing of the workforce is a general concern that age-related declines in health inevitably lead to the decreased productivity of older workers (Robertson and Tracy, 1998). Whereas earlier research has focused on the negative relationship between age and performance, more recently researchers have started to look at the ways in which age can facilitate task performance or how declines in performance can be avoided through accommodations and interventions. It is suggested that this positive focus should be continued in future research and also that looking at a much broader range of job performance behaviours may help to clarify the complex relationship between age and performance (HSE, 2011).

Given current policy directions focused on preventing premature retirement and prolonging workforce participation, identifying the factors affecting retirement decisions becomes crucial. Research on the issue of older workers’ employability has pointed out how the low participation of older people in the labour market is the result of a combination of wage conditions, rigidity in workplace organisation, inadequate skills and competencies and poor health status, rather than the wish to retire early (OECD, 2006b). Many aspects of working conditions correlate strongly with older workers’ employment rate; in particular, correlations are higher among the 45- to 54-year-old working-age population, whose working conditions can be interpreted as reflecting the average conditions facing older workers who are deciding whether or not to retire. Positive correlations are found especially in relation to work autonomy and access to learning and training (Eurofound, 2008a).

Exposure to poor working conditions is associated with greater intention to resign or retire, and reduced performance and motivation during earlier stages of employment. Analyses based on SHARE data have found that effort–reward imbalances at work predict intentions to retire early. This finding is particularly relevant because effort–reward imbalance at work was found to predict elevated risks of chronic diseases such as cardiovascular and affective disorders, and disability pensions. The percentage of the working population with work effort exceeding rewards is particularly high in Poland and Greece. Correspondingly, self-reported early retirement intentions are also above average.

Contrary to these countries, quality of work in terms of an effort–reward balance is high on average in the Nordic countries, the Netherlands and Switzerland. These countries also have the lowest percentage of older workers seeking early retirement (SHARE, 2012).

It is obvious that prolonging working careers strongly depends on the adaptation of workplaces and work organisation. Workplace accommodations are likely to benefit workers of all ages. Several studies acknowledge that more research is needed into how workplaces need to be designed and work organised to meet the needs of older workers (HSE, 2011). In this context, it is essential to analyse and understand the specific work-related risks with which older workers are confronted (European Parliament, 2011). As older workers have been exposed to occupational risks for a longer period of time, the duration of exposure, its effects and the possibilities of limiting it are issues of particular importance (European Parliament, 2011). Further research needs are related to flexible working arrangements (including the consideration of work–life balance), the adaptation of working time, shift work and the effect of overtime work on older workers, especially in physically demanding jobs (European Parliament, 2011).

Workplace interventions targeted at older workers, including improving work organisation, training and workplace accommodations, deserve the highest level of attention. Many intervention programmes have at least demonstrated some efficacy, but fewer have evaluated their efficacy specifically for older workers. Training is an intervention that is particularly relevant for older workers who are likely to be most distant from initial professional education/vocational training in a rapidly changing world where lifelong learning is key to employability. Workplace accommodations may allow older workers with a variety of chronic conditions to work productively without jeopardising their health.

There is substantial occupational health research on the adverse health effects of specific workplace exposures, but there is little research on the impact of these exposures on the trajectory of normal ageing throughout the life span. Further research is also needed on how these cumulative exposures affect physical, cognitive and social functions later in life and the occurrence of the major disabling diseases of older persons, such as heart disease, stroke, cancer and degenerative arthritis (David et al., 2004). Reviews of the literature on ageing, health and employment indicates a lack of longitudinal and good-quality intervention research (Crawford et al., 2009).

Priorities for research

- Investigate the physiological, pathological and psychological effects of prolonged workplace exposures to physical, chemical, biological and psychosocial hazards on older workers and how these exposures affect the trajectory of normal ageing throughout the life span and functional abilities and the occurrence of diseases later in life.
- Investigate the associations of work, health, work ability and work motivation with work participation. Further research on the determinants of early withdrawal from the labour market is needed, with a specific focus on the age group 45-54, to support the development of efficient interventions.
- Conduct high-level intervention studies, including organisational, training and accommodation interventions, and evaluate their efficacy for older workers and the cost-effectiveness of such interventions.

6.2 Women at work and gender aspects in OSH research

Within the past 10 years female employment rates have increased throughout Europe (EU-27), from 57.9 % in 2001 to 62.3 % in 2011, whereas male employment rates have remained more or less constant at about 76 % (European Commission and Eurostat, 2012a). However, the EU 2020 Strategy envisages a total 75 % employment rate in the EU by the year 2020. Thus, involving more women is seen as one of the major factors in meeting this target. The goal of greater female employment underlines the need to more effectively address health and safety issues that affect women (European Parliament, 2011).

Historically, there is a trend of increasing participation of women in the labour market since the 1960s. Higher education levels among women, in combination with the general trend to emancipation, has led to a stronger labour market orientation and higher participation rates (Eurofound, 2010a). Despite these developments, the labour market remains highly segregated and traditional gender roles continue to determine access to the job market. Women mostly work in traditionally female-dominated sectors such as in health and social services, personal and household services, education and retail. The increase in employment is accompanied by more atypical employment: almost one-third of women work part time. Precarious work is on the rise. Women are also less likely to hold executive positions. On the other hand, more women work in jobs that are traditionally considered to be male dominated. Although more women face similar occupational hazards to those faced by men, risk exposure patterns differ considerably according to gender (EU-OSHA, 2011a). For instance, because of the types of jobs they do, many female workers interact frequently with third parties, such as patients, students and customers, and they are more exposed to harassment and violence (see also section 7.3).

On the other hand, it is often assumed that women's work tasks are less physically demanding than those of men, but many jobs predominantly carried out by women involve manual handling of heavy loads, maintaining awkward postures, high levels of static muscular effort and prolonged standing and walking. Examples include healthcare work, cleaning, retail sales, factory work and work in the hairdressing and beauty sectors. The physical demands of these types of work need to be recognised and suitable accommodations may need to be provided (European Parliament, 2011; HSE, 2011).

EU-OSHA's most recent gender report (2011a) provides facts and figures concerning the specific challenges in terms of safety and health that arise from the increasing labour market participation of women and identifies a number of related OSH research issues. Generally, the link between occupational exposure and disease is insufficiently explored with regard to female workers. Many diseases are not assessed against occupational backgrounds. For instance, women have a high rate of developing certain cancers, such as breast, colorectal and endometrial, which have been linked to environmental factors and working conditions, and more research is needed to further explore these connections. The analysis of national data also showed that illnesses among female workers were significantly less often notified and, when they were notified, recognition rates were much lower (EU-OSHA, 2011a).

In addition to gender segregation in employment, there is also segregation with regard to domestic responsibilities. Women are still regarded as mainly responsible for family-related tasks, such as the care of children and/or elders. The concurrence of work and family-related responsibilities, which are still a 'female domain', and the associated multiple demands may result in chronic overload and deteriorating health. In order to minimise such problems (and to facilitate labour market participation of women), new forms of flexible work arrangements and other structural improvements at the workplace level need to be developed and implemented (Allmendinger and Ebner, 2005; Eurofound, 2012a).

Although there is some research on pregnant women and new mothers, there is far less research on women's other reproductive health issues, such as hormonal effects, menstruation disorders and the menopause (EU-OSHA, 2011a). In contrast to the risks to pregnant workers, the occupational risks that can cause menstrual disorders, such as occupational stress and exposure to heavy metals, solvents, environmental noise or hot and cold conditions, as well as the effect of shift work, in particular night shifts, on the menstrual cycle, have not been carefully researched or at all addressed in the legislation. Similarly, the effect of the menopause on the health of female workers, although a crucial topic for older female workers, has been overlooked by researchers and legislators. In addition, menstrual or menopausal symptoms (which include tiredness, stress and anxiety, headaches and migraines) can increase difficulties in coping with work (European Parliament, 2011).

In general, there is a need for a holistic approach to reproductive health in both women and men. Further scientific research on the effects of exposure to hazards associated with reproductive health problems (such as certain hazardous substances, physical work, noise, extreme temperature conditions and occupational stress) on male and female reproductive health is necessary, including on fertility and sexuality at large. Although numerous occupational exposures have been demonstrated to impair fertility (e.g. lead, some pesticides and solvents), the overall contribution of occupational exposures to male and female infertility is unknown (see section 9.1).

Taking into account the different health and safety risks to which female and male workers are exposed at work, the different effects of those risks on men and women, in terms of exposure to hazardous substances, their impact on reproductive health, the physical demands of heavy work, the ergonomic design of workplaces and the length of the working day, and also considering domestic duties (ILO, 2009), a more targeted gender-sensitive approach to research and prevention is needed. Integrating the gender aspect into all work-related research topics is necessary (Eurofound, 2012b).

Priorities for research

- Improve OSH research, epidemiological methods, monitoring and prevention activities by systematically including the gender dimension in order to provide the evidence base for gender impact assessments of existing and future OSH directives, standard settings and compensation arrangements.
- Further scientific research on the effects of exposure to hazards associated with reproductive health problems (such as certain hazardous substances, physical work, noise, extreme temperature conditions, and occupational stress) on the male and female reproductive health, including fertility and sexuality at large.
- Research on women's reproductive health issues, such as menopause and menstruation disorders, including the occupational risks that can cause menstrual disorders, and the effects of menstrual or menopausal symptoms (including tiredness, stress and anxiety, headaches and migraines) on coping with work.
- Focus on specific female-dominated sectors and types of jobs in which women are over-represented, such as health care, education, retail, hospitality, personal and household services, and part-time and precarious jobs. The health and safety needs of domestic workers (who are predominantly female) should be a particular focus, especially as they currently fall outside the terms of existing EU legislation.

6.3 Migrant workers and other vulnerable groups

Migrants represent a growing share of the European population, and thus are an increasingly important group on the labour market. Therefore, greater attention needs to be paid to their employment and working conditions (Eurofound, 2007). Although it seems very difficult to predict how the economic, social and political circumstances of migration — and thus the phenomenon itself — will develop in future years (European Commission and Eurostat, 2011, 2012b), it is obvious that in many countries employees with a migratory background are of high (and gradually increasing) importance within certain sectors of the labour market, such as the hospitality sector (ILO, 2012a). Therefore, the particular situations of these workers, including culture-specific perceptions and attitudes concerning work and occupational risks, must be taken into account when it comes to safety and health and related research. Certainly, not all migrant workers are exposed to above-average occupational hazards (EU-OSHA, 2008a). Nevertheless, there are several OSH issues that require special attention, such as the increase of migrant workers in high-risk sectors, cultural (e.g. language-related) barriers to communication and training in OSH, or the high prevalence of overtime work and related risks for accidents and ill health among migrant workers. Other important aspects are cooperation and leadership in multicultural teams and guidance on cultural diversity issues at work (PEROSH, 2009).

Priorities for research

- Identify major challenges for OSH arising from an increasing proportion of workers with a migration background in the labour force and ways of improving their integration in the labour market to make full use of their potential.
- More research is needed on migrants and other vulnerable groups of workers and the jobs they occupy: as the proportion of these groups in the workforce is increasing, monitoring and research on the changing scale and nature of the associated risks is needed.

6.4 Health inequalities and work

Despite significant improvements in life expectancy, the differences between socioeconomic groups are large in terms of both mortality and morbidity. Socioeconomic differences in health status and life expectancy can be observed between the higher and lower educated. Data indicate that not only do occupational inequalities persist but also that life gains are higher for non-manual than manual workers. The average life expectancy of a male upper-level white-collar worker aged 35 is 5–6 years more than that of a male blue-collar worker.

This differential in health and life expectancy persists over time. Over the past few decades these inequalities have widened rather than narrowed in most European countries. A body of research confirms that material factors such as material living conditions, physical working conditions, income and housing, as well as behavioural factors such as smoking, drinking and obesity, explain a large part of the existing health inequalities. Higher education may result in better health knowledge, and thus a healthier lifestyle. Higher education, and thus qualifications in general, lead to better working conditions and lower risk in the workplace. It also results in higher income, and thus a greater ability to care for one's health.

The workplace is an ideal arena for the promotion of working ability and health and the reduction of socioeconomic and gender-specific health inequalities in different ways. Opportunities in the workplace have still not been fully exploited. The workplace's ability to support and strengthen choices that promote health and healthy behaviour must be better utilised. In particular, measures to reduce health inequality must be directed to fields of business and professions with the highest levels of exposure and strain and in which unhealthy lifestyles are common.

Priorities for research

- Develop strategies and interventions to reduce socioeconomic and gender-specific health inequalities at work. Direct measures to business activities and professions with the highest levels of exposure and strain and in which unhealthy lifestyles are common.

6.5 Major health problems

There is a considerable body of evidence showing that health has strong effects on labour market participation in general and the labour supply of older workers in particular (CESEP, 2008). Ageing leads to an increase in the risk of developing disorders and diseases, and health issues are the most common reason for leaving the workforce before the statutory retirement age. Figures from Eurostat illustrate that, as workers get older, they are more likely to experience a long-term health problem (Eurostat, 2012a). The incidence of chronic illness or disability continues to rise as a result of an ageing population in the EU. The burden of illness within an ageing workforce has serious economic implications for businesses and social security systems in European countries (Bevan et al., 2009).

Musculoskeletal disorders (MSDs) and the growing incidence of mental ill health are the primary diagnostic causes for disability retirement (OECD, 2010). Therefore, it is crucial to design work organisation and workplaces in such a way that the manifestation (or, at least, the aggravation) of these illnesses can be prevented and more employees are enabled to work up to the regular retirement age (Winkemann-Gleed, 2011). This would also result in considerable economic benefits (European Commission, 2012a).

6.5.1 Work-related musculoskeletal disorders

Although a considerable amount of knowledge about the physiopathology and epidemiology of MSDs has been accumulated over the past two decades, they remain the most common work-related diseases (WRDs) in the EU and workers of all ages and in all sectors and occupations can be affected. They are also one of the most important causes of long-term sickness absence. The Labour Force Survey (LFS) ad hoc module 2007 showed that, in 61 % of persons with a work-related health problem in the past 12 months, musculoskeletal problems (bone, joint or muscle) were the main work-related health problem (Eurostat, 2009). This finding was supported by data from the 2005 European Survey on Working Conditions (EWCS) and the European occupational diseases statistics (EODS). Work-related MSDs also rank among the most serious health problems within the ageing workforce (Eurostat, 2010). According to the 2005 EWCS, 24.2 % and 22.8 % of workers aged over 55 who indicated that work negatively affects their health had backache and muscular pains, respectively (EU-OSHA, 2010a). Not included in these figures are those who had already quit working because of severe musculoskeletal conditions, which are, next to mental disorders, the most common reason for early ill health retirement (OECD, 2010). Part of these problems are because, despite declining physical capacities (Okunribido et al., 2010), exposure to certain physical risks, such as handling heavy loads, working in painful or tiring postures or repetitive hand/arm movements, remains considerably high in older workers (Eurofound, 2012b).

Although there is growing evidence that, in addition to mechanical load, psychosocial risk factors (Eurofound, 2012b) play a role in the development of MSDs (Hauke et al., 2011), more research is needed to clarify this influence in the context of multifactorial causation. A more holistic approach towards work-related musculoskeletal diseases must be developed that takes into consideration various risk factors and supportive and protective factors at work (European Commission, 2007; EU-OSHA, 2010a; European Commission and the Advisory Committee on Safety and Health at Work, 2011; PEROSH, 2012).

Multidimensional ergonomic interventions, including individual, technical and organisational measures and a participatory approach, seem to be the appropriate strategy for the prevention of MSDs. However, there is still limited evidence for the effectiveness of such interventions (Roquelaure, 2008). More high-quality intervention studies are needed to evaluate the effectiveness of the interventions in gender- and job-specific work situations, applying a multirisk approach in order to promote evidence-based practice in the prevention of MSDs (Roquelaure, 2008).

Priorities for research

- Clarify the interaction of combined physical and psychological factors in the development of MSDs.
- Develop and conduct high-quality multidimensional intervention studies combining technical, organisational and person-orientated measures and a participatory approach to prevent MSDs, and evaluate the efficacy and cost-effectiveness of such interventions.

6.5.2 Working with chronic diseases

Various forms of chronic ill-health such as heart diseases, stroke, cancer, diabetes or depression are highly, or even becoming increasingly, prevalent within the ageing workforce (Varekamp and Dijk, 2010). These diseases develop slowly but are of long duration (WHO, 2012c). Chronic conditions can lead to functional limitations and disability associated with ill health. Therefore, people with chronic diseases may be to some extent restricted in their ability to participate in the workforce (CESEP, 2008). Thus, intervention studies are required to evaluate how participation in working life can be managed by measures which are targeted to workplace and task design, work organisation, work–life balance or occupational health services.

There is agreement in the literature that work is generally good for the physical and mental health and well-being of people of all ages, including those with common health problems. In contrast, not being in work is associated with poor physical and mental health and well-being. Work is generally good for physical and mental health and well-being of healthy people, many disabled people and most people with common health problems. Work can be therapeutic for people with common health problems (Waddell and Burton, 2006). This applies as much to older workers as it does to their younger colleagues (HSE, 2011).

Although there is evidence that the prevalence of common health problems increases with age as a result of the normal and inevitable ageing process, this does not necessarily hinder work performance and is not a valid reason to exclude an individual from the workforce (Crawford et al., 2009). Dame

Carol Black's review, 'Working for a healthier tomorrow', states that is a fallacy that illness is incompatible with being at work and that individuals should be at work only if they are 100 % fit (Black, 2008). It is the match between work demands and the capabilities of the individual carrying out that job that will help maintain health and safety at work (Waddell and Burton, 2006).

Many older workers might have an existing chronic illness, disorder or health condition, including a mental illness or disorder that is under various levels of personal control, medical treatment or clinical management. Research is needed on how potentially harmful workplace exposures — physical, chemical, biological and psychosocial — affect the status, control and outcomes of chronic conditions (Wegman et al 2004).

Priorities for research

- Research is needed on the effects of harmful workplace exposures on individual and population outcomes among older workers with existing chronic conditions, both during employment and after retirement, to facilitate evidence-based interventions and improve accommodations.
- Evaluate models of integrated and collaborative health management (including work design, work organisation, workplace health promotion and rehabilitation) for workers with chronic diseases and health conditions, including mental illness and disorders, to prevent work disability and unnecessary job losses. Interventions also need to address the psychosocial aspects of working with a chronic disease.

6.6 Early retirement versus prolonging working life — work disability prevention and return-to-work research

Too many workers leave the labour market permanently as a result of health problems or disability, and too few people with reduced work capacity manage to remain in employment. Spending on disability benefits has become a significant burden to public finances in most OECD countries and hinders economic growth as it reduces effective labour supply.

Public spending on disability benefits totals 2 % of GDP on average across the OECD countries, increasing to as much as 4–5 % in countries such as Norway, the Netherlands and Sweden. Around 6 % of the working-age population rely on disability benefits, on average, and this figure increases to 10–12 % in some countries in the north and east of Europe. Employment rates of persons with a disability are 40 % below the overall level on average, and unemployment rates are typically twice the overall level. Most importantly, disability benefit take-up is a one-way street; people almost never leave disability benefits for a job (OECD, 2010).

Even with increased efforts in primary prevention, it must be assumed that the ageing of the workforce will still result in considerable numbers of employees affected by serious chronic health problems. However, fewer of these employees would have to face long-term sickness absence, work disability and early retirement if appropriate measures to facilitate return to work (RTW), rehabilitation and reintegration were taken. The need for evidence-based policies and practices in this area is emphasised in the OECD report (OECD, 2010), in the Community Strategy for Health and Safety at Work (European Commission, 2007) and in several national programmes (OECD, 2008; Swedish Council for Working Life and Social Research, 2009).

Work disability is a significant personal, economic and social burden that is often preventable. The body of knowledge concerning work disability has substantially grown in recent years and work disability prevention has become a separate growing research discipline. It has been recognised that work outcomes often do not correlate with health outcomes and the causes of work disability are multiple, complex and often distinct from associated health conditions. A transition from singular biological/medical models of work disability to a more function-orientated biopsychosocial model has taken place, recognising factors outside of the individual — such as workplace, including psychosocial factors, insurance, family, social and other systemic influences (Pransky et al., 2011).

As the most important causes of permanent work disability (OECD, 2010), mental health disorders and MSDs represent the primary target diagnoses in occupational rehabilitation and RTW research (EU-OSHA, 2010a). Irrespective of diagnosis-related issues, further research on the determinants of RTW outcomes, based on longitudinal data, is required. This research must take into account more thoroughly the complexity of processes related to the development of long-term sickness absence and disability, as well as successful reintegration after illness. There is still a great need for analysing the specific roles of (and the interplay between) the different factors that are involved in these processes by use of quantitative and qualitative methods. Organisational and behavioural factors (on the part of both the employees and the employers), especially, should be investigated in more detail (Pransky et al., 2011; Viikari-Juntura and Burdorf, 2011; Järvholm, 2012).

The main work-related factors influencing work ability and predicting disability are largely known. There is evidence that work strain may have far-reaching adverse effects on individuals' work ability from midlife to old age, and several physical and psychosocial working conditions predict future disability retirement (e.g. heavy work, long working hours, low job control, etc.), There is evidence that low socioeconomic position is strongly associated with unfavourable working conditions and increases the likelihood of both mental and musculoskeletal disability and disability pensions. Although the main factors predicting disability are to a large extent known, but there is only scattered information available from workplace intervention studies aimed at the prevention of disability in long-term settings (Härmä 2011)

Concerning intervention and evaluation research, it will certainly remain an important task to examine the effectiveness of specific measures (whether therapeutic, ergonomic or working time related) intended for preventing long-term absence or definite exit from work as a result of chronic health conditions. However, the focus of future research should be on systematic, integrated and collaborative approaches that follow generalisable evidence-based principles but are adaptive to varying contexts and needs for action. Models of coordinated action and cooperation between OSH services, healthcare providers, employers and workers have to be investigated with respect to their potential for improving work reintegration and retention (PEROSH, 2012). A major challenge for OSH research is to contribute to the development of 'solutions that are common across conditions and work situations', but at the same time recognise 'the unique impact of specific cultures, economic and insurance systems, workplaces and work arrangements, as well as the unique characteristics of the affected worker' (Pransky et al., 2011). Moreover, a consistent conceptual framework is required that provides reliable criteria for arranging appropriate RTW strategies and helps identify organisational barriers and facilitators (Viikari-Juntura and Burdorf, 2011).

Cross-disciplinary learning and the resulting application of innovative research methods are crucial issues (Pransky et al., 2011). 'Real-life' interventions, as represented by the introduction of large-scale RTW programmes at national level, provide excellent opportunities for researchers to further develop methodological approaches and deepen the knowledge on the determinants and mechanisms of work reintegration after serious illness (Aust et al., 2012).

Another area where important research contributions could be made is the development of rehabilitation and reintegration approaches that are suitable for 'non-standard' work arrangements (e.g. temporary workers) (Pransky et al., 2011). More attention should also be paid to women (EU-OSHA, 2011a) and young workers who are at risk of disability and related exclusion from work, as well as possible adverse effects of early RTW (i.e. presenteeism) in specific groups of workers (Järvholm, 2012). As the availability of financial resources is always a matter of debate, additional research efforts should also be directed at the cost-effectiveness of different sets of RTW and rehabilitation measures (PEROSH, 2012).

Finally, broadening comparative research (also on an international scale) will be important to reach a better understanding of the influence of different societal, institutional and regulatory contexts on the design and results of RTW and rehabilitation policies (Pransky et al., 2011).

Priorities for research

- Carry out research into practical and feasible ways of modifying the physical and psychosocial working conditions at both individual and company level to prevent work disability in long-term settings, targeting various industrial sectors and occupations in which the risk of work disability is particularly high.
- Develop the methodology for designing and implementing complex, high-quality workplace interventions aimed at reducing the duration of time off work and improving the sustainability of return to work following long-term sick leave or work-related disability, implementing a tailored and multifaceted approach directed at various stakeholders and settings, and including process, effect and cost-effectiveness evaluation.
- Further studies are needed to gain a better understanding of the individual, environmental and societal determinants of RTW outcomes and to identify principles and solutions that are common across health conditions and work situations.
- Priority target groups for work disability prevention and return-to-work research: are ageing workers with chronic health conditions at risk of early retirement, and temporary workers in insecure, flexible work arrangements without a job to return to after the disability occurred, which is a growing group of vulnerable workers representing 15–20 % of the EU's workforce.

7 Globalisation and the changing world of work — OSH research contribution to sustainable and inclusive growth

Context

In the past, globalisation has often been seen as a more or less economic process. Nowadays, it is increasingly perceived as a more comprehensive phenomenon that is shaped by a multitude of factors and events that are changing our society rapidly. It has created more opportunities for economic development, but it has also intensified the competition and increased economic pressure, resulting in the restructuring and downsizing of companies and outsourcing and offshoring of business activities. The consequences for workers include growing job insecurity and work intensification.

At the same time, increased economic integration of different countries has increased labour mobility. Although at the upper end of the job spectrum there is a group of highly skilled immigrants that includes, for example, professional support personnel and specialists in various fields, many economic migrants from low-income countries end up working in construction, manufacturing and low-paid jobs that are on the increase in the service sector (European Commission, 2006).

Globalisation is closely linked to the development of new technologies, in particular of **information and communication technologies** (ICT). Advances in transportation and telecommunications infrastructure, including the rise of the Internet, are major factors in globalisation, generating further interdependence of economic and cultural activities. The rapid spread of ICT and the Internet is changing the ways in which companies organise production and is increasingly allowing services, as well as manufacturing, to be globalised. The Internet makes real-time communication possible and provides new means of disseminating new products and services. The Internet also allows companies to take advantage of different time zones and low-wage cost zones in order to make cost savings by outsourcing and offshoring many functions that were once done internally (business process outsourcing). ICT contributed to the development of the 24/7 economy, which requires flexible work organisation and has resulted in new working patterns (Wolfe, 1999).

The on-going shift towards a **service- and knowledge-based economy** underlines the importance of the services sector. Today, worldwide, it contributes more to economic growth than any other economic activity sector and accounts for about 75 % of the gross domestic product (GDP) in the EU (European Commission and Eurostat, 2012c). This sector provides an increasing number of high-skill jobs, for example in ICT and marketing, but also low-skilljobs, often characterised by non-standard working conditions. The potential health hazards in the services sector include growing psychosocial pressures due to increased availability demand and frequent and new human contacts.

The economic crisis has increased the pressure on companies for restructuring activities, and, according to the European Commission, 'more jobs have been exposed to competitive pressures and deteriorating working conditions. In many instances, new forms of work and a higher number of job transitions have not been accompanied with appropriate working conditions, increasing psychological stress and psychosocial disorders. This has social and economic costs and may undermine Europe's capacity to compete: unsafe, unhealthy work environments result in more claims for disability benefits and earlier exits from active life' (European Commission, 2010b).

Many micro-, small and medium-sized enterprises are also severely affected by the crisis. Throughout the downturn, however, SMEs have retained their position as the backbone of the European economy, with some 20.7 million firms accounting for more than 98 % of all enterprises, 92.2 % of which have fewer than 10 employees, and employing more than 87 million people (ECORY, 2012). The highest number of all enterprises are sole proprietorships (i.e. self-employed) and micro-enterprises (Naumanen, 2012). There were 32.5 million self-employed people, including employers, in the EU-27 in 2009, accounting for nearly 15 % of total employment (European Commission, 2010c). In 2012 it is estimated that SMEs accounted for 67 % of total employment and 58 % of gross value added (ECORY, 2012). Self-employment is identified as an important OSH challenge in the EU (EU-OSHA, 2010b; European Commission, 2010b,c).

The importance of micro-, small and medium-sized enterprises and self-employment for job creation and recovery from the crisis is reflected in EU policies. SMEs provide two-thirds of all private sector jobs, pointing to the importance of paying due attention to their needs in the design of employment-relevant legislation. All initiatives will respect the ‘think small first’ principle to take into account the specific characteristics of SMEs (European Commission, 2010b).

Entrepreneurship, including social entrepreneurship, should become a more widespread means of creating jobs, as well as fighting social exclusion. The emphasis must be placed on training to ensure that both education systems truly provide the basis for stimulating the appearance of new entrepreneurs and those willing to start and manage an SME acquire the right skills to do so (European Commission, 2010b). This should include training on health and safety at work.

These changes — globalisation, the greater role of ICT and the shift from manufacturing to services — have also affected the world of work: employment and working patterns have undergone significant change. Altogether, the rapid changes in the nature of work, work organisation and production systems, the increasing importance of the services sector and the growing competitive nature of the global marketplace have notably increased workers’ exposure to psychosocial hazards. The current crisis accentuates the economic pressure on companies and its effects on workers.

7.1 Health management in restructuring

Restructuring — including company reorganisation, closures, mergers and acquisitions, downsizing, outsourcing and relocation — is necessary if companies are to remain competitive, but the consequences can be painful for all concerned. Restructuring is now becoming permanent and tends to occur in all Member States. The European Restructuring Monitor (ERM) (http://www.eurofound.europa.eu/emcc/erm/index.htm) recorded over 7 000 cases of large-scale restructuring in the Member States from the beginning of 2002 to the end of 2007.

Although already before the crisis restructuring had become a permanent structural component of the economy, in this difficult context, anticipating, managing, limiting and cushioning job losses, however they were caused (from mass redundancies following big company closures to sporadic lay-offs in SMEs and the termination of contracts of casual workers), is increasingly challenging (European Commission, 2008a). The issue of restructuring has been placed at the top of the political agenda of governments and social partners in the EU since the beginning of the economic crisis.

The only available measure of the prevalence of restructuring at the EU level is the European Restructuring Monitor (ERM). However, the collection of data is limited as the ERM covers only large enterprises and those that are reported in the media. Furthermore, data are not collected on the effects of restructuring on the health and well-being of workers. Therefore, data relating to health and restructuring are lacking and fragmented at both national and European levels. Collecting and evaluating data on workers’ health in restructuring processes, including in SMEs, even if it appears to be very difficult, is important for assessing the real situation and planning future activities in this area.

There is empirical evidence of the negative health impact of restructuring on the direct victims, that is those who lose their jobs, and the survivors of restructuring. There is also broad evidence linking employees’ health with the ways in which organisational change is planned, implemented and executed. The degree to which workers are involved in the process, for example, will affect not only their psychosocial reactions and strain levels, but also their future commitment to the company (Kieselbach et al., 2010).

According to the findings of 2012 ERM report in relation to restructuring and health, employees in restructured workplaces were significantly more likely to report (Eurofound 2012):

- higher exposure to psychosocial workplace risks;
- higher levels of psychosomatic disorders (especially depression, stress and sleeping problems);
- higher levels of work absenteeism and in particular of presenteeism;
- higher physical and psychosocial-type risks, especially among those employed in the health care sector.

The report concludes, that the issue of restructuring and its employment consequences will continue to have a strong relevance for policy and research given the accelerating technological and work organisational change in a globalising, multipolar world, high levels of recent restructuring activity in the wake of the 2008–09 recession, public sector cut downs consequent on fiscal consolidation and austerity measures.

Given the evidence of the potentially negative health effects of restructuring, occupational health services should promote prevention and workplace health intervention before, during and after restructuring. As the quality and content of occupational health services varies across European countries, research in this area should be strengthened. Practical and scientific evidence of the effectiveness of interventions should be collected and published (HIRES, 2009).

Priorities for research

- Monitor the health effects of restructuring, including in SMEs: collect and evaluate data and evidence on the effects of restructuring on health and well-being of workers.
- Conduct workplace health interventions aimed at providing psychosocial support to workers before, during and after restructuring processes to enable them to better cope with the transition and new demands placed on them during the transition while maintaining their health. Evaluate the efficacy and cost-effectiveness of interventions.

7.2 Changing organisations, new employment and work patterns and psychosocial risks

The changes described above — globalisation (resulting in more competition and increased economic pressure), restructuring, the rapid spread of ICT and the Internet, and the shift from manufacturing to services — have affected the world of work: employment and working patterns have undergone significant change, resulting in an increased exposure of workers to psychosocial hazards.

Globalisation and increasing competition have had a large impact on production methods and work organisation, resulting in a gradual transition from relatively standardised work organisation and working time patterns to more complex and diversified structures (Eurofound, 2012c). In the context of organisational changes and in particular of restructuring, **job insecurity** and **work intensification** appear to be major OSH risk factors (EU-OSHA, 2007, 2009b; European Parliament, 2008a; HIRES, 2009; INSERM, 2011; CIOP, 2012). Most of the forms of restructuring are aimed at enhancing organisational performance and competitiveness. This may lead to work intensification, stress and fatigue. Working to tight deadlines is a major source of stress, and a system that has continuous deadlines as one of its core features will lead to sustained levels of stress (Kieselbach et al., 2010). Work intensity has increased in most European countries over the past two decades. Although this increase appears to have slowed down since 2005, 62 % of workers in the fifth EWCS report working to tight deadlines (for at least a quarter of their time) and 59 % report working at high speed (for at least a quarter of their time). Similarly, the proportion of workers whose pace of work is determined by three or more external factors (such as the speed of a machine, client demands or manager) has increased over the past 20 years (Eurofound, 2012b). The 'just in time' concept also implies a considerable increase in work pressure. A second effect of just-in-time production processes may be an increase in night work. If not for reasons of just-in-time production, the introduction of night shifts is at least a means of optimising the use of costly production facilities. Night work, however, is strongly associated with health disorders (Kieselbach et al., 2010).

Since the 1980s, most industrial societies have experienced a market trend towards the diversification, decentralisation and individualisation of working time patterns, driven both by companies' needs for greater adaptability in order to meet market constrains and by large changes in the gender division of labour. The key theme of the nineteenth International Symposium on Shift Work and Working Time, held in August 2009 in Venice, Italy, was 'Health and well-being in the 24-h society'. The topics covered by the peer-reviewed original research papers address the direct and indirect effects of working time arrangement on the circadian system, sleep, performance, safety, well-being, work–life balance, work ability and depression. The research suggests that long and unusual working hours increase the risk of psychovegetative health impairments both directly and indirectly, moderated by the subjective work–life balance (Costa and Di Milia, 2010). There is also evidence that long working hours increase the risk of coronary heart disease (CHD) (Virtanen et al., 2012).

In addition to flexibility in working time arrangements, the necessity of adapting to an increasingly globalised economy has also increased pressures on flexibility in contractual arrangements and ease of hiring and firing. Temporary employment contracts are often used to manage fluctuations in demand for work and personnel staffing needs. Use of flexible staffing arrangements — including fixed-term contracts, temporary agency work and short-term, on-call or regular part-time work — is widespread and is likely to increase in the near future. The proportion of the EU-27 workforce reporting that their main job was part time increased steadily from 16.2% in 2001 to 19.5% by 2011. The incidence of part-time work differs significantly between men and women. Just under one-third (32.1%) of women employed in the EU-27 worked on a part-time basis in 2011, a much higher proportion than the corresponding share for men (9.0%). Having fallen to 13.6% in 2009, the proportion of employees in the EU-27 with a contract of limited duration (fixed-term employment) rose to 13.9% in 2010 and 14.0% in 2011 (Eurostat, 2012b).

As restructuring seeks to enhance profits, productivity and sales, it often results, in addition to job loss, in a tendency to increase the amount and the intensity of precarious work. Precarious work has been defined as a combination of a low level of certainty over job continuity, poor individual control over work (notably working hours), a low level of protection (against unemployment or discrimination) and a low level of training. Over the past decade, the number of workers employed under atypical arrangements (fixed-term contracts, self-employed, temporary agency workers) has risen quite significantly, coupled with a relaxation of legislation governing dismissal in various countries.

Studies on the OSH effects of precarious employment found a negative association with OSH and that the higher the instability of employment, the more it is associated with morbidity or mortality. More specifically, numerical flexibility (notably fixed-term contracts) leads to increased job insecurity. Low perceived employment security is associated with poor health across three indicators, especially among women. In general, the level of psychological distress and psychological morbidity is high among fixed-term employees. Fixed-term contracts may also lead to high levels of presenteeism — it was found that, despite lower levels of self-rated health, there is increased attendance during sickness among temporary employees.

Precarious and atypical employment arrangements and non-standard working times are associated with a disadvantaged status in the labour market and a low bargaining power, which makes workers in such employment vulnerable to unsafe, hazardous working conditions (European Commission, 2004). Temporary workers also have less access to OSH professionals, elude health monitoring over longer stretches of time and may be overlooked by workers' representatives in matters of OSH policy, which might explain the relatively poor OSH situation of those workers (Kieselbach et al., 2010). Atypical arrangement may also have a negative impact on workers' participation, access to training and occupational health care.

The increasing use of new technologies also modifies working conditions and work organisations. The Internet makes real-time communication possible and also allows companies to take advantage of different time zones and low-wage cost zones to make cost savings by outsourcing and offshoring many functions that were once done internally. ICT has also contributed to the development of the 24/7 economy, which requires flexible work organisation, high flexibility in working hours and quasi-continuing availability (Wolfe, 1999).

The growing use of computers and automated systems at work has led to an increase in fixed body postures and physical inactivity at work. Time demands and other constraints tend to enhance this phenomenon. Physical inactivity is associated with increased health risks such as coronary heart disease (CHD), certain types of cancers and psychological disorders such as depression and anxiety. It increases the risk of obesity, which itself can lead to several adverse health effects (Fogelholm, 2010; European Parliament, 2008a). The World Health Organization (WHO) estimated in 2002 that, worldwide, each year approximately 2 million people die prematurely because of an inactive lifestyle (WHO, 2012d). It has been pointed out recently that sedentary jobs, especially prolonged working in a seated position, common in office work and driving tasks, entail health risks that are not counterbalanced by leisure-time physical activity (Dunstana et al., 2012).

In such activity fields as ICT, marketing, consultancy, design and finance, high qualifications go hand in hand with high workload, high responsibility and high demand of flexibility, which may have a negative impact on work–life balance. The growing service sector also provides an increasing number of low-skilled and low-wage jobs in security, health care, personal care, catering, cleaning, hotels and restaurants, often characterised by non-standard working conditions and unsociable working hours. Particularly in the education and health and social sectors, employees experience distressing working conditions with high emotional load and may be exposed to violence and harassment at work (Eurofound, 2010b). The potential health hazards in the services sector include growing psychosocial pressures due to increased availability demand and frequent and new human contacts. It is likely that this phenomenon takes on more importance as the service sector continues to grow (EU-OSHA, 2007; European Commission, 2011b).

Structural, organisational and technological changes in the work environment described in the preceding sections increase the pressure on work–life balance. Factors such as the advances in ICT, information load, the need for speed in response, the importance attached to the quality of customer service and its implications for constant availability, and the pace of change can all be sources of pressure (Guest, 2001). Increasing use of ICT tends to lead to a situation where work is dispersed in both time and place: there is no longer a clear separation between work and leisure time. Work–life balance is a particular concern for single parents, households with dual careers and parents who have young children and possibly also dependent, older relatives to be taken care of (EU-OSHA, 2012a; PEROSH, 2012).

The economic crisis has increased the pressure on companies for restructuring activities, and, as stated by the European Commission, ‘more jobs have been exposed to competitive pressures and deteriorating working conditions. In many instances, new forms of work and a higher number of job transitions have not been accompanied with appropriate working conditions, increasing psychological stress and psychosocial disorders. This has social and economic costs and may undermine Europe’s capacity to compete: unsafe, unhealthy work environments result in more claims for disability benefits and earlier exits from active life’ (European Commission, 2010b).

Priorities for research

- Investigate the impact of new employment and working patterns on health and safety at work, including different forms of flexibility, considering both the potential psychosocial risks and the associated adverse health effects on one hand, and the opportunities they may provide for improving work–life balance and well-being at work to support evidence based policies and practices at societal and company level.
- Focus on the health and safety aspects of precarious work in terms of access to occupational health care, health surveillance and traceability of occupational diseases, worker participation and access to training.
- Carry out further research on the determinants of work–life balance in a wider societal context, including societal values and systems. Investigate further how new working patterns and different types of flexibility, as well as implementation of new technologies, have an impact on work–life balance and, consequently, health and well-being at work, and organisational performance at the same time, to provide the evidence base for policy development and good practices at company level.
- Monitor and analyse the impact of the economic crisis on health and safety at work.

7.3 Violence and harassment at work

According to the 2010 Enterprise Survey on New and Emerging Risks (ESENER), nearly 40 % of interviewed managers in the EU-27 in 2008 considered work-related violence or threat of violence and harassment to be of major or some concern (EU-OSHA, 2010c). The successive European Working

Conditions Surveys (EWCSs) have also highlighted a trend towards an increasing incidence of workplace harassment. The results of the fourth EWCS ([28]) indicated that there has been an increase in the level of physical violence in the period 1995–2005 from 4 % to 6 %. It revealed that 2 % of all workers were subjected to physical violence from fellow workers, 4 % from people outside the workplace, and 6 % reported being subjected to threats of physical violence. The highest exposure rates were found in services (6.6 % in education, 8.7 % in health and social work and 8.5 % in hotels and restaurants) (Eurofound, 2010b). This increasing trend is supported by the results of national surveys.

Third-party violence typically pertains to particular sectors and occupations, such as health care and social work, education, transport, public administration and defence, and commerce (EU-OSHA, 2010d). For instance, in the retail sector, the main new risks are antisocial behaviour, from verbal abuse to physical violence and robbery by third parties, in addition to the difficulties of reconciling work and life due to irregular working schedules and increased intensification following the introduction of ICT (Eurofound, 2012d). A secondary analysis of the EWCSs from 1995 to 2005 confirms an increase in third-party workplace violence where the aggressor is not a work colleague but, for example, a customer or patient. The reasons for this increase are not precisely known, although growth of the service sector and work intensification have been suggested as responsible. The nature and possibly the quality of client contact is changing, leading to higher risks of violence. Currently, not enough is known about what causes third-party violence in social service, health care and other settings for worker–client interaction. More research is needed to clarify the influence of various situational and environmental factors in different workplace settings.

Those affected by violence and harassment in the workplace tend to report higher levels of work-related ill health. Victims of violence and harassment experience, for example, depression, anxiety, nervousness, sleeping problems and concentration difficulties. Organisational consequences include absenteeism, accidents and impaired performance (European Parliament, 2008a; EU-OSHA, 2010d).

There is a lack of reliable data on the prevalence of harassment and violence in Europe. In surveys and statistics, very different definitions and classifications of different forms of work-related violence are used. This makes the comparison, particularly between countries and sectors, difficult. Commonly accepted definitions and classifications, as well as systematic strategies, are needed to better assess the prevalence of work-related violence at European level.

There is a lack of intervention evaluation research in relation to harassment and violence at work; so far, a very limited number of evaluated interventions have been conducted, and therefore too little is known about the most effective measures to prevent harassment and violence at different levels – policy, organisation, work unit/group and individual (EU-OSHA, 2010d). To support employers and practitioners in planning and implementing prevention programmes, credible, evidence-based and evaluated interventions and strategies need to be available. A primary research need in the prevention of harassment and violence at work is to obtain evaluation data on strategies and interventions for a variety of workplace applications.

Priorities for research

- Clarify the terms, definitions and classifications used in relation to different types of work-related violence and harassment. Commonly accepted operational definitions of what constitutes workplace violence and harassment will be necessary to facilitate uniform collection of data. Standardised data collection using common definitions is essential to draw conclusions on effective prevention.
- More sector-orientated research is needed to clarify the influence of various situational and environmental factors of third-party violence or harassment in worker–client interaction in different workplace settings.

[28] In the fifth EWCS no trend could be followed because of a change in the wording of the questions.

- Conduct high-quality interventions aimed at developing, testing and evaluating strategies to prevent harassment and violence in a variety of workplace settings and the negative consequences of such behaviours. Evaluate the process, efficacy and cost-effectiveness of the interventions.

7.4 Psychosocial risk factors, work-related stress and chronic diseases and health conditions

The causes of major chronic diseases/disorders and health conditions such as cardiovascular diseases (CVDs) and musculoskeletal disorders (MSDs) (see section 6.5) are often multifactorial and the working environment can play a role in their development. Psychosocial and organisational risk factors such as high workloads, tight deadlines, long and/or non-standard working time (long hours, shift work, night work), precarious or isolated work are — combined or not — associated with the development of certain chronic disorders and diseases such as mental health alterations, immunological diseases and occupational cancers (INSERM, 2011).

Psychosocial risk factors can impact health directly or indirectly, mediated by work-related stress. According to the 2010 ESENER , 79 % of interviewed managers in EU-27 countries in 2008 considered work-related stress to be of major or some concern (ESENER). Short-term stress at work does not normally have negative consequences. However, when prolonged, it becomes a safety and health risk and may contribute to the development of pathological conditions such as MSDs, CVDs and mental disorders (Chouanière et al., 2011; INSERM, 2011; EU-OSHA, 2012b; Eurofound, 2012e). Work-related stress can also lead to addictive conducts (Chouanière, 2012), for example increased use of alcohol and/or drugs, aggravating the risk to develop pathological conditions. Moreover, addictive conduct can worsen the impact of stress. For example, it has been reported that alcohol consumption and stress can feed each other (Childs et al., 2011).

There is also increasing evidence that obesity and overweight may be related, in part, to adverse work conditions. In particular, the risk of obesity may increase in high-demand, low-control work environments and for those who work long hours (Schulte et al., 2007). Physical inactivity at work also increases the risk of obesity (European Parliament, 2008a) (see also section 7.2). Evidence of varying strength suggests that obesity increases the risk of certain occupational diseases or conditions such as MSDs, CVDs, asthma and vibration-induced injury. Obesity may also modify physiological responses to neurotoxins and immune responses to chemical challenges, many of which are found at work. In addition, obesity may interact with occupational stress. Research is warranted to both explore how the work environment and work practices promote or discourage the development of obesity (and overweight in general) and define the extent to which obesity acts to modify the risk of occupational diseases and injuries (Schulte et al., 2007).

A recent meta-analysis based on individual records from 13 European cohort studies published between 1985 and 2006 has emphasised the association between job strain and CHD (Kivimäki et al., 2012). It has been estimated that 6 % of all CVD cases among men and 14 % of cases in women are attributable to job strain and that shift and night work increases the risk of CVD by at least 40 %.

The impact of organisational and psychosocial risk factors in the development of **immunological disorders and occupational cancers** has been less extensively studied (INSERM, 2011), although substantial evidence has been created, for example on the fact that night work may play a significant role in the development of certain types of cancer (Hansen and Lassen, 2012; Parent et al., 2012). The nature of many of the complex interactions between work-related psychosocial risk factors, risk behaviours and chronic diseases and health conditions, including occupational diseases and disorders, is not well studied or understood. A better understanding of the links between work-related psychosocial risk factors and morbidity and mortality is needed for the development of evidence-based policies and effective prevention strategies.

Priorities for research

- Investigate the complex interactions between work-related psychosocial and organisational risk factors, work-related stress, physical inactivity at work, risk behaviours and chronic diseases and health conditions to provide an evidence base for policy development and effective prevention strategies. Focus on groups particularly vulnerable to the adverse health effects of psychosocial risk factors at work.
- Develop interventions, programmes and strategies that merge traditional workplace health protection with workplace health promotion and address both work-related risks —organisational and psychosocial — and behavioural factors simultaneously. This logically includes a focus on both the work environment and individual choices and behaviours.

7.5 Well-being at work — a positive approach

Generally, when compared with worklessness or unemployment, work is good for physical and mental health (WHO, 2010). There is a strong evidence base showing that work is generally good for physical and mental health and well-being and that worklessness is associated with poorer physical and mental health and well-being. Work can be therapeutic and reverse the adverse health effects of unemployment. That is true for healthy people of working age, for many disabled people, for most people with common health problems and for social security beneficiaries. The provisos are that the nature and quality of work and its social context must be taken into account; jobs should be safe and accommodating (Waddell and Burton, 2006).

Traditionally, occupational health psychology has focused on risk factors in the workplace and their adverse health effects, and the vast majority of intervention research concerns the detection and management of occupational health problems rather than the reinforcement of positive aspects of work. The mechanisms that underlie employee ill health and malfunctioning, however, are not the same as those that constitute employee health and optimal functioning. Positive occupational health psychology advocates an integrated approach that achieves a balance between positive and negative aspects of work and well-being (Bakker and Derks, 2010). It focuses on the positive characteristics of the working environment that enhance workers' strengths and optimal functioning and contribute to organisational performance.

One of the central concepts of positive occupational health psychology (POHP) is **work engagement**, viewed as a positive, work-related state of fulfilment that contributes to health and well-being at work (Bakker and Derks, 2010).

No commonly accepted definition exists for the concept of 'well-being at work'. It can be described as a 'worker's experience of the safety and healthiness of work, good leadership, competence, change management, the organization of work, support of the individual from the work community, and how meaningful and rewarding a person finds his/her work' (FIOH, 2010). This definition implies that organisational factors and workplace relationships have an important impact on workers' well-being, but that individual resources may also contribute to it (Rissa, 2007; Naumanen, 2012; PEROSH, 2012).

Europe's commitment to smart growth has focused renewed attention on work organisation practices and these are now being discussed under the concept of 'workplace innovation'. As acknowledged by the European Economic and Social Committee, this concept needs to be clearly defined at the European level; a review of the literature, together with some EU policy documents, provides converging suggestions on the definition of workplace innovation (EESC, 2011a). Workplace innovation is an important part of successful innovation in an organisation. It is complementary to technological innovation. Workplace innovation combines interventions in the fields of work organisation, human resource management and supportive technologies. Areas for improvement can include 'work processes, work organisation, working methods, the physical working environment and tools, professional skills and working practices, and management and leadership'(EESC, 2011b). Research indicates that through workplace innovation a simultaneous improvement in quality of working life and productivity is possible, in particular in projects with strong employee participation (Ramstad, 2009). Companies exhibiting high levels of workplace innovation and human performance are thought to have a better quality of working life as well (EU-OSHA 2012).

Workplace innovation can be an effective means to develop well-being at work. The overlap between OSH management and workplace innovation is a promising perspective. OSH management is focused on health and well-being at work, whereas workplace innovation is directed at organisational performance and well-being. If purposefully combined, these approaches can reinforce each other (EU-OSHA2012; Pot, 2012; Van Hootegem, 2012).

Priorities for research

- Reinforce the positive approach in occupational health psychology research by focusing on positive job characteristics and well-being, including work engagement, job resources, psychological capital, job crafting and positive spillover.
- Explore further the relationship between workplace innovation, health and safety at work and company performance, and the possibility of improving health and well-being at work through workplace innovation.

7.6 OSH in small and micro-enterprises

As new technologies and globalisation reduce the importance of economies of scale in many activities, and larger firms downsize and outsource more functions, the weight of SMEs in the economy is increasing (OECD, 2000).

Perhaps the most striking phenomenon of SMEs is their contribution to employment. In 2008, two-thirds of the EU-27's non-financial business economy workforce was active in an SME. Some 23.3 million persons worked in SMEs in the distributive trades sector, 19.5 million in manufacturing and 13.2 million in construction; together, these three activities provided work to 61.9 % of the non-financial business economy workforce in SMEs. In a number of service sector activities, an absolute majority of the workforce was working in micro-enterprises (e.g. real estate services and the repair of computers, personal and household goods).

Entrepreneurship and rapidly growing SMEs are considered drivers of job creation, including enterprises with no paid employees (self-employed). These accounted for just over half (51.2 %) of all EU enterprises in industry, construction and services in 2007 and 63.4 % of all newborn enterprises — predominantly in deregulated service sectors with relatively low fixed costs for self-employed persons starting businesses (Eurostat, 2011b). The potential of small enterprises has been recognised and it is appreciated that employment and economic growth to a large extent depend on these enterprises. Both political and scientific interests in OSH in small enterprises have therefore grown considerably during the last decade (Hasle and Limborg, 2006). At the European level, the European Commission works on broad policy issues affecting entrepreneurship and SMEs, which is reflected in , several policy documents, such as the Small Business Act for Europe (SBA) and the ENTREPRENEURSHIP 2020 ACTION PLAN. Many Member States have launched programmes to support small enterprises.

In terms of OSH, small businesses present a challenge: they are difficult to regulate, as they are typically heterogeneous, geographically scattered, lack cohesive representation and have a short life cycle (Lamm and Walters, 2003). Less than one-half of small start-ups survive for more than 5 years, and only a fraction develop into the core group of high-performance firms that drive industrial innovation and performance (OECD, 2000).

Management in small businesses is more informal, the lines of communication are short, the communication is oral, the structure is simple and commercial pressures are very high and immediately felt. Moreover, it is impossible to separate OSH practices from other aspects of small business management. In addition, these results support the premise that the owner-manager is the key person in the small business and it is their values that determine the business's approach to health and safety management (Hasle and Limborg, 2006). Overall, health and safety management in small businesses is poor.

Small businesses are typically operated under very tight budgetary constraints. One of the greatest challenges for small businesses is securing financial resources to set up the business, survive and grow. This has important implications for OSH management. Tight budgetary constraints often mean that there is a lack of financial resources to implement health and safety initiatives, and interventions, such as paying for health and safety advice, information, tools and controls, will always be implicitly or explicitly evaluated by a cost–benefit analysis. In addition, small businesses are often unable to hire staff with specialist OSH knowledge (Legg et al., 2009). Since the benefits and the respective economic returns of investment in OSH are long term, it is unlikely that small enterprises will undertake it, especially when this investment is needed for their survival. This is particularly true in the context of the current economic crisis. Economic incentives and support schemes are therefore an important encouragement for small businesses to improve health and safety practices.

The need to focus OSH research on small businesses is now recognised, but effective mechanisms to reach, assist and impact on these companies continues to be a challenge. To date, most OSH research and interventions have been focused primarily on large companies. Conceptual frameworks for OSH and small businesses are theoretically vague and empirically not well supported. Until very recently, specific problems, limitations and needs of small businesses have not been thoroughly examined, and there is still a need to identify effective approaches and suggest future research strategies in this area. There is a consensus that the models developed for larger companies have proven ineffective and the difficulty of reaching small and micro-enterprises, their geographical dispersal and their short life spans present an additional challenge (Legg et al., 2009).

During the last couple of years there has been a significant increase in the number of studies of small enterprises, but the research community is scattered between many different disciplines and institutions. There is a lack of evaluation of intervention studies, in terms of both effect and practical applicability. However, there is strong evidence to conclude that employees of small enterprises are subject to greater risks than the employees of larger ones, and that smaller enterprises have difficulties in controlling risk. It is important to develop future intervention research strategies that study the complete intervention system: from the intermediaries through dissemination methods to the resulting preventative activities of the small enterprises (Hasle and Limborg, 2006).

In order to develop effective OSH strategies and policies targeted at small businesses, it is important to understand their organisational and cultural realities and to know their specific needs and motivations (Eakin et al., 2000). A sector-, branch- or craft-based approach would be appropriate in this context, as sector- and branch-based networks are useful for sharing information, coordinating, facilitating and possibly organising preventative actions. A thorough analysis of the needs and motivations would help to design the communication and information as well as the OSH tools, methods and incentives targeted to these entities.

Moreover, knowledge is needed on the specific success factors and obstacles in the different stages of the enterprise life cycle on one hand, and during different economic cycles (growth, recession) on the other. This knowledge would help SME owners and managers prepare their enterprise to different kinds of economic conditions beforehand and to maintain conditions that favour well-being at work (Naumanen, 2012).

There is evidence of even very small enterprises reporting high levels of OSH management practice in some EU countries and sectors. This suggests that, if an encouraging environment can be created, OSH management in SMEs (especially in those with fewer than 100 employees) could be substantially improved. Further research is needed to identify the key conditions that contribute to this development (EU-OSHA, 2012c).

It is known that knowledge-related barriers are more important for small enterprises. *SMEs, micro-enterprises and self-employed* lack specific, comprehensive information and guidance regarding OSH. The effectiveness of OSH risk communication targeted to these entities should be assessed and methods and strategies for a better communication should be developed, considering in particular the case of smallest enterprises and the self-employed which are the most difficult to reach.

A range of studies has identified the types of OSH information that small businesses require, the most acceptable style of guidance material, appropriate intermediaries to reach them and barriers to overcome. Almost universally, the studies have confirmed that ‘top-down’ strategies communicated by public authorities of one type or another, and based on written information, simply do not work, or at the very least do not work well with small businesses. Indeed, in many cases, such OSH messages may result in ‘tuning out’ to all OSH preventative messages. A number of OSH studies have identified that small business owner-managers prefer face-to-face contact over other forms of communication, listen to guidance from peers and absorb industry subgroup-specific information more than generic advice (Hasle and Limborg, 2006; Legg et al., 2009). It has also been found that, although there is a number of methods of how to approach small enterprises, only a limited number of these has been thoroughly evaluated.

The claim that good OSH brings financial benefits and contributes to improving company performance has not been sufficiently assessed, in particular within SMEs and micro-enterprises (EU-OSHA, 2009a). Interventions in small and micro enterprises should be evaluated for cost-effectiveness. Many of the existing tools to assess the costs and benefits of the investments in prevention are not suitable for SMEs and micro-enterprises and more research is needed to develop easy-to-use methods and tools responding to their specific needs. In addition to helping enterprises in their decision-making (WHO, 2010), the use of well-designed tools and methods is a means to raise the **awareness** of the fact that good OSH is profitable and enhances competitiveness (European Parliament, 2010). The BENOSH report points out that 'calculating costs raises awareness about the necessity of prevention' (European Commission, 2012b).

There are only a few examples of successful application of economic incentive schemes to SMEs and micro-enterprises. In addition to the classic insurance-related grant, award, tax incentive or education-centred schemes, new approaches targeted specifically to SMEs, micro-enterprises and the self-employed should be developed and their effectiveness evaluated (Elsler and Corth, 2003; BGAG, 2006; EU-OSHA, 2010e; European Commission, 2010c; PEROSH, 2012).

Priorities for research

- Further studies are needed on specific features of small and micro-enterprises, success and obstacle factors throughout the enterprise life cycle and in different economic contexts (growth, recession), and the key factors affecting OSH decision making in these entities.
- Improve the quality of research on small and micro-enterprises with an emphasis on the use of existing knowledge in new research and exchange of experience between researchers. Higher priority should be given to interdisciplinary studies and evaluation of the effect of the various interventions. Intervention research should cover the whole intervention process, from intermediaries through dissemination methods to preventative activities, evaluation of the efficacy and cost-effectiveness of the intervention.
- Develop, implement and evaluate innovative support schemes adapted to the realities and needs of small and micro-enterprises, including the self-employed, taking into account their special nature and combining different approaches (information, training, development of support networks or guidance from external OSH services and economic incentives). Develop cost-effective programmes that can be applied at a larger scale.
- Conduct further nationally comparable research to identify the key conditions that contribute to a 'favourable' environment by which levels of OSH management practice among smaller establishments (especially those with fewer than 100 employees) could be increased.

8 OSH research for safe, new technologies as a prerequisite for sustainable growth

If Europe is to achieve its smart and sustainable growth goals set in the Europe 2020 strategy, it must first invest in research. A greater capacity for research and development will assist in achieving innovation across all sectors of the economy, and this, combined with increased resource efficiency, will improve competitiveness and foster job creation (European Commission, 2010a). One of the key challenges is the need to urgently identify initiatives that will bring to market Europe's research strengths in emerging technologies (European Commission, 2010d). It is foreseen that over the next decade key enabling technologies (KETs) such as biotechnology, nanotechnology, advanced materials and advanced manufacturing systems will provide the basis for a wide variety of new processes, goods and services, and even the development of entirely new industries. However, although some of these new processes and technologies will create new employment opportunities through their rapid development, they can also have a negative impact on working conditions and working environments, and thus result in the emergence of new hazards. Research on the potential negative effect of these new technologies, and the new or emerging workplace hazards that they might present, is essential. It is therefore paramount that OSH research is integrated into the research and development of all new processes and technologies, as one of the key factors for fully exploiting their potential is a guarantee of their overall safety. All OSH risks and prevention measures need to be identified so as to ensure that the safety and well-being of workers are not being jeopardised. This OSH research can even be seen as a prerequisite for the long-lasting competitiveness of Europe and for the achievement of the goals of the Europe 2020 strategy.

The success of these new innovation processes depends not only on the technological innovation itself or the state of the economic and institutional environment, but also on the public acceptance of the innovation. Public acceptance of new technology is fundamental for its successful implementation. To allow these new technologies to grow and thrive, open communication on the risks and their prevention is essential. The dissemination of research results is an important aspect of this process because it can help avoid any potential fears of workers and/or the general public, which, on some occasions, can lead to the abandonment of novel innovations. A good example of such misconceptions is hydrogen and its potential use as a fuel and energy carrier. The introduction of hydrogen into the energy market is being pursued by governments around the world in an effort to abate climate change, provide security of supply and reduce air pollution; however, the public perception and acceptance of hydrogen is still uncertain. Various projects are being carried out to change this perception and gain the public's trust; for example, the HyTrust project (www.hytrust.de).

New technologies can also be applied in the development of new solutions and tools for the prevention of ill health and accidents. Here, again, there is a need to translate research into practice and ensure that OSH implications are considered; for example, new technologies that offer solutions to existing OSH risks should not introduce new hazards to workers or workplaces.

8.1 Occupational hazards in green technologies

Technological progress and economic development are both reliant on the availability of efficient and inexpensive energy sources. In today's world, sectors such as production and transport would not be able to exist without their heavy dependency on fossil fuels. However, it is now widely recognised that the level of greenhouse gases, such as carbon and methane, produced from human activities (e.g. burning of oil, natural gas and coal) affects the earth's atmosphere and is an important factor in observed climate change. The Europe 2020 strategy sets targets for reducing these greenhouse gas emissions by at least 20% (30%, if the conditions are right) as compared with levels in 1990. Such a target has generated a demand-driven emphasis on developing economic activities and jobs that have lower energy consumption and a smaller environmental footprint. Green jobs and the promotion of the green economy are pivotal for achieving an economic and social development that is also environmentally sustainable.

There are many definitions of what are considered 'green jobs'; however, this notion of what is considered 'green' is not absolute, as there are various 'shades' of green. The European Commission understands "Green Jobs" as covering all jobs that depend on the environment or are created, substituted or redefined (in terms of skills sets, work method, profiles greened etc.) in the transition process towards a greener economy'. The Green Jobs Initiative (European Commission, 2010b) defines green jobs as positions in agriculture, manufacturing, construction, installation and maintenance, as well as scientific and technical, administrative and service-related activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect and restore ecosystems and biodiversity; reduce energy, materials and water consumption through high efficiency and avoidance strategies; decarbonise the economy; and minimise or altogether avoid the generation of all forms of waste and pollution. Finally, green jobs also need to be good jobs that meet the longstanding demands and goals of the labour movement, offering adequate wages, safe working conditions and workers' rights.

A point that needs to be stressed is that, even if a job is categorised as 'green', it is not necessarily safe — the technology used may not be green at all. This advance towards a 'green economy', which has been influenced by economic and political factors, has caused the rapid creation of 'green jobs' and the 'greening' of current industries and production processes. Studies have demonstrated that the technologies sometimes being used in the development of 'green jobs' do not pay sufficient attention to the OSH risks they may create. In addition, existing time pressures result in a 'rush to green', which, at times, is pursued at the expense of worker safety and health concerns. Some examples of how and why OSH is given secondary consideration to 'green' technology development include the following:

- The desired speed to introduce green energy into the marketplace often does not allow adequate time for licensing and OSH training.
- Developing adequate OSH practices after identifying risks takes longer than procurement agents can wait; thus, OSH often follows installation and only occasionally precedes it.
- Because a variety of green energy systems are available, it has been difficult to establish consistent OSH standards across all of them, resulting in a lack of standards, occasional confusion and OSH being dropped to a secondary consideration.
- The 'drive to green' is emotional (concern for one's future) and economic. OSH, on the other hand, is typically regulatory driven and supported by a different emotional driver (concern for people one does not know). Thus, 'green' often has the stronger motivators (Department of Health and Human Services, 2009).

Overall, it can be said that 'green technologies' will decrease the risk of harmful exposures to the environment, although care must be taken before implementation, as some of these changes might have a negative effect on workers' health and safety. The replacement of some substances harmful to the environment with more environmentally friendly ones has proven to be more hazardous to workers' health. An example of such a shift in risk can be observed in the green building construction industry, in which recycling material such as paper flakes are used as insulation; however, these flakes are generally impregnated with 8 % borax (sodium tetraborate), which although a fire retardant is also classified as a reprotoxicant. Another example is that of green 'light bulbs', which depend on highly toxic mercury. A specialist medical journal, published by China's health ministry, describes a compact fluorescent light bulb factory in Jinzhou, in central China, where 121 of 123 employees had excessive blood mercury levels. It also reported a survey of 18 light bulb factories near Shanghai, which found that exposure levels to mercury were higher for workers making the new compact fluorescent light bulbs than for other lights containing the metal (O'Neill, 2009). Other risks include exposure to lead and asbestos during energy-efficient retrofitting in older buildings or the risks of falling during construction and maintenance of wind turbines. In these cases there seems to be a trade-off between reducing long-term emissions to the environment and short-term exposures that may harm workers.

Workers in 'green industries' may face hazards that are commonly known in traditional workplaces (e.g. falls, confined spaces, electrical, fire, chemical and others); therefore, it is fair to say that many of the risks associated with green jobs are not new. The OSH challenge, however, is how to deal with the combination of exposure to existing risks within new setting and conditions and how to transfer existing knowledge on them. Research is needed to identify traditional and new OSH risks found in different situations and combinations within green jobs. Job specific risk assessment tools need to be developed to ensure safe working environments and also to identifying OSH topics that training programs should be geared to address. Furthermore, the current speed of expansion in green jobs will also lead to a skills gap and a reliance on a large number of inexperienced and/or under- skilled workers who will be handling and interacting with new or unfamiliar technologies, for example new technologies and working processes for which previous OSH knowledge is not directly transferable. Whilst much of the attention focuses on technology, experience demonstrates that the weakest link of the production chain will determine the level of performance that can be attained. Without qualified skilled workers at all levels, new technologies will not deliver the expected environmental benefits and economic returns. For this reason in-depth analysis of methods are needed that can be used to identify current and future OSH skills needs at all levels within green jobs.

“Designing out” or minimising hazards and risks early in the design process is one of the best ways of preventing and controlling potential injuries, illnesses and fatalities within existing and new technologies. In the USA, the National Institute for Occupational Safety and Health (NIOSH) is leading a national initiative called ‘Prevention through Design’ (PtD) to promote this concept and highlight its importance in all business decisions. As part of the PtD initiative, a ‘making green jobs safe’ workshop was organised in 2009 with 170 OSH representatives. The main recommended themes that emerged for making OSH an integral part of the green economy included the following:

- Make OSH a priority by leveraging the purchasing power that government and industry already have, be it through contracts or grant authority.
- Integrate OSH data collection and monitoring into codes and standards of practice that already have wide support, so that improved safety and health protections also become standard practice.
- Improve the data collection process to identify and understand safety and health risks and use those data to promote OSH investment more effectively.
- Create better methods and better standard references that can be used by OSH professionals to better protect workers.
- Invest more time and resources to train exposed populations and to increase awareness among those who may be unaware of their exposure to controllable risks.
- Conduct market research to create new motivators that will inspire owners, employers and workers to make OSH a priority that cannot be ignored.

Notwithstanding the above, as with any new and developing technology, workers in ‘green jobs’ will also be exposed to new hazards, which are not likely to have been previously identified. Therefore, novel combinations of skills and prevention measures need to be identified during the design stage in order to eliminate any occupational hazards associated with the entire life cycle of green technologies.

As diverse as green jobs may be, they are characterised by a number of common OSH challenges, for example new materials that can give rise to new diseases, skills shortages, rapid rate of innovation, more automation, and end-of-life issues. There is an increasing trend towards decentralising work processes, workplaces are becoming more dispersed and more difficult to reach, and monitoring and enforcement of good OSH conditions and safe working practices is becoming more challenging. Therefore, safe working processes need to be developed in green industries, especially in the case of SMEs, to prevent putting workers at risk, as emphasised by the European Commission and the Advisory Committee on Safety and Health at Work (2011).

8.1.1 Occupational hazards in emerging energy technologies

It is estimated that meeting the EU’s objective of 20 % of renewable sources of energy alone holds the potential of creating more than 600 000 jobs throughout the EU. To be able to achieve this goal, emissions need to be reduced more quickly and new energy technologies must be harnessed. In comparison with many other sectors, job creation in these industries has been positive, even through the recession. Within only 5 years (2005–2009), the renewables sector in Europe saw an increase of more than 300 000 employees. Within these renewables sectors, solar power, wind power and biomass technology are the fastest developing (EU-OSHA, 2011b):

- Solar power: The growth in the solar sector has been rapid during the last two decades and this trend is likely to continue. The reduction in the cost of solar energy systems, with the availability of public funding and investments, has led to a high demand for domestic installations. Europe's substantial investment in solar power is reflected in the 320 000 employees in the sector in 2011, an increase of 86 % compared with 2009.
- Wind power: Wind energy is renewable, clean and produces no greenhouse gas emissions. It accounted for 9.1 % of the EU power capacity in 2009 and represented 39 % of all new power capacity in Europe in the same year. It has had tremendous growth over the past decades; between 2007 and 2010 the number of jobs in the sector increased by nearly 30 % and this growth is expected to continue, with the number of jobs increasing to 520 000 by 2020, an increase of more than 200 % over the next 10 years.
- Bioenergy: More than 300 000 jobs related to biomass fuel production are expected to be created throughout Europe by 2020.

Globally, an estimated 4.2 million people are currently employed in the renewable energy sector, and this figure has been predicted to soar to as high as 20 million by 2030 (UNEP et al., 2008).

According to Eurostat, the statistical office of the EU, the share of worldwide renewable energy in gross final energy consumption was 12.5 % among the EU-27 countries in 2010 (WHO, 2012a). Spain and Germany were the main wind energy generators in Europe, followed by the UK, France, Portugal, Italy and Denmark (Eurostat, 2012c).

The rapid expansion that is expected to take place in the development and deployment of renewable energy technologies means that activity volumes will be high, generating a sharp increase in the potential for health and safety related incidents and accidents to occur.

In the wind energy sector, as more turbines are being built, more accidents occur. RenewableUK, a renewable energy trade association, has reported that 1 500 accidents and other incidents have taken place on UK wind farms over the past 5 years, including four deaths and a further 300 injuries to workers. The Spanish Wind Energy Association has recently gathered detailed information on accidents that occurred at work during the period of 2007–2011 within 33 wind energy companies, giving a fairly representative sample of the sector with an average number of 12 529 workers (Spanish Wind Energy Association, 2012). The Spanish wind energy companies reported, on average, 301 accidents at work each year and 37.35 accidents for every 1 000 workers.

Emerging energy technologies can involve traditional risks or novel combinations of risks within new working environments. As with all new technologies, risks can also arise out of engineering unknowns as technologies are upscaled to major industrial output (the potential for mechanical failure, risks from machinery).

Solar energy

Most of the physical hazards encountered by workers when installing solar panel systems are similar to those that would be faced on a typical construction site; however, these hazards might be new for electricians or plumbers who have to install photovoltaic (PV) panels or solar water heaters on a roof. These hazards can include falls from heights, manual handling, high temperatures, confined spaces and electrocution during construction and maintenance. Occupational hazards also exist during the manufacturing, installation and the eventual end-of-life waste disposal of PV panels. Risks may also be associated with the use of known dangerous substances in the manufacture of panels that include arsine, carbon tetrachloride, hydrogen fluoride, phosphoryl chloride or silane. Many of the hazards can arise from the chemicals used in conjunction with silicon in various manufacturing processes.

Wind energy

The manufacture of wind turbines presents hazards that are similar to those in the automobile and aerospace industries. In addition, the hazards associated with their installation and maintenance are similar to those in construction. Workers may be exposed to epoxy resins, styrene and solvents used in the manufacturing of wind turbine blades or, alternatively, with the use of new materials such as engineered nanomaterials (ENMs). Knowledge on these materials and their potential health risks (see section 9.3 is needed throughout all stages of their life cycle: production, construction, operation, maintenance, prolonging operational life, decommissioning and waste disposal. Physical hazards during maintenance include falls from heights, MSDs from manual handling (research efforts concerning MSDs are presented in detail in section 6.5) and awkward postures when working in confined spaces, physical loads from climbing towers, electrocution and injuries from working with rotating machinery and falling objects. It is important to remember that risk combination factors are multiplied in offshore wind farms, which have the potential to become highly dangerous work sites; maintenance in offshore locations may have to be done in extreme weather conditions and maintenance access to offshore wind turbines may mean that workers have to climb onto the turbines from unstable boats.

Bioenergy

Bioenergy, including liquid biofuels, biogas and modern biomasses for heating and power generation, also raises OSH concerns. The hazards associated with feedstock production are similar to those present in agriculture and forestry, such as exposure to agrochemicals and heavy physical loads, often in hot environments (ILO, 2012b). During thermal processing, there can be exposure to carcinogens, gases, carbon monoxide, sulphur oxides, lead, volatile organic compounds (VOCs) and trace quantities of mercury, heavy metals and dioxins. Biomass storage and handling poses risks of high temperatures, fire and explosions due to the presence of methane. It may be difficult to store biomass materials; these stores may emit hazardous VOCs, dusts, moulds and endotoxins, which can be a health risk for workers if they are exposed. Hence, research is needed on the **long-term health effects of exposure to biological agents**, as well as on the good design of buildings and ventilation systems to ensure that the air quality is good during the storage and handling of biomass. Research is also needed on the **effects of the combinations of exposures** encountered in the bioenergy sector (high temperatures, formation of combustible gases, dusts and moulds, etc.) in order to fully understand the extent of exposure and assess the risk. Use of new organisms and third-generation biofuels may represent **unknown biohazards**. These may arise particularly from new third-generation biofuel organisms that operate at room temperature. The research efforts into exposure to biological agents are described in detail in section 9.4.

The drive for change towards creating a ‘green economy’ in the EU requires a need for further research that will identify how certain OSH risks may increase with ‘green jobs’. Research will also help to determine whether or not appropriate standards and/or guidelines are needed to overcome anomalies in the regulatory protocols throughout Europe, as these can result in inconsistencies across the whole renewable energy sector. Knowledge gained through research is a prerequisite for setting relevant regulations on OSH. The process of identifying hazards in the design (i.e. prevention through design) and developmental phases, and managing and controlling hazards should be part of the deployment of emerging energy and green technologies. In other words, organisations involved in the emerging green sector need to focus on ‘designing in’ safety, using a life cycle approach to sustainability and addressing it as an integral part of the development and roll-out of a new technology.

8.1.2 Occupational hazards in waste management and recycling

Recently, environment protection issues have largely acted as stimuli for the development, growth and industrialisation of waste recycling processes throughout Europe. A new waste management policy aimed at decreasing the amount of waste sent to landfill has been adopted by several Member States. As this regulation has been aimed to cover waste and developed for environmental purposes, OSH issues have not been adequately addressed, causing a shift in risk from the environment to the workers; pressure to recycle means that the risk of workers being exposed to a wide range of materials increases, as do the number of accidents.

The waste management and recycling sector is thriving and the number of workers is sharply increasing; ILO’s green jobs programme has identified waste management as one of the fastest growing sources of green employment (UNEP et al., 2008; ILO, 2012b). Recycling and waste management work can be dirty, polluting, unpleasant and even dangerous, and it is often poorly paid.

For example:

- a recent study of working conditions in recycling centres in Sweden identified several risks and detected a high frequency of injuries (Engkvist, 2010);
- occupational accidents in the collection and treatment of waste in France in 2003 were three times more frequent and serious than in other sectors;
- in Florida and Denmark injury rates in municipal solid waste (MSW) workers were found to be six or seven times greater than in the general workforce; and
- Danish studies indicate that MSW collection is one of the most hazardous occupations with an illness rate 50 % higher and an infectious diseases rate six times higher than in other workers (Waste Management World, 2005).

In addition to conventional OSH hazards, (for example those related to repetitive manual handling of heavy loads) new recycling technologies that will have an emphasis on preserving the performance qualities of existing or new materials, will introduce a variety of new occupational risks. Some of these new materials will include nanomaterials and other new types of chemicals as well as the ever-increasing amount of electronic waste. For example, solar PV panels have the potential to create a significant new wave of electronic waste at the end of their useful lives (which is estimated at 20–25 years), and they also contain a growing number of new and emerging materials, such as cadmium telluride and gallium arsenide, that can present a complex recycling challenge in terms of technology, safety and health and environmental protection.

The production of electrical and electronic equipment is one of the fastest growing industrial areas, which, unfortunately, has also resulted in the proliferation of waste electrical and electronic equipment (WEEE). The recycling of WEEE is also increasing because of the economic value of extracting precious or potentially rare earth materials from waste electronic material such as lanthanides, scandium and yttrium. However, very little is known about the potential health effects of exposure to these elements, and these will need to be evaluated. In the EU, the treatment, recovery and disposal of WEEE are regulated by the WEEE Directive (Council Directive 2002/96/EC, 2003), which aims to reduce the production of WEEE and promote the reuse, recycling and recovery of waste. One of the key challenges in recycling WEEE is the presence of many **hazardous substances in the waste**, such as heavy metals, flame retardants and nanomaterials, which may pose a health hazard to the workers (Rosenberg et al., 2011; Hebisch and Linsel, 2012). It is therefore necessary to identify and assess the exposures to chemicals and nanomaterials and the possible adverse health effects associated with the processes needed to treat WEEE. Furthermore, as raw material costs increase, future **landfill mining** for valuable resources will become economically viable, leading to potential exposure to harmful materials.

When working conditions in recycling centres were studied (Engkvist, 2010), it was concluded that there was a clear need for preventative action in several areas, such as machinery and equipment, for example for lifting and cleaning in order to reduce physical exertion, and to prevent both overexertion injuries and minor injuries, such as crush and cut injuries due to manual handling. In addition, the introduction of automation and the use of robots in waste processing and recycling will be highly beneficial in terms of OSH as it could mean that workers will be less exposed to manual handling and exposure to dangerous substances from waste. Therefore, this kind of technology needs to be developed.

Energy recovery is emerging as a new branch of the energy sector in which **waste-to-energy technologies** can produce energy in the form of electricity or heat from the incineration or combustion of organic waste. In addition to incineration, there is a number of other new and emerging technologies that are able to produce energy from waste and other fuels without direct combustion, such as gasification (producing combustible gas, hydrogen and synthetic fuels), thermal depolymerisation (producing synthetic crude oil, which can be further refined);; anaerobic digestion, (producing biogas rich in methane); or fermentation (producing, for example, ethanol, lactic acid and hydrogen). These waste-to-energy processes can generate human and environmental hazards from impure gas production, explosions, dangerous substances and gases in confined spaces (ILO, 2012b).

Resource recovery, the selective extraction of disposed materials for a specific next use, including the separation and collection of organic waste, is also a growing trend in Europe. It may lead to increased exposure to micro-organisms, as well as sensitising agents and allergens. Research efforts concerning the occupational **exposure to the biological agents** present in waste management and recycling are covered in detail in section 9.4.

Priorities for OSH research related to green technologies

- More "Prevention through Design" research is needed for the safe development of technologies, processes and substances during their conception and before their introduction into the market and taking into consideration their entire life-cycle in order to "design out" any potential hazards. Outcome of this research could be used to harmonise/standardise designs.
- Research is needed to evaluate traditional and new OSH risks found in different situations and combinations within green jobs. This would facilitate the transfer of existing OSH knowledge to green technologies, and the development of job specific risk assessment for green jobs, as well as identifying OSH training needs.
- In-depth analysis of methods is needed which can be used to identify current and future OSH skills needs at all levels within green jobs.
- Develop new toxicity research methods that support speed-to-market practices, and make it available quickly to apply to green technologies as they develop.
- More toxicological and epidemiological research is needed to assess health risks from occupational exposures to multiple substances and to new materials e.g. development of job-exposure matrices. This needs to be considered for the life cycle of new green technologies (cradle-to-cradle).
- Research is needed on occupational risks related to waste management in general, including collection, transport, and disposal and processing of waste and in particular on OSH risks of landfill mining, processing of bio-waste and waste to waste technologies. Investigate better exposure assessment (job hazard analysis) through improved research methodologies.
- The long-term health implications from exposure to biological agents in these new technologies needs to be studied e.g. risks from green construction materials, bio-energy or in waste management.

8.2 Information and communication technology

Smart growth means strengthening knowledge and innovation as drivers of the EU's future growth (European Commission, 2010a). This involves making full use of information and communication technologies (ICT) and ensuring that innovative ideas can be turned into new products and services that stimulate growth, create high-quality jobs and help address European and global societal challenges. The European Commission recognises that ICT can play a greater role in supporting sustainable growth. Significant EU funds have therefore been dedicated to driving research and development in this area. The main funding instruments are the Seventh Research Framework Programme (FP7) and the Competitiveness and Innovation Framework Programme (CIP). These ICT challenges are addressed by various flagship initiatives such as 'Innovation Union', 'A Digital Agenda for Europe' and 'An Agenda for new skills and jobs', all of which are detailed within the Europe 2020 strategy.

Deep transformations are under way in our society. These are both driven and supported by ICT innovations. New enabling technologies and applications are emerging that have the potential to promote cultural understanding between citizens, seed innovation in institutions and create competitive advantage for businesses in the future. These innovations include (European Commission, 2013):

- **Advanced interfaces**, such as touch screens, which have already transformed how businesses and consumers interface with technology.

- Developing **more intelligent and smart environments**, for example making use of adaptive, learning, cognitive and bio-inspired systems as well as distributed and embedded control and sensing. This is an important avenue for the medium- to long-term development of ICT.

These novel technologies will continue to play an important role in providing **responses to major societal challenges** such as an ageing population, health and social care, sustainable energy, education and security. These developments will have an influence on policies and drive economic, societal and cultural development for decades to come.

New ICT innovations that are based on recent technological advancements are rapidly being transformed into jobs and growth for the benefit of Europe's citizens, businesses, industry and governments. The implementation of these new technologies involves some changes of familiar working environments and working conditions. Often these changes can have a positive effect for workers in terms of improved quality of work; however, these same changes and demands can also lead to the emergence of new hazards (Eurofound, 2008b). The application of new technologies in industry usually takes place before there is a good understanding of their effects on health and safety. With little knowledge available on OSH risks related to new ICT's and with the expectancy that exposure to risks will increase with the development of new technologies, it is a priority for the respective risks of new technical solutions to be considered at the design stage — these new risks must be continually assessed to allow them to be controlled and to ensure that people can work productively and safely. Impact assessments on the application of any new technology in terms of OSH need to be carried out to ensure that new technologies and products are safe.

8.2.1 Opportunities and risks of new ICTs in the world of work

Over the past 20 years there has been a significant increase in the use of ICT at work (Eurofound, 2012b), and it is expected that the development of new ICTs, such as **ambient intelligence (AmI)**, will continue rapidly in all sectors. AmI refers to the extension of living and working environment with so-called intelligent functions that are ubiquitous and adapt unobtrusively to the needs and tasks of the user. Therefore, these systems are typically structured in a decentralised manner as a wireless network of sensors, actuators and computer processors, including RFID (radio frequency identification) and HUDs (head-up displays), that are integrated into intelligent homes, health care in hospitals or homes for the elderly, intelligent classrooms and offices. In addition to these intensively investigated and developed applications, AmI is also considered a suitable technology for developing intelligent workplaces. The objective is to enhance efficiency, well-being and health in both working and personal lives by means of technology.

ICT has a positive impact on the quality of jobs — particularly in terms of increased responsibilities, adaptable skills, new forms of work organisation, and additional opportunities for flexibility and work–life balance. However, it is the **ICT-related changes in the world** of work rather than the technology itself that brings about not only great opportunities but also a certain number of health and safety risks (European Commission, 2002). Those include, among others, stress symptoms due to excessive working hours, workload and increasing complexity of tasks, information overload and difficulty of distinguishing significant and insignificant information, stress of continuous up skilling, less face-to-face contact as humans are replaced by virtual contacts, and physical impairments such as repetitive strain injuries and other MSDs due to inadequate or ergonomically unadapted equipment and/or forced postures. Mobile and virtual offices, teleworking and social virtualisation represent specific cases of more flexible workplaces enabled by ICT-driven flexibility (PEROSH, 2009). These may have positive implications in well-being and confer workers with more control over their working day, as well as remove barriers to mobility, for example for people in remote areas or with disabilities. This flexibility may, however, also lead to higher demands for workers no longer restricted to 'normal' working hours or the company premises, and this could jeopardise the work–life balance of families (see also section 7.2). According to the fifth European Working Conditions Survey (Eurofound, 2012b), a quarter of European workers are so-called 'e-nomads' who do not work all their time at their employer's or their own business premises and habitually use computers, the Internet or email for professional purposes. On average, e-nomads were found to work longer hours, more often on Sundays and more often in the evenings than other workers. Furthermore, e-nomads experience changes in their working schedules more often than others; almost 24 % of e-nomads reported having changes to their work schedule the day before or the same day compared with around 15 % of others.

An example of ICT development is ambient-assisted working (AAW), which provides a flexible approach towards workplace adaptation for all, including people with disabilities and older people in the workforce. OSH research should pay close attention to the **usage and usability of this ICT** for people with various skill levels, physiological states and cognitive abilities (EN ISO 9241-–171:2008; EN ISO 9241-–20:2009; ISO/IEC 10779:2008). In particular, the ageing workforce, immigrants and employees with disabilities should be carefully considered. A systematic ergonomic approach should ensure that ICT and AmI are accessible for all. For instance, several cognitive variables are known to display age-related effects after 45 years of age, but this age-related decline in cognitive performance can be compensated in several ways, such as applying visual and cognitive ergonomics and the ergonomics of working hours (Kalakoski et al., 2007). Owing to the increasing cognitive demands of modern work, occupational health services need novel methods for assessing the slight variations in cognitive capacity that a traditional physiological test would fail to capture.

There have been only a few studies intended to estimate the effects of these new forms of ICT on end users, and hardly any on OSH-relevant issues. The rapid emergence and development of new technologies has raised some concrete research questions. Their impact on work organisation, in terms of performance, flexibility and workflow, has to be investigated. The degree of ambient intelligence-based safety devices in comparison with conventional solutions also has to be studied. Another important issue is the resilience of those new devices to manipulation. ICT has the potential to deal with existing and well-documented OSH issues such as real-time monitoring of workplace parameters, but it can also bring about new hazards and risks and throw into doubt known solutions, so the consequences of these new technologies on users and workplace design will have to be investigated (EU-OSHA, 2012d). For all of the above reasons, ICT has been recognised as a priority research area in the field of OSH, with a focus on technology assessment on the risks of these new ICTs in the world of work and their impact on working systems (PEROSH, 2012).

Even with the changing world of work and the emergence of new hazards and risks, traditional industrial working environments still exist and there are no signs that traditional work-related accidents and physical risks will vanish in the near future. For instance, exposure to physical risks, such as noise, vibration, high and low temperatures, chemical substances, tiring and painful positions, heavy loads and repetitive hand or arm movements has not diminished much in European workplaces in the last 20 years (Eurofound, 2012b). In fact, reported levels of exposure to some of these risks have even risen. We have already considered how the implementation of new technologies can result in new hazards and risks, but, on the other hand, new technologies can also offer opportunities for new and advanced solutions for existing OSH issues.

New sensor technologies offer opportunities to improve safety and health in the workplace, for example through the use of real-time monitoring of different environmental parameters to which workers are exposed, such as noise, radiation, chemical substances and temperature. **Development of adaptive/wearable measurement sensors** and displays, such as a shirt equipped with wireless, machine-washable textile sensors for real-time electrocardiography monitoring (e.g. CorusFit, Jyväskylä, Finland), also offers great potential for monitoring workers' physiological parameters (body temperature, heart rate, etc.) during various tasks and in different working environments. Furthermore, the combined evaluation of actual OSH risks to which workers are exposed and individual responses may be used to develop tailored solutions for different workplaces for improving OSH. As an example, a protective clothing system is currently being developed in which sensors will be integrated into outer garments and underwear in standard textile manufacturing processes for monitoring environmental and physiological parameters of personnel operating in high-risk and complex environments, such as fire fighters (European project i-Protect).. In general, owing to the recent advances in sensor technology, the sensor-based monitoring of a person's health and well-being has become a rapidly progressing research area.

8.2.2 OSH view in designing the new technology applications

As emphasised in the previous report on priorities for OSH research conducted by EU-OSHA (2005), there is still a need for an assessment and intervention methods and research into the principles of good design for new technology such as multiscreen workplaces, non-keyboard input devices, touch and touchless input and the use of handheld computers and smartphones. For example, their installation in vehicles could pose a risk of distraction. Furthermore, more intelligent but also more complex human–machine interfaces are being introduced into workplaces, and this will require **embedding of OSH into their design**; a poor ergonomic design of those kinds of interfaces can increase workers' mental and emotional strains, and thus increase the probability of human errors and accidents at work (Reinert et al., 2007; European Commission, 2010e).

Mobile IT-supported work is considered difficult to design and regulate with the aid of conventional OSH approaches. This is because many aspects of work that are fixed in traditional work settings become variable within mobile IT-supported work situations. OSH principles and measures based on such factors are thus no longer applicable within this new setting. In this way, mobile IT-supported work confronts corporate **OSH management** with new challenges. Many of the factors relevant for the OSH of mobile IT-supported workers are associated with organisation and processes. OSH management must, therefore, adopt an approach that will ensure compliance with the legal restrictions and OSH regulations. **It should encourage a more holistic approach in cooperation with other organisational management disciplines.** This seems to be a key factor for the successful application of OSH management in the mobile IT-supported work sector, and thus for the overall health of individuals at work.

Automation and the use of robotics in the workplace will continue to increase in the future. These technologies should make workplaces safer, for example by decreasing workers' exposure to physical and chemical risks. This can be achieved by creating more distance between the worker and the machinery, materials or products, as well as reducing the possibility for human error, for example by replacing humans with computers and automated systems. However, there may be risks of human–machine collisions, as in cases where personnel may have to enter robot work zones to carry out, for example, repair, programming or maintenance tasks, and hence be exposed to trapping points and crushing, shearing and impact injury risks. Risks may also arise from over-reliance on new technology.

New modelling and simulation methods and other three-dimensional visualisation techniques may be used to improve the performance of systems and the safe design of new processes and equipment. The **enhanced use of virtual and augmented reality applications** for designing safe new technologies and workplaces should be developed further.

Priorities for OSH research related to ICTs

- Explore the possibility of using AmI-based solutions for creating tailored support systems to adjust workplaces (ambient assisted working following the model of ambient assisted living), identifying the impact that usage and usability could have on older workers and on people with various skill levels, physiological states, and cognitive abilities.
- As more intelligent and more complex human-machine interfaces are being introduced into workplaces, research is required on their safe and effective use. This would include cognitive ergonomics and neuroergonomics studies for user-centred design of new ICT applications with particular focus on the needs of specific worker groups such as disabled, maintenance workers or migrant workers.
- Further research is needed on OSH relevant to (mobile) IT-supported work, such as mental workload, decision making, skilled performance, permanent accessibility, work-life balance and human computer interactions.

8.3 Risks regarding exposure to electromagnetic fields

Europe's workers are facing the burden of occupational exposures to many new physical or chemical agents, some of which may be potentially detrimental to their health or well-being. Among these agents, electromagnetic fields (EMF) are one of the most diffuse and ubiquitous, especially as many new technologies and novel applications based on EMF are being developed. Although most of EMF sources at work will produce field strengths that can be considered harmless, there are other devices such as high-field magnetic resonance imaging (MRI) scanners or activities such as arc welding that will expose a large population of workers (mainly industrial workers and health care staff) to EMF's exposure levels that could lead to health effects. These workers exposure characteristics (strength of exposure and interaction with the body) are significantly different from that of the general public, since they will be exposed to higher levels for longer periods of time, will be considerably closer to the source, and the modulation (frequency composition) of EMF will be more complex. In addition there are also synergistic effects due to simultaneous exposure to various biological, chemical, and physical agents that need to be considered.

In order to establish minimum EMF safety standards common across the EU, the EMF Directive (Directive 2004/40/EC), dealing with health and safety at work was adopted in 2004. The directive addresses the **protection of workers** exposed to electromagnetic fields and the carrying out of effective and efficient **risk assessments**, proportional to the situation encountered at the workplace. Member States originally had until 30 April 2008 to implement the directive into domestic law, but concerns were raised that it contained disproportionate requirements and was overly burdensome. As a result, the European Commission published a new proposal for an EMF Directive (European Commission, 2011d) to replace the original. The aim of this new directive is to:

- update the text to take on board new scientific evidence, particularly in relation to exposure limits of MRI in hospitals;
- help employers in their efforts to carry out the risk assessments required by EU law;
- balance the protection of workers' health and safety with appropriate flexibility and proportionality, not to unduly hamper the use and development of industrial and medical activities.

The new proposal will bring forth several issues that produce a need for research. According to the proposal, the action levels for exposure (International Commission on Non-Ionizing Radiation Protection, 2010) will be different from the previous international recommendations (International Commission on Non-Ionizing Radiation Protection, 1998). This new directive is expected to be transposed into national law by all Member States by July 2016 at the latest.

In order to be able to guarantee the safe use of EMF's worker's exposure assessment should be harmonised with scientific knowledge on health effects of EMF exposure and exposure patterns in real work places. Epidemiological and experimental studies of EMF exposed groups are essential. Most epidemiological studies have relied on magnetic field measurements linked to job titles. However, job titles alone explain only a small amount of variability in exposure. Recent results indicate that magnetic field exposure assessment should consider work environment in addition to job title to reduce exposure misclassification. Some of these studies have found weak associations between exposure to power-frequency EMFs and some forms of cancer, such as leukemia; while other studies have failed to find such associations. The primary limitation with most epidemiological studies has been with the methods of exposure assessment. Research on the health effects and exposure to particular agents, field measurements, estimates of exposure and the characterisation of populations are seen as the driving forces behind EMF risk assessment.

The categories of workers who can be identified as EMF exposed are extremely varied, as is the estimation of their number, which varies from a few million to a hundred million across Europe. Owing to this lack of systematic data, there is a need to conduct **a systematic evaluation of the number of exposed workers,** as well as a characterisation of the sources emitting EMFs (European Parliament, 2008a). This information is essential for conducting epidemiological research on the **long-term effects of EMF exposure**. Furthermore, there is a lack of data on the gender and age of exposed workers. The main uncertainty and knowledge gap in both epidemiological case–control and cohort studies is related to EMF exposure assessment. The methods used so far are prone to bias, and therefore objective measures of exposure are needed to reduce uncertainty.

New technologies represent a challenge for researchers. The communication industry is introducing systems that work at radio frequencies and modulations not fully investigated (long-term evolution, WiFi, high-frequency RFID). At extremely low and intermediate frequencies (up to about 10 MHz), a continuous introduction of new devices and appliances is also modifying the exposure scenario, and workers are being exposed to frequencies and harmonics not yet investigated (European Commission, 2011c).

The extensive use of wireless networks provides many opportunities for worldwide networking, but it also increases exposure to EMFs. Over the last few years, there has been mounting concern over the possibility of adverse health effects resulting from exposure to radiofrequency EMFs, such as those emitted by wireless communication devices. Recent studies on mobile phone exposure have shown that EMFs may have an effect on the brain's metabolism (Kwon et al., 2011; Volkow et al., 2011). Also, WHO, with the International Agency for Research on Cancer, has classified mobile phone radiation as possibly carcinogenic to humans (Group 2B), meaning that there could be some risk of carcinogenicity (Baan et al., 2011; IARC, in press), whereas the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) has concluded that exposure to radiofrequency fields is unlikely to lead to an increase in cancer among humans (SCENIHR, 2009a). However, it was noted that, as the widespread duration of exposure of humans to radiofrequency fields from mobile phones is shorter than the induction time of some cancers, further studies are required to identify whether considerably longer term (well beyond 10 years) human exposure to such phones might pose a cancer risk.

Regarding non-carcinogenic effects of exposure to radiofrequency EMFs, several studies have been performed on subjects reporting subjective symptoms. The symptoms most commonly experienced include dermatological symptoms (redness, tingling, and burning sensations) as well as neurasthenic and vegetative symptoms (fatigue, tiredness, concentration difficulties, dizziness, nausea, heart palpitation, and digestive disturbances). The collection of symptoms is not part of any recognized syndrome. This reputed sensitivity to EMF had been generally termed "electromagnetic hypersensitivity" or EHS. EHS is characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification (WHO, 2005). Since the health relevance is uncertain and mechanistic explanation is lacking, further investigation of these effects is needed,

Occupational **exposure to the intermediate-frequency range of EMFs** is rapidly increasing as a result of the expanding use of appliances emitting frequencies between 300 Hz and 100 kHz, such as antitheft devices, radiofrequency identification devices (RFID) and induction hobs. Experimental and epidemiological data from intermediate-frequency EMFs are very sparse (European Parliament, 2008a). Therefore, the assessment of acute health risks in this range is currently based on known hazards at lower and higher frequencies. Explicit data on the possible health effects of intermediate-frequency fields remain limited, and therefore further studies should be performed to address the lack of research data (SCENIHR, 2009b). Proper evaluation and assessment of possible health effects from long-term exposure to intermediate-frequency fields are especially important because workers are being increasingly exposed to such fields.

In the medical community, new health risks may be associated with the **increasing use of MRI** for diagnostics and therapy. At the moment, static magnetic fields with flux density of 1.5–3 teslas (T) are commonly used in MRI procedures. As a result, workers operating with MRI scanners belong to one of the groups most exposed to EMFs. Furthermore, MRI scanners of higher fields (up to 9 T) are currently under intensive preclinical investigations, leading to potentially even higher occupational exposures. Hence, research is needed to assess exposure and health risks arising from MRI scanners, and topics should include static and gradient magnetic fields, with a focus on workers (e.g. medical staff, technicians and cleaners) moving in the area of spatially heterogeneous fields.

Research is also needed on the evaluation of health effects related to new EMF components of working environments including **terahertz (THz) technology**, which exploits the region of the electromagnetic spectrum between the infrared and microwave frequency ranges. THz technology is growing rapidly and is being used in an increasingly wide variety of applications such as ICT, biological and medical sciences, non-destructive testing and security (Tonouchi, 2007). At present, workers exposed to THz radiation work mainly in universities and research establishments, where THz sources are being investigated and developed, but new emerging applications, especially in the fields of security and telecommunications, may increase the exposure of many more workers to THz radiation, for example during manufacturing, testing and installation of the next generation of whole-body security image scanners. There is also a need to conduct research on the risk assessment of new frequencies, develop measures to prevent harm and undertake risk communication related to the growing use of EMF-emitting appliances.

The EMF Directive identifies specific group of workers at particular risk from EMF at work (e.g. persons with medical implants, pregnant workers etc.) and requires them to be taken into account during the risk assessment. According to a recent study, in most cases workers can return to work after the implantation of a pacemaker, but an appropriate risk assessment is needed (Tiikkaja et al., 2012). Similarly, a risk assessment for pregnant workers is needed, although at the moment there is no common approach in Europe (European Parliament, 2008a). Research and a common EU approaches are also needed for medical checks when overexposure to EMF is suspected. Generally, there are no **tools for workplaces to manage workers at particular risk**.

Risk communication on the health effects of EMF is also an area of research that needs to be considered. According to the Eurobarometer 2010 (European Commission, 2010f), nearly half of respondents felt that the EU should inform people of any potential health risks.

Priorities for OSH research related to EMFs

- Systematic evaluation of the number of workers in Europe exposed to EMF as well as characterisation of the sources they are exposed to.
- Research is needed on the long-term health effects of occupational EMF exposures.
- Research is needed to identify better exposure assessments, which are crucial for the evaluation of exposure conditions of workers. A better understanding of real exposure is needed for: informing future experimental settings, designing more conclusive epidemiological studies and adequate risk assessment are key requirements of scientific studies on biological effects of EMFs.
- Research on assessing EMF exposure of workers at particular risk (e.g. persons with medical implants, pregnant workers) is needed.
- Development of accurate and reliable dosimetry and exposure assessment are key requirements of scientific studies on biological effects of electromagnetic fields.
- Exposure to IF fields such as such anti-theft devices or welding and their possible health effects should be studied as there are only a limited number of investigations into IF field exposures.
- Research on the exposure to ELF fields and their possible health effects is needed since the biological cause-effect relationship between ELF magnetic fields and disease causation is not understood.
- More research is needed on the health effect of static fields, including possible health effects from chronic short term exposure to several Teslas.
- Research into non-specific effects (cognitive and sensory functions, sleep disturbance etc.) of radio-frequency fields to gain a better understanding of mechanistic explanation.

8.4 Occupational hazards of biotechnology

The Europe 2020 strategy (European Commission, 2010a) calls for a bioeconomy as a key element for smart and green growth in Europe. To remain competitive, the EU needs to become a low-carbon society in which resource-efficient industries, bio-based products and bioenergy all contribute to green growth and competitiveness (European Commission, 2012c). Moreover, in 2009, the EU identified KETs for their potential impact in strengthening Europe's industrial and innovation capacity (European Commission, 2009a). In particular, KETs were recognised as exhibiting a vital role in addressing grand societal challenges and achieving three priorities: smart, sustainable and inclusive growth. KETs underpin innovation in many strategic sectors and contribute to the creation of a more productive, competitive and energy- and resource-efficient economy; products with enhanced features have the potential to carry a high economic value, as well as ensuring a more comfortable, healthy and safe life for European consumers and workers in a clean environment (European Commission, 2011e). In its 2009 communication (European Commission, 2009a), the European Commission selected six KETs for Europe after a screening of many high-technology areas and strategies at the Member State level, with industrial biotechnology being one of those sectors.

Biotechnology is defined by OECD as the application of science and technology to living organisms (e.g. enzymes and micro-organisms), as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, good and services. This implies the integration of a variety of biological sciences with chemical and process engineering in a way that optimises the biological system. Biotechnology is used in sectors such as chemistry, food and feed, paper and pulp, textiles and energy. As an example, instead of using high-temperature, energy-intensive processes involving chemical catalysts, biotechnology can achieve the same or even better results by using biological catalysts (enzymes) that operate at lower temperatures.

Modern biotechnology provides breakthrough products and technologies to combat debilitating and rare diseases, reduce our environmental footprint, feed the hungry, use less and cleaner energy, and have safer, cleaner and more efficient industrial manufacturing processes.

Medical examples: Biotechnology is helping to heal the world by harnessing nature's own toolbox and using our own genetic make-up to heal and guide lines of research by:

- reducing the incidence of infectious disease;
- changing the odds of serious, life-threatening conditions affecting millions around the world;
- tailoring treatments to individuals to minimise health risks and side-effects;
- creating more precise tools for disease detection; and
- combating serious illnesses and everyday threats confronting the developing world.

Fuel examples: Biotechnology uses biological processes such as fermentation and harnesses biocatalysts such as enzymes, yeast and other microbes to become microscopic manufacturing plants. Biotechnology is helping to fuel the world by:

- streamlining the steps in chemical manufacturing processes by 80 % or more;
- improving manufacturing process efficiency to save 50 % or more on operating costs;
- reducing the use of and reliance on petrochemicals;
- using biofuels to cut greenhouse gas emissions by 52 % or more;
- decreasing water usage and waste generation; and
- tapping into the full potential of traditional biomass waste products (Biotechnology Industry Organisation).

It has been estimated that, in the biotechnological sector, the value of biochemicals (other than pharmaceuticals) will increase from 1.8 % of all chemical production in 2005 to between 12 % and 20 % by 2015 (OECD, 2009).

The exploitation of biotechnology has the potential to improve OSH through decreased exposure to hazardous chemicals by replacing them with biochemicals. However, this is a recognised high growth sector and there are other OSH impacts that have received little study until now.

There are gaps in the knowledge, and hence a need for new research (see section 9.5 for details). There are no peer-reviewed data concerning populations in biotechnology, even though there is concern that the number of non-microbiologists engaged in biotechnology activities is increasing and they are not sufficiently trained to take the necessary precautions. Individual site populations are too small, the movement of trained personnel from employer to employer is too rapid and the enthusiasm of scientist-entrepreneurs for non-product research is too small to have encouraged any systematic looks at health outcomes among biotechnologists (Ducatman et al., 2001). In order to be able to understand the potential occupational hazards and risks present in biotechnology and set limit values for exposure to biological agents, better and more **comprehensive toxicological data and epidemiological studies** will be needed, together with specific research concerning the establishment of dose–response relationships. Infectious diseases have not yet proven an especially important epidemiological problem; however, the introduction of more dangerous research organisms is likely to change this.

Appropriate tools to perform **risk assessments of biological agents** also need to be developed for the industrialised biotechnological sector. Moreover, the risks of exposure to enzymes and the micro-organisms utilised in conventional industrial plants need to be assessed and appropriate preventative methods developed and, when applicable, the efficacy of existing prevention measures established. Another factor to take into consideration is that biotechnologies are used in many sectors that do not necessarily involve the handling of living organisms and still do not have suitable approaches for assessing the risks involved with those new technologies.

Priorities for OSH research related to biotechnology

- In order to fill the gaps in knowledge, a better understanding of activities, associated hazards, (including biological, chemical and physical hazards and including production scale-up), and exposures is needed, for example OSH risks in production, processing and use of biofuels.
- Further toxicological and epidemiological research into topics such as occupational exposure to the biological agents being utilized in the biotechnological sector needs to be carried out.
- As a result of the increasing use of biotechnologies in the industrial sector, there is a need to develop tools for risk assessment and prevention measures. The development of medical surveillance programs are also needed for the collection and use of medical information, biological monitoring, medical screening, or other health data for developing strategies for the prevention of disease

9 Research into new or increasing occupational exposure to chemical and biological agents for the benefit of a smart and sustainable economy

The priorities and innovations suggested in the **Europe 2020 strategy** will assist Europe to 'make up for the recent losses, regain competitiveness, boost productivity and put the EU on an upward path of prosperity ("sustainable recovery") (European Commission, 2010a). The development of innovative products and materials (fostered by one of the strategy's flagship initiatives, Innovation Union) and the shift towards a resource-efficient, low-carbon economy (supported by another flagship initiative, Resource-efficient Europe) that will lead to new (energy) technologies or to the rapid growth of the waste management industry will bring about new challenges for OSH that will need to be addressed. These will include new or increased exposures to **biological** and **chemical agents,** the exposure to **new technologies such as nanotechnology** and the combined or **mixed exposures to dangerous substances**. Such 'new exposures' (e.g. in the waste and recycling industry or of multifactorial origins) are also referred to by the Advisory Committee on Safety and Health at Work in connection with WRDs arising from them. Such diseases and their prevention should therefore be a core concern of a new European strategy on OSH, according to the Committee (European Commission and the Advisory Committee on Safety and Health at Work, 2011).

The burden of **work-related ill health** is still high in terms of human suffering and economic loss. No less than 8.6 % of the workers in the EU — 23 million people — reported a work-related health problem in 2007 (Eurostat, European Commission, 2010a, 2011f). Every year around 320,000 workers die worldwide as a result of communicable diseases caused by biological hazards, with some 5 000 casualties in the EU (EU-OSHA, 2007). As stated by EU-OSHA, 'Of the estimated 167,000 work-related fatalities occurring annually in the EU-27, 159,000 are attributed to work-related diseases with nearly 100,000 being cancers. Almost half of these work-related diseases (74,000) are estimated to be due to exposure to hazardous substances at work' (EU-OSHA, 2008b). The number of work-related diseases is considerably higher than the number of accidents.

Work-related diseases (WRDs) include occupational diseases and those diseases caused at least partly by occupational exposures. In many countries not all WRDs are included in official definitions of occupational disease, which specify a causal association between disease, exposure and work. According to the 2002 Protocol to the Occupational Safety and Health Convention, 1981 (No. 155), the term 'occupational disease' covers any disease contracted as a result of an exposure to risk factors arising from work activity (ILO, 2010). Two main elements are present in the definition of occupational diseases:

- the exposure–effect relationship between a specific working environment and/or activity and a specific disease effect; and
- the fact that these diseases occur among the group of persons concerned with a frequency above the average morbidity of the rest of the population.

In the fourth edition of the ILO's Encyclopaedia of Occupational Health and Safety, a distinction is made between pathological conditions that could affect workers due to occupation (occupational diseases) and diseases aggravated by work or having a higher incidence owing to conditions of work (work-related diseases). These two are separated from conditions having no connection with work. However, in some countries work-related diseases are treated the same as work-caused diseases, which are in fact occupational diseases. It is not always easy to designate a disease as work related. In fact, there is a wide range of diseases that could be related in one way or another to an occupation or working conditions. On the one hand, there are the classic diseases that are occupational in nature, generally related to one causal agent and relatively easy to identify. On the other hand, there are all sorts of disorders without strong or specific connections to occupations and with numerous possible causal agents, and this makes the collection of accurate data difficult. WRDs are estimated to be a much bigger problem than official occupational disease data show.

The EU has taken considerable action to protect workers from risks linked to exposure to dangerous substances in the workplace. The implementation of the Registration, Evaluation, Authorisation and Restriction of Chemicals (**REACH**) Regulation (Regulation (EC) No 1907/2006, 2007), which became effective in 2007, aims to ensure 'a high level of protection of human health and the environment as well as the free movement of substances, on their own, in preparations and in articles, while enhancing competitiveness and innovation. This regulation also promotes the development of alternative methods for the assessment of hazards for substances'. The registration process requires the industry to prove the **safe use** of chemicals and to hand down information on safe usage to manufacturers, workers and citizens. REACH also calls for the progressive substitution of the most dangerous chemicals when suitable alternatives have been identified. Additionally, the United Nations has created a globally harmonised system of classification and labelling of chemicals (GHS) to identify hazardous chemicals and to inform users about these hazards through standard symbols and phrases on the packaging labels (United Nations, 2005). The EU Regulation on classification, labelling and packaging ('CLP Regulation') contributes to the GHS aim that hazards will be described and labelled in the same way all around the world. The European Commission has also proposed to **amend five existing EU health and safety directives** on the protection of workers from exposure to harmful chemicals to align them with the latest rules on classification, labelling and packaging of chemicals (Regulation (EC) 1272/2008).

At an international level, it has been recognised that sound **management of dangerous substances** (including chemicals, biological agents and nanomaterials) is needed in order to guarantee sustainable development that seeks to maximise the benefits of these dangerous substances and minimise the negative impacts throughout their life cycles.

With regard to exposure to hazardous chemical and biological agents, there are diverse framework conditions that affect priority setting for future research:

1. **More innovation and more resource efficiency and green thinking**, as required by the Europe 2020 strategy, aiming to foster economic growth and thus the competitiveness of European economies against the background of progressing globalisation and the recent financial crisis.
   Resulting from this is a number of developments that could strongly impact on OSH: **new materials** (e.g. nanomaterials), **innovative technologies** (e.g. use of alternative energy sources) and increased **waste management and recycling activities**, potentially leading to new or increased exposure to hazardous substances and/or biological agents and/or multifactorial exposure.
2. A strong vote for **sustainability** (European Commission, 2010a), expressing the endeavour to live safely and in a healthy environment in the broadest sense of the term. As stated by the European Commission (2011f), 'a sustainable working life is characterised by (…) healthy (…) workplaces', including the protection from exposure to hazardous substances and the prevention of WRDs.
3. The current **economic and budgetary context**, which urges policy makers to 'focus on the core aspects of health and safety at work', and thus optimise the use of resources, as the employers' group puts it in the annex to the Mid-term review of the European strategy 2007–2012 on health and safety at work (European Commission, 2011f).

Considering all of these aspects, future research into hazardous chemical or microbiological exposure is essential.

9.1 Carcinogenic, mutagenic, reprotoxic (CMR) and sensitising substances

Despite greater international and national regulations for the management of chemicals, the use of new substances that may be carcinogenic, mutagenic, allergenic, or sensitising continues to be of major concern. In the last 20 years there has been enormous growth in the number of industrial chemicals, many of which have not been adequately tested. The impracticability of systematically testing all new materials means that many risks may go undetected until there is a demonstrable threat to human health or the environment. There are many examples of the impact of known mixed exposures, for example multiple pesticides, diesel fumes and other fuels, and mixed solvents. A major gap remains in our understanding of the potential impact of mixed chemical exposures and how they may interact with non-work exposure, such as cigarette smoking (ILO, 2011). There are implications for manufacturers and suppliers, as well as governments and their social partners, for the sound management of chemicals at work. Research into the safe use of chemicals is vital, especially for new products, as is adequate information and labelling concerning safe usage. International collaboration is also needed to ensure concerted efforts to manage chemicals in the global marketplace.

In 2012, the European Chemical Agency (ECHA) received information from the first REACH registration deadline and the CLP notification deadline, which together should cover all the existing hazardous substances in the EU market (ECHA, 2012). This was the first opportunity to observe which CMR substances had been registered and/or notified as being placed on the market. A raw data analysis was conducted on more than 25 000 registration dossiers and 3.5 million CLP notification records that had been matched with the EC and CAS number of around 1 100 individually identified CMR substances listed in Annex VI of the CLP Regulation. This provisional comparison revealed that 60 % of the substances have been either registered under the REACH Regulation or notified to the Classification & Labelling (C&L) Inventory under the CLP Regulation. For approximately 40 % of the substances, no match could be found. There is a variety of potential reasons for the 40 % of CMRs without a match. For example, some substances on Annex VI are very rare and unlikely to be on the market. Others have been substituted by less hazardous substances. The ECHA is planning to further analyse some information gaps highlighted by this report. The new analysis will focus on those substances that industry has self-classified as CMRs but which nevertheless have not been included on Annex VI to the CLP Regulation. It is important to stress that REACH does not cover all carcinogenic and mutagenic substances in workplaces and that REACH-registered carcinogens caused only a fraction of the known occupational cancers.

Taking the REACH legislation into account, the European Commission is currently working on a revision of the directive on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Council Directive 2004/37/EC, 2004) that will broaden the scope of this directive. The inclusion of carcinogenic substances that emerge unintentionally during work processes (for example diesel exhaust emissions, respirable crystalline silica, wood dust or welding fumes), and are not intended for sale and distribution (i.e. not included in CLP or fall under REACH) have has been discussed. The risk of these substances needs to be addressed by research, monitoring and prevention. The inclusion of reprotoxic and mutagenic substances and the introduction of additional occupational exposure limits (**OELs**) for CMRs are also being considered.

Considering the vast number of chemicals in use today and their broad range of application, it is obvious that **exposure to CMR and sensitising substances** occurs not only in the chemical industry, but also in various other occupations. The waste and recycling industry, for example, will have to deal with increasing chemical exposures due to the treatment of novel types of waste (e.g. brominated fire retardants, which may lead to reproductive system effects or cancer), as well as potential exposure to increased levels of recycling of substances that were formerly sent to landfills (EU-OSHA, 2011c). The **'greening' of industrial products and processes** will bring about new types of chemicals and/or growing workforce populations exposed to new and known hazardous substances, as, for instance, in the case of exposure to lithium as a result of an increasing number of electric cars (Enderlein et al., 2012) or the exposure to sensitising substances in the waste industry. Additionally, new substances, new combinations of substances and new technologies have to be accounted for as a consequence of the high speed of innovation and the urgent need to counterbalance shortages in raw material by developing substitution materials. Even though the REACH Regulation places greater responsibility on industry to manage the risks from chemicals and provide safety information on the substances to allow their safe handling, further sound scientific and health-related information is still needed.

Substitution is always the preferred solution to minimise exposure to hazardous substances. The increase in occupational and scientific concern on OSH problems associated with the handling of chemicals and the implementation of REACH has contributed to more research focusing on the substitution of chemicals. The practical implementation of substitution has shown that it can be a complex process. Implementation is often disregarded and can be difficult in practice. Also, in order to avoid shifts of risks, all areas of potential risk have to be assessed and a comparison of levels and types of hazard factors is necessary. For this purpose, the **methods of risk quantification** have to be refined and harmonised and improved **quantitative data** are required. The experiences from large substitution projects could help scope future actions and decision making.

9.1.1 CMR substances

Occupational CMR substances are a major cause of concern not only because of the serious health effects on individual workers, but also because of the economic impact on businesses and the social costs to European countries. For example, one occupational death from cancer costs an average of EUR 2.14 million and the total cost of occupational deaths from cancer across the EU is over EUR 70 billion per year (EU-OSHA, 2008b).

Since 2009 carcinogenic substances are classified into two categories according to the Regulation on Classification, Labelling and Packaging of Substances and Mixtures (**CLP**), (United Nations, 2005; Regulation (EC) Nos 1272/2008 and 1999/45 and amending Regulation (EC) No 1907/2006, 2008). Category 1 includes known or presumed human carcinogens and is divided into two subcategories: category 1A, 'known to have carcinogenic potential for humans, classification is largely based on human evidence'; and category 1B, 'presumed to have carcinogenic potential for humans, classification is largely based on animal evidence'. Category 2 contains 'suspected human carcinogens' (Regulation (EC) Nos 1272/2008 and 1999/45 and amending Regulation (EC) No 1907/2006, 2008).

Work-related cancer continues to be one of the major sources of work-related fatalities. In 2007, WHO estimated that at least 152 000 cancer deaths each year were due to occupational cancers. Approximately 3–11 % of all **cancer deaths**, and an even higher proportion of cancer cases, are caused by **occupational carcinogens** (Fritschi and Driscoll, 2006; Rushton, 2009). Diesel exhaust is the fourth most common carcinogen found in the workplace. Another example is man-made mineral fibres, which are continuously evolving materials. The inhalation of fibrous structures fosters inflammatory, cytotoxic and carcinogenic processes in the human organism. For Great Britain, Rushton et al. (2008) found that 8 % of deaths from six types of cancers in men and 2.3 % in women were attributable to work, which corresponds to around 8 000 deaths each year, more than 30 times more than fatal work-related accidents in the years 2005/06. For the predicted future burden of cancer, Rushton et al. (2008) estimate that work-related cancer deaths will increase from 8 023 in 2005 to nearly 13 000 by 2060 given current trends in employment and exposure levels, if current exposure levels are maintained. No impact will be seen until 2030 because of a general increase in cancers as a result of the ageing population. With modest intervention, over 2 000 cancers can be avoided by 2060, and with stronger intervention nearly 8 500 can be avoided by 2060. Given that most occupational cancers are considered preventable (Clapp et al., 2005–2007; Cherrie, 2009), the need for further research in the **prevention of occupational cancers** is evident.

In order to reduce occupational cancers a detailed and scientifically sound registration of the risk factors leading to occupational cancers is required. Research efforts estimating the burden of disease and building on the links between occupations and exposures are very helpful for setting priorities for prevention and disease recognition. However, more research is needed on new ways of identifying carcinogens, strengthening epidemiological research and improving risk assessment methodologies. Biological monitoring of workers should be fostered (Gil and Pla, 2001). **Biomonitoring** has advantages over environmental monitoring because it covers the internal dose of a compound, the toxic effect or the individual susceptibility to environmental chemical compounds. In most cases a risk-related OEL for **carcinogens** can be derived if appropriate quantitative data are available and if there is socio-political consensus about acceptable risk levels. With sufficient information on the **specific mode of action** of a substance it would be possible to have **toxicological threshold**. This would allow the **derivation of safe exposure levels**, which would contribute to improved protection of workers.

Research, interventions and recognition of work-related cancers also need to consider changes in the world of work (e.g. increase in subcontracting, temporary work, multiple jobs, working at a client's premises with limited possibilities for adaptation, increasingly static work, moving from industry to service sectors, increasing female employment in exposed occupations, night-time and shift work, multiple exposures).

In addition, more comprehensive **international exposure data** determining the type of carcinogenic substances in use, the line of industry where exposures occurs, vulnerable groups of workers, the extent of exposure and the part of the workforce concerned need to be collected. The methodology and use of job exposure matrices should be further developed to identify exposure risks in the working environment. It is important to consider that more workers are increasingly exposed to dangerous substances such as CMRs as the increasing unemployment rate pushes them to accept low-quality jobs.

A broader view on the causes of work-related cancer also is needed. Life-style factors such as obesity, tobacco smoking, alcohol use, etc are not solely personal, but can also be determined by the living and working environment (e.g. economic insecurity, access to healthy food and facilities, easy access to alcoholic beverages at work, the way work is organised). The common practices and attitudes towards safety in an enterprise or industrial sector may also have an influence.

With better medical treatments cancer has become a more chronic condition. However, only few targeted rehabilitation and return-to work strategies currently exist, and these have been originally developed for a number of other work-related health conditions (e.g. musculoskeletal disorders). Interventions to address return to work problems could benefit from experiences that have shown to work effectively. The first days after the return to work are crucial, so enterprises should be prepared to adapt working conditions to the specific conditions from an early stage.

Lack of research and exposure data is also a shortcoming associated with substances having mutagenic and reprotoxic effects. There is significant occupational health concern about the potential effects of exposure to toxic substances on reproductive outcomes. Worker exposure to reprotoxic agents and factors, such as epoxides, isocyanates, solvent mixtures, specific pharmaceuticals, endocrine disrupting chemicals, nanomaterials and stress will increase and can harm individual workers or groups of workers. This is indicated by the trends in the world of work, for example, more complex mixtures of chemicals and other agents, increased used of plastics and composite materials due to energy saving and faster production cycles, workers changing their place of work and their professional frequently, short contracts etc. The term reproductive toxicity is used for agents which cause adverse effects on sexual function and fertility in males and females, developmental toxicity in the offspring and effects on or via lactation. Therefore, reprotoxic agents may affect not only the individual or the group but may affect also their children or prevent them from having children at all, and thus endanger the future of our society. Exposure to reprotoxic substances is erroneously stigmatised as a ‘women issue’ even though they can have adverse effects on men too.

Several toxicants with reported reproductive and developmental effects are still in regular commercial or therapeutic use, and thus present potential exposure to workers. Examples of these include heavy metals, organic solvents, pesticides and herbicides, and sterilants, anaesthetic gases and anticancer drugs used in healthcare. Many other substances are suspected of producing reproductive or developmental toxicity, but lack sufficient data. Overall information on the reprotoxic effects of substances is still poor. There is a lack of data regarding substances, factors, mixtures and conditions that may have adverse effects on workers, and this leads to a lack of knowledge as to the reproductive and development toxicity of chemicals. Progress has been limited in identifying hazards (effects difficult to see and sometimes first visible in next generation), quantifying their potencies and separating the contribution of these hazards from other aetiological factors. Identifying the causative agents, mechanisms by which they act and any potential target populations, presents the opportunity to intervene and protect the reproductive health of workers. Further research on reprotoxic substances should focus on: epidemiological studies which are performed relatively infrequently and do not form part of the requirements in regulations on chemicals, the lack of testing routines and research on effects on the offspring/cross-generational effects (propensity to develop cancer, depression and allergies, behavioural changes), and the development of new testing routines for the assessment of reprotoxic substances. The importance of physical and organisational factors (prolonged sitting, lack of access to rest and toilet facilities) also needs to be studied.

Gender aspects in occupational CMR research also needs to be considered. For carcinogenic substances, studies on men are far more numerous than studies on women for this topic – many studies have focused on male dominated jobs. Most research on reproductive health has concentrated on pregnant women and foetal protection. The possible influence of working conditions on some women’s health issues, such as menstruation and the menopause, has been almost completely ignored. Research on the effects of reprotoxic substances on males is also needed.

9.1.2 Sensitising substances

The development of allergies and asthma is typically a two-step immunological process in which sensitisation is the initial step (Inter-Organization Programme for the Sound Management of Chemicals et al., 2008). The number of substances (e.g. epoxy resins or isocyanates) that are predicted to have sensitising effects on humans and the potential to cause allergies (such as contact dermatitis or allergic asthma) is steadily increasing (Muñoz-López, 2006). **Allergic diseases** have the potential to become chronic, and consequently may not only reduce people's ability to work and their quality of life, but also result in **high costs** for society (Inter-Organization Programme for the Sound Management of Chemicals et al., 2008). According to the **GHS** (United Nations, 2005), substances that are likely to cause allergies have to be classified as sensitising substances without much scope for differentiation between strong and weak sensitisers (Inter-Organization Programme for the Sound Management of Chemicals et al., 2008). In the second adaption to technical progress to the **EU Classification, Labelling and Packaging Regulation** (European Commission, 2011g), however, two subcategories (1A, 1B) were introduced for sensitisers, taking into account the (predicted) sensitisation rates and the severity of reaction.

Considering the increasing number of sensitising substances and the fact that about 20 % of the general population in Europe are sensitised to one or more substances (Pietrangeli, 2008), and taking into account that sensitisation can be prevented, it becomes obvious that further research is needed to **identify sensitisers** and **reduce exposures** to acceptable levels.

Skin disorders are the second most common occupational diseases in the EU, and chemicals are responsible for 80–90 % of these. However, there is no validated scientific method to assess dermal exposure to dangerous substances; factors for the assessment of dermal exposure are therefore very important.

Prominent examples of the increasing use of sensitising substances are epoxy resins. There is a continuous demand for new epoxy resins with enhanced properties, for example for the manufacture of adhesives, paints, coatings and polymer composite structures. Epoxy resins are a major cause of occupational allergic contact dermatitis. Skin sensitisation, irritation of the eyes and respiratory tract, contact urticaria, rhinitis and asthma are also reported. Epoxy skin sensitisation is particularly problematic in the construction sector, where a safe and healthy working environment (e.g. clean workspace) and the use of protective clothing (e.g. gloves) are often impractical.

Sensitising substances are also an important issue for the cosmetic industry. The testing and safety evaluation of the products have to be carried out to a greater extent by the use of alternative methods since the regulatory framework of the **Cosmetic Directive** (Council Directive 79/661/EEC, 1976) stipulates a ban on animal testing as of March 2013. For workers in the cosmetic industry this means working with less well examined substances and being **increasingly exposed** to potentially sensitising substances.

In order to minimise the risks when dealing with sensitising substances and to establish safe work routines, it is mandatory to establish a more detailed system for an allergenic **potency ranking** resulting in **different categories** of sensitising substances. This would facilitate establishing safety standards that are better adapted to the actual sensitising potency of a substance in use.

Whenever substitution of a potentially sensitising substance is not possible a priori, a toxicological threshold model is helpful to decide whether or not protective action must actually be taken. For this purpose scientifically sound and reliable **toxicological thresholds** need to be established to provide information on the 'dose' of a substance that must be reached to produce a sensitising effect. In this context, interindividual differences have to be thoroughly investigated. In addition to the rising numbers of sensitising substances, the **increasing sensitivity** of the human subject is another cause for concern (Muñoz-López, 2006). A better understanding of the reasons for this increased sensitivity will help to improve **prevention measures** and allow for new ways of preventing sensitisation at the very source of its generation.

9.1.3 Analytical methods for extremely low detection limits

The first step towards reducing workplace exposures to CMR and sensitising substances to tolerable risk levels are reliable **measurement methods**. **Tolerable risk levels** should be very low, especially for carcinogenic, mutagenic and sensitising substances. Consequently, further refinement of analytical methods is needed to be able to detect **minimal amounts** of these substances.

Priorities for OSH research on CMR and sensitising substances

General

- The need of alternative analytical methods for testing toxicology of chemical agents, e.g. detect minimal amounts of CMR and sensitising substances.
- Development of reliable tools for quantitative risk assessment that will generate better quantitative data for the potency / potential of carcinogenic, mutagenic and sensitising substances.
- Bio-metrology for occupational exposure – development of appropriate biomarkers: that will help to identify the nature and amount of chemical exposures in occupational situations and that will permit the prediction of the risk of disease in individuals and groups exposed (including "vulnerable" groups).
- Need for gender- specific research - most carcinogenic exposure studies have been generated from studies of men whilst reprotoxic studies focus on women. Few studies have estimated variability in exposure measurements based on gender, race, ethnicity, or related variables. Research methods are needed to evaluate for example occupation cancer among women and minorities that will allow determining if same external exposure may result in different internal doses
- The methodology and use of job exposure matrices should be further developed to identify exposure risks in the working environment.

CMR

- Need to develop existing knowledge on CMR effects by conducting research on health problems and their link to work (e.g. collection of exposure data). This will improve understanding of the relationship between occupational risk factors (including "hidden" CMR risk factors) and the incidence of occupational diseases
- Research is needed that will cover more occupational groups and involves long-term population studies e.g. should include service industry, vulnerable workers like young migrant females in maintenance work, organisational factors or lifestyle factors often influenced by the way work is organised.
- Validation and improvement of models for worker exposure assessment: measuring, modelling and risk assessment. These can be used to identify exposure reduction needs and methods, define exposure-response relationships in epidemiological studies, and demonstrate the effectiveness of interventions and engineering controls. Research and development of instruments and tools for workplace management of CMR substances.
- Research on the criteria or process for setting occupational exposure limit values for CMR substances Investigation is needed to develop a clear overview of occupational carcinogens and related work processes outside the scope of REACH. These substnaces/processes need to be addressed by research, monitoring and prevention so that the same level of protection is provided to workers.
- Reprotoxic studies in humans have mostly looked at effects closely related to the course of pregnancy, for example abortion, gestation length and birth weight. Additional research is needed in functional disorders related to e.g. the immune, cardiovascular and nervous systems.
- Additional research is needed to update reproductive and developmental toxicity databases which have limited information for many chemical exposures in the occupational setting.

Sensitisers

- Establish a more detailed system for an allergenic potency ranking resulting in different categories of sensitising substances.
- Identify factors leading to an increasing chemical sensitivity of the human subject.
- Establish scientifically sound and reliable toxicological thresholds that provide information on the “dose” of a substance that must be reached to produce a sensitising effect.

9.2 Endocrine disruptors

Within this priorities report it has been stated that for some emerging risks there is insufficient knowledge available to make reliable risk assessments. This problem is even more fundamental with endocrine disruptors (EDCs), as validated methods for measuring negative impacts are not yet available. According to a recent study requested by the European Parliament’s Committee on Employment and Social Affairs, ‘the absence of adequate exposure data is the weakest link’ in connection with EDCs (European Parliament, 2008a). The report underpins that ‘prevention very much depends on uncertainties about the effects of EDCs’ while exposure data are missing to determine ‘whether the observed health effects in humans are linked to EDCs’.

‘An endocrine disruptor is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations’ (Community strategy for endocrine disruptors) (European Commission, 2012d). Some chemicals, such as polychlorinated biphenols (PCBs), dioxins, several pesticides, plasticisers (phthalates) and nonylphenol, can act on the endocrine system to disturb the homeostatic mechanisms of the body or to initiate processes at abnormal times in the life cycle. Concerns have been raised in recent years over the potential adverse effects that may result from exposure to these chemicals. The European Commission considers EDCs to be substances of such high concern that they may be subject to authorisation with respect to the REACH legislation. For more than 10 years the Commission has increased its research activities on EDCs. In 1999, following consultation with stakeholders from across the EU, the Commission adopted the ‘Community strategy for endocrine disruptors’ (COM(1999)706). This strategy focused on short-, medium- and long-term actions that, when implemented, would contribute to ensuring a better environment for, and health of, EU residents. International initiatives and collaborations have been established under the short- and medium-term actions of the Commission’s strategy to achieve its goals:

- EU/WHO/IPCS: coordination of international research and development through the formation of the Global Endocrine Disruption Research Inventory; and
- WHO/IPCS: global assessment of the state of the science of EDCs — an assessment prepared by an expert group on behalf of WHO, the ILO and the United Nations Environment Programme.

In the **Seventh Community Framework Programme** for Research and Technological Development (2007–2013), research on EDCs was mainly funded under the theme of ‘environment’, but also under ‘health’ and ‘food, agriculture and biotechnology’.

Analysis of health effects on humans, while generating concerns, has, until recently, failed to provide firm evidence of direct causal associations between low-level exposure to EDCs and adverse health outcomes. Despite these difficulties, it has been suggested that exposure to EDCs plays a role in adverse health outcomes, and serious concerns remain. Several studies indicate that EDCs **do have reproductive effects**, change neural development and functioning, affect immune function in different forms of cancer such as testicular and prostate and may lead to breast cancer. It is known that occupational exposure to **pesticides** may cause reduction in human fertility and sterility (European Parliament, 2008a). Research on EDCs is still needed to be able to address the following:

- Many endocrine-related diseases are on the rise. Disease risk owing to EDCs may be significantly underestimated.

- Almost 800 chemicals are known or suspected to be capable of interfering with hormone receptors or hormone synthesis or conversion. However, only a small fraction of these chemicals have been investigated in tests capable of identifying overt endocrine effects.
- Significant knowledge gaps exist as to the association between exposure to EDCs and other endocrine diseases.
- The absence of adequate exposure data is the weakest link in determining whether the observed adverse effects in humans are linked to EDCs. Data are limited for accidentally highly exposed groups. Most exposure information has focused on the presence of persistent organic pollutants in Europe and North America. Data on the magnitude and trends of global human exposure are limited.

In human epidemiology there are considerable difficulties in finding ways of recognising the health risks that may stem from EDCs. Complications arise mainly from the time lag between disease causation and the diagnosis of health effects, the absence of methodologies for dealing with exposures to multiple chemicals in epidemiology and the lack of information about the full spectrum of chemicals that might contribute to risks.

The evidence that high-level exposure may impact humans indicates that this potential mechanism of toxicity warrants special attention.

Uncertainty about the possible effects of chronic, low-level exposures to a number of chemicals with endocrine-disrupting potential and the fundamental roles played by the endocrine system in maintaining homeostasis make understanding the potential effects posed by exposure to such chemicals an obvious OSH priority.

Priorities for OSH research on endocrine disruptors

- Expand and strengthen knowledge of EDCs on occupational populations. Research is needed in exposure assessment strategies that will help pinpoint and identify unrecognised substances with EDC properties within workplaces. With current assessment methods the full spectrum of chemicals that potentially contribute to endocrine-related diseases is far from known.
- Establish new approaches to examine the effects of mixtures of EDCs on disease susceptibility, as examination of one EDC at a time is likely to underestimate the combined risk from simultaneous occupational exposure to multiple EDCs. Assessment of human health effects due to EDCs needs to include the effects of occupational exposure to chemical mixtures on a single disease as well as the effects of exposure to a single chemical on multiple diseases.
- Develop more specific and sensitive biomarkers for detecting endocrine-mediated effects in workers exposed to endocrine disruptors.
- Focus work on the occupational populations/subgroups that are most likely to be susceptible to endocrine disruptors EDCs.

9.3 Nanomaterials in an innovation-driven society

The term nanomaterial has been used for a broad range of materials. In October 2011, however, the European Commission published a first recommendation on a **common regulatory definition** of nanomaterial in the EU: ‘A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm–100 nm’ (European Commission, 2011h). Unlike ISO/TS 27687 (2008) (European Commission, 2011h), which defines the individual nanoparticle, the **European definition** addresses a material that is much closer to workplace reality. Yet, Maynard et al. (2011) consider the existing definitions based on size range alone to be ‘of convenience, not of science’.

There is an estimated gap of 10–20 years between technological progress and nanosafety research. Most of the research is aimed at developing nanoparticles and nanotechnologies, whereas, according to Iavicoli et al. (2009), only a minimal amount targets potential health effects and toxicology. This **knowledge gap** is likely to grow with the accelerating development of **new sophisticated materials** — multicomponent materials and hybrid materials — that are expected 'to resemble the complexity of human-scale engineered devices, rather than the simplicity of unique chemical entities' (Maynard et al., 2011). Size, form, surface, structure, chemical composition, reactivity and charge define the properties of nanomaterials. Considering this, each nanomaterial has to be considered separately when judging the toxicology, physico-chemical properties and long-term health effects (Krug and Wick, 2011). If nanosafety is to keep pace with the rapid emergence of new-generation nanomaterials, **risk evaluation** must be possible even on the basis of incomplete information on exposure and hazard. This calls for special research efforts into new **toxicity testing methods** and **risk prediction tools** to allow for safety aspects to be considered as early as in the product development phase (safety by design).

Nanomaterials possess unique chemical, physical and mechanical properties, and may have different toxicological properties and a different hazard potential from their larger counterparts. They are used for a steadily **growing variety of applications** widely spread through different industrial branches including applications in 'information technologies, electronics, energy generation and storage, material sciences, bio-physico-chemical processing and catalysis, food and feed refinement, environmental remediation, security, transport and space, diagnostic and therapeutic applications in medicine' (JRC et al., 2011). Developing these **innovative materials** is an important driver for European competitiveness. It has been estimated that the size of the world market of products containing ENMs will reach USD 2.5 billion by 2014 (JRC et al., 2011). The corresponding innovative technologies and industries are expected to increase accordingly. As a consequence, exposure of workers to nanomaterials is assumed to increase during the handling of nanomaterials and mechanical operations of nanocomposites. **Exposure situations** will not only be restricted to manufacturing processes, but also appear during the whole life cycle of nanoproducts. In the near future, increased nanomaterial release/exposure can thus be expected in maintenance, disposal or recycling activities related to materials and products containing nanoparticles. Prominent examples are the construction industry, the waste and recycling industry or the energy storage sector in which, for instance, hydrogen fuel cells or lithium ion batteries will pose problems in terms of exposure to nanoparticles (EU-OSHA, 2011c).

Therefore, research and development in the field of nanomaterials needs to be accompanied by risk assessment, risk management and adjustment of the appropriate EU regulations and their implementation (JRC et al., 2011). While the new properties of engineered nanomaterials (**ENMs**) offer great possibilities for medical, scientific and industrial applications, the **risk assessment** and the **safety issues** of nanomaterials are still far from being resolved (Maynard et al., 2011). Also, progress in material science, technology, chemistry and other areas fosters and accelerates the appearance of sophisticated new-generation materials engineered at the nanoscale, of which the **harmful potential** to human health may deviate from that of investigated nanomaterials so far.

At present, even for well-studied, relatively simple nanoscale materials, there are no comparable and reliable scientific data on their biological effects or nanotoxicity (Bünger et al., 2000; Krug and Wick, 2011). Efforts are already deployed — and should be further supported — to refine toxicology research with the aim of identifying representative (benchmark) nanomaterials with various modes of action, characterising their physico-chemical properties and delineating their interactions with biological systems, as well as investigating and grouping new materials accordingly (Maynard et al., 2011; Kuempel et al., 2012).

So far, nanomaterials and related products are dealt with under existing broader **regulatory schemes** in the fields of chemicals, food, cosmetics, drugs and so on. Although not explicitly mentioned, nanomaterials as chemical substances are regulated by REACH (CA/59/2008 rev. 1), and the existing EU regulatory framework 'covers in principle the potential health, safety and environmental risks in relation to nanomaterials' (European Commission, 2008b). Considering the body of research into their toxicology, there is a need for **specific adjustments** of various methods to test and characterise nanomaterials owing to their special material properties.

9.3.1 Novel measuring methods for workplaces

The measurement of workplace exposure to engineered nanoparticles is challenging, as they have to be separated from the background of various other particles. Risk management requires exposure assessment based on realistic exposure data, which in turn requires the development of appropriate methods to quantify concentrations of nanomaterials in the workplace and to characterise (qualify) their chemical identity. At present, there are no **standardised methods** for either the qualitative or quantitative measurement of nanoparticles providing scientifically sound, reproducible and reliable exposure data (Hirsch et al., 2011; Krug and Wick, 2011). For the future it is vital to establish such measuring methods to facilitate the development of targeted risk management tools and regulations for workplace exposure to nanomaterials. What is more, **internationally harmonised measuring strategies** are indispensable (JRC et al., 2011; Brouwer et al., 2012) for achieving comparability of measurement data worldwide, and thus allowing the broadest possible scientific-based and evidence-orientated risk management.

9.3.2 Exposure assessment and management

There is evidence that some nanoscale particles are toxic to human health. Many studies indicate that the toxicity of particles increases with decreasing diameter and increasing surface area, and thus challenge current mass-based risk evaluation approaches. However, decisive scientific information is still lacking. As there is no universal nanoparticle to fit all cases, it is not possible to apply generic rules to their potential health effects. Accurate information on the physico-chemical characteristics of nanoparticles — especially size, chemistry and structure-dependent toxicity — is needed to allow for reliable risk assessment.

However, even though quantitative data are lacking, sufficient information is available to begin a preliminary assessment and develop interim working practices to reduce workplace exposure. Schulte et al. (2008) consider the available information as sufficient to treat nanoparticles as hazardous substances. A precautionary approach should therefore be applied to nanoparticles. Priorities in risk management should be given to the assessment and management of nanomaterials at workplaces where hazard and exposure information is missing, incomplete or uncertain. Therefore, it is important to provide companies with pragmatic, easy-to-apply **exposure assessment methods** that allow for an estimation of the related health risks. Such assessment should be supplemented by congruent **risk management approaches** to design workplaces with exposure to nanomaterials to be as safe as possible. In this context **control banding** appears to be a suitable technique, especially for **SMEs** (van Broekhuizen, 2011). At present, a couple of control banding techniques have been developed and applied in different European countries, among them the control banding scheme according to Zalk, Paik and Swuste (Zalk et al., 2009), the TNO Stoffenmanager (TNO, 2011), the NANOSAFER tool from Denmark (Industriens Branchearbejdsmiljøråd, 2013), the French ANSES approach (ANSES, 2010) and the EMKG concept from Germany (BAuA). All of these approaches need further research to be validated and compared (Zalk et al., 2011). The aim is to implement **harmonised risk assessment and management** across Europe and beyond.

Data on **workplace exposure** to nanoscale materials are the prerequisite for targeted and efficient prevention. This data can help to build exposure scenarios, model future exposure or develop benchmarks. As the measurement of nanoparticles is difficult and expensive as described above, further research commitment is required for designing **information databases** to compile available measurement data that give a realistic overview of the occurrence of nanomaterials in the workplace and the exposed workforce. In this context, initiatives such as the Nano Exposure and Contextual Information Database (NECID) of the Partnership for European Research into Occupational Safety and Health (PEROSH) serve as good examples worthy of further development.

In parallel, further research should be undertaken to guarantee the development of ‘responsible’ nanotechnology, which integrates health and safety considerations. In the light of new available information on nanomaterials, the European Commission will examine and propose adaptations of EU regulations in relevant sectors. The European Environment and Health Action Plan 2004–2010 and the Community Strategy on Health and Safety at Work 2007–2012 also provide a basis for future possible initiatives.

Priorities for OSH research on nanomaterials

- Increase the knowledge on nanomaterials in occupational settings including new generation nanomaterials.
- Increase understanding of how chemical and physical modifications affect the properties of nanomaterials. Develop risk characterisation information to determine and classify nanomaterials based on physical or chemical properties.
- Understand generalisable characteristics of nanomaterials in relation to toxicity in biological systems
- Develop new toxicity testing methods and risk prediction tools to allow for safety aspects to be considered as early as in the product development phase (safety by design). Research will allow for 'responsible' nanotechnology which integrates health and safety considerations.
- Develop standardised measuring methods for both qualitative and quantitative measurement of nanoparticles to obtain reliable exposure data as a basis for exposure assessment as a basis for exposure assessment and risk management.
- Develop exposure assessment and risk management tools for the field that will help to understand and improve best workplace practices, processes, and environmental exposure controls.

9.4 Biological agents in a greener yet globalised economy

'Biological agents' are defined as '**micro-organisms**, including those which have been **genetically modified**, **cell cultures** and human **endoparasites**, which may be able to provoke any infection, allergy or toxicity'. 'Micro-organism' refers to 'a microbiological entity, cellular or non-cellular, capable of replication or of transferring genetic material' (Council Directive 2000/54/EC).

Micro-organisms are present in various workplaces. Workplace exposure to biological agents can be **direct or indirect** as an unintended result of work processes. Direct exposure may, for example, occur as a result of the use of micro-organisms in the food industry or in a microbiology laboratory, whereas indirect exposure occurs during activities such as waste treatment or agriculture (EU-OSHA, 2003; HSE, 2005). The crucial difference between biological agents and other dangerous substances lies in the former's **ability to reproduce**. Given favourable conditions, a small number of micro-organisms may grow considerably. Another specific characteristic of micro-organisms is their genetic adaptability, especially relevant in the case of bacterial resistance issues. The spectrum of health effects attributable to biological agents ranges from **sensitising effects** and **allergic reactions** to **acute and chronic disease**. The main health effects of exposure to biological agents are infections caused by bacteria, viruses or parasites, allergies triggered by, for example, mould, organic dusts, enzymes or mites and poisoning or toxic effects due to exposure to micro-organisms, in part or in whole, or their metabolites (EU-OSHA, 2003). Worldwide, it is estimated that more than 300 000 workers die every year as a result of diseases caused by viral, bacterial or animal-related biological hazards (Driscoll et al., 2005). Furthermore, some biological agents have the potential to cause cancers. At least 15 % of new cancer cases worldwide are attributed to biological agents such as viruses or bacteria (Bosch et al., 2004). Examples are liver cancer related to a hepatitis B infection or cervical cancer caused by papillomavirus, frequently in interaction with other infectious agents such as certain herpes viruses (IARC, 2012).

The development of a **greener** and more **resource-efficient economy** gives rise to new technologies and materials, which in turn may result in **increased exposure** to biological agents or combinations of different potentially harmful factors (see section 8.1.2). The expanding recycling industry, for example, employs an increasing number of workers. These workers have to face various **health problems** (pulmonary, gastrointestinal and skin problems) as a result of exposure to biological agents such as **airborne micro-organisms** (specific numbers for occupational diseases in this sector are still lacking) (EU-OSHA, 2007). The increasing segregation of waste, for instance, could multiply contact with potentially harmful materials and increase exposure to them; the collection and separation of organic waste may lead to exposure to bacteria, fungi or sensitising substances (EU-OSHA, 2011c). The waste treatment industry employs an increasing number of workers. However, its regulation was developed primarily for environmental purposes and fails to sufficiently address OSH issues. The major health problems observed in workers are caused by bioaerosols, which contain a variety of airborne micro-organisms, including mould and endotoxins, as well as VOCs. Health effects reported include upper airway inflammation and pulmonary diseases, organic dust toxic syndrome, gastrointestinal problems, allergic reactions, skin diseases and irritation of the eyes and mucous membranes. Handling medical waste and sharp equipment may lead to other infections.

The more prevalent use of bioenergy is another factor that might add to the exposure to biological agents. Biomass, for instance, may not be stored as well as conventional energy sources such as coal or oil and may produce hazardous VOCs, dust, moulds and endotoxins (EU-OSHA, 2011c).

While Directive 2000/54/EC (2000) lays down the principles for the management of **biological risks** in the workplace, the state of knowledge on biohazards still leaves a number of research issues to be solved in order to protect workers.

9.4.1 Detection methods for micro-organisms

Considering the speed and volume of international trade and traffic, a biological agent such as a virus may spread around the world within a very limited period of time resulting in a global epidemic (earlier pandemics circled the globe in 6–9 months; today new biological agents travel between continents in less than 3 months because of air travel). **Globalisation** may promote epidemics of old and new pathogens such as severe acute respiratory syndrome, avian flu or viral haemorrhagic fever (EU-OSHA, 2007; Cusick et al., 2012). It is difficult to identify the occupations most at risk, as sources of exposure vary and involve people, animals, plants and goods. Among the variety of workers' groups that can face a growing risk of contamination are airport staff, public transport and public service workers, healthcare workers, workers involved in handling livestock and personnel responsible for border controls and policing (EU-OSHA, 2007). While virus-related risks are high, **standardised methods** for sampling, especially for **airborne viruses** in the workplace, and analysing them in the laboratory are widely lacking. In order to curtail the spreading of viral diseases, further research is needed to develop improved tools for the detection of viruses.

The current biological risks in the working environment and their possible negative results on workers' health are still far from being fully understood. For example, the effects of mycobacteria on the development of respiratory diseases in metalworking were not recognised until the late 1990s (Zacharisen et al., 1998).

Antimicrobial agents have reduced the threat of infectious diseases. However, this achievement is put at risk by the emergence and worldwide spread of antimicrobial-resistant organisms, mainly as a result of the overuse or misuse of antibiotics. **Healthcare workers** are at risk because of the emergence of organisms such as methicillin-resistant staphylococcus aureus and extensively drug-resistant tuberculosis (XDR-TB).

Although methods for sampling bacteria, fungi, parasites or their components and metabolites do exist, it is still impossible to **identify the whole spectrum** of these micro-organisms for the simple reason that suitable analytical laboratory methods are lacking (ABAS). This shortcoming is opposed to a **growing number** of new and upcoming **biological risks** in the working environment that need prescient identification: the rapidly progressing introduction of new green materials, technologies and work processes is but one development that will result in greater challenges in terms of microbial exposure. Much research effort must therefore be put into the development of **analytical methods** that will enable stakeholders in OSH to correctly identify both known and new micro-organisms in the workplace.

There are various workplaces and professional activities for which exposure to microbiological agents may occur unexpectedly and in an uncontrolled way. The issue of **uncontrolled microbial exposure** is particularly true for waste treatment and for retrofitting activities, both growing sectors of employment in a greening society. The Worldwatch Report 177, for example, attributes the largest potential for reducing greenhouse gases to energy-efficient retrofitting (Renner et al., 2008). More biodegradable materials are expected to be used, such as wood, bamboo or straw, but also water-based paints and adhesives. These materials are much more prone to microbial growth, and thus represent an even higher exposure risk when being replaced or removed in the future. For such exposure scenarios **quickly accessible information** on the nature and the amount of exposure to microbiological agents is needed; conventional **microbiological measurement** needs time-consuming breeding in the laboratory before the exposure information requested can be delivered. Therefore, the development of **direct measuring techniques** for microbiological agents is a prerequisite to allow for quick decisions on suitable protective measures and must be the subject of further research.

9.4.2 Association between exposure to bioaerosols and diseases

Work-related exposure to **bioaerosols** is associated with a wide range of **health effects** including respiratory diseases (bronchitis, asthma and hypersensitivity pneumonitis), skin problems and possibly gastrointestinal symptoms. It is present in various fields of work, ranging from agricultural and waste treatment activities to biotechnology and the metallurgy industry (Zacharisen et al., 1998; EU-OSHA, 2007). Specific microbiological parameters are hard to relate to particular health effects in workplaces with complex bioaerosol exposure (Bünger et al., 2000; Eduard et al., 2001). The same is true for chemicals contributing to potential health effects of mixed exposures (Silins and Högberg, 2011). Even if the quality of microbiological measurement data is improved by enhancing sampling and analytical methods as described above, these data must be evaluated for risk assessment and prevention purposes. Such evaluation means establishing associations between workplace exposure and observed diseases. However, methods to investigate these associations are lacking. In this context, a better understanding of the toxicology, mechanisms of action and interactions of bioaerosols is needed. Another prerequisite is further epidemiological research into the relationship between microbiological exposure in occupational settings and the observed health effects. This is true both for individual biological agents of particular interest, such as allergens or microbial fragments, and for mixed microbiological exposures in the workplace.

Although in recent years research has made significant progress possible in the assessment of exposure to bioaerosols in workplaces, there are still knowledge gaps and technical problems that need to be investigated.

Priorities for OSH research on biological agents

- Develop methods to investigate the relationship between occupational microbiological exposure and observed health effects. The precise role of microorganisms in the development and the aggravation of symptom is poorly understood.
- Need to develop dose-response relationship for most biological agents.
- The study of occupational biological risks is insufficiently developed; there is a need for research into metrology, epidemiology, appropriate measurement and assessment methods and prevention of risks.
- Develop accurate sampling and analytical methods for micro-organisms to identify the whole spectrum for example airborne microorganisms, allergens in bioaerosols, microbial fragment etc.
- Develop direct-measuring techniques for microbiological agents as a prerequisite for quick decisions on suitable workplace protective measures.
- Conduct further research on the evaluation of bioaerosol occurrence and their variability of exposure.
- Work on determining OEL values standardised analytical methods are still lacking.

9.5 Mixed exposures in complex workplace settings

In many cases, exposure is not one dimensional, as described above. **Mixed exposures** to different chemicals and biological agents at the same time or to combinations of chemical, biological physical and other factors are often closer to the reality of today's and future workplaces — one example is a foundry, in which workers are simultaneously exposed to radiation, noise, vibration, heat, heavy loads and harmful compounds and particles in the air. In a way, any working condition is **multifactorial**, and as workplaces, technologies and work tasks are becoming more complex, the issue of mixed exposures is becoming more important.

Synergistic effects are not easy to predict; interactions may differ depending on the type of mixture, dose and dose ratio (Silins and Högberg, 2011). For example, calcium cyanamide (a fertiliser) has a synergistic effect with ethanol; on the other hand, ethanol is an antidote for methanol (Pietrangeli, 2008). The exposure to noise and the solvent toluene results in a higher risk of hearing loss than the exposure to either stressor alone (NIOSH, 2005; EU-OSHA, 2009c).

While the range of potential subsequent health effects is wide, it is difficult to determine which constituent primarily accounts for a specific health effect. More research is needed to enhance our understanding of **multifactorial exposure** and its occurrence, mechanisms of action and toxicology.

The subject of chemical mixtures and their potentially harmful effects is not a new one. As stated by the European Commission (2012e), 'methodologies for the **identification of chemical mixtures** of potential concern as well as for the assessment of chemical mixtures are available'. A standard approach to estimate the effect of such a chemical mixture exposure is the dose additive model, which is based on the hypothesis that all the chemicals have the same target organ and a similar action on that organ. In reality, however, chemical compounds can also have an action independent of other chemicals, a synergistic action with others. Therefore, a couple of **scientific challenges** still have to be met to allow for a systematic and effective use of these methodologies. In its recent communication on chemical mixtures (Bünger et al., 2009), the European Commission summarises the central knowledge gaps, referring to the latest European and international state of the art compiled by three scientific committees in a common opinion (European Commission, 2011i). Thus, research is needed to develop more and improved **exposure descriptions** (where, how often and to what extent). In this context a 'coherent approach to the generation, collection, storage and use of chemical monitoring data' (European Commission, 2011i), as well as **exposure modelling approaches,** is required. Also, a better understanding of the **modes of action** of chemical mixtures is necessary. For this purpose, research should aim at defining criteria that can help 'to characterise or predict a mode of action' (European Commission, 2012e) and at establishing an inventory of action modes as well as assessment groups. Research is also needed 'to define criteria that predict **potentiation** or **synergy** of chemical mixtures' (Renner et al., 2008) and to identify 'substances that are the main drivers of mixture toxicity' (European Commission, 2012e).

Regarding research needs in the risk assessment of chemical mixtures, and, according to a state of the art report on mixture toxicity (European Commission, 2009b), the following research needs were highlighted:

- There is a lack of studies in which the requirements of independent action are met. Furthermore, relatively little information exists about the ability of chemicals that themselves do not produce the effect under investigation to modulate the toxicity of other mixture components.
- Information about relevant exposure scenarios, in terms of the nature of active chemicals and their number, is fragmentary for most human exposure scenarios. Exposure assessment strategies that adopt a more holistic approach are needed to overcome that situation.

Further, with reference to the SCENIHR report (European Commission, 2011i) on the toxicity and assessment of chemical mixture, the following research areas were highlighted:

- Increase the knowledge of the rather limited number of chemicals for which there is quality information on mode of action.
- Develop robust and validated tools for the prediction of interactions.
- Increase knowledge of how exposure and/or effects change over time.

Another important field of synergistic effects is that of ototoxic substances (EU-OSHA, 2009c), which may impair, particularly if combined with noise, hearing organs and their functioning. The effect of a combination of noise and certain solvents has recently been investigated, but data are lacking or do not exist for certain chemicals or chemical mixtures, for example pesticides, polychlorinated biphenyls and solvent mixtures.

Finally, there are the multifactorial impacts on MSDs, in which psychosocial factors appear to play an important role. MSDs are the most prevalent occupational disease in 12 EU Member States: more than one-third of workers suffer from work-related MSDs. It is known that both exposure to workload and psychosocial risk factors may lead to MSDs. However, there is not enough information on their combined effect with regard to the occurrence of MSDs. For more information on MSDs, see Chapter 6.5.

Regarding work-related MSDs, PEROSH has included the following topics in its research needs:

- Research on the development of work-related MSDs due to the interaction of combined physical and psychosocial risk factors.
- International research should conduct high-quality MSD intervention studies on primary, secondary and tertiary MSD prevention levels.

Priorities for OSH research on mixed exposures

Chemical and Biological mixtures

- Investigate the toxicology and mechanisms of action of chemical/biological mixtures.
- Increase the knowledge of the rather limited number of chemicals / biological agents for which there is quality information on mode of action. Develop more and improved exposure descriptions for chemical mixtures (where, how often and to what extent).
- Develop robust and validated tools for the prediction of interactions.
- Increase knowledge of how exposure and/or effects change over time.
- Define criteria to predict potentiation/synergy of chemical mixtures.

Ototoxic substances

- Toxicity testing of new chemicals should be improved to properly evaluate their ototoxicity.
- Levels of simultaneous noise and specific chemicals exposures considered safe to the human auditory system should be identified.

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