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Research Synthesis 4

Gender in Research Content and Knowledge Production

Authors

Elizabeth Pollitzer in collaboration with Rachel Palmén

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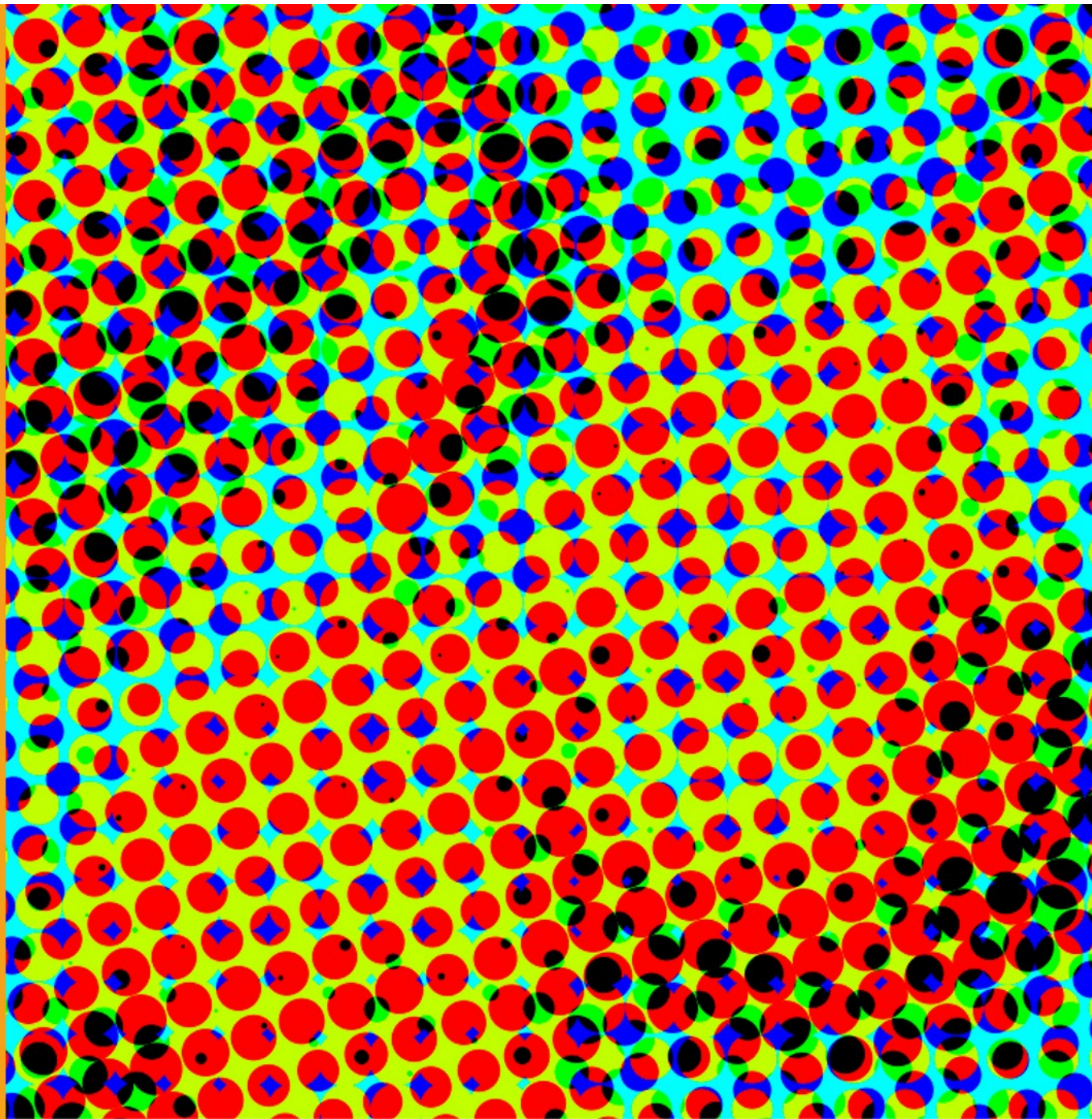

Executive Summary

Historically, science was assumed to be ‘gender neutral’, i.e. it was generally accepted that research outcomes will be the same regardless if the researcher or the subject of research is female or male. However, extensive scientific evidence is now available to challenge this paradigm: it shows that gender neutrality in science is an illusion that hides widespread ‘male’ bias in science knowledge, science practice, and science institutions. Firstly, science has more evidence for males than for females, though in some cases the reverse is true, e.g. there are gaps in knowledge about breast cancer and osteoporosis in men. Gender bias in science knowledge can lead to worse outcomes for women, or for men. Secondly, since men occupy the majority of top-level positions in science, women’s voices stay unheard when research priorities and programmes are planned.

Three strategic approaches have been taken in Europe over the last 15 years to address gender equality issues in research:

1. "Fix the Numbers of Women" which focuses on increasing women's participation in research and leadership
2. "Fix the Institutions" which promotes gender equality in science careers through structural change in organisational processes and practices.
3. "Fix the Knowledge" which promotes excellence in science and technology by integrating sex and gender analysis into research content and process (Schiebinger, 2008).

With Horizon 2020, the European Commission made gender a criterion of success measured through improvements in all these three areas.

This report focuses on the need to ‘fix the knowledge’ by removing and preventing gender bias in science knowledge, which is caused by: (i) the failure of researchers to properly consider sex-gender differences as research variables (the gender dimension) by either using ‘male’ as the norm; or (ii) having imbalance between female and male research subjects; or (iii) not organising, analysing or reporting data according to sex/gender.

The aim of this synthesis report is to show that knowing when, why and how biological and sociocultural differences between females and males - alone or in interaction with one another and the environment – influences the quality of research

results, contributes to scientific excellence, and provides more effective solutions to societal challenges. This analysis is presented through the lens of scientific evidence applied to the seven societal challenges that frame Horizon 2020:

1. Health, demographic change and wellbeing (SC1)
2. Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bio-economy (SC2)
3. Secure, clean and efficient energy (SC3)
4. Smart, green and integrated transport (SC4)
5. Climate action, environment, resource efficiency and raw materials (SC5)
6. Europe in a changing world - inclusive, innovative and reflective societies (SC6)
7. Secure societies - protecting freedom and security of Europe and its citizens (SC7)

The scientific literature showing how sex-gender analysis enhances quality and impact of research and innovation is today most abundant for SC1: Health, Demographic Change and Wellbeing. It shows that the patterns of many types of illness are different for women and men, and that understanding their underlying causes and consequences is important for health policies promoting better prevention, diagnosis and treatments.

Also to consider are potential cross cutting impacts of sex-gender analysis, which can apply to SC2, SC3, SC4, SC5, SC6 and SC7 (Watts, 2016). For example, understanding the processes involved in sexual reproduction and maturation in plants or animals is relevant for maintaining biodiversity, preserving the wellbeing of natural ecosystems, as well as contributing to better food production (SC2, SC5).

Involved in planning the Horizon 2020 programme are the Expert Advisory Groups on each societal challenge whose role is to identify research priorities for each phase of the programme. Since the start of Horizon 2020, there has been marked improvement overall in how these groups perceive the role of gender. For example, the scoping report on SC1 (health) issued in 2015 was largely ‘gender blind’, containing only one mention of the word “gender” in nine pages of text. This was disappointing, given how much supporting scientific evidence was available for this area at the time. By contrast, in the scoping report issued in 2016, the words “sex” and “gender” are mentioned 75 times. The 2016 reports from the other Expert

Advisory Groups have also produced more thoughtful analysis of the role of gender. But there are still important gaps, the 2016 report from the Expert Advisory Group for SC2 (food) identifies 64 topics as research priorities but lacks any explicit mention of the potential role of the gender dimension (European Commission, 2016a). The purpose of this report is to show that may of the recommended topics could benefit from having sex/gender highlighted as of potential influence when the calls for proposals are formulated for the 2018-2020 phase.

The EU policy to integrate gender into Horizon 2020 as a criterion of success, and in particular the specific goal to enhance the integration of the gender dimension in research content and process has been admired around the world, and started producing impact. For example, in May 2016, the Global Research Council recommended that its members adopt actions to advance gender dimension in research activities they fund (Global Research Council, 2016).

The purpose of this report is to provide the Expert Advisory Groups and the EU policy makers, in particular, with a synthesis of recent research on sex and gender issues relevant to the seven societal challenges that frame Horizon 2020, to continue to improve the quality of funded research and innovation projects, and of the impact of the programme itself.

Recent and New Insights from Research

Gendering science, technology and innovation systems

In 2010, the GenSET Science Leaders Panel analysed a large number of scientific studies that reported on gender and sex differences. They concluded that medical treatments for women are often less evidence-based than for men, and asked that editors of peer-reviewed journals, medical and other, should require analysis of sex and gender effects in research results when selecting papers for publication (Buitendijk, 2011). They also recommended that integrating the gender dimension into research content and process contributes to scientific excellence and opens up new opportunities for innovation based on gender knowledge. For example, research has shown that important anatomical differences between female and male bodies, e.g. bone size and structure, spine configuration, and flexibility of ligaments (Parenteau, et al., 2013) can play crucial role in determining risks of serious injury in a car crash for women and men. During a crash, the car seat acts like a trampoline

and the resulting shaking impacts more on the smaller bodies of women than on men's because the spine vertebrae are further apart in women and they have less muscles around the neck and torso, as well as less tick bones than men. Analyses of car crash injuries have demonstrated that these risks are higher for women than for men, and that the injury patterns are different for both groups, as well (Bose, Segui-Gomez and Crandall, 2011). Therefore, cars appear to be less safe for women than for men. This, in turn, suggests that the way safety of cars is tested should be improved. In general, cars are tested using male crash test dummies, only. The dummy represents the average adult male. 'Female' crash test dummies are constructed by scaling down the standard male dummy. Comparison of data for male and 'female' dummies in artificial crash conditions shows differences in the types of damage experienced by each, and that the necessary bio-fidelity between artificial and real crash injuries is not as good for females as it is for males. Therefore, further research is needed to understand the female-male differences in biomechanical response to crash conditions. Making cars safer for women should be seen as an opportunity for better innovation, which will benefit women, men and society (e.g. through lowering health and insurance costs, and creating less impact on families).

"Integrating the gender dimension into research content and process contributes to scientific excellence"

Such scientific evidence has been instrumental in influencing the European Commission's new commitment to improve how gender issues are addressed within Horizon 2020, in the content of research and in the design and implementation of the programme. A novelty of Horizon 2020 is that the Commission's staff, potential applicants, the Helsinki Group, NCPs, as well as expert evaluators, and other actors involved in the implementation of Horizon 2020 were issued advice on how the gender dimension and equality issues should be integrated at each stage of the research cycle: from programme design through implementation, monitoring and programme evaluation (European Commission, 2016b).

The Commission's priorities for gender in Horizon 2020 include three objectives: 1) fostering gender balance in Horizon 2020 research teams; 2) ensuring gender balance in decision-making; and 3) integrating gender/sex analysis in research and innovation content. A novelty of H2020 is promotion of cross cutting impacts of

gender. To encourage submission of proposals with a gender dimension, the relevance of gender to different topics is highlighted in the programme. The proportion of the topics with such a condition added was over 20% in the first phase of the programme for 2014-2015, which compares to around 2% in the Horizon 2020 predecessor the Framework Programme 7.

Highlighting the benefits of including gender analysis in the proposals helps promote awareness of available evidence and methods for gender analysis, which Horizon 2020 further supports by allowing proposals to include gender training among the eligible costs of a project. The aim is to help researchers to further develop and share gender expertise in relation to their area of research. This also applies to the Commission staff involved in the drafting and implementation of the work programmes.

An early (2015) evaluation of the proposals submitted to Horizon 2020 in 2014 showed a much greater response to addressing gender considerations in the calls that flagged gender as a relevant topic than those that have not. This evaluation also concluded that much “more needs to be done” in the next phases of the H2020 programme(European Commission, 2015), and specifically to: 1) improve gender balance in evaluation panels; 2) widen the range of flagged topics and improve how gender issues are presented (i.e. asking for more than to “consider a gender dimension”); and 3) continue the efforts to address gender dimension in the preparation and implementation of the work programme” (European Commission, 2015).

In their recommendations for the 2018-2020, the Expert Advisory Group on SC6 has asked for the following actions: 1) promote closer connection between gender and other sources of inequality such as age, young people, immigrants, ethnic, cultural and linguistic minorities; 2) promote systematic mainstreaming of gender into each call, and throughout the application process (e.g. from research and innovation planning, through developing methods and tools for implementation, to evaluation; 3) ensure transparency in mainstreaming gender into evaluation criteria and process; and 4) enable active encouragement for transformative change to eliminate the gendered nature of science institutions, structures and norms. They proposed the following improvements:

- “Research and innovation actions addressing gender issues, explicitly and systematically embedded in projects where the issues have acknowledged relevance to the underlying research topics. Project proposals that have thought this through systematically should be more highly rated in evaluations.”
- “Training should include requirements to raise awareness of gender issues within the substance of the training and target an appropriately-balanced mix of trainees”.
- “Where the connections between gender-issues and the underlying research area are not so obvious or acknowledged, some fraction of research (possibly within independent research and innovation projects or support actions), should aim to investigate the extent to which gender issues exist but are not widely realized”.

The seven societal challenges that frame the research priorities of Horizon 2020 overlap the 17 challenges that define the goals of the UN Sustainable Development Agenda 2030, and to some extent also the drivers of the OECD’s Inclusive Innovation programme. Both, the UN and the OECD missions see scientific knowledge as a source of sustainable solutions, and both perceive the role of gender as limited to improving women’s empowerment and human rights. This narrow perspective has been criticised by gender experts (Lee and Pollitzer, 2016) who argued for much greater sensitivity to how gender can influence success of intervention measures. This presents the EU with an opportunity to advance its leadership in mainstreaming gender into research and innovation, and promote the mechanisms developed as part of Horizon 2020 through the policy of Open Science, Open Innovation, Open to the World (European Commission, 2015b).

Sex and gender in research content and methods

In their recommendations for the 2018-2020 programme, the Horizon 2020 Expert Advisory Group on SC6 highlighted the need to both sharpen and strengthen representation of gender as a dynamic concept that challenges researchers to: 1) question gender norms and stereotypes; 2) systematically address the evolving needs and social roles of women and men; and, 3) depending on the field of research, widely and intensely apply methods of sex-gender analysis in research content, process, and impact. In the sections that follow, we summarise the scientific reasons why this advice applies to all the seven societal challenges.

Health (SC1)

Sex and gender factors in biomedical, health and clinical research can influence quality and safety issues because outcomes can depend on differences in biochemical and physiological processes, and in how women and men experience risks for developing health problems and certain diseases. For example, new research involving adult subjects with Asperger's syndrome shows distinct sex-specific biomarker profiles for male and female subjects. Males have altered levels of 24 biomarkers and females of 17, including growth factors and hormones such as androgens, and insulin-related molecules (Lai, et al., 2015). Similar biochemical differences have been shown for metabolic profiles in women and men, which are significant for diagnosing diseases linked to metabolic disorders such as diabetes and Alzheimer's (Siegert, et al., 2012). Sex-gender differences in the onset, duration and effects of illness in women and men have been now demonstrated for a range of health problems, including: the cardiovascular, pulmonary and autoimmune conditions, and diseases involving gastroenterology, hepatology, nephrology, endocrinology, haematology and neurology.

"Sex-gender differences can also influence effectiveness and safety of treatments"

Sex-gender differences can also influence effectiveness and safety of treatments. For example, among the 668 drug treatments most frequently used in the United States, half produced sex differences in adverse effects (Yue, et al., 2016) , and of the 10 prescription drugs withdrawn from the market in the USA during 1997-2000, eight were more dangerous to women than to men (GAO, 2001). These disparities point to gender-sex biases in our understanding of pharmacokinetics and pharmacodynamics, i.e. how the female and male body metabolises drugs, and what effects different drugs have on the body (Oertelt-Prigione and Regitz-Zagrosek, 2012).

Peer review used for the assessment of scientific excellence has not prevented sex-gender bias in life sciences and clinical research, which has often gathered more data from males and men (Buitendijk, et al., 2011) than from females and women: many studies excluded females and women completely. A review of sex bias in research on mammals in 10 biological fields showed male bias in 8 disciplines.

Single-sex studies of male animals outnumber those of females by 5.5 to 1. Studies of both sexes frequently fail to analyse results by sex. In effect, our understanding of female biology is compromised by these deficiencies (Beery and Zucker, 2011). Furthermore, studies that fail to apply gender analysis reduce the quality and applicability of systematic and meta-analytical reviews to compare and synthesise key scientific findings for particular health-related conditions, which may be subject to sex-gender difference effects (Runnels, 2014).

Gender bias in research also impacts on the quality and applicability of new, clinically relevant discoveries to new treatments, and better health care. For example, although scientists have put forward the hypothesis that the time of personalized medicine has come (or will soon arrive), the chasm between new discoveries and medical application of new insights is very wide (Plebani and Lippi, 2013) because the vast majority of epidemiological and clinical trials conducted over the past 30 years have reported results only in one sex/gender, and often outcomes have not been adequately stratified for sex/gender (Baggio, et al., 2013). Even more importantly, there is poor evidence that a sex-gender analysis has been incorporated into evidence-based medicine for developing clinical guidelines, recommendations or best practices throughout most areas of healthcare.

There is a real paradox: how can the expectations placed on personalized medicine be realised when there still is such poor appreciation of how sex-gender factors contribute to disparities in health outcomes for women and men, and produce different effects of treatments via hormonally and non-hormonally mediated mechanisms. Pre-clinical and clinical trials carried out during drug development phases have rarely considered sex-gender as a stratification parameter in therapeutic outcome investigations. Evidence supporting sex-specific therapeutic outcomes mainly stems from Phase IV post-marketing studies (Fenech and Grech, 2014).

A further concern over quality of health research outcomes for women and men is raised by the increasing use of digital technologies for the collection and analysis of health information, which may combine ‘omics’ analyses (e.g. genomics, metabolomics, proteomics), electronic health records, personal monitoring devices, population and patient cohorts and registries, and data on environmental exposure, nutrition, lifestyle, and socio-economic status. There is a risk that ‘gender blind’

algorithms and models will perpetuate gender biases in existing knowledge, and will not improve clinical decisions where sex-gender difference effects are important.

Food (SC2)

The fight against hunger and food insecurity is one of the biggest challenges global societies have been facing in the last decades. The debate around food security issues has evolved in parallel with the definition of food security itself and reflects changes in the policy priorities, often induced by new emerging threats (global warming, migration, draughts, desertification).

According to the UN Sustainable Development Goal 2, Zero Hunger: “if done right, agriculture, forestry and fisheries can provide nutritious food for all and generate decent incomes, while supporting people-centred rural development and protecting the environment. Right now, our soils, freshwater, oceans, forests and biodiversity are being rapidly degraded. Climate change is putting even more pressure on the resources we depend on, increasing risks associated with disasters such as droughts and floods.”

The research priorities for the H2020 2018-2020 programme recommended by the Expert Advisory Group on Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research, and the Bio-economy (SC2) are devoid of specific comments on the possible role of the gender dimension. This omission should be corrected in the follow-up process of the programme planning. This section offers examples of scientific evidence to show why SC2 cannot be left as ‘gender neutral’.

The SC2 Expert Advisory Group has recommended 64 specific topics for research and when examined through a gender lens 44 cover issues where a gender dimension could improve results by identifying conditions needed to ensure sexual reproduction, maturation, and reproductive success, which can play an important role in the survival and resilience of plants and animals grown for food, and in sustaining the wellbeing of natural ecosystems and biodiversity. For instance, one topic is “malnutrition and micronutrient deficiencies in certain population groups, for example the elderly, those hospitalised or in care, lower socioeconomic groups, and diverse minority groups”. This does not specify big health issues caused by severe malnutrition of women and children in developing countries, who have little or no

access to formal health services, especially in rural areas, or the chronic effects of deficiencies in macronutrients (protein, carbohydrates and fat, leading to protein–energy malnutrition) and micronutrients (electrolytes, minerals and vitamins), which produce different outcomes for women, men, girls, boys, and infants (Müller and Krawinkel, 2005) .

Consideration of the gender dimension in SC2 applies also to the production of fish for food. We know that in some fish species the male grows bigger more quickly (e.g. tilapia, popular in Africa) and in others it is the female (e.g. turbot, widely eaten in Europe), a knowledge that may be used to improve management of aquacultures. Research on age-related effects on egg quality in fish shows that older and larger female cod are healthy, produce lots of eggs with no signs of deterioration in quality due to age: by contrast, older males show indications of physiological aging and of lower health condition. These results emphasize the importance of conserving old mature fish, in particular high egg-productive females, when managing fisheries (Carney, et al., 2012).

Similarly, production of food crops that rely on animal pollination can benefit from intervention measures based on research that shows how availability of pollinators can improve yields and quality of crops, thus requiring less land and fertilizer to produce the same results (Garibaldi, et al., 2011). Understanding how bees are attracted to male and female flowers, and when a plant's fertility is highest, could also help enhance pollination success, whilst understanding how specific plant traits affect male and female reproductive success (e.g. amount of pollen produced per plant) could help enhance quality and resilience of plants grown for food, as well as methods to protect biodiversity, and sustainable agriculture (Geber, Dawson and. Delph, 1999).

Gender equality issues in relation to SC2 extend beyond women's empowerment into concerns over the role of women in plant biodiversity management, in their roles as housewives, plant gatherers, home gardeners, herbalists, seed custodians and informal plant breeders, is generally overlooked. Experience shows that when research to develop new varieties of cassava is 'gender blind', it means that the knowledge and needs of women who produce and process much of the cassava in Sub-Saharan Africa are neither considered nor met. When research on the root is 'gender-responsive', researchers seek input from both women and men in new

variety development, which results in higher adoption rates of the new varieties (GREAT, 2016).

“Taking an ecosystem perspective on sex-gender issues in research and innovation helps unravel the real conditions in value chains”

When plant use, management and conservation occur within the domestic realm, and the principal values of plant genetic resources are localised and non-monetary, they become invisible to outsiders, and are easily undervalued. Gender bias has prevailed in scientific research about people-plant relationships, and conservation policies, and programmes are still largely blind to the importance of the domestic sphere, of women and of gender relations for biodiversity conservation, and to the importance of plant biodiversity for women’s status and welfare. Traditional knowledge and indigenous rights to plants are everywhere sex-differentiated, and gender inequalities are also implicated in processes leading to biological erosion (Howard, 2003)

Similarly, the role of women is crucial, but overlooked, in the fisheries and aquaculture sector and value chain. Worldwide, fishery and aquaculture production activities provide revenues to an estimated 155 million people, of whom a substantial proportion is female. In developing countries most fishing activities fall into the small-scale fisheries sector, employing roughly37 million people, and directly affecting the livelihood, poverty prevention and alleviation, and food security of approximately 357 million. Gender analysis in fishing communities is still in its infancy, and is mostly limited to the different occupational roles according to gender. The belief that men do the actual fishing, with women more involved in post-harvest and marketing activities, remains prevalent across most cultural, social, political and economic strata. Global average figures, which support this perception, mask the real importance of women in the fishing sector at country level .

Taking an ecosystem perspective on sex-gender issues in research and innovation helps unravel the real conditions in value chains, not covered by trade treaties or codes of conduct, which often depend on underpaid labour of women and girls in primary food production. For example, in the context of marine ecosystems, livelihood necessities interlink with opportunities to benefit from ecosystem services,

and the need to protect marine habitats and marine biodiversity (ESPA, 2008) . These actions are more difficult for women who have less time for training and education due to the extra burden of domestic work and family responsibilities. The Vietnamese government has tried to fill the gender gap in the coastal areas through several policies such as more training courses open for women to set-up small businesses at home, and involvement of Women's Unions who support poor families through credit channels to create more varied livelihoods in order to reduce the exploitative pressures on the natural resources .

Energy (SC3)

Historically, discussions of energy issues have been 'gender blind'. Women and their views are generally missing in the energy economy (Brody, Demetriades and Esplen, 2008) ; in the governance of the energy sector; in discussions concerning energy needs or energy supply; in evaluation of site-specific impacts (e.g. population displacement); in managing energy end-use (e.g. domestic) or social development (e.g. better livelihood and poverty reduction); and in environmental effects of waste flows and emissions as part of energy production (ETC/ ENGERGIA, 2010a).

Gender experts in the area of energy recommend that research is needed to define the main gender connections with energy supply and use in the context of: access to energy services; sitespecific effects of energy development, production, and transportation; welfare gains for society including battling energy poverty and local job creation; improved air quality, health and productivity gains inside buildings; and reducing greenhouse gas emissions to slow down Climate Change and make human adaptation more possible. There are also two major areas of gender issues within energy sector institutions (both public and private sector), namely employment equity and working conditions and women's participation in decision-making .

The historical 'gender blind' position of the energy sector has resulted in a general lack of gender disaggregated data in relation to energy, which can be attributed, in part, to policy makers and planners being unaware of the significance of gender in energy planning (ENERGIA, 2008), as well as not knowing about the availability of gender analysis tools, or how to use them (Gendered Innovation, 2016) . For these reasons, there is currently a limited capacity for mainstreaming gender into design of energy policy at national, regional and global levels, a shortcoming that needs urgent action. Horizon 2020 offers an important opportunity to mainstream gender into

energy research and innovation, which is critical because while expectations and acceptance of energy solutions often differ between sexes, it is the male-dominated energy policies that influences views with regards to market needs, user expectations and behaviours.

For example, energy uses differ between women and men. Research shows that energy used in European countries in transport is greater among men than among women: in Germany and Norway men consume 70-80% more energy than women; in Sweden 100%; and in Greece 350% (Ratty, R & Carlsoon-Kanyama, 2009). In general, women are considered to be more eco-friendly as energy consumers, with higher environmental awareness. Men are less likely than women to make energy decisions based on environmental reasons (Hau, D. & Swenson, A., 2013). For example, in the case of shale gas extraction there is a sharp gender divide, with 31.5% of women in favour of extraction versus 58% of men, as more women learn about the growing environmental concerns (Vaughan, 2015; Council of Canadian Academies, 2014). And, even though women make the majority of household decisions, the male bias in energy sector "might explain why smart homes have not yet entered the market despite being around for some years – because the needs of those who spend most of the time in homes (women, children, elderly) have not been appropriately addressed" (European Commission, 2016c)

In general, improvements in energy supply are aimed at supporting three main components of the economy: productive activities, domestic (also called reproductive or care) activities, and public services, and it should, therefore, matter for decision making that a great deal of the work within these components is done by women. Abandoning the gender neutral position will enable decision-makers and managers to understand why large sections of a population may not have benefited as much as others from improved energy services. Adopting a more gender sensitive approach to SC3 will help raise awareness of the benefits of creating an energy sector that is more directly focused on societal needs instead of the preoccupation with production and supply system, and more able to make connections with users' needs and the conditions of their energy use (the demand side) (ECT/ENERGIA, 2010b).

"Adopting a gender sensitive approach helps of creating an energy sector more focused on societal needs"

The H2020 Expert Advisory Group on: Secure, Clean and Efficient Energy (SC3) has made several important gender-related recommendations for research priorities to be included in the 2018-2020 Programme (European Commission, 2016c):

- “Key success factor for the transition of the European Energy system is the understanding of actual and future citizens needs including diversity in its broadest meaning. Changing life styles, behavioural aspects, expectations, acceptance and economic and non-economic motivation and drivers have to be understood in detail. A special focus should be given towards gender aspects. The full integration of the gender dimension is required in R&I and the design process of technologies and infrastructure.”

- “Lack of awareness of benefits of energy efficiency remains one of the main barriers in energy transformation. When considering how to encourage behavioural changes that will contribute to energy efficiency and uptake of renewable energy, it is critical to judge the ‘readiness of society’ to change and understand the behaviour of consumers or the citizen in general, including having a gender perspective.”

- “Gender is part of Research Excellence and enhances the societal relevance of produced knowledge, technologies and innovations, contributes to goods and services better suited/accepted by potential markets, questions gender norms and stereotypes. Therefore full integration of the gender dimension is required in R&I and the design process wherever it is needed and further full attention has to be given to gender balance in teams and for funding. For example new innovative building solutions for energy savings in heating, cooling will have a different perspective considering gender, and may impact integrating circular economy ideas and integrating smart applications that are flexible and demand oriented. Women are homemakers and therefore want safe, secure and nice homes and therefore their drivers are different. As an example, they would be more focused to: security in energy supply;ease of handling and flexibility;close proximity services in case of problems;smart integration of health and safety issues on demand.”

Transport (SC4)

Transport infrastructure and services are often incorrectly considered to be ‘gender neutral’, i.e. that they equally benefit men and women. However, gender differences become evident when transport is viewed in terms of enabling the mobility of people for different purposes and needs, and by different modes—rather than in terms of mere investment in hard infrastructure that ‘equally benefit’ all social groups (European Parliament, 2006) .

For example, women have daily mobility patterns that are more complex than men’s, owing to their gender roles, which combine domestic and care giving tasks with paid employment, income-earning activities, and community and social obligations. Women tend to make more combined and frequent trips than men, often for shorter distances and for multiple purposes within one journey (e.g. taking children to school en route to their workplace, or stopping at the market on their way home), commonly referred to as “trip chaining.”

Women are also much more likely to travel with children or elderly dependents, and during off-peak times (e.g. after school pick-up in the early afternoon or when taking elderly parents to medical visits). Men, on the other hand, tend to make fewer and more direct trips daily, such as to/from their workplace, often on their own and for a single purpose, and often during peak rush-hour times. Gender transport patterns can also be influenced and determined by sociocultural practices, such as in societies were women are required to be escorted by male or elderly female relatives as chaperones.

There is emerging consensus that planning, design, construction, operation, and maintenance of transport infrastructure and services should involve the participation of all key stakeholders, including transport user groups and affected communities but this should also mean equal representation of women and men, to take into account any difference in their needs and preferences (Asian Development Bank, 2013). The focus should be on the dynamics of transport-related behaviours and lifestyles to identify the main factors that impact on key policy interest, such as urban congestion, emissions and noise reductions. Understanding gender differences in transport behaviour can help design effective countermeasures to reduce the highest rate of injury crash for females and males.

“Understanding gender differences in transport behaviour can help design effective measures to reduce the highest rate of injury crash for females and males”

Another aspect of the gender dimension in transport research is the issue of personal safety and sexual harassment on public transport, which are significant concerns for women. Women are often subjected to various forms of harassment when using transport services. Therefore, for women, perceptions of safe travel go beyond physical road safety to include risks of stalking, sexual assault, or rape. The opportunity costs of poor transport systems and services that are unreliable and inflexible are often borne disproportionately by women who cannot afford the lost time. For example, women may turn down employment opportunities further distances away from home if the transport system does not enable them to travel to and from work in time to also meet their domestic family care obligations, or provide ample space and flexibility for women to travel with dependents and household goods. Instead, they may have little choice but to accept lower-paid local job opportunities or informal income sources closer to or at home, so they can combine their dual responsibilities of managing household and productive activities (Law, 1999).

A very important gender dimension of transport, and an example of cross cutting benefits of gender sensitive research, concerns road safety strategies, which should take into account gender differences in injury crash rate prediction models for specific target collision type (e.g. frontal, side, back) (Ameratunga, Hijar and Norton, 2006) and types of transport (e.g. car, scooter) (Hung, Stevenson and Ivers, 2006). The harms that are caused by different collision types affect women and men differently (Bose, Segui-Gomez and Crandall, 2011; Tsai, Anderson and Vaca, 2008). There are important gender difference effects in the performance of vehicle occupant safety protection systems (Parenteau, 2013). The relative risk of being seriously injured in a car crash is higher for females than for males for crash severities of up to 65 km/h. In the ranges of 25-65 km/h females are more at risk of spine injuries, chest, and extremity injuries than males. This is concerning since crashes in this range represent the regulated test conditions for which restraint systems are optimized. The risk for serious spine injury is 1.77 to 1.94 higher in females than in males in 25-65

km/h crashes. Correspondingly, the risk for serious chest injury is 1.80 to 1.96 higher for females.

There is an astonishing lack of studies on the sex/gender differences in the biomechanical response during car crash and the role of anatomy and tissue (muscle, ligaments, bones) characteristics in determining injury criteria for women and men. Research suggests that the stiffness and hysteresis of tendons are significantly lower for females than males, implying that viscoelastic material properties may be gender dependent. Significant correlation has been demonstrated between ligament injury risks in females and the menstrual cycle phase, indicating that hormones may play an important role in failure thresholds. Furthermore, females of child-bearing age have the highest risk for hip injuries in side impacts .

However, regardless of the extent of the available evidence of sex/gender differences in injury patterns, cars are still tested primarily using the HYBRID III 50th percentile crash test dummy, which represents the average adult male. The performance requirements for a 5th percentile version of the 'female' crash test dummy, i.e. representing a small female, is based on physical scaling down the male dummy using anthropometric parameters, but this does not produce the necessary bio-fidelity between the crash data from real crash situation and those produced under lab conditions.

Therefore, the benefits of integrating gender dimension into transport research and innovation are wide and considerable, and this has been recognised in the Expert Group's on SC4 recommendations for H2020 2016-2017 programme. The topics where gender factors have been highlighted include:

- Protection of all road users in crashes – where the advice said that "consideration should be taken of gender aspects such as body structure and stature and other demographic factors such as the disabled (persons of reduced mobility), ageing, obesity, etc.".
- Behavioural aspects for safer transport – where the advice said that: "key factors that influence safe transport user behaviour, both individually and collectively, taking into account demographic factors (gender, age, socio-cultural aspects, etc.), and societal framework conditions (changing living conditions etc.)"

- The development of effective, efficient and affordable mobility solutions which respond to the specific needs of particular population groups such as the elderly, the young, the disabled, taking into consideration the gender aspect. Gender disaggregated data collection and analysis could contribute to a more thorough analysis.
- The employment prospects and gender balance of the sector – where the advice focused on future requirements for skills and training tools/methods across transport modes and systems, in order to improve the potential of the workforce and improve the gender balance in the field of transport.
- Big data in transport: using disaggregated data analysis by users' groups (e.g. age, gender) to better focus specific needs and trends.
- Social and demographic factors such as: variations in safety behaviour, socio-cultural issues, gender, age and disability and their impact on risk assessment and exposure of each individual or group
- Increasing the take up and scale-up of innovative solutions to achieve sustainable mobility in urban areas. The gender dimension was not highlighted here but is of relevance here in relation to societal and industry attitudes, which tend to perceive women as “hostile” to innovation whilst considering young well educated men as the target ‘innovation adopters’ (European Commission, 2005). Such attitudes can create barriers to the societal acceptance of change through technological innovations.

Climate change (SC5)

Climate change affects all living things, human and non-human species, often with different consequences for females and males, partly through their biology, which influences the capacity of each sex to physically adapt to the changes in the environment, such as higher temperatures or extreme weather events, and partly through socially constructed conditions (IPCC, 2014). Furthermore, gender differences in adaptation behaviours may intersect with age, ethnicity, socioeconomic status, as well as the social condition that control how women and men access available resources, services, and decision-making processes . For women in the developing world, in particular, the capacity to respond may be restricted through socio-cultural and economic constraints.

Gender responsive approaches must be developed and implemented in adaptation, mitigation and low-carbon development. Finance, technology sharing and capacity

building, as well as outreach and participation, must also be gender responsive to meet the needs of women and men. Equal participation of women and men, and commitment to gender justice in international agreements is an important step, yet this alone is not sufficient. International arrangements and national plans need to integrate inclusive and gender responsive climate policy (Gender CC, 2016).

Horizon 2020 and the EU policy vision of Open Innovation, Open Science, Open to the World provide important mechanisms for promoting gender responsive approaches to mobilise the potential of women as agents of change for climate mitigation and adaptation by bringing into the climate discourse their extensive theoretical and practical knowledge of the environment and resource conservation (GIZ, 2010), across different areas, including energy, water, food security, agriculture, fisheries, health, industry, human settlements, disaster management, and conflict and security (McNab, 2002).

In their advisory reports issued in 2015 and 2016, the H2020 Expert Advisory Group on: Climate Action, Environment, Resource Efficiency and Raw Materials (SC5) have adopted a largely 'gender neutral' position in relation to making specific recommendations for research priorities. In the text for the 2018-2020 Programme (European Commission, 2016d) the role of gender is included in only three general statements:

- "There is an emerging need for more integrated, participatory planning approaches to shape resilient and healthy urban and rural environments, including gender dimensions"
- "Both producers and consumers need to be associated in future societal evolution, with education of present and future generations and gender dimensions taken into account".
- "Research on alignment of policies necessary to enable systemic transformation; development and demonstration effective participatory approaches on policy design, inclusive of gender equality and vulnerable groups"

The 2016 report from the Expert Advisory Group on SC5 assumes that gender issues can be addressed through Social Science and Humanities research, and by promoting the EU policy of Responsible Research and Innovation. This strategy may help empower women and make their 'voices' heard when policies and intervention

measures are designed and implemented but it will not exploit the full potential of the gender dimension in research connected to SC5, where sex and gender may interact at several different levels.

For example, research focused on mitigation and adaptation problems would benefit from taking a 'holistic', ecosystem-based perspective that examines impact at several levels where human action taken place. This should take into account the different knowledge and skills and preferences in natural resource use and management between women and men, due to their different social and economic roles (Ringler, et al., 2010).

Understanding sexual reproduction and conditions needed for reproductive success can help, for example, develop measures to protect forests from insects and pests, which will thrive in hotter temperatures, as well as develop more tree varieties that are more resilient to pest-related diseases or environmental pollution. There is an opportunity to develop bio-monitoring technologies that use female and male biomarkers to identify sex of plants before they flower, or the effects of exposure at toxic pollutant at molecular, cellular, organ, organism levels.

Already, global warming, deforestation and changes in precipitation have been linked to variations in the geographical distribution of vectors of some infectious diseases (malaria, leishmaniasis, lyme disease, etc.) by changing their spread, whilst a warm and humid environment can also encourage the colonization of skin by pathogenic bacteria and fungi (Balato, et al., 2012). The environmental consequences of higher temperatures due to climate change will increase occurrence of malaria, cholera outbreaks, cardiovascular disease hospitalization and deaths, increase child under-nutrition, diarrhea occurrence, meningitis, Ebola, asthma and respiratory diseases (Amegah, 2016).

A neglected aspect of global warming is the direct impact on humans (men and women) and other mammals in the form of heat stress, which may provide a climate impacts benchmark that is relatively well-constrained by physical laws. For non-human species, and in relation to biodiversity, heat stress can disrupt natural sexual reproduction creating imbalances in the number of males and females born, as well as affect sexual maturation and reproductive success in animals and plants.

The role of skin in enabling adaptation to high temperatures caused by climate change is limited by biophysical functions that are strictly controlled by the body. For humans the core body temperature is near 37 °C and varies slightly among individuals but does not adapt to local climate. Human skin temperature is strongly regulated at 35 °C or below under normal conditions, because the skin must be cooler than body core in order for metabolic heat to be conducted to the skin .

The skin is the major border organ of human body, being the most exposed to environmental variations, and climate change may increase the occurrence and severity of skin diseases, in general, but since there are sex differences in the properties of female and male skin, e.g. females have thinner skin, the consequences may be also different for women and men.

There is an urgent need to develop methods of sex-gender analysis for research linked to CS5 to tackle the research priorities identified by the Expert Advisory Group on SC5 (European Commission, 2016d) , including:

- The processes and tools developed to manage complex systems such as natural ecosystems (e.g. to include their role as the source of livelihood for women and men) (ESPA, 2008).
- How risks of environmental degradation due to climate changes are modelled and assessed (e.g. women have much greater risk of dying in natural disasters than men)
- Education on the effects of climate change, and cultures promoting mitigation and adaptation (because women play an important role in the adoption of intervention measures such as improved, less polluting and less energy hungry cooking stoves, for example)
- Behavioural response to take into account the growing socioeconomic position of women and their role as consumers and decision makers
- Measuring and monitoring transformation because current gender indicators of improvements being made in the inclusion of women in participatory policy design and implementation are inadequate.

Changing World (SC6)

Several major global policy initiatives expect science and technology to provide knowledge and solutions for actions to address societal challenges. For example, the World Economic Forum advocate fusion of technologies, involving physical, digital, and biological knowledge domains, described as the Fourth Industrial Revolution. Others, such as OECD, focus on applying innovation to improving the lives of the most vulnerable and poor groups in society, e.g. the Inclusive Innovation programme, whilst the UN is promoting the seventeen goals of the UN Sustainable Development Agenda 2030.

These high expectations that science can deliver the knowledge needed raise a number of questions. Gender related issues cut across all societal implications of the role of science, including in relation to work, education and social relations. How will our present-day gendered stereotypes and imagination influence the way societal advancement and technological development will happen in the future? Will the "changing world" also change gender roles: release women from unpaid care and domestic work, and remove barriers preventing women from rising to positions of leadership and governance? Will the nature of political power change to ensure that it is equally shared between women and men?

"A gendered perspective should not only focus on women."

The arguments for technology led change are generally 'gender blind'. The advocates of Fourth Industrial Revolution are unaware of the gender bias in biological knowledge. They see ICTs as the new ubiquitous general-purpose technology that can provide a common thread, underpinning and enabling innovation to surge in many other technology areas. But, historically, women have been, and continue to be, greatly underrepresented in ICT fields, at all levels, and we know what such exclusion has meant for the quality of today's scientific knowledge. Will women's absence in ICTs influence how ICTs are used to create new products, services and business models? Will eHealth, eCare, eMobility, eGovernment, 'big data' applications, or digitization of science for personalised medicine deliver equal benefits for women and men, or will they reproduce and reinforce the male bias that characterises knowledge production and application today? How will the Fourth Revolution address the needs of the urban poor, where women are the biggest group, who disproportionally suffer from

higher rates of many chronic conditions, including obesity and diabetes (Elbel, B, et al., 2015). . How will the Fourth Revolution improve the socio-economic conditions of the poor living in mega-cities in areas beyond the reach of public services such as clean water, electricity, healthcare, transport, and schools.

One of the key research priorities recommended for SC6 in the H2020 2018-2020 Programme by the Expert Advisory Group involves migration. “The transformation of migrant and refugee communities in Europe is a specifically gendered topic which needs to be researched separately. The complexities of tendencies such as the radicalisation and populism of individuals in different communities cannot be understood without a gender dimension. A gendered perspective should not only focus on women. There are many young single male refugees who need to be included into society in a productive manner, so that their abilities can be used and enhanced, their welfare secured, and the stability of European societies can be maintained. However, it is clear that in some cultures and ethnicities, women are the family carers and this has been widely used as a positive strategy, so that for example financial resources are entrusted to them. This implies that research and innovation needs to include a wide range of different approaches to tackle the ‘integration’ topic”.

Another priority for SC6 research involves governance policies, decision-making, legal and regulatory frameworks, etc., many of which have roots in historical periods when socio-cultural differences between women and men were often strongly reinforced and when women were subject to significant exclusion in most walks of life, both domestically and in the public sphere. “Although many formal structures reinforcing these mind-sets have since been dismantled in Europe, much still needs to be done and many vested traditional attitudes remain which still erect significant barriers making it difficult for women to lead full, equal and active lives. Gender issues are thus central to the governance debate, not least because in almost all European countries, female politicians are in a small minority and are thus in practice largely on the edge of political power and influence, despite making up half of the population”.

Secure Societies (SC7)

The primary aims of the H2020 Secure Societies Challenge are:

- to enhance the resilience of our society against natural and man-made disasters, ranging from the development of new crisis management tools to communication interoperability, and to develop novel solutions for the protection of critical infrastructure
- to fight crime and terrorism ranging from new forensic tools to protection against explosives
- to improve border security, ranging from maritime border protection to supply chain security and to support the Union's external security policies including conflict prevention and peace-building
- and to provide enhanced cyber-security, ranging from secure information sharing to new assurance models .

All these elements have a societal dimension and require development of (intersectional) gender analysis methods to help understand vulnerabilities of different groups in society to security issues; societal attitudes and responses to risk; types of threats; and how specific groups or services are targeted, etc. For example, understanding how gender stereotypes create obstacles to effective prevention of gender-based violence; how the conceptions of masculinity can put boys and men at risk of living a life of violence; better understanding of the connections between migration and violence; identifying barriers to women's full participation in social movements; identifying gender related perceptions, the real extent of, and economic cost of corruption .(Lee, h. & Pollitzer, E., 2016)

The Advisory Group on Secure Societies have identified a range of relevant gender issues in the context of the programme for 2018-2020:

- Borders and Security where gender impacts on the nature of flows of people, immigration and border control
- Fighting Crime and Counter Terrorism gender is relevant in relation to perpetrators and victims of crime and strategies, instruments and processes of counter-terrorism
- Secure Societies with increased resilience need to take account of gender through understanding of different ways of engaging, and assessing the impact on, different groups in society. Growing emphasis on live and adaptive responses to crises – whether due to crime, terrorism or natural disaster – needs to consider gender in terms of social roles, risk factors and constraints.

- Cybersecurity and Privacy Technologies need to take account of gender in developing more user-friendly and accessible security systems and encouraging individual users in different work, consumer and service environments to be active participants in safeguarding the resilience. Specialized systems in sensitive areas such as health and finance are major spheres of innovation to aid public confidence. Gender aspects of security and privacy risks feature as part of innovation processes recognizing diversity of end-users as part of market segmentation. In this way gender considerations can inform strategies for keeping security and privacy central to digital innovation.
- Growing a Competitive European Security Industry presents a number of challenges linked to wider debates about the need to bring more women into science and technology as well as measures to help them start and grow their own businesses.

Cyber security is of special interest because it affects everybody. Until now, decisions over Internet security solutions favoured purely technical approaches, e.g. monitoring unusual data flows over networks, with technical experts interpreting the observed patterns to identify occurrence of potential risks of attack. Cyber attacks could target services involving hospitals or schools provided by local authorities; essential services such as water and electricity; public transport; or specifically children and women. Common examples of such activities include cyber hacking, identity theft, cracking, spamming, social engineering, data-tampering, online fraud. Few cyber security solutions have been designed with the human factor in mind, e.g. the risk arising from user behaviour, and even fewer have included a gender dimension as a factor in usability and effectiveness of performance.

Implications for Policy

'Fixing the knowledge' is about removing and preventing bias in science knowledge, caused by failure of researchers to properly consider sex-gender differences as research variables – the sex-gender dimension - by either using 'male' as the norm; having imbalance between female and male subjects; or not organising, analysing or reporting data according to sex-gender (e.g. pulling all the data together or not stating if the subjects were male or female). The consequence is an often worse outcome for women but also in some cases for men, e.g. breast cancer or osteoporosis. This has implications for polices promoting excellence in science (e.g.

what is funded and valued) and for the application of science knowledge in design and implementation of new policy initiatives (e.g. sex-gender sensitive vaccination strategies promoted through public health measures).

The sex-gender dimension may involve a variety of biological (e.g. chromosomes, biochemical pathways, anthropomorphic) features and socio-cultural characteristics (e.g. roles in society, identities, attitudes) by which females/women and males/men can be identified and compared. Of specific interest for research is to identify when, why and how female-male differences impact on results, and the role of the environment (biological, physical, social) in contributing to these difference effects. More recently, commentators pointed to the influence of environment on the 'femaleness' and 'maleness' of individuals and the inadequacy of the 'binary' female-male categorisation, in particular with respect to humans. This has implications for policies promoting social responsibility of science, science communication, engagement of citizens in research, and open innovation.

To help 'fix the knowledge', and to advance new, gender sensitive research and innovation, continued efforts must be made to improve existing and develop new methods for sex-gender analysis in research content, process, and impact. Research that is sensitive to the potential effects of sex-gender enhances the quality of research outcomes and contributes to scientific excellence. It also has better chance to provide the right solutions to tackle societal challenges. This has implications for policies seeking to promote sustainable technologies, user-centred innovation, and societal acceptance of new technologies.

The EU policy to integrate the gender dimension into Horizon 2020 has been hugely innovative and admired around the world by policy makers, science communities, and stakeholders in science endeavours. By adopting gender as a criterion of success, Horizon 2020 has set a benchmark for other research funders to follow, with already positive consequences, for example in May 2016 the Global Research Council recommended that members should adopt actions to advance the gender dimension in the research activities they fund. This has implications for policies promoting open science, international and multi-stakeholder collaborations, knowledge transfer, and interdisciplinary research.

The EU policy to mainstream gender into research and innovation through Horizon 2020 has also influenced such STEM stakeholders as journal editors (e.g. The

Lancet, Nature and many others), science publishers (e.g. Elsevier), practitioners advancing intervention measures for development (e.g. UN, IDAB), and policy makers promoting socio-economic advancements (e.g. OECD). This has implications for policies promoting research for development, and collaborations between research funders, researchers and development communities.

As evidence of when, why and how the sex-gender dimension makes a significant impact on research results, we need to look ahead and decide how this new knowledge should be systematised; and integrated into STEM curriculum, researcher training, and promoted as a source of innovation ideas. In one area, namely health, we now have accumulated huge knowledge on sex and gender differences in biomedicine and healthcare and we know that frequently women are less well treated than men are. However, findings are dispersed and do not yet translate to clinical practice and drug development or lead to socio-economic benefit. In order to achieve these aims, we need more coordinated and systematic approaches in gender medicine, covering the whole field in a more systematic manner. To connect and to integrate sex and gender related research in all its complexity, we need to consider all possible confounders, like age, ethnicity/strain in animals, comorbidities, housing conditions, stress factors and so on. We also must include pharmacology and drug development, an area where sex and gender is still neglected so far. Finally, we have to consider and to evaluate in a systematic manner awareness of sex and gender in the general population and in healthcare professionals in order to address lack of awareness in specific campaigns (e.g. vaccination, preventative diagnostics) . This has implications for policies promoting quality of higher education, knowledge transfer, professional development, and evidence based innovation.

Whilst there has been progress in integrating the gender dimension into H2020, much still needs to be done before a synergy is achieved between the different steps and phases of integrating gender into the programme and into projects' design, implementation, and evaluation. This is a learning process for policy makers and the science community but the lessons learned, and the best practices developed, will be valuable for other efforts to use science and technology to make the world a better place for all. This has policy implications for H2020 evaluation and the planning of future Framework Programmes, as well as for policies advancing the use of science to create sustainable economies and societal wellbeing.

Certain Expert Advisory Groups (SC1, SC4 and SC6, in particular) have recommended that the range of topics where the relevance of the gender dimension is highlighted should be widened. Although not specifically recognised in the reports of all the Advisory Groups, the evidence presented in this report shows that the sex-gender dimension should be part of all the seven societal challenges that frame Horizon 2020. The Expert Advisory Group on SC6 has commented that "to date, the framing of gender equality is implemented in an unclear and generally unformulated way, for example by only generally mentioning the integration of gender equality into the content of research and innovation, or related merely to diversity issues and included as just one aspect of socio-economic inequality. The structural understanding of gender in relation to inequality and as part of intersectionality, is mainly left untouched". Another current shortcoming is conceptualization of the gender dimension around human-oriented research and overlooking the role of sex in research on plants and animals, which is relevant to the goals of several H2020 societal challenges. (e.g. promoting sustainable agriculture, measuring adaptation to climate change, bio-monitoring environmental wellbeing). This has implications for policies promoting interdisciplinary research with cross cutting benefits, as well as enabling challenge-based research and innovation.

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Note: The present document gives a brief overview of recent research findings regarding Gender in Research Content and Knowledge Production. Further research syntheses on (1) Education and Training, (2) Qualifications and Career, (3) Institutional Practices and Processes, (5) Agenda Setting, Policy and Implementation, and (6) Histories and Futures are available at www.genderportal.eu

An **up to date** version of the bibliography and further relevant resources can be found at the following address:

http://www.genderportal.eu/tags/research-synthesis-4-gender-research-content-and-knowledge-production

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