Digital Future Society

Developing inclusive gendered innovations through deep tech venture-building programmes

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About
Digital Future Society

Digital Future Society is a non-profit transnational initiative that engages policymakers, civic society organisations, academic experts and entrepreneurs from around the world to explore, experiment and explain how technologies can be designed, used and governed in ways that create the conditions for a more inclusive and equitable society.

Our aim is to help policymakers identify, understand and prioritise key challenges and opportunities now and in the next ten years in the areas of public innovation, digital trust and equitable growth.

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Introduction

Recent years have seen gender equality debates in the field of research giving more attention to overcoming gender bias in scientific knowledge production and mainstreaming sex and gender analysis into basic and applied research (Schiebinger, 2008). Indeed, there is now wide recognition that the quality of research processes and outcomes is at stake. Accordingly, bringing gender and sex into the research process, scientific knowledge creation, and the science value system represents a critical challenge for enhancing the quality and excellence of scientific endeavours.

There has been less focus on the stage of technology transfer processes and how to integrate the gender dimension into innovation processes, even as innovations resulting from this integration could lead to a diverse range of new products, services, and production methods that not only align with user needs but also expand the boundaries of what is technologically and commercially feasible (Best et al. 2016; Palmén et al. 2020).

To unlock these there is a real need for interventions promoting inclusivity to occur throughout all stages of the innovation process, through generating ideas, capturing ideas, beginning innovation, developing a business-effectiveness strategy, and applying business improvement strategies. However, intervening in the earlier stages of technological development offers a greater potential for inclusivity, although this will depend on the specific deep tech innovation. For example, artificial intelligence for facial recognition provides a clear example of the dangers associated with using a homogenous dataset with biases amplified throughout machine learning and the use of certain algorithms. Interventions ensuring a more representative, inclusive dataset at the outset provide a better chance of developing more inclusive innovations.

In the realm of deep tech innovation, characterised by extreme gender imbalances in the STEM and entrepreneurial workforce, debates on gender equality tend to be reduced to creating a more gender-balanced workforce (EIT, 2023b). There is a small but growing body of research that emphasises how to integrate the gender dimension into research and innovation processes, however, this tends to focus on how potential users can become involved in the 'design' stage of innovations thereby ensuring maximum relevance and business viability (Kumar, 2009).

Unfortunately, there is less work examining how deep tech innovations can be made more gender inclusive at the stage of technological development. These guidelines, therefore, attempt to provide insights into how this can be done, provide concrete examples of deep tech innovations, and provide an evidence base on useful policy interventions in this field.

What is deep tech?

Deep tech can be implemented in different sectors with different applications. Deep tech technologies include:

- Advanced Computing / Quantum Computing
- Advanced Manufacturing
- Advanced Materials
- Aerospace, Automotive and Remote Sensing
- Artificial Intelligence (AI) and Machine Learning, including Big Data
- Biotechnology and Life Sciences
- Communications and Networks, including 5G
- Cybersecurity and Data Protection
- Electronics and Photonics
- Internet of Things, W3C, Semantic Web
- Robotics
- Semiconductors (microchips)
- Sustainable Energy and Clean Technologies
- Virtual Reality, Augmented Reality, Metaverse
- Web 3.0, including Blockchain, Distributed Ledgers, NFTs

> "Deep technology or deep tech is a classification of an institution, an organisation or a start-up company, with the expressed objective of providing advanced and emerging technology solutions to deep societal challenges. They present scientific or engineering challenges requiring lengthy research and development, and large capital investment before successful commercialisation. Their primary risk is technical risk, while market risk is often significantly lower due to the clear potential value of the solution to society. The underlying scientific or engineering problems being solved by deep tech companies generate valuable intellectual property and are hard to reproduce. Moreover, the solutions provided by deep technology and applications are critical for solving the complex global challenges that humanity faces, including climate change, sustainable energy or health."

European Institute of Innovation and Technology (EIT, 2023b)

Due to its potential for impact across a range of different areas (see figure 1), these guidelines tend to concentrate on AI. Research on AI and gender equality is an emerging field with most literature highlighting the biases inherent in AI and how it reinforces and amplifies existing gender inequalities (Ramboll, 2020). This results from how datasets reproduce and amplify existing inequalities and flaws in the design of the algorithm or solution (Ramboll, 2020). The following table highlights the different AI capabilities and identifies potential applications.

AI capability		Potential application
Image analysis (computer vision)	Person identification	Identifying individuals in images and video. Commonly referred to as facial recognition.
	Object detection	Detecting objects in images and video. For instance, detecting faces in video surveillance footage.
	Image and video classification	Classifying objects, animals or individuals in images or videos. Can be used for detecting explicit content online or violent situations in surveillance video.
	Similarity detection	Detecting similarities between different videos and images
	Emotion recognition	Measuring emotions of individuals in images and video. Could be used to measure engagement during a video meeting.
Speech and audio	Person identification	Verifying an individual's identity using speech analysis. Could be used to provide online verification of identity without codes or apps.
	Speech-to-text	Automated transcription of speech. Can be used to transcribe audio files of speech further enabling analysis.
	Sound detection	Identifying voices or sounds from audio files.
	Emotion recognition	Analysing emotions of individuals by examining the way they speak. Could also be used to measure engagement.
Natural language processes	Person identification	Identifying the author by analysing the writing style, handwriting or other text.
	Sentiment analysis	Analysing the sentiment of the author by examining text. Potential uses include scanning posts on social media to discern public opinion.
	Language understanding	Any task relating to comprehension of a text; from text classification to understanding poetry. Allows chatbots to understand ambiguous language and abstract concepts.
	Content generation	Generation of text, video, and audio content
Others	Structured deep learning	Machine learning algorithms that use multiple layers to extract advanced features using structured data.
	Analytics	Any analytics technique not involving deep learning: journey mapping or network analysis.
	Reinforcement learning	Type of machine learning that differs from other types of learning by not requiring supervision.

Figure 1: Data source: Ramboll (2020).

Given its current prevalence across all sectors (algorithmic-based decision-making in public administration, generating educational content, personalised biomedicine, facial recognition, etc.) AI is currently a high-profile technology and provides emblematic examples of where gender and racial bias in AI have harmed groups of people.

For example, in 2019 Reuters reported that Amazon shut down its automated hiring tool because it was found to be negatively biased against women (Dastin, 2018). According to Reuters the tool "penalised resumes that included the word 'women' as in 'women's chess club captain'. And it downgraded graduates of two all-women's colleges (Gebru, 2000)." The under-sampled majority (a term coined by Joy Buolamwini) is "unlikely to succeed because the environment is known to be hostile towards people of African, Latinx, and Native American descent; women with disabilities; members of the LGTBQ+ community; and any community that has been marginalised in the tech industry and in the US. The person may not be hired because of bias in the interview process or may not succeed because of an environment that does not set up people for success. Once a model is trained on this type of data, it exacerbates existing societal issues driving further marginalisation (Gebru, 2020)."

To counteract this, other strategies, rather than those correcting the problems that occur after the stage of technological development are necessary (Ramboll, 2020). This points to the need for intervention in the early stages of technological development meaning deep tech venture-building programmes could potentially be key in shaping and leveraging more inclusive deep tech innovations.

While work in this area is novel and to date emerging, the consolidated methods and examples that have been developed to integrate the sex and gender dimension into research content provide a solid basis from which to work.[1] There is also a range of illustrative, in-depth case studies that can be taken from scientific methods applied transversally to different disciplines and product development as well as various policies and interventions undertaken by research-performing organisations, research and innovation funders[2] and national authorities (Hunt et al. 2022).

What are deep tech venture-building programmes?

A Tech Transfer Programme facilitates the transition of innovations and technologies developed in research institutions (such as government agencies, universities, or private companies) into practical applications for broader use.

Deep Tech Venture Builder Programmes foster the creation and growth of technology companies focused on cutting-edge innovations.

[1] See: https://genderedinnovations.stanford.edu/
[2] This work mainly stems from research funding organisations but there are some examples of innovation funders that develop different types of interventions and policies.

Objective

The objective of these guidelines is to apply some of the previously discussed methods (Schiebinger et al. 2020) to the field of deep tech innovations and highlight effective policy interventions.

Therefore, these guidelines will attempt to:

A. Explain why integrating the gender dimension into deep tech innovation is crucial.

B. Demonstrate how this can be done in a few emblematic areas.

C. Provide examples of how big players in the deep tech innovation ecosystem can encourage inclusive gendered innovations with a particular focus on deep tech venture-building programmes.

Why gender-inclusive innovations are important

Danilda and Granat Thorslund (2011) identify different ways innovation ecosystems can use a gender perspective to increase innovative capacity. This section of the guidelines will go through some of these arguments.

Firstly, gender diversity is seen as a driver of creativity and innovation: “Innovation is about creating something new and is enhanced by diversity in gender experiences, perspectives, knowledge and networks. There is a positive relationship between gender diversity in the firm’s knowledge base and its innovative capabilities.

Employees' different dimensions such as education, training and experience along with demographic dimensions such as gender, age and cultural backgrounds also affect the application and combination of existing knowledge and the communication and interaction between employees. Ideally, gender diversity should increase a firm's knowledge base and increase the interaction between different types of competencies and knowledge (Danilda and Ganat Thorslund, 2011)."

More recent research has highlighted how collective problem-solving and collaboration alongside the effective sharing of collective expertise can lead to new discoveries and broaden viewpoints (Nielsen et al. 2017) and shown how increasing diverse perspectives on tackling the clean energy transition could unlock creative solutions (Carroll, 2024).

Secondly, increased competition with user-driven innovation occurs by creating "new concepts, products and services for companies and organisations. Successful and profitable innovations can be developed by working with users and including them in the process, thereby tapping knowledge of their problems and needs (Danilda and Ganat Thorslund, 2011)." While gendered design can run the risk of "reproducing stereotypical patterns" based on some kind of binary and essentialist view that women and men are different, research by Rommes (2007) highlights how designer's beliefs about women do not often conform to the skills, preferences and experiences of most women. Rather, methods that incorporate a feminist direct user approach, which promotes participatory techniques, where potential users are involved in the design from an early stage hold the greatest promise for creating inclusive gendered innovations (Danilda and Ganat Thorslund, 2011).

The European policy framework

Much of the solid work done on gendered innovations (mainly in the field of research) in Europe has been developed within the European Research Area (ERA) framework of priorities and objectives. Since 2012, gender equality and mainstreaming in research has been one of the six ERA priorities with three different objectives: more women in research and innovation, gender balance in decision-making, and integrating the gender dimension into research content and innovation.

In the Horizon 2020 proposal template applicants were asked to describe, when relevant, "how sex and gender analysis is taken into account in the project's content" (EC, 2017).

Despite these advances, the interim evaluation of gender equality as a cross-cutting issue in Horizon 2020 highlights various issues linked to the problematic implementation of integrating the gender dimension into research content. The evaluation states, "the wording of topics is often vague, and gender is not explicitly mentioned (EC, 2017)", it also notes that the concept of the gender dimension is "not well understood" and is "often confused with 'gender balance in research teams' (EC, 2017; Palmén et al. 2020)."

This has been a recurrent finding on this topic. The research content tends to be forgotten and the representation of binary understanding of men/women in research teams comes to the fore. While gender representation is undoubtedly important, keeping an explicit focus on how research and innovation content can be made more inclusive can lead to new topics for research or innovations and is something policymakers in these fields have been grappling with (Nielsen et al, 2017).

The transition to Horizon Europe[3] has strengthened the integration of the gender dimension into research and innovation. The Horizon Europe rules for participation state "the gender dimension in research and innovation (R and I) projects is an award criterion and needs to be integrated in all the topics by default. This is a mandatory requirement unless the concrete topic establishes that sex/gender analysis is not mandatory." By doing this, Horizon Europe intended a shift from the "flagging gender topics" model to the "by default" model (Rogg Korsvik et 2023).

The sex/gender analysis in Horizon Europe proposals will be evaluated under the 'Excellence' criterion for Research and Innovation Actions (RIAs) as well as Innovation Actions (IAs). This means the gender dimension in R and I represents a relevant aspect of the project's objectives and an indicator of whether the proposed work is ambitious and goes beyond the state of the art. The proposal evaluation will particularly look at the "soundness of the proposed methodology, including the underlying concepts, models, assumptions, inter-disciplinary approaches, appropriate consideration of the gender dimension in R and I content, and the quality of open science practices and engagement of citizens, civil society and users where appropriate (Rogg Korsvik et al. 2023)."

In Europe, the relevance of integrating the gender dimension in R and I for innovation and the private sector has been highlighted for many years (from the Helsinki Group high-level advisory body to the European Commission to the European Research Area and Innovation Committee (ERAC)). However, despite this recognition, integrating the gender dimension into innovation and the private sector has lagged (Rogg Korsvik et al. 2023). Regarding policy, it has been noted that there are "two fields of the R and I systems — research and innovation — at two distinct speeds when it comes to considering gender bias and women's needs in the production of knowledge, products, or innovations (Rogg Korsvik et al. 2023).

[3] Horizon Europe is the European Commission's Framework Programme running until 2027. Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion.

> Although more than 50% of the respondents with specific policies on the gender dimension in R and I have indicated that they consider the innovation and private sectors in the field (7 Research Funding Organisations [RFOs] out of 12 with specific policies), innovation gets very few mentions in RFO Gender Equality Plans (GEPs). In one case 'Gender and innovation' has been stated as a subsection within the field of gender dimension in R and I... Yet it is primarily the funding agencies with the strongest focus on innovation that provide valuable examples. VINNOVA, for instance, stresses the error of excluding groups in society whose needs for new solutions are not met, and supports the message that new solutions where sex and/or gender perspectives are integrated can be also economically beneficial.

Rogg Korsvik et al, 2023

The European Institute of Innovation and Technology (EIT) has identified three transversal dimensions for deep tech. These are innovation and entrepreneurship, gender and inclusion, and the Global Challenges/Sustainable Development Goals (SDGs) (EIT, 2023a). Education and training programmes that include these three dimensions within the deep tech space will be eligible for participation.

The EIT defines gender and inclusion as "the balanced integration of male and female scientists and researchers as well as innovators and entrepreneurs in deep tech. It also refers to other forms of inclusion, e.g. youth, disadvantaged groups, minorities and related groups. Specific aspects [...] are open to participation by youth at the secondary level, for example, Girls go Circular, while other related initiatives, for example in women's entrepreneurship, will also be included. (EIT, 2023a)."
The definition recognised going beyond gender as an axes of discrimination/privilege as crucial. This is in line with an increasing acknowledgement that examining the gender dimension without applying an intersectional perspective is becoming increasingly problematic. Factors such as racial or ethnic origin, age, socioeconomic status, sexual orientation, or disability, combine with sex and gender to shape a person's or a group's experience and social opportunities, thereby influencing the form of discrimination and inequality encountered (EC, 2023). In this sense, an intersectional approach is important to consider when setting research priorities, developing hypotheses and formulating study designs.

Research shows taking an intersectional approach can ultimately lead to more inclusive research and engineering solutions (Weber et al. 2007). For example, sex, socioeconomics, gendered division of labour, and language interact to determine how agricultural workers are exposed to endocrine disruptors. Recent research also demonstrates how an intersectional approach can improve the accuracy of AI-based facial recognition and energy efficiency measures.[4]

[4] See: https://genderedinnovations.stanford.edu/methods/intersect.html

How to develop inclusive gendered innovations

The following section will highlight some of the different methods that have been developed within the framework of the European Commission's Gendered Innovations project as a basis to apply to deep tech case studies.[5] These methods will be applied to three broad areas of particular interest — ICT, health and energy — to demonstrate the challenges, applicable methods and inclusive innovations that came from applying these methods.

[5] See: https://genderedinnovations.stanford.edu/index.html

Methods

The general arguments for integrating the gender dimension into innovations are convincing. However, there is a general lack of understanding on how to do this, specifically in the realm of deep tech. This is due to a range of different reasons including the deep specialisation and knowledge needed in very specific technological areas to make these kinds of innovations more inclusive.

Deep tech developments tend to occur much further away from the user than in other areas of research and innovation. This added difficulty means some of the tried and tested methods for promoting inclusive gendered innovations, like integrating a diverse user base in the needs assessment and design stage of the technology become more challenging.

These guidelines use the framework of the Gendered Innovations project to shed light on how deep tech venture-building programmes can encourage more inclusive gendered innovations.

The project provides a solid methodological framework as well as providing concrete examples in a range of different sectors. The overall framework seeks to include the sex and gender dimension into every phase of the research and innovation cycle by:

- Rethinking research priorities
- Rethinking concepts and theories
- Formulating research questions
- Analysing sex
- Analysing gender
- Analysing how sex and gender interact
- Intersectional approaches
- Engineering innovation processes
- Co-creation and participatory research
- Rethinking standards and reference models
- Rethinking language and visual representation

Case studies from across a range of different fields complement these methods, offering insight into how applying the range of methods to certain disciplines can produce more inclusive innovations in different sectors.[6]

The guidelines also build on work developed by Vinnova, which is Sweden's innovation agency.[7] Vinnova has long been at the forefront of promoting gender-inclusive innovations through its' norm-creative innovation work[8] (Wikberg Nilsson and Jahnke, 2018).

[6] See: https://genderedinnovations.stanford.edu/fix-the-knowledge.html
[7] See: https://www.vinnova.se/en/
[8] Norm-creative innovation is defined as "a two-step process. First the designer must be norm-critical, and after norm-creative. The aim of the first step is to critically analyse relevant social norms including socially constructed mental models, outlooks and values; perceptions of difference; and perceptions of which roles and characteristic we value and devalue – all of which contribute to inequality and social exclusion. The second step involves norm creative design thinking – developing design solutions that counteract such norms through reflection on what might be. We...explore the notion that norm-creative innovation has the potential to produce outcomes that are desirable, valuable, and satisfying because they are socially sustainable (Wikberg Nilsson and Jahnke, 2018)."

Accordingly, these guidelines aim to provide insights into how deep tech venture builder programmes can build on previous work creating inclusive innovations. They offer emblematic examples in three different fields (ICT, health and energy) to highlight the relevant challenges, methods and subsequent inclusive gendered innovation(s). Integrating the sex and gender dimensions is unsurprisingly most developed in health and biomedicine, while it is also advancing in machine learning and artificial intelligence and beginning to emerge in other fields (Hunt et al. 2022).

Case studies: ICT, health and energy

ICT: AI facial recognition

Challenge:

Facial recognition systems (FRS) identify people by reading their facial features. FRS are increasingly used for a range of different purposes from verifying a whole range of administrative and bureaucratic procedures to surveillance, security, authorising payments, unlocking phones, and more. Estimates from 2022 valued the facial recognition market at approximately 5 billion USD with projections estimating it to grow to 19.3 billion USD by 2032 (Borgeaud, 2023).

The work of Joy Buolamwini exposed widespread gender and racial bias in facial recognition services developed by tech giants around the world. In her work with Timnit Gebru in the 2018 Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification paper Buolamwini explored how facial analysis algorithms display increasing error rates that range from only 0.8% for lighter-skinned males to 34.7% for darker-skinned females. Together they exposed most commonly used datasets as being overwhelmingly composed of lighter-skinned subjects (average of 82.9%), leading to darker-skinned females being the most misclassified group by commercial companies relying on FRS (Buolamwini and Gebru, 2018).

Method: analysing gender and intersectionality in machine learning

FRS are built using machine learning (ML) and bias can occur at different stages of the process including data collection, data preparation and labelling, and model selection. For example, if a dataset is skewed and does not provide a representative sample of the target population (gender, colour, age, etc.) the subsequent model will not work as well (or at all) on certain groups of people. The work of Buolamwini and Gebru (2018) recognised that racial classifications are problematic when considering their operationalisation into ML systems for facial recognition. Accordingly, their research built on the dermatologist-approved Fitzpatrick Skin Type classification system.[9]

Other research has demonstrated how recognition of emotions is a challenging problem in ML that includes building classifiers to recognise emotion in facial recognition systems (Mehta et al. 2019). There is also evidence that charts the questionable reliability of FRS built on adult faces when recognising young people (Howard et al. 2017). The ability of these systems to be accurate when facial cosmetics are worn has also been disproved by Dantcheva et al. (2012) who established the impact of facial makeup on automated biometric systems.

[9] The Fitzpatrick Skin Phototype is a classification based on the skin's response to sun exposure and takes into account the tendency that the individual presents to get sunburned and tanned. It is a questionnaire that is based on genetic predisposition, reaction to sun exposure, and tanning habits. This enables the classification of skin according to one of six types: from pale white skin, always burns, never tans to dark brown skin, never burns (Oliveira et al. 2023).

The researchers illustrated that non-permanent facial cosmetics can significantly change facial appearance, both locally and globally — by altering colour, contrast and texture — reducing accuracy by 76%. Other authors, for example, Keyes (2018) have noted that increasingly popular FRS may incorrectly recognise transgender people, especially during transition.

What can be done? Gendered innovations

Bias prevention must be incorporated into the earliest stages of AI mechanism creation processes. This involves ensuring, among other things, that training, validation and testing datasets are sufficiently relevant, representative, error-free and complete in view of the intended purpose of the system (EPRS, 2022).

To prevent discrimination in AI, it is crucial to prioritise fairness and trustworthiness at every stage of the AI development lifecycle. This involves addressing biases during data collection and pre-processing, as well as throughout model building, training, evaluation, deployment, and impact assessment when AI systems are used by end users in real-world scenarios (EPRS, 2022).

Training datasets may need to include intersectional characteristics, such as gender and race. The Gender Shades project,[10] based at MIT, developed and validated such an intersectional training dataset for four categories: darker-skinned women, darker-skinned men, lighter-skinned women and lighter-skinned men (Buolamwini and Gebru, 2018).

[10] See: http://gendershades.org/

Health and wellness

Challenge:

Medical devices are products or equipment intended for a medical purpose.[11] According to the World Health Organisation (WHO), medical devices are essential for the safe and effective prevention, diagnosis, treatment, and rehabilitation of illness and disease (Phillips et al. 2022). In 2019 an examination of 340,000 reports to the United States Food and Drug Administration (FDA) found women made up 67% of those either killed or injured by medical devices (Guevara, 2019; Phillips et al, 2022). To overcome this situation, the FDA produced specific guidelines and a strategic plan to better inform medical device research and regulation for all women.[12]

Medical devices can be supported by artificial intelligence and machine learning has the potential to simplify and mitigate risks as well as cut costs (Haleem et al. 2019; Campesi et al. 2024). Despite the recognised and well-established influences of sex and gender on health and medicine, most AI technologies used in biomedicine do not consider sex and gender (Cirillo et al. 2024). Fewer women are included in AI studies, including those focused on digital biomarkers:

> "Digital biomarkers are physiological, psychological and behavioural indicators based on data including human-computer interaction (e.g. swipes, taps, and typing), physical activity (e.g. gait, dexterity) and voice variations, collected by portable, wearable, implantable or even ingestible devices (Coravos et al. 2019). They can facilitate the diagnosis of a condition, the assessment of the effects of a treatment and the predicted prognosis for a particular patient. In addition, some digital biomarkers can inform on patient adherence to treatment"
>
> Cirillo et al. 2020

Research claims that the analysis of sex differences on digital biomarkers can be prevented by skewed datasets used by the models that provide the health indicators. For example, a study assessing digital biomarkers for Parkinson's disease involved only 18.6% women (Cirillo et al. 2020). If an algorithm is built with data mainly obtained from men, it will be more accurate for men than for women.

There is also evidence that current studies for testing digital biomarkers are often carried out with small sample sizes in the range of tens to hundreds of subjects and do not provide sufficient sex and gender demographic information (Snyder et al. 2018 in Cirillo et al. 2020). They will, therefore, more accurately detect symptoms more frequent in men — in the case of Parkinson's there is a body of evidence showing how the disease presents itself differently in men and women, for example, men tend to display rigidity and rapid eye movement, while women display uncontrolled shakes and depression (Miller et al. 2010).

[11] In the European Union (EU) they must undergo a conformity assessment to demonstrate they meet legal requirements to ensure they are safe and perform as intended. They are regulated at EU Member State level, but the European Medicines Agency (EMA) is involved in the regulatory process. See: https://www.ema.europa.eu/en/human-regulatory-overview/medical-devices

[12] See: https://www.fda.gov/media/155461/download

How well medical devices function also depends on a range of other characteristics beyond gender. For example, pulse oximeters which measure oxygen levels without drawing arterial blood work less well for people with darker skin (Keller and Harrison-Smith, 2022). A study compared oxygen saturation measurements taken with pulse oximeters against those taken from arterial blood gas. The findings, based on an analysis of over 47,000 paired readings, found that oximeters misread blood gases 12% of the time in Black patients compared to 4% of the time in white patients (Sjoding et al. 2020).

Method: analysing sex and gender

Medical technology often prioritises development for men, which unfortunately means that the benefits do not extend to everybody. To address this, sex and gender-related factors must be considered from the outset of development. This includes taking sex and gender into account during problem identification, research design, and data collection and analysis. For instance, in the context of a total hip replacement, analysing sex differences in immune responses becomes crucial. Similarly, when bioprinting kidneys or other organs, it is essential to consider sex differences in cells and the complexities related to X-inactivation.[13]

Method: intersectional approaches

Medical technology can exhibit biases in various interconnected and cumulative ways. Technologists should incorporate relevant intersectional analyses, particularly during the development and calibration of medical devices.[14] The proposal for a Diversity Minimal Item Set developed by Stadler et al. (2023) is a useful place to start.[15]

Gendered innovation 1: automated gender-Parkinson's disease detection via a hybrid deep model using human voice

In one study, Kaya (2022) aimed to create a reliable system for detecting Parkinson's disease (PD) and identifying gender. They used a combination of techniques, including a type of wavelet transform (TQWT), a convolutional neural network (CNN), and a feature selection method called minimum redundancy maximum relevance (mRMR).

They carried out the following steps:

1. Data introduction: they started with data related to PD and gender.
2. Feature extraction: they used a pre-trained model to extract feature vectors from specific layers of the network.
3. Feature selection: they then filtered the features obtained with the process helping to focus on the most relevant features.
4. Classification: finally, they classified the data using the k-nearest neighbours' algorithm (k-NN).[16]
5. Results: The system achieved an impressive accuracy rate of 98.9% for fine-tuned k-NN, and the Kappa statistic (a measure of agreement) was 98.4%.

[13] See: https://genderedinnovations.stanford.edu/case-studies/medtech.html#tabs-2
[14] See: https://genderedinnovations.stanford.edu/case-studies/medtech.html#tabs-2
[15] Stadler et al. (2023) propose a brief, efficient Diversity Minimal Item Set (DiMIS) for routine data collection in empirical studies to contribute to closing the diversity and gender data gap. While the authors focus on the example of health they consider the DiMIS as applicable across scientific disciplines.
[16] The K Nearest Neighbour is a simple algorithm that records all the available cases and classifies the new data based on a measure of similarity. It is often used to classify a data point based on the classification of its neighbours (Subramanian, 2018).

In summary, the researchers developed a powerful system that combines different techniques to accurately detect PD and determine gender based on relevant features.

Inclusive innovation 2: Pulse Oximeters adjusted for skin tone

Pulse oximeters are devices used to measure oxygen levels in the blood. However, they may not work as effectively for people with darker skin tones. This is because both deoxyhaemoglobin (a molecule in blood) and melanin (the pigment responsible for skin colour) absorb light. When skin is darker, the melanin absorbs more light, which can affect the accuracy of pulse oximeter readings.

Researchers have known about this issue for a long time. In 1999, an early patent was filed to adjust pulse oximeters based on skin tone (Chin, 1999). More recent patents — 2019 and 2020 — also address this concern (Barker et al. 2019; Bechtel et al. 2020). These newer designs take tissue colour (including skin tone and melanin content) into account to improve accuracy.

In summary, efforts are being made to develop pulse oximeters that consider skin colour variations, ensuring more accurate oxygen level measurements for all patients.

Energy and sustainability

Challenge:

Climate change is arguably one of the most pressing societal challenges and subsequent efforts to foster the green transition and honour the Paris accord to keep the global temperature increase under 1.5 degrees requires multiple actions. The intersection of gender equality, climate management and AI systems has important implications for sustainability and the energy transition. AI systems have been deployed in natural resource management sectors such as fishing, agriculture, energy, mining and other extractive industries. Estimates expect AI in the agricultural market alone will be worth 4.7 billion USD by 2028 (Goddard et al. 2023).

Energy is increasingly perceived as a key element of security and while critical to improving livelihoods, most actors in the energy transmission and transition points are men with the sector having been highlighted as lacking a substantive gender perspective (Goddard et al. 2023). In recognition of this, in 2018 "the European Parliament adopted a resolution [...] which calls on the EU Commission to include a gender dimension in a structured and systematic manner in their climate change and energy policies for the EU, not just in policies targeting the Global South (Carroll et al. 2024)."

The gendered dimensions of different facets of the energy sector are multiple. For example, more women than men live in energy poverty, while more women use public transport. Carroll et al. (2024) highlight how the use of analytical tools to uncover the gender dimensions of energy and transport policies can play a key role in leveraging the full potential of energy and climate policies to foster more equitable impacts on all men and women.

Increasingly, the deployment of AI tools as part of sustainable solutions will rise. For example, in agriculture, AI is being used for robot harvesting, automatic forecasting, and more (Goddard et al. 2023). At the same time, AI can be used to analyse policy approaches, particularly for identifying where gender-responsive policies are either in place or there is a lack of such policies (Carroll et al. 2024).

[17] See: https://unfccc.int/process-and-meetings/the-paris-agreement

Method: analysing gender

AI value chains represent the organisational processes through which individual AI systems are developed and deployed. These chains consist of essential innovation ecosystems as well as sociotechnical factors. To mitigate potential exclusion and inequity, it is crucial to examine gender-based disparities and constraints related to decision-making authority within the AI value chain (Goddard et al. 2023).

Method: intersectional approaches

The discourse around energy often overlooks the human element. To address this requires an intersectional perspective — one that acknowledges the various interconnected and overlapping facets of people's social identities, including gender, socio-economic status, and age.[18] Gender, for instance, not only influences but is also influenced by other social characteristics like ethnicity and socio-economic status. Collectively, these factors shape the life experiences of individuals who interact with the intricate sociotechnical networks comprising our energy system.

Inclusive gendered innovations 1: solution design-responsibility loop

Indigenous AI and data protocols should be woven into value chains including team composition, research and development of data sets, algorithmic design, and impact assessment of AI systems, etc. Protocols require local knowledge before expanding to a global contest. Each indigenous group will have their own approach and concerns regarding AI systems. An example of an indigenous matriarchal approach to governance protocols includes truthfulness, respect for life, and all generations, reciprocity and cultivating enduring relationships. Protocols also include mutual accountability, shared benefits, avoiding extractive data collection and use, and promoting data sovereignty (Goddard et al. 2023).

Inclusive gendered innovations 2: using Natural Language Processing (NLP) to analyse the gender dimension of policies

NLP techniques have been used to quantify the degree to which the language used in national energy policies considers the gender dimension. The work of Carroll et al. (2024) shows the current gap in suitable tools. Key findings include a review of methods used in energy/gender nexus analysis, an empirical approach to analysing energy/gender concepts in the Global North, as well as measurement of gender dimension (bias) in the language used in European Union National Energy and Climate Plans (NECPs).

Specifically, by using NLP they demonstrate that all EU NECPs tend to use more male-associated language than female. In a ranking of EU member states, the Portuguese NECP demonstrated the most bias, while the Slovenian demonstrated the least. Their work "provides novel insights using NLP to understand the genderised use of language and contributes a methodology to conduct empirical analysis of energy policy documents (Carroll et al. 2024)."

[18] See Grzanka et al. (2023) for a discussion of intersectionality in social and technology studies.

Checklist of suggested actions

Various actions have been taken by research funding organisations throughout Europe to integrate the gender dimension in research and innovation including:

- financial incentives/support to promote the gender dimension in research and innovation,
- funding programme for gender studies,
- requiring applicants to specify whether they are considering sex/gender in their research/innovation proposal,

- encouraging the inclusion of gender experts in the research teams in R and I calls,
- considering sex/gender analysis training for research teams as an eligible cost in Research Funding Organisations (RFO) funding schemes,
- establishing processes to evaluate the integration of sex/gender analysis in R and I,
- positive action measures to favour projects that integrate sex/gender,
- guidelines on the gender dimension of R and I for applicants/evaluators,
- training on the gender dimension of R and I for applicants/evaluators,
- including experts on gender and R and I on evaluation committees,
- communication campaigns to make visible the support for sex/gender analysis,
- dissemination of the available materials on the gender dimension in R and I (Rogg Korsvik et al, 2023).

According to the GENDERACTIONplus[19] survey, 60% of the RFOs surveyed have adopted some kind of specific policies for integrating the gender dimension into R and I content. Of the policies analysed, 50% include an intersectional approach. The most common measure to promote the gender dimension in R and I content is requiring applicants to specify whether they are considering sex/gender in their research/innovation proposal with 70% of RFOs having this in place (Rogg Korsvik et al. 2022).

While RFOs are distinct from deep tech venture-building programmes, given the lack of actions and interventions developed to integrate the sex and gender dimension into deep tech innovations in the latter, it is worthwhile considering how an inclusive gender dimension can be integrated into broad phases of the programme cycle and specific actions linked to each of these phases:

- **Programme design:** definition of terms, call language, definition of programme activities
- **Programme implementation:** implementation of actions, trainings
- **Programme evaluation**

We build on the framework developed by Hunt et al. (2022) to implement and evaluate policies for sex, gender and diversity analysis in research policies and look at how these might be relevant and subsequently adapted to the innovation sector.

[19] See: https://genderaction.eu/

RFOs vs deep tech venture-building programmes

- RFOs distribute funding to researchers mainly through competitive calls to which researchers apply in order to receive funds to carry out basic and applied research in a range of different disciplines.
- In contrast to RFOs, deep tech venture-building programmes bring together scientists/ technologists with entrepreneurs in order to successfully launch a deep tech innovation into the market.
- While the aims of these two different types of entities are distinct RFOs have been grappling with how to successfully integrate the gender dimension into research content and subsequent innovations for a number of years (Palmén et al, 2020). Some of the different types of interventions employed by RFOs therefore might also be applicable to deep tech venture-building programmes.

Programme design

Definition of terms

When designing the programme, all stakeholders must be working from the same definitions. These should be clear and readily available to all applicants, evaluators, and staff. The Gendered Innovations website offers definitions of terms across prominent granting agencies[20] (See Annex 1 for commonly used definitions).

There is no need to reinvent the wheel in this area, but all stakeholders should use the same solid references. Furthermore, in recognition of the emerging nature of creating a solid evidence base for these kinds of interventions, it is crucial to ensure all stakeholders attribute the same meaning to each of the terms. It also means programme designers, call writers, evaluators and applicants build up transferable competencies in this field, which can be applied across calls, while also facilitating cross-organisational collaboration and networking.

Launching a call

When launching a call, a range of different interventions can foster more inclusive innovations. These range from keeping gender-biased language out of the call to including a section that highlights taking an inclusive approach to innovations. The call could also refer to promoting an inclusive innovation methodology. Other types of interventions employed include requesting the involvement of gender experts in R and I teams in the text of the call or considering training on sex and gender analysis for the team as an eligible cost (Rogg Korsvik et al. 2023).

[20] See: https://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-major-granting-agencies1.html

Proposal guidelines for applicants

Hunt et al. (2022) identified three basic approaches in their requests for applicants to integrate the gender dimension into their proposal where relevant. The most common approach is to encourage applicants to integrate sex and gender analysis. Some agencies require this analysis while others only encourage applicants but then instruct the evaluator to score based on the element. Hunt et al. (2022) also noted how the "where relevant" is crucial and that it is legitimate to explicitly state where it might not be applicable.

The European Commission is perhaps one of the most complete examples of a funding body requiring the applicant to integrate the gender perspective into their proposal.[21] The Horizon Europe application form says: "Describe how the gender dimension (i.e. sex/gender analysis) is taken into account in the project's research and innovation content". For example, if you do not consider such a gender dimension to be relevant in your project, please justify why.[22]

It is worth considering how this could apply to innovation funders and venture-building programmes. Asking applicants to consider how they integrate a sex/gender (and intersectional) dimension into proposed innovations may provide a catalyst for developing more inclusive innovations. That this would occur before applicants receive funding means it may serve to shape innovations to be more inclusive. To ensure a greater impact this could also be accompanied by training (see section on training for applicants, evaluators and staff).

Instructions for evaluators (stages of assessment and decision-making)

Research has demonstrated that "targeting applicants alone to adopt new science policies without concomitant pressure by evaluators... may not be effective" (Haverfield and Tannenbaum, 2021). Since 2018, the Canadian Institutes of Health Research (CIHR) has required evaluators to rate the quality of integrating the sex and gender dimension as a "strength", "weakness", or "not applicable" and to provide a rationale for their rating along with recommendations for applicants to improve (Haverfield and Tannenbaum, 2021). The evaluation process must then be monitored to confirm that the sex and gender dimension is addressed in high-quality reviewer comments.

Effective procedures for assessing the incorporation of sex/gender analysis in R and I include institutional mandates, well-established guidelines and targeted training for evaluators on the gender dimension of R and I. Additionally, involving gender experts in R and I evaluation committees and implementing positive action measures — such as assigning specific weights to this criterion or considering it as a factor when projects receive similar scores — can promote projects that integrate sex/gender considerations (Rogg Korsvik et al. 2023).

[21] The Horizon Europe Programme Guide states: "The integration of the gender dimension into R&I [research and innovation] content is mandatory. It is a requirement set by default across all Work Programmes, destinations and topics, unless its non-relevance for a specific topic is specified in the topic description, e.g. by the mention 'In this topic the integration of the gender dimension (sex and gender analysis) in research and innovation content is not a mandatory requirement.' (European Commissions, 2024)"

[22] "Note: This section is mandatory except for topics which have been identified in the work programme as not requiring the integration of the gender dimension into R and I content. Remember that that this question relates to the content of the planned research and innovation activities, and not to gender balance in the teams in charge of carrying out the project. Sex and gender analysis refers to biological characteristics and social/cultural factors respectively." See: https://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-major-granting-agencies

Implementation and evaluation of policy

Training for applicants, evaluators and staff

The most comprehensive online interactive agency training currently exists in health and biomedicine (Hunt et al. 2022). While training is also available for specific domains such as the natural sciences, engineering, computer science, and environmental sciences, there remains a need for further expansion. Agencies can assess the effectiveness of this training by incorporating both pre- and post-tests. Although most trainings are voluntary, some funders mandate that applicants submit a certificate of completion (Hunt et al. 2022)

It is important to use the same training materials for all applicants, evaluators and staff as it helps to ensure consistency in the policies, terminology and expectations. Some agencies foster training in this area.

Various online tools can support training (see Annex 1 for useful resources).

Evaluation of policy implementation

When an agency adopts a policy, it must then evaluate the effectiveness of the policy. Hunt et al. (2022) set up a framework to capture the following indicators:

1. The number and proportion of proposals that include sex, gender and diversity analysis.
2. The number and proportion of proposals that include quality sex, gender and diversity analysis.
3. The quality of evaluators' scoring and comments.
4. The number of applicants, evaluators, and staff who engaged in training and in what type of training.
5. The number and proportion of peer-reviewed applications (or other recognised modes of dissemination) that result from funded proposals that incorporated sex, gender and diversity analysis.

Conclusions

These guidelines have covered and built upon the vast knowledge and evidence base on integrating the sex and gender dimensions and including an intersectional perspective into research content to illustrate how this can be fostered in the sphere of deep tech innovation.

Leveraging well-known examples provided by Gendered Innovations in the fields of AI, health and energy, the guidelines attempt to link further to a range of deep tech innovations, primarily in the fields of artificial intelligence and machine learning. These types of emerging technologies have the potential to either exacerbate or tackle existing inequalities, meaning integrating sex and gender dimensions throughout the whole research and innovation cycle becomes key — if the resulting innovation is to be of high quality and maximum reach.

The guidelines also utilise the increasing evidence base showing this work is taking place in research policy throughout the different policy/programme stages, i.e. design, implementation, and evaluation. The increasing evidence base in this area can be applied creatively to the innovation sphere. Deep tech venture-building programmes have real potential to shape the future of emerging technologies by requiring that inclusivity is considered and successfully implemented to create more inclusive deep tech innovations for the benefit of all.

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Annex 1: Useful definitions and resources

Gendered Innovations

The European Commission's peer-reviewd Gendered Innovations[23] project develops practical methods of sex, gender, and intersectional analysis for scientists and engineers and provides case studies as concrete illustrations of how sex, gender and intersectional analysis leads to innovation.

[23] See: https://genderedinnovations.stanford.edu/

The project reference is: Schiebinger, L., Klinge, I., Paik, H. Y., Sánchez de Madariaga, I., Schraudner, M., and Stefanick, M. (Eds.) (2011-2020). Gendered Innovations in Science, Health and Medicine, Engineering, and Environment (genderedinnovations.stanford.edu).

This website is peer-reviewed. All materials were developed in a series of Gendered Innovations Workshops and reviewed by experts. • This website is peer-reviewed. All materials were developed in a series of Gendered Innovations Workshops and reviewed by experts.[24]

Definitions used by Gendered Innovations:

- European Commission (EC)
  - Sex: https://genderedinnovations.stanford.edu/terms/sex.html
  - Gender: https://genderedinnovations.stanford.edu/terms/gender.html
  - Intersectionality: https://genderedinnovations.stanford.edu/terms/intersectionality.html
- Canadian Institutes of Health Research (CIHR)
  - What is gender; What is sex: https://cihr-irsc.gc.ca/e/48642.html
  - Gender-Based Analysis Plus: https://cihr-irsc.gc.ca/e/50968.html
  - Intersectionality: https://cihr-irsc.gc.ca/e/52352.html
  - Indigenous Health Research: https://cihr-irsc.gc.ca/e/50340.html
- US National Institutes of Health (US NIH)
  - Sex and Gender: https://orwh.od.nih.gov/sex-gender
  - Inclusion across the Lifespan: https://grants.nih.gov/policy/inclusion/lifespan.htm
- German Research Foundation (DFG)
  - Sex, Gender, Diversity: https://www.dfg.de/en/principles-dfg-funding/developments-within-the-research-system/diversity-dimensions
- German Research Foundation (DFG)
  - Sex, Gender, Diversity: https://www.dfg.de/en/principles-dfg-funding/developments-within-the-research-system/diversity-dimensions
- Gendered Innovations
  - Race and Ethnicity: https://genderedinnovations.stanford.edu/terms/race.html
- National Sciences and Engineering Research Council of Canada (NSERC)
  - Equity, Diversity and Inclusion (EDI): https://www.nserc-crsng.gc.ca/_doc/EDI/Guide_for_Applicants_EN.pdf
- National Health and Medical Research Council (NHMRC), Australia, uses the Australian Commonwealth definitions
  - Aboriginal and Torres Strait Islanders: https://aiatsis.gov.au/explore/indigenous-australians-aboriginal-and-torres-strait-islander-people

For more information see: https://genderedinnovations.stanford.edu/sex-and-gender-analysis-policies-major-granting-agencies1.html

[24] See: http://genderedinnovations.stanford.edu/people.html

Vinnova

Vinnova[25] is Sweden's innovation agency. Its mission is to strengthen Sweden's innovative capacity and contribute to sustainable growth. They work to ensure that Sweden is an innovative force in a sustainable world. Vinnova has developed **NOVA: Empowering Norm-Creative Solutions.**[26] NOVA provides practical tools and hands-on methods for individuals seeking to create norm-creative solutions. These solutions prioritize inclusivity, accessibility, and sustainability.

In today's world, products, services, and environments often fall short because they are designed with a narrow perspective of people's situations and needs. One contributing factor is a lack of awareness about how societal norms and values impact the outcomes of innovation and development efforts. NOVA aims to bridge this gap by assisting developers in analysing needs and translating knowledge into innovative solutions that add value while considering diverse perspectives.

Health and biomedicine online training materials

The most comprehensive open-access interactive training to date is available for the biomedical and health fields. In 2015, the Canadian Institutes of Health Research (CIHR) launched 3 online courses:

- Integrating sex and gender into biomedical research
- Sex and gender in primary data collection with humans
- Sex and gender analysis of secondary data from human participants Completion of the training modules is mandatory for some large, strategic funding competitions.

CIHR also found that evaluators appreciated tailored training within their specific discipline. Some of their projects include:

CIHR: Sex and gender research and methods: https://cihr-irsc.gc.ca/e/49629.html

CIHR: Institute for Gender Health videos and webinars: https://cihr-irsc.gc.ca/e/48641.html

Karolinksa Institute: Gendered Innovation Alliance: https://staff.ki.se/gendered-innovation-alliance-gender-dimension-for-better-health

[25] See: https://www.vinnova.se/en
[26] See: https://www.vinnova.se/en/publikationer/nova---tools-and-methods-for-norm-creative-innovation/

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