CENTER FOR SUSTAINABLE ICT - CESICT

September 26 - 2022 – John Krogstie

The IE faculty together with NTNU Digital have taken the initiative establish a new center for sustainable ICT (CESICT). It will promote interdisciplinary and intersectoral approaches to ensure that the development and evolution of ICT-solutions to is done in a sustainable manner. The center will act as a NTNU-coordinated network of activities for research institutions, industries, and the public sector, and will be hosted by the IE-faculty and administrated by NTNU Digital.

The center will play an important role in the achievement of a climate-neutral sustainable economy as set out by the EU Commission and the Norwegian Climate Plan. To achieve this goal, there is an urgent need that the ongoing digitalization both contribute to sustainability in other fields, and at the same time is sustainable in itself.

Vision: Knowledge leading to the development and evolution of sustainable ICT solutions for sustainable development

Mission: Mobilize multidisciplinary expertise collaborating to guide digitalization of society in a sustainable direction

Goal: Develop innovative, holistic methods, technologies and solutions to support a sustainable digitalization of society, where the research-based knowledge developed is to benefit both nationally and internationally

The **success of the center** will be measured by supporting existing initiatives and contributing to the launch of new research and development projects in the area, with a main acquisition goal of achieving an SFI in the next round of calls, alternatively an FND (Forskningssenter for næringsrettet digitalisering) as described in the Digital21 Strategy and Hurdalsplattformen, given this initiative materializes and is funded by the Norwegian government. The centre should also be involved in the next call for SFF. The center will contribute towards achieving the national CO2 targets and support the green shift, measured in form of significantly reduced CO2 and greenhouse gas emissions in a way that is sustainable also on an economic, social, personal, and technical level.

1. Role of ICT in sustainable development

Climate change and its consequences will provide enormous challenges to society over the next decades (IPCC 2019) (Cook et al. 2016). Society needs to address these challenges, both by mitigating the changes and by adapting to them. At the same time, we need to assure that the resulting society is both economically viable and socially desirable.

ICT plays an important role in assuring both environmental, economic, and social sustainability. The need for the ICT field to address sustainability has been acknowledged for some time in areas such as Information systems (vom Brocke et al 2013), HCI, and software engineering, as seen for instance in the Karlskrona manifesto (Becker et al. 2015). The impact of information technology can be seen as both direct and indirect effects of the software and hardware (Hilty et al. 2006). Direct effects such as energy consumption are what Hilty et al. denote first-order effects. Second-order effects include the consequences of processes being changed (e.g. in transportation or production) by the application of

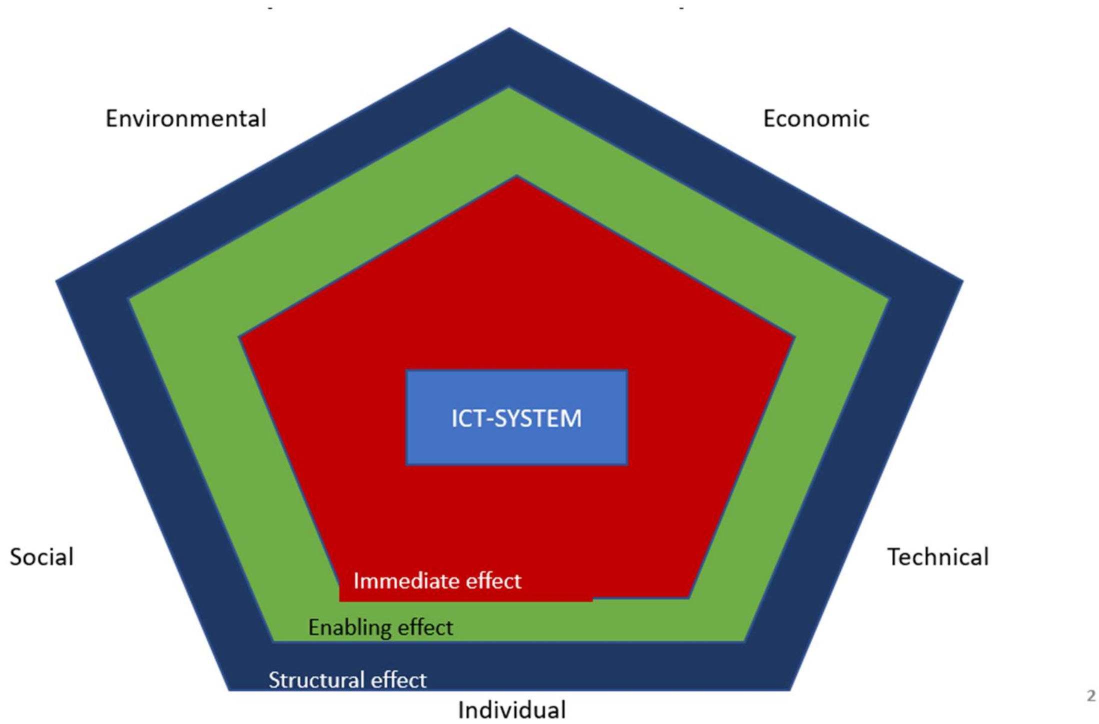
ICT. Third-order effects are seen as long- and medium-term change in behavior, such as change in consumption patterns, and change in economic structures. These effects come with a considerable number of possible challenges. For instance, increased effectiveness of an algorithm might on the one hand lead to less energy use, but might also lead to extensive use of a system and the first-order effect of requiring more server capacity and using more electric power in one or more physical locations. The need for more transportation of goods might be a second-order effect of extensive use of a hugely popular app connected to a web shop. The change in purchasing habits of a large amount of people can lead to the third-order effect of physical shops in city centers closing down. Those responsible for creating/acquiring/adapting the IT solutions have to be aware of such consequences to be able to take well-informed decisions and give good advice e.g. to clients and regulators. From being an expert comes responsibility for awareness, information seeking, collaboration, and concern for the common and long-term good.

The software development process is the most important enabler for a future where trustworthy software impacts the quality of people's lives in society. Software engineering holds the scientific theory for the design, implementation and maintenance of software systems.
Today, processes for designing and evaluating software are based on direct functionality, cost and value for industry, without sufficient focus on the wider societal and environmental impact of software, which is changing the way software is developed. A shift towards a focus on sustainable development constitute a major change in perspective.

One of the core competence areas of professionals involved in the development of ICT is the identification and representation of requirements, and turning this into operational software. For modern ICT-solutions, sustainability can be considered a key non-functional cross-cutting requirement. Becker and colleagues (Becker et al. 2016) have developed a model structuring the effects of software systems into five dimensions. Three of them are used in several sustainability models and originate in (Brundtland 1987): The economic (monetary), the environmental, and the social dimensions. To this, Becker and colleagues add the individual and the technical dimension, and these five dimensions are often depicted as a pentagon as seen below.

For each of the five dimensions, this pentagon model distinguishes between immediate, enabling and structural effects, corresponding to the first-, second- and third-order effects outlined in (Hilty et al. 2006). The pentagon model has been used in the development of a model for sustainability evaluation of ICT projects (Porras et al. 2017) where it is denoted as 'sustainability analysis diagram'. Other models in use combine the personal and social levels (Bischoff et al., 2022).

The model depicts the IT-systems in the middle, discussing this from a software engineering point of view. In an information systems, one would also directly include aspects such as improved business processes that reside on the second level.



The five dimensions can be described in more detail in the following way: (Becker, 2016)

- *The individual dimension* covers individual freedom and agency (the ability to act in an environment), human dignity, and fulfillment. It includes individuals' ability to thrive, exercise their rights, and develop freely.

- *The social dimension* covers *relationships* between individuals and groups. For example, it covers the structures of mutual trust and communication in a social system and the balance between conflicting interests.

- *The monetary dimension* covers financial aspects and business value. It includes capital growth and liquidity, investment questions, and financial operations.

- *The technical dimension* covers the ability to maintain and evolve artificial systems (such as software) over time. It refers to maintenance and evolution, resilience, and the ease of system transitions. According to (Davidsen & Krogstie, 2010, Holgeid et al 2022) only between 20-25 % of the work used on ICT is used on developing new functionality in new or existing software systems, whereas the rest of the time is used to keep the existing systems operational. The technical dimension on sustainability has to be seen in the light of that there is an external pressure to change the ICT-systems, i.e. one must be able to change existing systems for them to not become obsolete.

- *The environmental dimension* covers the use and stewardship of natural resources. It includes questions ranging from immediate waste production and physical resource and energy consumption to the balance of local ecosystems and climate change concerns.

These dimensions are often interlinked, so that an effect in one can have positive or negative effect on another.

Also the level of effect can be blurred, and we will in the analysis primarily look upon this so that what is immediate effects are the immediate consequences of developing and using an ICT system, whereas enabling effects relates to the how (new) behavior is enabled when using the system (even if this effect is planned through for instance new business processes that are made possible through the use of the system). We will briefly exemplify issues typically discussed on the 15 different parts of the model (the 5 dimensions on all the three levels) below. Although we do not intend to cover all aspect in the center, it should be possible to position projects belonging to the center within this framework in a way so that it covers two or more sub-areas.

Examples of immediate effects:

- *The individual dimension*: The systems are developed and maintained by people having good working conditions. Data about individuals used for training purposes of machine learning components is not misused for purposes that the person do not have knowledge about, and not having the opportunity to opt out of.

- *The social dimension:* The social system on the immediate level relates to the interplay of core users and stakeholders (including developers, testers, and operators) that is involved in the development and evolution of the system. The system should provide fair access to resources and services, and the interest to the different stakeholder groups should be balanced in the development and implementation of the requirements to the system.

- *The economic dimension*: The monetary value of the system in use is higher than the cost of development, evolution and maintenance of the system. This includes standar project management practices and the use of traditional models in investment analysis as part of benefits management (Holgeid et al, 2021).

- *The technical dimension:* The technical artifact would need to be properly tested so that the system does not break down unduly. It is possible to keep the system operational as soon as it released (devops), with the possibility of rapid updates to fix errors (continuous deployment). It needs to be possible to change the system in an agile fashion in a way that is not making the system harder to maintain and use in the future (Belady and Lehman, 1976).

- *The environmental dimension*: This includes aspects of direct and indirect carbon and resource footprint of the development, maintenance and use of the system. For instance will the use of a more efficient algorithm at this level provide a smaller carbon footprint than a less efficient algorithm, if the system is used equally much. Implementation using some programming languages is more resource-craving than others (Pereira et al. 2021). Similarly the use of cloud resources (Gill and Buyya, 2019) and the training of machine learning components (Schwartz et al 2020) can be more or less energy-efficient.

Examples of enabling effects:

- *The individual dimension*: The systems are easy to use, not burdening the user unnecessary. The system support practices that are looked upon as positive for individual freedom, e.g. with having the possibility for the user to use different channels, that makes it possible to support the individual's preferences, but do it in a way not exploiting the end-user and end-user data.

- *The social dimension:* A system might enable new human collaboration, e.g. support people getting together for joint activities. It does not discriminate certain users or user-groups unduly.

- *The economic dimension*: The system provides the opportunity to make value by e.g. providing new channels for buying and selling of goods and services. The system might make certain processes more efficient e.g. by improving logistics.

- *The technical dimension:* The system might make the development and evolution of other systems more efficient. For instance can the provision of open source solutions as part of in-house solutions or development of common components for public sector services enable a long-term ability to maintain and evolve the overall IT-solutions in an area.

- *The environmental dimension*: The system can provide support for a more efficient work and business processes in connection to supporting a circular economy (Zeiß et al 2020). If a product is designed for being possible to be repaired, then one can accommodate this by providing the possibility to produce spare parts through 3D-printing, rather than depend on distribution of physical parts.

Many areas look to ICT and digitalization to make their area more sustainable, e.g. as witnessed in work on circular economy (Zeiß et al, 2020) and smart sustainable cities (Bibri and Krogstie, 2017). This opens for a specialization of the enabling effect - level. It is in these cases also often relevant to anchor the effect on the improvement of practice according to one or more SDG (e.g. SDG 11 for smart sustainable cities).

Examples of structural effects

- *The individual dimension*: Systems that are based on being easy to use through personalization do this by capturing information about individuals. If this is done not taking privacy into concern, the information might be sold and resold for others to provide personal adds, or for manipulation e.g. as seen in the Cambridge Analytica case.

- *The social dimension:* For effects on the social dimension, typically many systems would need to use the same platform. Many systems and organizations piggyback e.g. on Facebook for social media services. With many using the same service-platform, it might force many additional users into the same platform, and provide further lock-in and potential dependency on the use of such platforms. Another example is how one by bundling more and more functionality that was earlier found on several devices into one device (the smartphone), more and more people need this for some service. People change phones very often, not necessarily to get new ICT-functionality, but to get e.g. a new camera. Given the addictive way of designing systems that has been used on the smartphone, more and more people use more and more time on this, at the cost of more social face to face encounters. On the other hand, having such common platform can make it easier to have people interested in certain phenomena to meet, also potentially physically.

- *The economic dimension*: The widespread use of ICT-services has a potential decrease of the cost of doing business all around the world and provide public services on all areas, possibly offsetting the cost of the equipment and energy usage to run these systems.

- *The technical dimension:* As the portfolio of ICT-systems supporting an organization ages it can be increasingly hard to change the systems to accommodate new needs. This so-called technical debt must be addressed through a conscious application system portfolio evolution in the organization. The cost of having an updated system and infrastructure can be offset by using generally available services in digital ecosystems (although this might not be the most energy-efficient way of providing IT-services. It might often be hard to know the carbon footprint of digital ecosystem services, unless this is mandated to be provided).

- *The environmental dimension*: The overall digitalization of society increases the carbon footprint of IT activities (Freitag et al, 2021). As one is expected to provide services in all areas on a digital platform and make it accessible by the latest end-user devices this can provide a setting that pushes an unsustainable use of resources. On the other hand, the new way of providing services enabled by IT can reduce the overall carbon footprint of the human activities (but might also increase it, e.g. through enabling ordering goods from anywhere in the world which better could be procured from providers near-by).

Some areas that need to be taken into account in the future of IT development and evolution are:

- There is a limitation of available human resources to develop, operate and evolve the software base. How to manage this in a way not overexploiting the available resources, with depleting the IT-resources in developing countries to fill the needs of the western world?
- How to ensure that sustainability aspects are taken into account in functionality decision in (agile) software development, when a large part of society is potential stakeholders?
- Whereas the focus in software engineering has been shorter and shorter release cycles with agile development, devops, and continuous deployment, it has recently been recognized that one need to also support a slower, more traditional mode for certain long-term functionality such as security and safety. Is the so-called bi-model view of software development possible to extend into also taking all aspects of sustainability on the structural level into account?
- How to develop and maintain and operationalize sustainability requirements? This includes the next point.
- How to support LCA (life-cycle analysis) for software products and systems, coordinated with LCA analysis of physical products (that more and more include software as part of the total product)? In particular there is a challenge when basing solution on data and services in loosely coupled digital ecosystems, where numbers from LCA of the provided services are also to be taken into account.
- How to capture necessary data for following up sustainability goals in a sustainable and privacy-preserving manner?
- Understand and address the gender imbalance from the point of view of technology to identify and establish those aspects that must be considered to achieve a more inclusive and fair technology
- Understand and address citizens' engagement in sustainable regeneration processes to establish and apply a set of measures to empower them for sustainable practices in and by new technologies
- Understand and address geographical differences that affect egalitarian and inclusive processes in and by technology to propose new ways of understanding and collaboration that remove these barriers
- Additional ethical issue, e.g. how algorithms and AI influence human activity, and the undemocratic power of large technology providers.
- Negative structural effects are hard to foresee and ensure to avoid on individual projects. How to inform and support policy makers to develop and enforce policies that ensure sustainability on the structural level?

This is not an exhaustive list.

2. The Center

The primary objective of the centre is to establish a new paradigm in ICT research. The centre will rethink software processes to incorporate sustainability aspects on all levels. The secondary objectives are to:

O1. Establish a sound theoretical base to include environmental and social values in the information system and software processes

O2. Establish an open science research platform for coordinated longitudinal empirical studies on ICT development and evolution in different domains

3. Research and innovation activities

The center's research and innovation activities are focused on value creation for the ICT industry including organizations which actively use digitalization to ensure sustainable operations.

The center's research will be organized according to the pentagon model in Fig. 1. Research-projects could cover one or more dimensions, and in most cases more than one level, to shed light on the *dilemmas* that arise when not sub-optimizing along one dimension (e.g. the economic dimension). Projects only applying ICT for development of sustainable solutions in a domain would typically not be included under the center umbrella.

The center's research projects portfolio will be related to digitalization in different domains. They will be based on concrete use-cases from partners as well as on related research challenges formulated by the NTNU academic team. This portfolio together with collaboration, innovation and training activities will constitute a project-based ecosystem. Potential topics to consider in the project-based ecosystem of the center's activities is listed in Table 1 below.

Table 1: Potential research topics for research and innovation activities

1. Sustainable digital transformations in various domains
2. Interdisciplinary Research to Better Understanding and Using the Digitalization and AI for Sustainability from the Lenses of Gender Perspective, Geographical Dimension, and Citizens' Engagement
3. Sensible Urbanizing: A Toolbox for the use of Sensor Data in Sustainable Smart Cities
4. SWELL- Sustainable Built Environments for better Health and WELL-being
5. Pervasive and Trustworthy Digital Technologies for Evidence-based Sustainability
6. Sustainable, circular, and secure e-waste ecosystem
7. The Maths of Sustainability in Public Opinion Formation: Heuristics, Biases, Simplification, and Exploitation
8.
9. Sustainable software processes
10. Development and maintenance of IT based on sustainability requirements – Sustainability by design
11. Life-cycle analysis (LCA) for ICT-solutions in digital ecosystems
12. Sustainability through low and no-code approaches to ICT
13. Sustainability practices for a sustainable software product.
14. Sustainable data governance
15.
16. Data management and enterprise management for sustainable smart cities
17. Cities as learning innovation ecosystems - the role of ICT to support learning within and across cities
18. Sustainable AI
19. Responsible AI
20. ICT in the circular economy
21. Ensuring democratic control of platforms in digital ecosystems such as those provided by Facebook, Google and Apple.
22. ...

The center will also collaborate with existing IE strategic area on Energy Efficient Computing Systems - NTNU and NTNU Sustainability - NTNU

4. Organization and management

The center will be organized virtually at NTNU's campuses in close collaboration with NTNU Digital and NTNU Sustainability and other R&D partners and user partners from around Norway. On a national level the center will liase with the research network within GoforIT. GoforIT is a Norwegian initiative focusing on how to build knowledge and competence on sustainability among IT professionals. The centre will engage across the whole of NTNU and targeting research on large-scale national-/international projects that need two or more research domains, that need a holistic focus, that has a technology and digitalization focus and need for multidisciplinary teams to solve the problem. Based on the recent call for project in the area of sustainable transformation at NTNU, the following departments and faculty of NTNU are potential candidates to be represented in the centre through various roles in the centre's organisation.

Internal management

The idea to establish the center was presented to IE Board 1/10 2021, and to the IE leader-group in December 2021. It was also discussed with NTNU Sustainability December 2021 and presented to the vice-rector for research early 2022

Faculty/TSO	Departments
NTNU Digital TSO Sustainability	NTNU
Faculty of Information Technology and Electrical Engineering (IE)	Department of Computer Science Department of Electronic Systems Department of ICT and Natural Science Department of Information Security and Communication Technology Department of Mathematical Science
Faculty of Engineering (IV)	Department of Civil and Environmental Engineering
	Department of Energy and Process Engineering
	Department of Ocean Operations and Civil Engineering
Faculty of Architect and Design (AD)	Department of Architecture and Technology Department of Architecture and Planning Department of Design
Faculty of Humanities (HF)	Department of Interdisciplinary Studies of Culture
Faculty of Social and Educational Sciences (SU)	Department of Geography Department of Sociology and Political Sciences
Faculty of Economics and Management (ØK)	Department of Industrial Economics and Technology Management
Faculty of Medicine and Health Sciences (MH)	Department of Public Health and Nursing Department of Neuro-medicine and Movement Science

An NTNU *executive board* will be established to advise the centre leadership on the direction, priority and control of all high level managing issues such as planning, financial and technical matters. The executive board will meet 2-3 times per year and is responsible for – the centres overall budget, developing and rotating of the long term strategies plan and the follow -up on the annual working plan for the center.

The Scientific Advisory board will have three representatives from outside Norway, one each from Scandinavia, Europe and outside Europe. In addition we will have one or two member from other Norwegian research institutions. The centre leader will appoint a person to coordinate the advisory board. The advisory board will be invited to attend at least one executive board meeting to present their recommendations.

Department of Computer Science (IDI) will be the *host department*, and run the centre daily business. Routines will be established to secure efficient co-operation between the different partners and ensure best possible integration of knowledge and competence transfer.

The *centre leader* is responsible for the daily management within the frame set by the executive board-see long-term strategic plan and annual working plan. The *centre management team* (**CMT**) will consist of a centre leader, deputy leader, innovation facilitator, administrative support, and theme/crosscutting area leaders and will report to the centre board and the host facility (IDI). Area leaders will be recruited from different parts of NTNU. This will also ensure that science-based innovation is delivered within all thematic areas is optimally prepared to enter the next stage in their TRL life, supported by associated science-to-practice mechanisms (e.g. Innovation Norway and ICT Norway) and eventually reach the national and international market.

The CMT will identify new and relevant opportunities from Horizon Europe, RCN, Innovation Norway, or any other potential sources.

The center's research program consists of research projects conducted together with partners from industry on the crossroad between digitalization and sustainability and PhD/postdoc projects. Both types of projects will aim for developing practical results that has an impact on how we use ICT to reach national and international sustainability goals. The center will develop/establish a research portfolio of new research projects together with partners from public and private sector in 2022 and 2023. The center will start up 2- 3 new research projects annually from 2023.

The center will offer an arena for collaboration and disseminating activities for ongoing research projects. It will support new project proposal and facilitate development of new research projects. The center will provide support to studies in particular contributing to the activities within NTNU SFU Excited to introduce sustainability in ICT studies as a part of the follow-up of the results from the FTS – project at NTNU (Future technology studies).

5. Recruitments and Education

The center's research program consists also of PhD and Postdoc projects organized in close collaboration with the research projects. A key aspect of the center is to create a Norwegian Centre of Excellence hosted by NTNU and able to deliver innovation towards both the national and international markets. As such, education and training of highly qualified research personnel is a key activity which will be accomplished by recruitment of post-docs and their enrollment in interdisciplinary research, training of PhD students also linking up to a wide array of taught courses the partners are involved in, providing an additional critical mass of PhD and master and bachelor students.

Two of the current projects financed throught the NTNU sustainability call (with ten announced PhD-positions) is so far affiliated with the center. In addition so far 3 PhD positions (hired), one adjunct associate professor (hired) and 1 Postdoc position (announced) is affiliated.

6. Relation to existing centers and major efforts

The center will build on several RCN and EU projects/centers, industry funded projects, and internal initiatives. A few are FME-ZEN, +cityxchange, NTNU sustainability call (SWELL and sustainable digital transformation), and SFU Excited, The center will draw knowledge and experiences from these projects and collaborated with scholars that has developed expertise through these projects.

7. Relation to the opportunities in Horizon Europe

The center will also actively pursue international funding. The center is very much aligned with what in EU is termed the twin transition, the interrelationship between sustainable development and digitalization. As part of the NTNU Digital, the opportunities in this direction will be investigated in more detail based on the following:

Pillar 1:
PhD and Postdoc education is the major focus of the center. The center aims to establish at least one MSCA Doctoral Network (DN earlier known as ITN) in the period 2023-2024. We also will pursue MCSA – PF (former IF) scholarships.

Pillar 2
Clusters 4 (Digital, industry and space) and 5 (Climate, energy and mobility) are the most important clusters for CESICT. The total budget for these clusters are 15 billion Euros each. In other words, these clusters in total represents almost 1/3 of the total budget of Horizon Europe program. Norway's success rate around 15 % and almost 48% for the topics related to climate, environment and energy in Horizon 2020 suggests that the center is well positioned for Horizon Europe.

In the work programme for 2023-2024 (Cluster 4), specifically destinations and calls marked with 'TWIN TRANSITION" , "DATA", "DIGITAL EMERGING" and "HUMAN" is of specific interest. Many of these are supported by the AI Data and Robotics Partnership (DAIRO) which NTNU belong to through the membership in BDVA, and we should aim to be more active in the future for making the calls relevant.

Pillar 3:

To increase the international network, we will investigate COST action. We will also team up with the efforts for the Norwegian EDIH run by Digital Norway

8. Economy model, partnership, and KPIs

The economy model for the center is two folded.

(1) Initial investments by NTNU
The initial operational costs will be funded by NTNU. The daily operation of the center will be taken care of by NTNU Digital and the host department/faculty. The daily operation of the center includes center management, dissemination activities, arrangement of workshops, networking, proposal writing, coordination with the partners, and management of a researcher program. In addition, NTNU will make an initial investment (currently funding one PostDoc specifically, but also the additional PhDs affiliated can be counted in this regard) to strengthen internal coordination between various departments. NTNU has also funded a number of the existing projects within the area that was established prior to the center.

<u>Annual operational costs:</u>

1. In 2022-2023 the center will use administrative resources from NTNU Digital. From 2024 it will be determined how operational costs will be covered. This will be looked upon in parallel to the establishment of new thematic areas and enabling technologies - programs at NTNU starting 2024

(2) Externally funded projects and partnerships
The center will have key strategic partners. On the national level we are building up a researcher network including both academic and professional partners co-led by the current center manager, the center will together with the partners draft a technology roadmap for joint proposals to Horizon Europe, Norwegian research Council, spin-offs and a plan to exploit and build upon the new challenges and opportunities created by the research. The partnership will be on the project level where the partners

will define the areas and topics for research and innovation together with NTNU. The selection of the research projects shall be based on potential for ensuring sustainable digitalization. Funding from the involved partners in each project shall be utilized in a systematic process with a scoping and planning phase; a feasibility study; and a further development phase supported by testing, validation, and demonstration of the solutions under operating conditions. Along the process, spin-offs such as joint proposals to Horizon Europe, NFR/RCN, patenting, publications, proposals, technology transfers etc. will be in focus.

(3) Key performance indicators of the centers
Instead of setting up a total budget for the center at this stage, the following key performance index (KPI) are set for the next five years.

- 50 master- and bachelor theses related to sustainable digitalization
- 15 proposals to the Norwegian Research Council (in collaboration with partners and the proposed research activities in section 4)
- 15 proposals to Horizon Europe (in collaboration with partners and the proposed research activities in section 4)
- 15 PhDs/PostDocs funded
- 10 funded projects by the industry and public sectors (in collaboration with partners and the proposed research activities in section 4)
- 10 Seminars/Workshops
- 5 FRIPRO proposals (based on proposed research activities in section 4)
- 2 ERC grant proposal (based on proposed research activities in section 4)
- 3 International conferences/workshops
- 1 MSCA Doctoral Training Network proposals
- 1 SFI/FND proposal (based on proposed research activities in section 4)
- 1 SFF proposal

- 1 EVU master program related to IT for sustainable development

The success of the center will be measured by supporting existing initiatives and contributing to the launch of new research and development projects in the field of sustainable digitalization, which will reduce CO_2 emissions in a social and economically sustainable manner by focusing on the research areas addressed in section 4. This will provide a positive contribution towards achieving the CO_2 targets and a sustainable society.

9. Impact

The anticipated impact of the center:

- ***National policy priorities:*** The center results promote research, innovation, development, and utilization of new technologies in sustainable development. Using the GoForIT-network we will use results as part of influencing Norwegian policy

- ***Global challenges*:** Depending on the example areas of projects we envision impact on a number of United Nations (UN) Sustainable Development Goal (SDG) in particular:
    - GOAL 3: Good Health and Well-being
    - GOAL 4: Quality Education
    - GOAL 5: Gender Equality
    - GOAL 9: Industry, Innovation, and Infrastructure
    - GOAL 11: Sustainable Cities and Communities
    - GOAL 13: Climate Action

- ***Innovation based growth in ICT sector:*** The collaboration in GoforIT makes us confident that the industry realize the need to change practice in a more sustainable direction. By supporting the

Norwegian industry to change in this direction early, they will become more competitive also on an international market.

- ***Optimize planning, design, operation, and maintenance:*** The center provides developers and operators with tools and knowledge to optimize development and governance of ICT.

- ***Creating high quality employment:*** The center will provide Norwegian stakeholders with high quality competence base to offer sustainability-centric and safer solutions.

- ***Strengthening the uptake of research and innovation in society*:** Through the envisioned collaboration with Norwegian industry, interest organizations, and public sector.

- ***Horizon Europe:*** Clusters 4 (Digital, Industry and Space) and 5 (Climate Energy and Mobility) in Pillar 2 alone has a total budget of 30 billion Euros.

- ***Creating and disseminating high-quality new knowledge*:** The center will promote publications in open access high-impact peer-reviewed scientific journals, as well as participation at conferences and international events.

- ***Future Technology Education:*** NTNU has a national responsibility to educate candidates with up-to-date knowledge so that they can serve the nation better. The center-results will be implemented in NTNUs strategic initiative to revitalize technology studies[i], in particular in how it is followed up in SFU Excited which has as a central part how to ensure that the studies include sustainability aspects. The center-results will enhance the combined sustainability and digital competences of our students/participants who are enrolled for individual courses or complete *bachelor, master or PhD education through ordinaryeducation, and lifelong learning programs.*

- ***Strengthening competence and capacity*:** The center will through the recruitment and educational program provide the industry with highly qualified personnel at BEng, MSc, and PhD level. These candidates are expected to serve society for approx. 40 years of their work-life, taking on various roles to support the green shift in Norway[ii]

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[i] *NTNUs FTS project https://www.ntnu.no/fremtidensteknologistudier*

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