Anthropocène, Décroissance et Numérique

Anthropocene, Degrowth, and ICT

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- **Title**: ADN
- **Scientific Leader**: Sophie Quinton
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Abstract

The environmental impacts of human activities have increased so dramatically since the beginning of the Industrial Revolution that they now represent a major driver of the Earth system, prompting the use of the term Anthropocene to describe this new epoch. Which role do Information and Communication Technologies (ICT) play in this, and how could they most significantly contribute to mitigation and adaptation strategies for tackling these environmental impacts? The ADN project team seeks to address this question by rethinking ICT through a strong sustainability via degrowth approach. For this, we will 1) study the place and contribution of digital technologies in prospective scenarios, 2) taking into account their political nature through a value in design approach, and 3) with a focus on key software technologies and infrastructures as commons and dedigitization.

Contents

1 Project-Team Composition / Institutional context **3**

2 Scientific Context and Objectives **4**
The Anthropocene represents a major challenge for our societies . . . 4
ICT in the Anthropocene: a systemic and interdisciplinary question . . . 5
Scientific positioning and objectives . . . 5

3 Research Themes **6**
3.1 ICT in mitigation and adaptation scenarios . . . 6
3.1.1 ICT in existing prospective scenarios . . . 6
3.1.2 ICT in alternative prospective scenarios for degrowth . . . 7
3.2 Ethical and epistemological foundations of computer science in the Anthropocene . . . 8
3.2.1 Values in computer science and IT design . . . 8
3.2.2 Designing for conviviality . . . 10
3.3 Towards ICT alternatives for strong sustainability through degrowth . . . 11
3.3.1 ICT infrastructures as polycentric commons . . . 11
3.3.2 Dedigitalization through hybrid information processing . . . 12

4 Application Domains **13**
ICT infrastructures and communication networks . . . 13
Smart city . . . 14
Artificial Intelligence . . . 14
Information Systems . . . 14

5 Transfer, Software and Technological Development **14**

6 Project-Team Positioning **15**
6.1 Within the Grenoble ecosystem . . . 15
6.2 Within Inria . . . 15
6.3 National . . . 16
6.4 International . . . 17

7 Frequently asked questions **17**
7.1 Why insist on degrowth ? . . . 17
7.2 What values for ADN ? . . . 18
7.3 As computer scientists, are we legitimate to work on degrowth ? . . . 18
7.4 What interdisciplinarity in ADN ? . . . 19

8 Project-team Bibliography **19**

9 Permanent Member Curriculum Vitæ **25**

1 Project-Team Composition / Institutional context

The ADN team consists of the following permanent members, with Sophie Quinton as the scientific leader.[1]

Name	Title/affiliation	Provenance	Expertise
Sylvain Bouveret	Mcf G-INP/LIG	STeamer	Computational social choice, Combinatorial optimization, Geographic Information Systems
Arnaud Legrand	DR2 CNRS/LIG	POLARIS	HPC, Performance modeling and optimization, Reproducible Research
Kevin Marquet	Mcf UGA/LIG	POLARIS	Operating Systems, Low power architectures, Low Tech
Sophie Quinton	CRCN Inria/LIG	SPADES	ICT and sustainability, Real-time systems, Formal verification, Embedded systems
Jean-Bernard Stefani	Ingénieur général des Mines Inria/LIG	SPADES	Concurrency theory and process calculi, Component-based software engineering, Programming languages

The ADN team is the result of a series of individual and collective actions of its members towards a new research activity related to ICT and sustainability since 2018. To name of few notable facts:

- Sophie Quinton and Jean-Bernard Stefani were members of the so-called MakeSEnS Inria working group in 2018 and 2019, which made several proposals for Inria to take actions with respect to the environmental emergency.[2]
- Sylvain Bouveret and Kevin Marquet have been members of the EcoInfo GDS[3] for several years, and contribute to three of its working groups on teaching, AI and 5G, respectively. Kevin Marquet was vice-director of EcoInfo for two years. Sophie Quinton was a member of EcoInfo from 2018 until 2023.
- Sylvain Bouveret has actively contributed to setting up a pedagogical team at the Ensimag engineering school focusing on social and environmental responsibility issues. He benefited from a six-month teaching dispense (CPP) in connection with this.
- Kevin Marquet and Sophie Quinton co-supervized, with Jacques Combaz and Alain Girault, the PhD thesis (CORDI-S) of Aina Rasoldier on the potential of IT for Green technologies to help face the ecological emergency.
- Sophie Quinton leads the SIA AEx on ICT in the Anthropocene. She has set up with Éric Tannier a series of one-day workshops called Ateliers SEnS[4] to help researchers reflect on the social and environmental implications of their research. The initiative has now spread nationwide.
- Arnaud Legrand has not been involved in sustainability so far but rather on energy measure and optimization of supercomputers, and on frugal use through carefully planned experiment designs. He has been heavily involved in the open science and reproducible research movements, in particular through the design of two methodological MOOCs targeting scientists in the wide (biology, chemistry, computer scientists, economists, digital humanities, ...) and in the setting-up of a national transdisciplinary network on reproducible research.[5]
- The ADN team has been meeting weekly since September 2023.

Several nonpermanent researchers are already contributing to the interdisciplinary ADN research agenda:

- Baptiste de Goër, 2nd year PhD student co-supervized by Micha Hersch, Florence Maraninchi and Sophie Quinton, works on how to teach ICT related sustainability issues in computer science classes.
- Ludmila Courtillat--Piazza has started in November 2024 a PhD on dependence on ICT as a vulnerability facing the ecological emergency, from a mobile network resilience perspective, co-supervized by Marceau Coupechoux, Clément Marquet and Sophie Quinton.
- Antoine Hardy, a sociologist and politist, will start in February 2025 a postdoc on how the ecological emergency challenges and possibly redefines research in computer science.
- Galaad Langlois, an intern co-supervized by Arnaud Legrand and Kevin Marquet, explores research directions on hybrid (digital and human) workflows and potential needs for dedigitization.

The ADN members have a large panel of expertise related to computer science. They also have strong ties with researchers in social and human sciences. Sylvain Bouveret, in particular, has a long experience of collaborating with economics scholars due to his work on computational social choice. Sophie Quinton has collaborated with Clément Marquet since 2020 in the context of the CIS-PEN[6] interdisciplinary working group which they co-organize. Other colleagues, listed below, have expressed an interest in collaborating with ADN.

External member Clément Marquet (CSI, Mines de Paris), whose expertise lies in social sciences with a focus on political, social, and environmental tensions caused by the deployment of digital infrastructures.

[1] Sophie Quinton is planning to defend her HDR in 2025.
[2] https://hal.inria.fr/hal-02340948
[3] https://ecoinfo.cnrs.fr
[4] https://sens-gra.gitlabpages.inria.fr/atelier-impacts-recherche/
[5] https://www.recherche-reproductible.fr/
[6] https://cis.cnrs.fr/politiques-environnementales-du-numerique/

Envisioned collaborators in the humanities and social sciences

- Gilles Bastin (PACTE, Sciences-Po Grenoble), whose expertise lies in sociology of culture, media and information with a focus on the *algorithmic society*.
- Antoinette Baujard (GATE, Saint-Étienne), whose expertise lies in economics with a focus on normative issues and analysis of public decision tools, voting procedures and deliberation processes.
- Liliana Doganova (CSI, Mines de Paris) whose expertise is at the intersection of economic sociology and Science and Technology Studies with a focus on prospective.
- Marlène Jouan (IPhiG, Grenoble), whose expertise lies in moral philosophy and psychology with a focus on gender studies and bioethics.
- Camille Paloque-Bergès (HT2S-CNAM, Paris), whose expertise lies in history and science and technology studies of computer science with a focus on the materiality of networking infrastructures.

2 Scientific Context and Objectives

The Anthropocene represents a major challenge for our societies

The environmental impacts of human activities have increased so much since the beginning of the Industrial Revolution, and especially since the 1950s, that they now represent a major driver of the Earth system, prompting the use of the term *Anthropocene* to describe this new epoch [41].[7] Six of the nine *planetary boundaries* identified in [16, 42] and defined as *"processes that are critical for maintaining the stability and resilience of the Earth system as a whole"* are transgressed [128], meaning that human-driven change not only influences the Earth system, but it also threatens to destabilize it. Whether we consider the ongoing biodiversity collapse [73] or global warming [114]—or in fact almost any planetary boundary—the situation is bleak.

Addressing this ecological catastrophe requires urgent and major *mitigation* and *adaptation* strategies, as emphasized by the IPCC (focusing on climate change), and the IPBES (focusing on biodiversity collapse) [73, 114]. Mitigation could be achieved by dramatically reducing the damages caused by some human societies to the environment. Adaptation would entail preparing societies to upcoming and future environmental disruptions so as to mitigate their impact on the living conditions of populations. One key component of adaptation strategies is *resilience*, usually defined as *"the ability to maintain essential function, identity and structure [after a disturbance], but also the capacity for transformation"* [114]. While these objectives are widely shared, their implementation is, however, highly complex and disputed as it requires arbitrating between biophysical boundaries and social thresholds [55, 64] as well as dealing with inequality issues and diverging interests (between different countries, social classes, cultures, generations...). Furthermore, all decisions must be taken based on uncertain knowledge of many aspects of 1) the current situation, and 2) possible options and associated risks regarding the future.[8] There is in particular no scientific consensus regarding the possibility of *green growth*, which is based on the assumption that *absolute decoupling* of economic growth and environmental pressures can be achieved (meaning that one could continue while the others would decrease) [76].

Beyond the need for emergency measures, the broader issue is that of inventing sustainable alternatives—and pathways to them—to our current, unsustainable way of life. The notion of *sustainability* itself is however hotly debated by the scientific community, in particular regarding economic aspects [102]. For example, the original definition of sustainable development, introduced in the Brundtland report [10] as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*, has been criticized for relying on infinite economic growth and the assumption that environmental damage can be remedied thanks to technological and scientific advancement enabled by economic growth [102]. Because of this lack of consensus, any research dealing with sustainability has to choose one nonconsensual definition of the term, and, as a result, a different objective. We adopt the *strong sustainability* view, which assumes that *"some attributes of nature cannot be replaced by artificial capital"* and therefore adopts a precautionary approach towards environmental degradation [102].

In coherence with this view, we are particularly interested in *degrowth*, defined as a "*planned and democratic reduction of production and consumption in rich countries to lower environmental pressures and inequalities while improving well-being*" [113]. Mitigation and adaptation scenarios for degrowth are explicitly acknowledged in the latest IPCC report [119] as having some plausibility, although being understudied so far.[9] This lack of scientific knowledge is all the more regrettable given that, in the same report, it is indicated that "*all scenarios that limit warming to 1.5°C with no or limited overshoot, or that limit warming to 2°C, involve rapid and deep and in most cases immediate GHG emission reductions in all sectors*".[10] Such reductions require: 1) "*transitioning from fossil fuels without carbon capture and storage to very low- or zero-carbon energy sources*", which might be achieved by the few countries with enough capital and technology, 2) "*deploying carbon dioxide removal methods to counterbalance residual GHG emissions*, and 3) *improving* (energy, materials, technology) *efficiency*", many of these technologies being currently at early development stages.[11]

[7] Note that the International Union of Geological Sciences (IUGS) has rejected the proposal to use the term *Anthropocene* as a formal unit of the Geologic Time Scale. Yet, it is still considered as relevant by Earth and environmental scientists, economists, and social scientists as a clear marker of human impact on the Earth system and it is also a well established term in the public discourse.

[8] This is true in particular for Information and Communication Technologies (ICT) [96], as will be detailed later.

[9] https://timotheeparrique.com/degrowth-in-the-ipcc-ar6-wgiii/

[10] The report also states that, even if Nationally Determined Contributions announced prior to COP26 were respected, such reductions will not happen.

[11] The report for example points out that, as of today, reforestation and improved forest management are the only mature and effective technology for carbon dioxide removal.

Even assuming the (uncertain) advent and deployment of such technologies, the GHG emissions reductions in the modeled pathways also require "*demand side measures and socio-cultural and behavioural changes*" of customers, thereby calling for "*(regionally and sectorally differentiated) sufficiency policies*", hence the relevance of studying degrowth-based scenarios. There is now a growing literature [60] and active research[12] on degrowth, and we intend to contribute to the ICT related part of this research agenda.

ICT in the Anthropocene: a systemic and interdisciplinary question

So, what could ICT look like in a world on a path towards strong sustainability via degrowth? There is surprisingly little research on the subject in the ICT and sustainability field, as we explain now.

Research related to ICT and sustainability tends to focus on contributions to mitigation strategies[13] by reducing ICT's own footprint (*Green IT*), or by using ICT to help other sectors reduce their own footprint (*IT for Green*), typically through energy optimization. In particular, a significant research community has been working on evaluating and reducing the direct energy consumption of the ICT sector, defined as the energy used during the life cycle (manufacturing, use, end of life) of ICT equipment, which accounts for around 3-4% of global greenhouse gas (GHG) emissions [96]. This is a difficult task because of the complex and global material reality underlying ICT, ranging from countless end-user devices to numerous data centers and a worldwide network infrastructure.

Green IT and IT for green are, however, restricted in their scope, which limits their relevance for research on strong sustainability and degrowth. Indeed, ICT are now so much intertwined with the other economy and society sectors [116] that it is difficult to precisely separate ICT from other technologies[14] and it would be misleading to study them without considering 1) the international production chains they depend upon and their associated social, political and economic organization, and 2) the indirect effects they have on other sectors through their applications, in particular rebound and structural effects, which are suspected to be the largest environmental impacts of ICT [46].[15] To quote Lorenz M. Hilty and Bernard Aebischer in their seminal paper [38], "*It should be clear that no single product, process, policy, region, or technology can be 'sustainable' in the sense of 'sustainable development'*[16] *as the latter concept has a global scope by definition.*" That is why GHG emission mitigation strategies such as those described in *Stratégie Nationale Bas Carbone* [84] (SNBC) or ADEME transition scenarios [132] are based on a proposed arbitration between activity sectors regarding their expected GHG emissions. As a result, whether for mitigation or adaptation purposes, one cannot consider a specific technology—or even ICT in general—without a *systemic* approach [136].

Note that, the above mentioned arbitrations required for mitigation and adaptation having a wide range of consequences on people's life, the development and deployment of technologies is thereby intrinsically a political process that would benefit, in a democracy, from an in-depth analysis of its underlying values and its expected or potential consequences. Besides, *science and technology studies* (STS) [25] have amply demonstrated how scientific and technological developments are enmeshed in a political, economical and social environment that hosts them, exploits them and is impacted by them, but also in return contributes to shaping and orienting them. Putting it another way, technical systems are *ambivalent* [6], and, "*consciously or unconsciously, deliberately or inadvertently, societies choose structures for technologies that influence how people are going to work, communicate, travel, consume, and so forth over a very long time.*" [7] (see also [24]). Because of the entanglement of science and technology in the societies that host them, and the tremendous impact of ICT technology on society, we consider that researching and developing ICT technologies consistent with a strong sustainability standpoint can only be done in full awareness of the values to uphold and the social goals to pursue. More generally, this implies that an *interdisciplinary approach* including at least STS, ethics, and epistemology, is required to understand how social or personal values influence the design of these tools, and, as a consequence, their use.

Scientific positioning and objectives

It should be clear from the preceding discussion that studying computer science and ICT in the Anthropocene cannot be disentangled from studying what sustainability means—including the fundamental values it harbors, and the political, economic and social, but also the material organizations that structure it— and how to achieve it. In this document, we will call for the sake of brevity *responsible ICT* the research and development of ICT technologies consistent with both (1) a strong sustainability standpoint, (2) social and ecological justice, and (3) democracy.

In this context, **the ADN project team seeks to lay the ground for rethinking ICT for strong sustainability through degrowth scenarios by following an Ethics and Values In Design** (E+VID) **approach**. E+VID approaches take many forms (see, e.g., the recent survey [94]), but one can argue that they typically exhibit three main facets as in Value Sensitive Design [36]: *theoretical*, to articulate the ethical, political and technical underpinnings of the approach; *methodological*, to propose effective methods for applying the approach; and *empirical*, to apply the approach in identified contexts and case studies. To these facets, we add a fourth one, the *teleological* facet, i.e., related to finality,

[12] See e.g., the REAL ERC project https://www.realpostgrowth.eu/ which follows a comment in Nature entitled "Degrowth can work – here's how science can help" [110], or the recent "Beyond growth" conference at the European Parliament [124].

[13] There is also research on using ICT to make our societies more resilient, but, to the best of our knowledge, very little on ICT as a potential vulnerability.

[14] There are embedded processors in cars, vending machines, elevators, traffic lights, etc.

[15] Just to give an example, consider for instance the acceleration effects of digital technologies to the sector of logistics and online delivery services.

[16] The original definition of *sustainable development* stems from the Brundtland report [10]: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*. This statement remains valid when replacing 'sustainable development' by 'strong sustainability' which could then be roughly defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

which can be qualified as strongly normative in the terminology of the aforementioned survey [94], and whose aim is to articulate the vision of the "good society" it purports to contribute to—in our case, a strongly sustainable, just and democratic society. This translates in our proposal into three interdisciplinary research axes:

1. *ICT in mitigation and adaptation scenarios (teleological facet)*: In our first axis, we will study the place and contribution of digital technologies in prospective scenarios, so as to understand the key factors that would shape alternative developments in ICT. We will study ICT in existing prospective scenarios such as those proposed by ADEME [132] with a focus on their material dependencies, the potential of IT for green technologies, and resilience issues. In addition, we will contribute to building alternative scenarios based on degrowth with a focus on two specific developments for ICT: the governance of ICT infrastructures as commons, and dedigitalization of society. This research will combine high-level modeling and evaluation tools with STS and prospective approaches.
2. *Ethical and epistemological foundations of computer science in the Anthropocene (theoretical and methodological facet)*: A second axis will study the fundamental underpinnings of values in digital technologies, drawing from Science and Technology Studies, with input from moral philosophy, epistemology and political philosophy, as well as the numerous applied ethics methodologies (such as Value Sensitive Design) that have been proposed in the past two decades to tackle issues such as sustainability, social acceptability etc. Our goal in this axis is to confront this state of the art, as well as existing IT tools, with our strong sustainability objective in order to propose a framework (conceptual, formal, and practical) to design IT tools for responsible ICT.
3. *Towards ICT alternatives for strong sustainability through degrowth (empirical facet)*: A third axis will revisit or develop alternative key software technologies and infrastructure for a degrowth society with specific values and properties in mind (simplicity, conviviality, etc.), as identified in our second axis. Specifically, we will focus on 1) ICT infrastructures designed as polycentric commons; and 2) hybrid (i.e., digital and human) information processing for dedigitalization.

Beyond the expected research contributions of the ADN team, we want to contribute to the emergence of a new interdisciplinary research community around a common question: what computer science research is needed, or could be useful, in the Anthropocene? To do so, we will strive to keep a reflexive and critical look at how knowledge is built around this topic, and how it is used, transferred and taught [135]. As an example, we will study, from an STS perspective, the research questions and methods of academic communities related to ICT and sustainability, e.g., ICT4S,[17] LIMITS,[18] but also smart city or IoT research communities.

3 Research Themes

3.1 ICT in mitigation and adaptation scenarios

In this first research axis, we will study how ICT fit into various prospective scenarios. *Prospective* is a powerful toolbox to explore the future in order to help today's decision making.[19] It is particularly useful for making explicit known facts and uncertainties that are relevant for this exploration, in particular regarding possible social, political or technological choices and their consequences. The most prominent prospective method is based on *scenarios*, i.e., coherent sets of hypotheses that relate an origin and a future situation [132]. One often distinguishes between *forecasting*, which explores the future starting from the present situation (for example a study of the potential of a given IT for green technology), and *backcasting*, which aims at building strategies to reach a target future situation (for example mitigation scenarios such as those from ADEME [132], which proposes various ways to reach carbon neutrality in France by 2050). The ADN research team is specifically interested in (1) studying how ICT fit into *existing* mitigation scenarios such as the aforementioned ones [132]; and (2) contributing to building *new* scenarios from the degrowth perspective, by focusing on the place of ICT in them. Scientifically speaking, we aim at combining high-level modeling and evaluation tools of infrastructures and society with STS methods such as sociological surveys to address the questions raised in this axis.

3.1.1 ICT in existing prospective scenarios

Participants: Sylvain Bouveret, Kevin Marquet and Sophie Quinton

Various organisations have performed prospective studies to help define mitigation strategies, notably ADEME [132], or energy scenarios (directly related to mitigation) such as négaWatt [112] and RTE [117] for France. A systematic analysis of 14 such studies [134], representing a total of 35 scenarios, points to a number of limitations of these scenarios, mainly due to a lack of systemic view on ICT. Among those limitations, we plan to investigate in particular: (a) the material dependencies of ICT; (b) the potential of IT for green technologies; and (c) resilience issues.

The material dependencies of ICT. We have argued in Section 2 that one should not, when designing a mitigation strategy, consider ICT without considering the productive system they depend upon (and the applications that depend upon them, more on this later). Simply put, what happens to ICT in a given scenario must correlate to what

[17] https://conf.researchr.org/home/ict4s-2024
[18] https://computingwithinlimits.org
[19] https://www.polytechnique-insights.com/tribunes/societe/la-prospective-a-t-elle-vraiment-des-fondements-scientifiques/

happens to the mining and the semiconductor industry and their associated environmental impacts. There is, however, limited knowledge about the current state of these dependencies, partly because of the complexity of the production chain. This is reflected by the lack of knowledge about the environmental impacts of ICT other that GHG emissions, such as raw material extraction, water consumption, ecotoxicity etc. [129], which are mainly due to the production and end-of-life phases of the ICT equipment lifecycle. We plan to contribute to a better understanding of the material dependencies of ICT and their social implications. The challenge will be to combine quantitative and qualitative information, as well as different spatial and temporal scales (e.g., water consumption and pollution are both local and global issues, metal depletion is both a global and a nationwide issue, etc.) in order to provide a systemic view on the issue. This will require in particular a sociological approach to the production, circulation and use of quantitative information (*"sociologie de la quantification"* [125]). This work will build upon work undertaken by several members of the ADN team in the context of the CIS-PEN[20] and EcoInfo[21] academic collectives.

The potential of IT for green technologies. As stated by Aurélie Bugeau and Anne-Laure Ligozat [134], "*Many scenarios give a central place to IT for Green applications (smart farming, smart building, ecological monitoring). Some structural changes come from innovations in ICT, such as teleworking or autonomous driving.*" Such reliance on ICT for mitigation may be risky if the promises of IT for green cannot fulfilled, hence the need to better anticipate the actual potential of these technologies. Previous work of ADN team members in the context of Aina Rasoldier's PhD thesis [115] has underlined major limitations in existing analyses of such potential. In particular, our results on the potential of digital carpooling platforms for local travel [127], based on the analysis of a synthetic travel demand, show that the objectives of the SNBC and the corresponding local mobility plan for the Grenoble area (PDU[22]) may be very optimistic. We intend to pursue this work for other IT for green technologies. One major challenge of this work will be to put these analyses of the IT for green potential into perspective within specific mitigation strategies, which requires refining the existing mitigation scenarios. Another challenge will relate to ethical, epistemological and political issues surrounding modeling [34], which must be addressed to avoid misusing the results produced by such models. This part of the work will be carried out in collaboration with members of the Archipel working group focusing on this topic[23] and benefit from our extensive state of the art research in the second axis.

Resilience. The vulnerabilities and risks associated with our dependence on digital infrastructures are left out of existing prospective studies [134]. These risks are now recognized by public authorities [107, 108] and recent work in academia focuses on the resilience of ICT infrastructures faced with natural disasters amplified by climate change [69, 88]. There is, however, no literature on the consequences of structural, long term and progressive disruptions such as a limited access to semiconductors, although this could be a direct consequence of geopolitical tensions that are mentioned explicitly in some IPCC mitigation scenarios. As a starting point, in the context of Ludmila Courtillat--Piazza's PhD thesis, we will focus on mobile networks and nonreplacement of ageing hardware, working at a local and national level. What would be the consequences for mobile networks of a long term semiconductor shortage leading to the nonreplacement of ageing hardware? What level of quality of service could be maintained and for how long? How would this impact the resilience of our society? These questions require a systemic approach to better understand the social implications, for example in terms of equity, of different levels of quality of service and resilience of ICT networks. More generally, the trade-off between mitigation and adaptation seems to be understudied in prospective planning for ICT. Our work on this topic combines mobile network modeling and evaluation tools (so far using a stochastic geometry approach) with STS methods such as sociological surveys.

3.1.2 ICT in alternative prospective scenarios for degrowth

Participants: Arnaud Legrand, Kevin Marquet, Sophie Quinton and Jean-Bernard Stefani

In addition to a critical analysis of existing scenarios, we aim to contribute to building alternative scenarios based on degrowth. To the best of our knowledge, there are so far no comprehensive scenarios for degrowth: the Shared Socioeconomic Paths (SSP) studied by the IPCC, the Transition 2050 scenarios by ADEME etc. all assume at least some level of economic growth. Our objective here is not to entirely build such scenarios, but rather to contribute to their ICT related components, thus participating in an interdisciplinary endeavor that is so far mostly carried out by economists.

The role and the nature of ICT in degrowth scenarios remain to be investigated, and there are many possibilities. One challenge for us is to ensure some coherence between our technological and scientific developments in the third research axis and global, systemic degrowth scenarios. As a result, work in this axis will be organized around two main directions, which we intend to investigate further from an empirical perspective: (1) what dedigitalization strategies might look like; and (2) how ICT infrastructures governed as commons might fit into a degrowth scenario.

Dedigitalization. We intend to approach dedigitalization from two complementary angles, one looking at IT infrastructures, and the other focusing on information processing.

First, we will consider it as a follow-up to the work on resilience described in the previous section, this time with a larger set of possibilities regarding the evolution of our dependencies on ICT. For example, if we cannot or do not

[20] https://cis.cnrs.fr/en/digital-technologies-and-environnemental-politics/
[21] https://ecoinfo.cnrs.fr/
[22] https://smmag.fr/investir-pour-lavenir/pdu-2030/
[23] https://archipel.inria.fr/groupes-de-travail/groupe-de-travail-contre-modelisations/

want to replace ageing infrastructures (e.g., because we consider them as *negative commons* [90]), what can be done with the infrastructures we already have? To what extent must we reduce and transform our reliance on it? This raises challenging research questions such as: what would be good metrics to measure network quality of service in such cases? How could we share such limited communication and computation resources? What could be the social organization around them, for example in societies with strongly intermittent energy sources, or where only a few computers are available and shared in each village, or where a universal basic income is globally implemented? Here a combination of computational social choice and participatory modeling might represent a promising approach.

Besides, a large part of the digital transformation of our societies involves the development of information systems dedicated to the digitalization and automation of data and activities manipulated or carried out in for-profit or non-profit companies, associations, local and governmental administrations, etc. If we want to understand how to reduce the impact of digital technologies, and reduce the digital divide which accompany the current accelerated digitalization of our societies, we must reconsider how these information systems are organized and developed. Hybrid information processing strikes us as a good mindset to explore toned-down digitalization, and workflow management in particular as a sweet spot touching at the core of the digitalization of administrative work. Our objective here will be to understand how dedigitalization might fit into global degrowth scenarios, the practical issues related to dedigitalization being addressed in our third research axis.

ICT infrastructures as commons for degrowth. Because ICT infrastructures, comprising hardware (computers, switches, routers, cables, etc) and software (operating systems, runtimes, middleware, compilers, etc) are the cornerstone of our digital world, thinking about the future of digital technologies in a degrowth scenario must include in-depth considerations on the architecture and organization of ICT infrastructures that would support them. One interesting approach to move away from the current oligopolistic and capitalistic governance that characterizes the modern day ICT infrastructures [57, 66, 80], and move toward responsible ICT infrastructures in line with our strong sustainability through degrowth agenda, is to study more decentralized and more democratic forms of governance where ICT infrastructures cease to be private properties under the ownership of profit-driven companies and become publicly shared resources under the collective governance of multiple constituencies, i.e. commons. We will start from input provided by STS on the topic, e.g., [74, 95] and will strive to bridge the gap between these studies and our prospective degrowth scenarios for ICT.

3.2 Ethical and epistemological foundations of computer science in the Anthropocene

In the first research axis, the focus was on understanding how ICT could fit into various prospective scenarios. In this second axis, we will study how, voluntarily or not, technical systems can embody moral and political values [7]. Understanding how to take values into account (at design time and later on) in computer science research and development, but also discussing which values fit our strong sustainability through degrowth research position, are key to proposing empirical contributions in the third axis of the ADN research program. Our second research axis will consist in (1) a broad survey of the relevant state of the art in design, ethics and epistemology, (2) a study of the values underlying various IT tools, and (3) an investigation of whether and how Ivan Illich's concept of conviviality can be used to design responsible ICT. Ultimately, we expect this work to contribute to a better understanding of how research projects in computer science should be shaped in the Anthropocene, and to provide us with a framework (conceptual, formal, and practical) to design IT tools for responsible ICT, e.g., via a library of design patterns and anti-patterns.

3.2.1 Values in computer science and IT design

Participants: Sylvain Bouveret, Arnaud Legrand, Kevin Marquet, and Sophie Quinton

Technological deployment in general, and digital deployment in particular, is a political, economical and social process that is strongly influenced by values held regarding these different areas. Digital tools have in return a strong impact on the sustainability, resilience, and fairness of society. As we aim for strong sustainability, social and ecological justice and democracy, we advocate that computer science and IT design must be investigated in full awareness of the values to uphold and the social goals to pursue if we want any potential benefits of digital tools to happen.

There is an emerging body of work on *identifying patterns* and *values* at the heart of the design of many existing digital tools. Maraninchi [111, 137] for example highlights how operating systems and languages have been designed to provide the *illusion of unlimited resources* (dedicated machine through multi-tasking, infinite memory though virtual memory) to both program designers and users, thereby obeying the supposedly good design principle of software *extensibility* as well as the moral injunction to positively scale up, instead of providing them with abilities to limit and control their resource usage (i.e., to design *shrinkable* code). Ko [99] identifies another notable pattern in computer science as the trend to *abstract* the world, thereby preventing the expression of diversity, nuances, and exceptions, and *automate* processing, thereby removing people and their unpredictable decisions, which supports the vision of *homogeneity* as a positive value. Such cultural view appears to be deeply rooted in computer science, denying agency to minorities and encouraging social segregation. Tackling this will require designing computer systems with and for a much larger diversity of people than highly educated WEIRD[24] people.

[24] Western, Educated, Industrialized, Rich, Democratic.

We intend to contribute to this line of work through the following complementary angles. First, we will investigate the values and properties that have been discussed in various areas of humanities and which we consider as potentially useful for strong sustainability through degrowth. Second, we will revisit value sensitive design in the light of these values and properties to propose a value-based design and analysis framework for strong sustainability through degrowth. In parallel, we will root our work in computer science and IT design by studying, both for inspiration and analysis purposes, various examples of IT tools which have already tried to address some of these concerns.

Identifying relevant values and properties. Since almost none of the existing work in computer science appears to address strong sustainability through degrowth[25], a first mean to envision the design of responsible IT tools is to start from a wider perspective. A first line of research will thus be to identify properties and concepts that are key to understanding how and under which conditions digital innovations do hold moral virtues, in particular in relation to strong sustainability. We will study the notion of *low-tech*, taken in a broad sense, which would include Mumford's democratic technics [1], Schumacher's appropriate technologies [4], Bookchin's liberatory technologies [2], Illich's convivial tools [3], as well as recent related work [33, 104, 126, 130]. This broad state of the art does not consider digital tools and the specific ways they tend to reshape society (e.g., through their efficiency and their complexity, w.r.t. personal privacy and their impact on social interactions, or through their invisible materiality). We will thus investigate and compare the key concepts of existing works, exploring their strengths and weaknesses with respect to strong sustainability and degrowth, identifying incompatibilities and similarities between them, and exploring if and how key criteria can be useful once revisited, such as subsidiarity[26] and collaboration[27] (from the low-tech literature), local autonomy, decentralization, and labor intensity[28] (appropriate technologies).

We intend to complement this study of the related work from the philosophy of technics with an interdisciplinary survey and analysis of key concepts taken from the philosophy of sciences (Helen Longino, Donna Haraway, Bruno Latour, post-normal science), political philosophy (Hannah Ahrendt, Françoise d'Eaubonne, Serge Moscovici, Ivan Illich, André Gorz, Hartmut Rosa), and ethics (in particular virtue ethics and care ethics). This is motivated by a need to understand how the conditions in which scientific knowledge is produced influences it, and how to align this process with our strong sustainability, social and ecological justice and democracy agenda.

All in all, we expect to identify through this work relevant properties and concepts that should be considered to analyse and redesign digital tools, and more generally to develop a more responsible computer science.

Proposing a value-based design and analysis framework. With such desirable properties and concepts in mind, is it possible to take into account specific desired values at design time so as to ensure they will last through the life of ICT artifacts? In the computer science field, a prominent approach is *Value Sensitive Design* [36] (VSD), which provides a framework to *account* for human values when designing technologies (e.g., privacy by design). VSD was originally introduced in computer science by HCI experts in the 1990s with a strong emphasis on practical methodologies [75]. VSD has however received several criticisms, notably in [23], which highlight its lack of an overarching ethical framework. Recently, a survey of *Ethics and Values In Design (E+VID)* approaches [94] drew a similar conclusion: "*If designers are to invest their time and energy in the difficult work of creating more meaningful spaces for designer agency, such work must be situated in a clear and more compelling vision about a morally positive future.*".[29] In agreement with this statement, we want to revisit this state of the art in the value-based context of ICT for strong sustainability through degrowth.[30]

By building on the aforementioned interdisciplinary survey, we will propose a new *value-based analytical and design framework* for responsible ICT that considers—and possibly allows for arbitrating between—these different criteria. We would like in particular to build a collection of *design patterns* [5] (possibly including anti-patterns) helping with the design of software and architecture for strong sustainability through degrowth. We are specifically interested in the redesign of existing IT tools, considering that a key issue involving ICT and sustainability revolves around how to deal with the *negative commons* [90] that our current, unsustainable ICT infrastructures constitute.

Evaluation through case studies. We will test the relevance of, and improve, our framework by studying both mainstream and more confidential tools for information sharing, storage, and preservation, in interaction with their ecosystems. We may for example study `git`, which is a rather transparent tool designed to work fully locally and to parsimoniously interact through the network only when it is available ; and which is is at the same time at the core of globalized and dominant infrastructures like GitHub [105, 133] and is perfectly compatible with the development of centralized and disempowering black-box extensions like `git-lfs`.[31] We will also apply our framework to more confidential tools which have been specifically designed to address *energy*-related or environmental issues (i.e., with sustainability in mind), *usability* and *complexity blow-up* issues (i.e., with conviviality in mind). Among the initiatives proposing a (more) convivial software ecosystem with less powerful and black-box functionalities to end-users, let us

[25] There is a very small body of knowledge (see for instance the special issue [61]) to which we intend to contribute.

[26] Social, political, and technical issues should be dealt with at the most immediate or local level that is consistent with their resolution.

[27] Development is foremost an opportunity to encourage the exchange of skills and experiences, to catalyze the commitment of citizens from diverse backgrounds.

[28] With a high proportion of manual labor compared to capital for production.

[29] *Agency* is the capacity of an actor to act in a given environment, and represents a prerequisite to any ethical consideration [47]

[30] A preliminary, very partial review can be found in Ludmila Courtillat--Piazza's internship report [122].

[31] See for example this LWN.net article by Antoine Beaupré for a comparison of `git-lfs` and `git-annex` as well as testimonies of `git-lfs`'s severe limitations by Stéphane Peter and Gregory Szorc.

mention the Garage[32] distributed object storage service (tailored for low requirement *self-hosting* by releasing strong coherency properties), Katzele[33] for a *post-personal* computer science, or `git-annex`[34] whose carefully thought design makes it suited to both (1) manage on a daily basis large neuroscience data at a world-wide scale, and (2) connect very widely distributed, often rural communities, in Brazil, whose repositories are synced over satellite Internet and sneakernets. Other useful sources of knowledge for our purposes here are *crisis informatics* (technological support for disaster planning and response) and *ICT for development* (ICT technology adapted to the resource-constrained context of poor communities and developing countries). For instance, works such as [40] on ICT infrastructure in response to the 2010 Haiti disaster, digital technology, or [51] on networking infrastructure in rural communities in Guatemala and Zambia, can be useful sources of patterns for resilience and sustainability in ICT infrastructures. Our study will combine STS methods with our expertise in various areas of computer science, similar to the interdisciplinary approach followed during Ludmila Courtillat--Piazza's internship [122].

3.2.2 Designing for conviviality

Participants: Sylvain Bouveret, Sophie Quinton and Jean-Bernard Stefani

While the previous research topic aimed at a broad review of the state of the art, we aim in this axis to study in more depth the theoretical foundations of Illich's concept of conviviality [3] as a basis for a full-fledged approach for designing responsible ICT. We are interested in conviviality because, in contrast to most other E+VID approaches:

1. It articulates a vision of technique and technology in a "good society", one which is respectful of each person's autonomy, dignity and creativity in their social and environmental relations, and respectful of ecosystemic limits.
2. It comes equipped with a convincing critique of the main threats it faces from imbalanced technical tools and technology, which applies remarkably well to modern day digital technologies [138]. Such a critique provides a clear starting point for a methodological development, as exemplified for example by the recent work of [62].

Designing for conviviality is not a new idea in computer science. In the middle of the 1970s, individual computer pioneers such as Lee Felsenstein [141] made explicit reference to Illich's conviviality, touting the nascent tool as a more convivial contribution to information technology and a key milestone for the spread of computing literacy. Since the 1980s, Illich's conviviality has been invoked by HCI researchers in relation to questions of accessibility and inclusivity, in particular in work by Gerhard Fischer [9, 82]. But it has only more recently been considered as an analytical framework for the design of technical artifacts [62, 67, 68, 91], and much work remains to turn it into a full-fledged approach to the design of responsible computer systems.

Our main aim here will be to study the theoretical underpinnings of designing for conviviality, exploring its ethical, political, and technical foundations in two pluri-disciplinary streams. In the first one, on ethical and political foundations of conviviality, the main drive will be from a moral philosophy and political philosophy perspective. In the second one, on technical foundations of conviviality, the main drive will be from a computer science perspective.

Ethical and political foundations of conviviality. Illich ties conviviality to a deep respect for human autonomy and creativity, the absence of domination, and distributive and participative justice. The notion of conviviality seems predicated on a fundamental ethos of balance and restraint which is clearly reminiscent of virtue ethics [123], with the collective dimension of care that comes with a responsible society, in the spirit of Jonas' principle of responsibility [27], or of the ethics of consideration developed by Pelluchon [65]. Respect for human autonomy and creativity, and the insistence on absence of domination invoke a definite appraisal of human dignity which it will be interesting to confront to modern views on human dignity, human rights and capabilities, as developed e.g., by Gilabert [59] and Sen and Nussbaum [12], but also with political theories of radical democracy such as that proposed by Castoriadis [86]. On justice, Illich's insights resonates well with recent theories of distributive justice that deal explicitly with notions of limits on resource consumption and wealth such as *sufficientarism* [52] and *limitarianism* [139], but also with theories of justice that cater for a fundamental respect for human abilities, such as Sen and Nussbaum theory of human capabilities [12, 17]. In cooperation with moral philosophers, political philosophers and political scientists, we would like to start the investigation of the ethical and political foundations of conviviality by exploring the above connections, in the process questioning for example human creativity as a key component of human dignity and a key capability for a theory of convivial justice, conviviality as a key approach to a degrowth society, and the role of participative justice in the radical democracy project of a convivial society.

Technical foundations of conviviality. The work of Illich questioned major technical systems of the industrialized world (medicine, education, transport), but we are missing an Illichean analysis of information and communication technologies, to understand in particular the convivial balance in digital technologies, the thresholds where information speed and automation threaten human creativity, autonomy and control. We aim here, together with philosophers of science and technology, to develop such an analysis, confronting in particular the apparent paradoxes that come with conviviality, and analyzing the key principles in ICT system design which can be conducive to convivial ICT systems.

Conviviality in technical systems is confronted from the outset by a paradox of *complexity* and *scale* in system design and construction, which both seem naively antithetic to conviviality. Yet Illich himself notes that large, complex

[32] https://garagehq.deuxfleurs.fr/
[33] http://katzele.netlib.re/
[34] https://git-annex.branchable.com/

technical systems such as the telephone system (of the 1970s) can be convivial. This apparent paradox needs to be questioned and analyzed for a clearer understanding of conviviality in technical systems. Is conviviality tied to *simplicity of purpose* or *explainability*? And what to make of the industrial scale at which the production of ICT currently operates? Is conviviality recovered at scale by alternative modes of productions consistent with a society having degrown [39, 70]?

Focusing on the design side, we need to identify principles of design in computer systems conducive to conviviality. Discussing designing for conviviality, Voinea highlights several design criteria, organized around the "axiological pillars identified by Illich, namely personal autonomy and social cohesion" [68]: *flexibility*, *transparency*, *simplifiability* and *usability* along the first one, *sharedness*, *creativity* and *sociality* along the second one. These constitute a useful initial set to analyze, but other criteria, long studied in computer science and software engineering, such as *dependability*, *maintainability*, *compositionality*, *auditability*, and *administrability*, together with software engineering and computer system design principles and patterns, need to be considered as well.

3.3 Towards ICT alternatives for strong sustainability through degrowth

In this third research axis, we will experiment with practical alternatives that can help us imagine what ICT could look like in a degrowth scenario. There are plenty of relevant tools and approaches to draw inspiration from, and many possible degrowth scenarios to explore. For example, what tools and infrastructure would be able to operate in degraded environments where network access or power supply are regularly disrupted? If we aim at a gradual dedigitalization, what tools and infrastructure could be designed (or redesigned) for degrowth, or even self-obviation, rather than extensibility? How would we ensure that the values underlying these IT tools and infrastructure are consistent with our strong sustainability through degrowth positioning? We will approach this broad field from two complementary directions, by (1) studying technical and organisational aspects of ICT infrastructures designed as polycentric commons; and (2) investigating dedigitalization through hybrid information processing. Both fields will provide opportunities for research on architecture and software engineering, for interdisciplinary work and for *action research*.[35]

3.3.1 ICT infrastructures as polycentric commons

Participants: Sylvain Bouveret, Arnaud Legrand, Kevin Marquet, Sophie Quinton and Jean-Bernard Stefani

We will study alternative software architectures, software support and governance for ICT infrastructures, built on the idea that ICT infrastructures could be designed and operated as *commons* [35], i.e. as a set of non-private, non-exclusive resources and capabilities under the governance of various human collectives acting mostly in cooperation at various spatial, temporal and organizational scales. We believe rethinking ICT infrastructures as commons is a good way to inject eco-systemic awareness and democratic accountability into infrastructures and platforms that have become excessively *polarized* in Illich's terms, i.e., the subject of dire imbalances of power and excessive encroachments on human autonomy (see, e.g., [80]). Work on this topic will be organized around two major themes: *governance*, which is at the core of the concept of commons, and *architecture*, which lays the ground for building ICT infrastructures.

The main goal here is threefold: (i) to study principles and functions required for a *polycentric governance* of ICT infrastructure commons, (ii) to design a software framework for supporting various forms of governance that can be applied in ICT commons, and (iii) to define an architecture reference model for ICT infrastructures that can be used as a basis for governance and management of ICT infrastructure commons.

Governance. Polycentric governance [78] is a form of governance that involves multiple semi-autonomous, interacting decision centers (a federation is an example of a polycentric form of governance), which seems intrinsic to the governance of commons [71]. The relevance of Elinor Ostrom's principles for governing commons [11] and of polycentricity in governing ICT commons such as open source projects has already been noted in the literature, e.g., in the study of Wikipedia governance [15]. More recently, Ostrom's work has attracted the interest of blockchain communities, in particular to build distributed autonomous organizations running on blockchain infrastructure [101, 131].[36] Ongoing efforts to understand decentralized ICT platforms for governance [92] also represent relevant related work for us.

Our focus is on ICT infrastructures as commons, which is quite different from digital commons[37]. A first contribution will thus be to identify key features of ICT infrastructures that influence their management and governance as commons. For instance, they feature both physical components, with inherent *spatiality*, and virtual components that are only partially constrained by spatial considerations. Classical forms of commons studied in the literature, centered around physical resources such as water basins or forests, do not exhibit these characteristics. As another instance, resilience of ICT infrastructures cannot be only considered locally, within a single physical locale, but must involve the coordination of multiple locales, and thus inherently requires a polycentric point of view.

[35] Quoting the Wikipedia entry on *Action research*, "*Action research is a philosophy and methodology of research generally applied in the social sciences. It seeks transformative change through the simultaneous process of taking action and doing research, which are linked together by critical reflection.*"

[36] Note that we do not think relying on blockchain technology is required, useful or desirable for managing infrastructure commons, but rather that technical requirements (e.g., in the form of architectural patterns or indispensable management functions) for enabling the whole infrastructure as a polycentric governance will be needed.

[37] Digital commons can be defined as "*a subset of the commons, where the resources are data, information, culture and knowledge which are created and/or maintained online.*" [81]

A second line of work will be on formalizing and making operational design principles for polycentric governance, which does not appear to have been much addressed in the literature so far. A recent proposal for developing a general-purpose framework for governance for online communities, called "*Modular Politics*" is outlined in [103], which meshes well with our goal. Our objectives here are more focused. First, we will put a stronger emphasis on providing support for Ostrom's principles and their extensions [32], in order to derive them into programmable concepts or guidelines. Second, we will study how to exploit for our purposes specific theoretical models of polycentric systems such as the one sketched in [71]. A possible outcome of this research could be a software platform to formalize and help implement governance rules for ICT infrastructure commons.

Architecture. The main goal here is to develop a reference model, in the tradition of the ODP reference model [28], which can help identify common concepts and structures among potentially heterogeneous ICT infrastructures and platforms, and serve as a basis for protocol and API standards for enabling a polycentric management and governance structure. Contrary to the RM-ODP which purported to encompass concepts and viewpoint languages involved in the design of whole distributed information management systems, our reference model will focus on minimal concepts and functions required for enabling polycentric governance and management of ICT infrastructures. We expect these should encompass *resource* and *configuration management* which are two key enablers for managing ICT infrastructures. Resource management is indispensable to reflect the basic functions of low-level software in ICT infrastructures (operating systems, middleware), whereas configuration management is the prime building block of system management functions in ICT systems. The challenge for us is that the wild heterogeneity and spatial diversity of resources incurred by polycentric infrastructures will require a fresh new perspective on these functions.

We expect the two properties of compositionality and auditability to be prime requirements on our reference model. Compositionality is an enabler for the definition of resource and configuration management, whereas auditability is required for the definition and enforcement of governance policies. *Compositionality* means that we expect our reference to be primarily component-based, able to describe hardware and software structures in a modular fashion, with explicit component interfaces and component dependencies [53, 58]. This is key to enable configuration management and system management functions in a systematic fashion. *Auditability* means that infrastructures conforming with the reference model we envision can be analyzed for compliance with given properties or policies [31]. Such property is essential for building trust in a polycentric environment but requires a system architecture meeting key constraints or obeying key patterns [22]. Note that although both properties appear as desirable to us, they should obviously be handled with the same critical look as in Section 3.2.1 since excessive compositionality can lead to undue complexity and excessive auditability can lead to major privacy issues.

Achieving both compositionality and auditability by design in an ICT system remains a challenging research question on its own. While we do not exclude making contributions on these topics as part of our work (for instance, w.r.t. compositionality we definitely can build and improve on the Hypercell framework developed by one of us [77]), the main emphasis will be on consolidating existing work to build our reference model, typically identifying key architectural patterns that need to be applied in conforming systems.

Potential for action research. Our work on polycentric governance of ICT infrastructure commons offers good potential for conducting or complementing our studies via an action research endeavor. This could be conducted for example with specialists in commons governance, coming from political economy, political and management sciences, as well as actors in ICT commons (e.g., Picasoft, Framasoft, Rezine, CHATONS), be they tied to a territory as in a metropolitan network commons or to a set of online software services. Developing our work as action research would help exploring governance principles and their application, developing and tuning software support for governance, uncovering and validating key aspects of ICT commons governance and of our supporting reference model, etc. While we are at the very early stages of setting up such collaborations, action research is a high priority goal for our team.

3.3.2 Dedigitalization through hybrid information processing

Participants: Arnaud Legrand, Kevin Marquet, Sophie Quinton and Jean-Bernard Stefani

In this work, we propose to study examples of information processing that would by construction involve a mix of humans and ICT technologies. The explicit goal is to study in what respect one can do away with, reduce, or alleviate the complexity of the use of ICT technologies in various information processing contexts. We call *hybrid information processing* this form of computing, where the explicit participation of humans as autonomous information processors is taken into account, and considered as the controlling factor in computations. We believe this can be beneficial to reduce the ecological footprint of information processing and, critically, to reduce the digital divide in its various incarnations [87] by insisting on a human-centric approach to information processing (see below for a discussion of our approach in workflows). We already have several examples of hybrid information processing, with Amazon Turk as a striking dark pattern [72]. Another example is given by *self-obviating systems* [43] where ICT technologies are used initially—typically for learning purposes—and then progressively discarded in everyday use by humans, which can still rely on the persistent results of previous computation.

Our notion of hybrid information processing can be seen as an instance of *human computation*, a computer science subfield that is concerned with the "*design or analysis of information processing systems in which humans participate as computational elements*", according to the journal Human Computation [140]. However, this field is very much focused on crowdsourcing, with a much different emphasis than our own, namely that of harnessing crowd intelligence for

information processing. Our own emphasis is on systems where human activity is aided, potentially by obviating the recourse to ICT technologies, rather than the other way around.

Business process management To initiate our study we will have a look at the well-established subfield of business process management or workflow management for short. Workflow management aims to model and automate processes that arise in human organizations such as companies and administrations (e.g., logistics and administrative tasks) with the overarching goal of increased productivity [30, 79]. They are well supported by industry consortium specifications such as Oasis BPEL [13], OMG BPMN [26].

Taking into account human involvement in automated workflows has been a well recognized concern in the business process management community, leading for instance the Oasis consortium to the development of the BPEL4People specification [20] to complement its BPEL specifications. Supporting human activity is also the primary concern of case management systems, which provide a view of human activities in an organization not through well-defined processes but through a more informal array of tasks and data needed to handle a given case (the notion of case management emerged initially in health care [49] and has a consortium standard of its own, OMG CMMN [50]). Recent developments in the workflows community have in particular emphasized the need to combine process management and case management, as well as formal and informal forms of process descriptions [45, 97]. However business process management still overwhelmingly takes a process-centric approach and case-management a data-centric approach. Shifting the emphasis of workflow tools from being process-centric to being worker-centric is clearly expressed as a necessity in a recent paper detailing key research challenges for the workflow community [89]:

> *Workers interfacing with these [process-centric] tools are now dealing with overhead of duplicate work, mundane set of tasks, and inefficient processes that are tailored to the tools rather than the workers.*

For our part, our hybrid computing approach to workflows adopts a human-centric approach to process or case management, where the design of an ICT system for workflows should center around the needs of human workers involved in a workflow, as well as the needs of end-user beneficiaries of the information processing performed by a worfklow. We think a good starting point is to consider the related issues of handling exceptions and flexibility in workflows. The handling of exceptions, the flexibility and adaptability of computer supported workflows is of particular importance to tackle the questions we are concerned with. Dealing with exceptions has been known from the early 1980s to occupy a large part of human work in office processes [8], and is still the topic of active research [18, 54, 106]. Ditto for the study of flexibility and adaptability in workflows [54, 56, 98, 120]. Yet, to the best of our knowledge, the current state of the art is far from providing suitable support to handling exceptional situations highlighted by Suchman [8]. We believe a sustainable way forward does not necessarily lie in more ICT intensive systems, but in building self-obviating or convivial flexibility in workflow systems.

Potential for action research. In cooperation with specialists in business management, sociology of organizations, and with actual end-users (for instance in local authorities and administration), we intend to develop an action research programme, where we can address such questions as: how to design and support workflows so that different trade-offs can be made for the reliance on ICT technologies? how to design and support workflows so that switching between human processing and computer processing can take place smoothly, with minimal disruption of human activities? how to preserve human autonomy and creativity in the design and support of a workflow? A first idea we would like to investigate is the design of *defeasible* workflows, where any computation undertaken can easily be undone or interrupted, under solid and explainable semantical consistency guarantees for its human users. Previous work by members of the team on reversible models of computation (e.g., [29, 48]) can provide a starting point to understand the semantical foundations of defeasability. As a first step in this direction, we may mention the internship of Galaad Langlois in our group who currently investigates how the evolution of administrative processes (hiring, business travel, budget management, etc.) in academia and of their associated digital tools and information systems has impacted the daily life of administrative staff. Such work could be pursued in order to identify where processes could be dedigitalized in order to give administrative workers back their agency where it may be missing.

Beside business management processes, we are very much interested in setting up action research with local actors in order to study the practical, technical, scientific and organizational implications of dedigitalization and ICT degrowth in its various possible forms. An example would be to investigate what *shrinking networks* [37] could look like for ICT, or how the regular or permanent nonavailability of internet connection could be handled by reducing the need for it.

4 Application Domains

Our research project builds upon the idea that ICT and society are closely entangled, and can naturally be applied to every domain where ICT plays a major role. Beyond the few examples that have already been listed throughout our document, we list here some examples that are natural and direct application targets of our research.

ICT infrastructures and communication networks

Communication networks are at the heart of ICT infrastructures and a main driver of their growth. Nowadays, most of our electronic devices have been designed and developed to work inside a rather reliable and relatively high-performance network, and most of them (from smartphones to IoT for instance) would become quite useless if they

lost their communication capabilities. Communication networks and cloud infrastructures are thus now a primary condition to the development and deployment of these electronic devices. Just like electrical networks, the development of ICT requires the implication of several public actors and big private operators that support the deployment and the maintenance of these large infrastructures. Beyond the technical questions, this deployment also raises critical environmental, economical, social, political and also geopolitical[38] questions: where to deploy the material infrastructure, which territorial and social inequalities this will entail, who should be in charge of deploying it, is it even desirable to deploy a new infrastructure... On this matter, the controversy surrounding the deployment of the fifth generation of mobile phone, that has started in 2020 in France, is a prototypical example of the conflicts underlying the development of such large infrastructures [85]. Beyond these political questions, the complex entanglement between ICT and communication networks also raises the critical question of how the dependency to these potentially fragile networks critically impacts the resilience of our society. Such questions will be addressed in our studies of prospective scenarios in Section 3.1, in our analysis of digital tools in Section 3.2.1, and in our investigation of ICT infrastructures as polycentric commons in Section 3.3.1, as well as possibly in research action on dedigitalization and ICT degrowth in Section 3.3.2).

Smart city

Smart city is another natural application of our research. This application domain is directly built upon the promise that ICT can substantially improve our quality of life while dramatically reducing our environmental impacts. This promise relies first on the increase of measuring capabilities thanks to the deployment of sensor networks, second on the improvement of acting and driving capabilities thanks to IoT devices, and finally on a better optimisation of network management systems. It appears very clearly that the development of the smart city corresponds to a political project relying on the idea that the environmental benefits obtained by the optimisation permitted by the use of ICT will completely offset the impact of the massive deployment of these technologies. However, most questions related to indirect effects, increased dependency to the technology, induced autonomy loss, or more generally the conviviality of these systems have not been very much tackled in the scientific literature, to the best of our knowledge. Moreover, the promised enabling effects of ICT for smart cities still require evaluation. Such questions will be addressed in our studies of prospective scenarios in Section 3.1, in our analysis of mainstream digital tools in Section 3.2.1, in our investigation of conviviality in Section 3.2.2 and of polycentric commons in Section 3.3.1.

Artificial Intelligence

Artificial Intelligence perfectly illustrates the profound entanglement between society and the development of technology. Deep neural networks, on which a big part of modern (and generative) AI is based, have outperformed all other approaches on classification and generation tasks, mostly because of the dramatic increase in computing capabilities (including all the material aspects that underlie this increase) on the one hand and the disponibility of huge datasets that have fed learning algorithms for years, and still feed them on the other hand. This development hence relies on an extractivist political project that (i) exploits the natural resources needed to make the AI infrastructure work (networks, datacenters, supercomputers, ...), (ii) considers the digital world as a huge source of data, where every single information can be extracted regardless of its kind, status or privacy, and (iii) is built to a large extent on the availability of a cheap workforce in charge of labelling the datasets [93]. On the other side, the advent of AI systems have disrupted many sectors of society, for the better and the worse, starting from teaching, research, journalism, art, or even software development, whose practices have been overwhelmed and have to quickly adapt to them. We will study such disruptions and potential adaptations in our analysis of mainstream digital tools in Section 3.2.1, in our investigation of conviviality in Section 3.2.2 and of hybrid information processing and workflows in Section 3.3.2.

Information Systems

Our work on hybrid information processing and workflows described in Section 3.3.2 concerns key information systems technologies (business process management and case management systems). It addresses concerns of activity automation in various forms of collectives, including company administration, local and governmental administration, and takes the stand that adopting a human-centric approach to design such automation, with the potential to tune it out, or reduce its deleterious impact on human autonomy, is very well worth investigating. If our research action programme is successful, we expect our studies to be at least applicable to local administrations or on a local scale. We also expect our work to influence prospective scenarios for degrowth in Section 3.1.2.

5 Transfer, Software and Technological Development

In academia. As already mentioned, one major goal of the ADN team will be to support the emergence of an interdisciplinary research community sharing a common question: what computer science research is needed, or could be useful, in the Anthropocene? Beyond that, we believe that the research output of such a research community would be of interest to all academic colleagues whose expertise lies in computer science. In particular, we believe our critical analysis of digital tools and related work (in Sections 3.2 and 3.3), built with the help of colleagues from social science, political science, economics, philosophy, and science and technology studies, to be of interest for them, as well as our analysis of prospective scenarios in Section 3.1. Conversely, we intend to use our expertise in various computer science

[38] Because these networks are globally interconnected and are a major driver of economical exchanges.

fields (e.g., IoT, HPC, AI, embedded systems) to help collaborators in STS, economics, etc. advance the state of the art in their own field. An important part of our dissemination strategy will focus on how computer science is taught in universities and engineering schools. This will be achieved through the involvement of several members of ADN in teaching activities related to sustainability, as well as through research projects and mediation activities on the subject.

Outside academia. Beyond colleagues in computer science and other fields, our transfer strategy will mostly target public institutions, such as local authorities and administration (e.g., SMMAG, Métropole de Grenoble), national bodies (ADEME, ARCEP, etc.), but also associations (e.g., ATD Quart-Monde). More specifically, we believe that our work on prospective scenarios (Section 3.1) could be useful for public institutions, and we target local authorities and administration as well as associations for research action on our work on ICT alternatives (Section 3.3). We may also develop software, e.g., as a proof of concept for our theoretical contributions, or to support existing projects. The Whale platform, developed by Sylvain Bouveret since 2010 to help collective decision making, provides an illustration of the type of software development that we will consider.

6 Project-Team Positioning

The interdisciplinary approach proposed in the ADN project is quite original, which may make it difficult for our work to fit into classical categories (e.g., CNRS/Inria keywords), laboratory research axes, and publication venues. Yet, the challenges raised by the environmental impacts of human activities, and in particular of ICT, have attracted more and more attention in the last few years and new research communities are emerging. We now briefly describe the current state of the ecosystem related to these topics and how we fit into it.

6.1 Within the Grenoble ecosystem

The Grenoble research ecosystem appears to be particularly rich and active when it comes to the environmental impacts of ICT and the ADN team will participate in the animation and structuring of the community. The following projects are particularly significant.

STEEP (LJK) (Sustainability, Transition, Environment, Economy and local Policy) is an interdisciplinary research team at Inria Grenoble and the Laboratoire Jean Kuntzmann. This team is dedicated to the systemic modeling and simulation of interactions between environmental, economic and social factors. Like the ADN team, their goal is to disseminate knowledge rooted in material realities. Their application domains however are urban economy, land use, ecology, or territorial foresight studies rather than ICT. We value the pioneering work of the STEEP members and we are particularly interested in the experience of Mathilde Boissier on *participatory modeling* and *counter-modeling* as well as that of Sophie Wahnich on the history of democratic institutions and radical change.

ETiCS (Verimag) is one of the five research axes of the Verimag laboratory and studies the role and use of digital technologies in the environmental crisis. This group, whose background lies in the design, modeling, programming and validation of critical embedded systems, focuses on questions such as: (1) can digital technologies help reduce our environmental impact? (2) how can computer science be used as a modeling tool for the environment? (3) how to rethink digital systems for sobriety, sustainability, and simplicity? Members of the ADN project also intend to address similar questions but with a different background (in particular in networking, social choice, and learning) and a radically interdisciplinary approach.

Persyval (Pervasive Systems and Algorithms) is a Labex in Grenoble that federates 800 researchers and academics from 10 laboratories in Grenoble working on computer science, hardware architecture, signal processing, control and mathematics towards a common scientific goal: Mastering the convergence between physical and digital worlds. The future organization will feature a new *ICT and sustainability* research axis (coordinated by Sophie Quinton and Maud Rio) whose goal will be to foster research on questions such as how to compute within physical limits and how digital technologies impact the resilience of our societies, with an emphasis on the clarification of uncertainties, hypotheses and arbitrations underlying the scenarios under study.

6.2 Within Inria

The aforementioned **STEEP** team is the first Inria team specifically addressing the challenges of environmental change, sustainability and resilience. Since then, a few other teams have been created and address related topics.

SEMIS (Inria Lyon) is an Inria team currently under review for creation whose goal is to study how information science and technology affect and are affected by societies and ecosystems, and in particular the political dimension of the production, circulation and control of information enabled by ICT in the face of planetary limits. Their first research axis is centered on agroecology with a particular interest in digital platforms (similar to e.g., SWIFT, Uber, Doctissimo, Airbnb, ...) for agriculture, the design of volunteer botanical platforms, and self-obviating computer science (in relation with PlantNet) and innovation through withdrawal. This latter topic is of particular interest for the ADN members and will also be studied but in very different contexts (in Sections 3.2.1 and 3.3.2). More generally, their interest for digital platforms is oriented towards the geopolitical consequences (social conditions, food crises) of their introduction with a particular emphasis on scale, rather than on the governance of underlying

ICT infrastructure. Their second research axis is centered on the role of knowledge production in the Anthropocene (again, with a specific interest on scale properties) and of prospective methods (such as SEnS workshops [4] which have been co-created by Sophie Quinton and Éric Tannier, who is the head of the SEMIS team).

Magellan (Inria Rennes) aims to enable the creation of efficient, robust, environment-friendly and rigorously-evaluated decentralized computing infrastructures. It focuses its research efforts on reliable decentralized computing infrastructures, reliable decentralized application runtimes, distributed infrastructure frugality, and evaluation methodologies and tools. We have long-standing collaborations with members of the Magellan team (e.g., Martin Quinson and Anne-Cécile Orgerie) and our work will be complementary as these colleagues focus more on quantitative and disciplinary approaches while we propose an interdisciplinary approach which will not be restricted to distributed infrastructures.

Several other colleagues in Rennes (e.g., Simon Castellan in **Épicure** team) have started also working on low tech and interest in alternative computer tools and environmental constraints is rising amongst several teams but has not yet led yet to the creation of an other specifically dedicated team.

SPIRALS (Inria Lille) is conducting research in the domains of distributed systems and software sciences and some of its members are in the process of creating a new research project on *Software Systems within Environmental Limits*. The precise perimeter is not clearly defined yet but the approach will again be disciplinary with a particular emphasis on quantitative and actionable contributions (*measuring* the end-to-end emissions of software deployed in the wild and drastically *reducing* software-induced wastes throughout their life cycle).

Inria Bordeaux There is currently no team whose research topic is specifically related to the challenges raised by the environmental impact of ICT but several researcher have already significantly investigated closely related topics. Aurélie Bugeau, whose research interest originally lies in image and video processing has shifted her research topics toward the analysis of environmental impacts of ICT (and in particular AI), the sustainability of digital technologies, and how to teach these topics. Gaël Guennebaud, whose current team **Manao** works at the convergence of digital optics and computer graphics, has already started working on measuring and estimating direct and indirect impacts of digital systems and services.

ARCHES (Inria Paris) is a team using AI for climate science, mitigation and adaptation to climate change. There are similarities with the first research axis of the ADN proposal. One major difference is our emphasis on the systemic nature of mitigation and adaptation, and thus on the necessary interdisciplinary collaboration with social sciences.

6.3 National

At the national scale, the ecosystem is currently under rapid evolution and research initiatives are flourishing. We mention the most significant ones.

LISN Anne-Laure Ligozat has conducted for a few years a significant research effort on environmental impacts of ICT, in particular of AI, and on how to transpose such work into CS teaching curricula.

Phenix (CITI) is also a project challenging the hypothesis of a perpetual growth. Kevin Marquet is a former member of this research group focusing on frugal computing (how to reduce the resource requirements of digital technology, while retaining the most useful services) and emancipatory security (how to ensure that the Internet remains at the service of all, and that it is secured according to the needs of its users). The goals of Phenix are therefore particularly close those of ADN except they follow a more technical and constructive approach (e.g., through a deep dive in projects like CollapseOS, by trying to port it on Arduino micro-controllers and aiming at a minimalist software foundation suited to frugal activities) than that of ADN, whose interdisciplinary approach is stronger.

LIRIS Aurélien Tabard (in the *Situated Interaction, Collaboration, Adaptation and Learning* team, and currently on sabbatical at Inria Lille, in the **Loki** project) studies convivial informatics through the design and development of alternatives to existing computational platforms. This involves platforms that take into consideration digital limits and foster sufficiency, maintenance, autonomy, and durability. This also requires some work on better understanding software obsolescence and collaborations with Fairphone designers.

CIS (Centre Internet et Société) is both a CNRS research center and a GDR depending of the INSHS, which gathers researchers from sociology, law, history, economics, political science, information and communication sciences, computer science and engineering. The CIS aims to build independent, interdisciplinary research and expertise, capable of shedding light on major technical controversies and on the definition of contemporary policies linked to ICT. Clément Marquet and Sophie Quinton are both coordinators of the *Politiques environnementales du numérique* working group, which will ease collaborations with this interdisciplinary community.

EcoInfo is a GDS (which should evolve in a GDRS in the next years) from the CNRS, which gathers both engineers and researchers in academia and whose goal is to act to reduce the negative environmental and societal impacts of ICT. Typically addressed topics fit in the sustainable development, quantifying the materiality of ICT (metals, pollution, energy, waste), GreenIT, network equipment, and target political institutions and users.

PEPR *Numérique Éco-responsable* A new PEPR coordinated by Laurent Lefèvre is currently under construction and gathers many of the aforementioned teams and researchers as well as social science teams interested in this topic. The ADN team has been contacted to participate in the PC1 (*Understanding, measuring, estimating, and characterizing direct and indirect impacts of digital systems and services – LifeCycle and Systemic effects*) and in the PC5 (*Digital resiliency with limits, constraints and risks of disruption*).

6.4 International

The ADN work programme aims to contribute to the degrowth interdisciplinary field. However this field is currently mainly the target of ecological economists and political ecologists (e.g., G. Kallis and J. Hickel group at U. Autonoma Barcelona), with a limited presence of computer scientists.

The ADN work programme intersects the interests of two main communities with a strong computer science component. On the one hand, we find communities built around various issues and meanings of sustainability, exemplified by the ICT4S (ICT for Sustainability), IGSCC (Green and Sustainable Computing Conference), LIMITS (Computing within Limits) and LOCOS (Low Carbon Computing) conferences and workshops.

On the other hand we find communities concerned with ethically-aligned and value-based design, such as Value-Sensitive Design (VSD) [14, 44] with strong footholds in the US (U. of Washington) and the Netherlands (TU Delft and U. Utrecht), and Responsible Research and Innovation (RRI) [83, 100], with strong support from the European Commission.

Compared to these two communities at large, our originality stems from the strong normative approach we take when it comes to imbuing technology with values, and our insistence on degrowth. Within the ICT for sustainability communities, the emphasis on degrowth is for the time being in the minority, but it is a clear concern for the LIMITS community, which cites continuous economic growth as a phenomenon detrimental to a strong sustainability agenda [63]. Well-established contributing groups in the LIMITS community can be found in U. Lancaster (UK), KTH Stockholm (Sweden), U. Louvain (Belgium), U. Toronto (Canada), U.C. Irvine (CA, USA), and U. Southern California (CA, USA). One of the research groups which is most closely aligned on our scientific positioning is that of Christoph Becker which aims to develop methods and tools for just sustainability design in software engineering and computing [121], and which includes as a research goal a critical analysis of the politics and values in design.

7 Frequently asked questions

7.1 Why insist on degrowth ?

Concerns about the sustainability of our societies has been a concern since at least a century and has led to the proposal of many terms among which degrowth, agrowth, steady-state economy, post-growth, post-development, sufficiency, sustainable development, etc. The definition and meaning of these concepts sometimes wildly varies from one field (economics, sociology, political ecology, philosophy, etc.) and one language[39] to the next, and has also evolved through time. We refer for example the interested reader to the work of Martínez-Alier *et al.* [19] for a historical and conceptual perspective on *sustainable degrowth*, which points to the differences of perception from one country and domain to another (the prominent *décroissance* term rooted in philosophy and political ecology is referred to *degrowth à La Française* and compared to the concept of *sustainable degrowth* used by economists in English-speaking countries).

Let us thus first clarify what we mean by *degrowth*. Schmelzer *et al.* offer the following definition of a *degrowth society* [118, p. 195], a synthesis which we wholly agree with:

> *A degrowth society, we propose, is one which, in a democratic process of transformation:*
>
> 1. *enables global ecological justice – in other words, it transforms and reduces its material metabolism, and thus also production and consumption, in such a way that its way of life is ecologically sustainable in the long term and globally just;*
> 2. *strengthens social justice and self-determination and strives for a good life for all under the conditions of this changed metabolism; and*
> 3. *redesigns its institutions and infrastructure so that they are not dependent on growth and continuous expansion for their functioning.*

For us, the term *degrowth* refers to an interdisciplinary research agenda [60] that aims to tackle the eco-systemic crises facing humanity and life on Earth, and that is based on two basic premises:

1. That the decoupling between economic growth in present productivist societies and growing deleterious ecosystemic impact is highly unlikely.
2. That it is possible to organize a transition to, and live well in, a degrowth society.

If one accepts the first premise – decoupling is highly unlikely –, it seems to us a degrowth strategy is a clear moral choice. Following Hans Jonas's responsibility principle [27], we should choose degrowth if we want to avoid waging the survival of humanity against unpredictable advances in science and technology that are supposed to bring about the hoped-for decoupling.

We thus have two main incentives to place the ADN proposal squarely in a degrowth perspective:

1. Degrowth is a strategy worth investigating because it has clear moral advantages on the alternatives that leave intact a productivist mindset: it is a responsible choice, following Hans Jonas' responsibility principle, and, contrary to the productivist alternatives, it confronts heads on the *perfect moral storm* brought about by climate change [21].

[39] As explained by Schmelzer *et al.* [118], in German, using *De-* or *Ent-* alongside *Wachstum* (growth) is awkward so *Postwachstum* is usually preferred while in Dutch, *ontgroei* (roughly, '*ungrowth*') is used, and earlier English translations of *décroissance* were associated with the notion of *declining* [19].

2. Degrowth is a serious interdisciplinary endeavour (see, e.g., [60], and the recent ERC Synergy project *Pathways towards post growth deals* [109]), that has currently not received enough attention from computer scientists. As highlighted in chapter 7 of [118], "*A third void in the degrowth debate is the relationship between degrowth and digitalization*", and much research is needed to understand the place and nature of ICT technologies in this debate.

Our ADN proposal takes its place in this research agenda by focusing on the following questions :

1. What role and place for ICT technologies in a degrowth scenario ? (Section 3.1 of the ADN proposal, esp. Section 3.1.2)
2. What ethical and epistemological foundations for the design of ICT technologies in a degrowth perspective ? (Section 3.2 of the ADN proposal)
3. What ICT technologies can contribute to an effective degrowth strategy ? (Section 3.3 of the ADN proposal)

Whether or not one agrees, as a citizen, with the goal of transitioning towards a degrowth society, these questions are worthy of scientific inquiry, especially if one cares, as a scientist, for the values inherent with a degrowth society (see below). For instance, our research axis on ICT infrastructures as commons is certainly an imperative in a degrowth perspective, to avoid the un-democratic nature, excessive ecological footprint and moral failures manifest in modern day ICT infrastructures. But it will also be useful knowledge to further the development of alternative infrastructures that may exist alongside current capitalistic ones (much as Mastodon and the numerous other services participating in the Fediverse coexist with the current dominant social media and web services).

A subsidiary question in this respect is: why use the term *degrowth* and not other, possibly less ideologically[40] connotated terms such as *post-growth*, or *agrowth* ? We could have indeed chosen one of those terms since as noted by Schmelzer *et al.* [118, p. 28], "*'Post-growth', when used as a normative rather than a descriptive term, is often seen as a safer, less negative, and more aspirational concept.*" But, they argue [118, p. 28], and we agree, that "*While there is certainly some truth to these arguments [in favor of using the terms post-growth or agrowth], and eventually there may come a time to drop the term 'degrowth', they miss one of the key goals of degrowth: to tear down the cracked edifice of the hegemony of growth.*". Finally, post-growth and agrowth, just like degrowth, have also been also subject to controversies in various communities (in particular in economics) and the definition of degrowth proposed in the beginning of this section offers the ideal moral framing for our project.

7.2 What values for ADN ?

The ADN proposal aims to develop an EViD approach for the development of computer systems. A question arises as to the nature of these values, and their origin. For instance, do we adopt a universalist approach with a given set of overarching values, or a relativist one, where values for system design are not predetermined and may arise from moral debate among the system stakeholders?

For our part, we believe in the overarching set of values induced by the end goal of transitioning to a degrowth society: eco-systemic responsibility, ecological and social justice, self-determination and democracy. However, these are high-level values that need to be, and are, debated among scientists of all disciplines and the general public. For instance, ecological and social justice are topics of active consideration among political scientists, jurists, economists, etc. In the ADN proposal, we lay out in Section 3.2.2 of our research program the necessity to study, with colleagues from humanities, the ethical foundations of conviviality, a potentially fruitful constituent of a degrowth strategy.

Eco-systemic responsibility, by which we mean responsibility according to Hans Jonas, in taking care of the conditions for a survival of humanity worth living, is not only for us a collective imperative but also an overarching imperative for scientists in the development of their research and their technologies.

We thus adopt in ADN a strongly normative point of view, with overarching values that need to be adopted universally, but recognize that much work is needed to make clear what ethical values and ethical foundations are necessary for the design of responsible technologies, and especially responsible ICT technologies, in a degrowth strategy.

7.3 As computer scientists, are we legitimate to work on degrowth ?

As mentioned above, degrowth is an interdisciplinary research agenda, and certainly not the preserve of a single discipline such as economics or political science. We believe on the contrary that many scientific disciplines are concerned by this agenda, computer science included. This is well recognized by degrowth scholars. As highlighted in chapter 7 of [118], "A third void in the degrowth debate is the relationship between degrowth and digitalization", and, as said above, much research is needed to understand the place and nature of ICT technologies in this debate. As computer scientists, it seems to us we are actually well-positioned to contribute to this research, with help from our "critical friends" [121] in humanities and Science and Technology Studies (in French *sciences, techniques et société*), of course. Conversely, we believe it is critical for computer scientists to help our colleagues in humanities when it comes to understanding the role, impact, threats and opportunities raised by ICT technologies in society, and the role they should play in a degrowth strategy.

Let us not forget that the initial proponents of Value Sensitive Design, one of the most well-known Ethical and Values in Design (EViD) approach for the development of ethical computer systems, were computer scientists (specialists

[40] We use here the term *ideology* in the same way as in the Transitions 2050 ADEME report, without any negative connotation, and to mean "*a coherent view of the world*" ("*un prisme cohérent d'interprétation du monde*").

in human computer interaction). As mentioned in the ADN proposal, an overarching goal for the ADN team is to contribute to the development of a full-fledged EViD approach for ICT technologies that is consistent with, and effectively contributes to, a degrowth strategy, and we think we are not illegitimate to do so.

7.4 What interdisciplinarity in ADN ?

As the ADN proposal makes clear, our research program in inherently interdisciplinary. We have established several discussions with colleagues in the humanities and social sciences, launched two PhD theses co-advised by colleagues in the humanities, identified already several external collaborators from humanities and social sciences, and recruited a postdoc in sociology of science who will be working with us and the École des Mines de Paris. We do not yet have commitments from colleagues in the humanities and social sciences to devote a large part of their research to ADN axes (in part because working on ADN research themes may require an inflection in their own studies), and thus no permanent member of ADN is currently from these disciplines. However we believe we are just at the start of a long process and we certainly expect to attract non-computer scientists as permanent members of ADN not long after the team is created and active. Also clear in the ADN proposal is the fact that we intend to develop a substantial part of our research as action research endeavours, meaning with the involvement of members of society at large. Our research axes on ICT infrastructures as commons and hybrid information processing are clearly flagged as such. We have not yet formalized specific programs in these two areas but hope to do so shortly after the ADN team has been initiated.

8 Project-team Bibliography

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9 Permanent Member Curriculum Vitæ

Sylvain Bouveret

Education

- 2025: Habilitation, Computer Science, University Grenoble Alpes
- 2007: PhD in Computer Science, Université de Toulouse
- 2004: Master of Research in Computer Science, Université Paul Sabatier, Toulouse
- 2004: Engineering degree, École Nationale Supérieure de l'Aéronautique et de l'Espace (Supaéro), Toulouse

Employment

- 2011-...: Associate Professor, Grenoble INP, Laboratoire d'Informatique de Grenoble
- 2007–2011: Research Engineer, ONERA, Toulouse
- 2004–2007: PhD student, Université de Toulouse, ONERA/IRIT/CNES, Toulouse

Professional activities

- 2021–...: Member of CNRS Research and Service Group Ecoinfo
- 2017: Co-organiser and main developer of the voting experiment *Voter Autrement* during the 2017 French presidential election (more than 37,000 participants online and 6,000 in polling stations).
- Main developer of Whale (*WHich ALternative is Elected*), used for everyday voting situations (e.g., committees), research, teaching and dissemination purposes (a few hundreds regular users)
- 8 articles in peer reviewed international journals, 20 articles in peer reviewed international conferences, 3 book chapters.

Research themes

- Computational Social Choice
- Knowledge Representation and Reasoning
- Constraint Programming
- Geographic Information Systems
- Environmental Impacts of ICT, and especially AI

Arnaud Legrand

Education

- 2015: Habilitation, Computer Science, University Grenoble Alpes
- 2003: PhD, Computer Science, École Normale Supérieure de Lyon

Employment

- 2018-…: Senior Research scientist, CNRS, Grenoble
- 2004–2018: Junior Research scientist, CNRS, Grenoble
- 2004–2005: Post-doc, University of California, San Diego, USA
- 2001–2004: PhD student, École Normale Supérieure de Lyon, Laboratoire de l'Informatique du Parallélisme

Professional activities

- 2022–2025: Section 6 of the CoNRS (hiring committees for CNRS)
- 2022–…: Scientific Committee of the Inria center of Univ. Grenoble-Alpes
- 2020–…: Head of the SRCPR axis of the LIG
- 2016–2024: Leader of the POLARIS team
- Performance modeling: co-Developer of the SimGrid framework, which has been cited more than 2200 times according to Google Scholar and has been used in the experimental section of 630+ articles and thesis.
- Reproducible Research: co-author of two MOOCs on Reproducible Research. Over the 3 editions (Oct.–Dec. 2018, Apr.–June 2019, March 2020–end of 2024) of the 1st one, more than 20,800 persons have followed this MOOC and about 2100 certificates of achievement have been delivered. The 2nd one has been launched on May 2024 (and has attracted 1,200 participants so far).
- 31 articles in peer reviewed international journals, 66 articles in peer reviewed international conferences, 2 textbooks.

Research themes

- High Performance Computing (modeling and optimization of performance and energy consumption)
- Scheduling, combinatorial optimization, game theory
- Discrete event simulation, fluid modeling, emulation
- Trace analysis and visualization
- Machine (statistical/reinforcement/active) learning
- Methodology, design of experiments and reproducible research

Kevin Marquet

Education

- 2007: PhD, computer science, Univ. Lille 1.

Employment

- 2024: Associate professor (permanent position) at University Grenoble-Alpes (UGA), UFR IM2AG.
- 2023–2024: Associate professor (*mise à disposition*), UGA, UFR IM2AG, LIG (Polaris).
- 2011–2022: Associate professor, CITI lab, Insa Lyon.
- 2008–2010: Post-doctoral researcher, Synchrone team, Verimag, Univ. Grenoble.
- 2007–2008: ATER, Polytech'Lille.

Professional activities

- 2018–...: Member of CNRS Research and Service Group Ecoinfo
- 2019–2021: Co-director of CNRS Research and Service Group Ecoinfo.
- 2017–2021: Leader of *Défi ZEP* (*ZEro-Power Computing systems*).
- 3 articles in international peer reviewed international journals, 32 articles in international peer-reviewed conferences.

Research themes

- Low-tech / energy efficient embedded systems
- Operating systems, memory management
- Direct and indirect environmental impacts of 5G
- Potential of ICT for sustainable societies

Sophie Quinton

Education

- 2011: PhD, Computer Science, Université Grenoble Alpes
- 2005: Master, Computer Science and Telecommunications, École Normale Supérieure de Cachan

Employment

- 2013-…: Junior Research scientist, INRIA, Grenoble
- 2011–2013: Post-doc, TU Braunschweig, Germany
- 2006–2011: PhD student, Université Joseph Fourier, Verimag

Professional activities

- Since 2021: Co-creator (with Éric Tannier) of the Atelier SEnS, a 1-day workshop for members of the research community to reflect on the social and environmental implications of their research. Ateliers SEnS are now organized on a regular basis, all across France, outside of INRIA and across many disciplinary fields.
- Since 2019: Co-chair (with Clément Marquet) of the CIS-PEN working group, focusing on environmental issues, of the "Internet, IA and society" GDR associated with the Center for Internet and Society.
- 2019–2021: Member of the executive committee of the ACM SIGBED
- Since 2016: Member of the executive committee, and then of the advisory board of the ECRTS conference
- 8 articles in peer reviewed international journals, 34 articles in peer reviewed international conferences.

Research themes

- Social values in computer science
- ICT as a risk to resilience
- (Previously) Formal verification of real-time embedded systems
- (Previously) Contract-based theories for component-based design

Jean-Bernard Stefani

Education

- 1984: Engineer, Ecole Nationale Supérieure des Télécommunications, Paris, France.
- 1984: Master Th. Comp. Science, U. Paris VII, France.
- 1982: Engineer Ecole Polytechnique, Palaiseau, France.

Employment

- 2001–present: Senior Scientist Institut National de Recherche en Informatique et Automatique (INRIA), Montbonnot, France.
- 1989–2000: Group Manager and Laboratory Director, Centre National d'Etudes des Télécommunications (CNET), Paris and Grenoble, France.
- 1984–1988: Group Manager, Service d'Etudes Communes des POstes et Télécommunications (SEPT), Caen, France.
- 1983: Research Engineer, National Bureau of Standards, Gaithersburg, MD, USA.

Professional activities

- 2015–2021: Scientific Director, INRIA Grenoble-Rhône-Alpes research center
- 2015–2020: Co-Director, IO Lab joint INRIA/Orange research laboratory
- 2012–2018: Chairman IFIP WG6.1
- 2013–2015: Head Spades research team, INRIA Grenoble-Rhône-Alpes research center
- 2002–2012: Head Sardes research team, INRIA Grenoble-Rhône-Alpes research center
- 2000–2003: Member Section 7 of Comité National de la Recherche Scientifique, CNRS
- 1993–2000: Chairman WG 4 (ODP, messaging, directory services) and 5 (OSI and ODP), ITU-T Study Group 7
- 22 articles in international peer-reviewed journals, 76 articles in international peer-reviewed conferences, 1 book

Research themes

- Distributed and operating systems engineering
- Formal methods for software engineering
- Component-based software engineering
- Program semantics and concurrency theory
- Reversible programming languages and systems