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Degrowth and Technology:

towards feasible, viable, appropriate and convivial imaginaries

Christian Kerschner
Petra Wächter
Linda Nierling
Melf-Hinrich Ehlers

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1. Introduction

The role of technology for a sustainable society without continuous economic growth and beyond unquestioned technological optimism (Kerschner & Ehlers 2016), eco-efficiency, eco-innovation (Lizarralde & Tyl, this issue) and eco-modernisation (Grunwald, this issue) is a key theme in the activist and the academic community around "Degrowth": symbolically, practically and theoretically[1]. Symbolically there is a strong presence of technological devices in the visual representation of Degrowth. Besides the well-known images of snails, low-tech devices (see Alexander & Yacoumis, this issue) - particularly bicycles in various shapes[2] - are *the* Degrowth-symbol par-excellence[3] (see Image 1,2 below). Ivan Illich, Degrowth's most

[1] For Degrowth's history consult (Demaria et al., 2013; Kallis et al., 2015; Martinez-Alier et al., 2010; Muraca, 2013; Paech, 2012; Petridis et al., 2015; Postwachstum, 2016)
[2] Interestingly the bicycle was prominent in early Science and Technology Studies (see Pinch & Bijker, 1984)
[3] Often symbolic purposes outweigh practical effects. A bicycle washing machine at Can Mas Deu, a famous Barcelonian squat and Degrowth activist hub, was used rarely and the community had an electricity powered version as "back up". A self-made wind turbine at the 2017 Climate Camp near Vienna, Austria, provided only a tiny fraction of electricity consumed (approximately 300 watt) – which was used mostly for charging the phones of participants. The rest came from industrially manufactured solar panels (email conversation with organisers).

popular author on technology, starts his “Energy and Equity” with the famous quote “Socialism can arrive only by bicycle” (1973, p.xxxiii)[4]. Cars, in turn, seem to be the ultimate Degrowth counter-image[5]. Other images use personal overloading with modern high-tech for illustrating this contrast (see Image 3 below).

Image 1

Image 2

Image 1, 2: The symbolic use of bicycles in its many shapes and combinations

Source: Image 1 courtesy Can Decreix, Francois Schneider; Image 2 Fahrradbus, Robin Dirks

[4] Illich originally quotes José Antonio Viera-Gallo (Assistant Secretary of Justice in the government of Salvador Allende) in Spanish: ``El socialismo puede llegar sólo en bicicleta.''

[5] At the time of writing the first 200 google images for "Degrowth" show that images of snails clearly dominate as symbols (21 out of 30 symbols are snails), but this is immediately followed by images of technological devices (13). Among those 4 are bikes and 5 cars. The bicycle also features prominently in Degrowth documentaries like “Life after Growth”(Medina & Temper, 2009) and conference presentations.

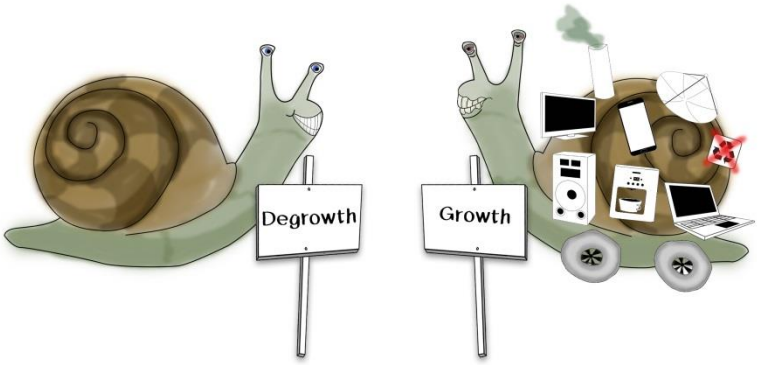

Image 3: Personal overloading with technological artefacts as Degrowth anti-thesis.

Source: Illustration by Monika Rygálová adapted from (Munk et al., n.d.)

Practically some Degrowth-related communities and projects literally define themselves around particular technologies both low- and high-tech. Examples are communities around the Fairphone (Haucke, this issue), open source and hacking (Hankammer & Kleer, Kostakis et al., Likavčan & Scholz-Wäckerle, March, this issue), digital commons, makerspaces and fab labs (; Morell, 2014; Kostakis et al., March, this issue) and bicycle kitchens (Bradley, this issue)

Theoretically there is a large body of classical literature that addresses technology (see section 2) but despite the rapidly growing contemporary scholarship there have been no related scientific articles (Weiss & Cattaneo, 2017) nor was there a respective entry in the "Degrowth Vocabulary" (D'Alisa et al., 2015). In fact until now the community completely lacked any common perspectives on technology (Grunwald; Strand et al., this issue). This special issue with its 26 (including one book review) contributions is a first step towards closing this gap. The remarkable breath of these contributions shows that the Degrowth community has already been waiting for this opportunity.

Preparations for this special issue (SI) started after the 4th Degrowth conference in Leipzig in 2014, including an editorial workshop in Austria in 2016 and lively debates among authors, editors and audiences during conference presentations and special sessions at several international conferences. The quantity, quality and diversity of submissions was extraordinary. From the 41 submitted abstracts, we accepted 35 papers and 25 passed rigorous

review. The authors have diverse expertise. 17 of them have background in economics (which includes also ecological economics), 11 in political sciences, 10 in social sciences, 9 in philosophy, 6 in engineering, 4 in sciences, 2 in sociology and 1 in environmental science and geography. More authors have background in more than single discipline.

In 2008 the linguistic invention "Degrowth" was officially introduced as a translation of the French "décroissance"[6] at the first international Degrowth conference in Paris. Since then over 273 (Web of Science, accessed 21st November, 2017) articles and many special issues in scientific journals have been published (Asara et al., 2015; Cattaneo et al., 2012; Kallis et al., 2012; Paulson, 2017; Saed, 2012; Schneider et al., 2010; Sekulova et al., 2013; Whitehead, 2013) that push the Degrowth research agenda ahead. This special issue follows this tradition of assembling cutting-edge research and at the same time it marks the beginning of a division of Degrowth research into different "focus groups". Hence we expect and hope that many timely "Degrowth and …." collections will follow e.g. Environmental Justice, geography, socialism, demography, the state, agriculture etc.

"Degrowth" has been described as a "movement of movements" (e.g. (Demaria et al., 2013; Petridis et al., 2015), a "multi-faceted framework" (Kallis, 2011), an "interpretative frame" (Demaria et. al. 2013), an "umbrella keyword" (Kallis, 2011) and a "political project of dispossession" (Garcia et al., this issue) that connects and gives purpose to different actors and their more specific ambitions such as Indignados/Occupy, Reclaiming the Commons, Solidarity Economy, Transition Towns, Voluntary Simplicity and Slow Food. They may use Degrowth as a "missile word" (Drews and Antal, 2016), a (subversive) slogan or a scientific concept (Petridis et al., 2015) and may be attracted by its potential to deepen democracy (Cattaneo et al., 2012), to re-politicize sustainability (Asara et al., 2015; Wächter, 2013) and to advance a biophysical path towards a globally equitable Steady State Economy (Kerschner, 2010) They all see an urgent need to "decolonize our imaginaries" (Kallis et al., 2009) from the idiom of economism (Kallis et al., 2009) and "economic growth" as a social goal (Kallis et al., 2015).

Attempts to provide short definitions of Degrowth (e.g. Schneider et al., 2010, p. 512), have remained controversial (Haucke, this issue) as they tend to ignore some aspects of the multi-

faceted concept that is effectively "in the making" (Petridis et. al. 2015). Rather than a weakness, we see life itself as a self-ordering, self-finding endeavour that only stops with death. Hence, as long as Degrowth scholars and advocates are active in trying to define Degrowth, we know it is very much alive.

Defining 'technology' and differentiating it from "tools" or "techniques" is the subject of an extensive and sophisticated literature, an appropriate account of which goes beyond the purpose of this special issue. Instead it emphasises context-related attributes of technologies such as 'convivial', 'appropriate', 'viable', 'feasible', 'low vs. high', 'radical', 'autonomous', 'intermediate' and 'appropriate' to allow more specific analysis of alternative imaginaries of technology in a Degrowth society. Nevertheless, some authors provide their own preferred definition e.g. (Alexander and Yacoumis, this issue) "a tool, method, or design practice that helps humans solve problems and achieve goals", or Grunwald (this issue): "the set of use-oriented, artificial, concrete objects (artifacts or object systems), the set of human actions and institutions in which object systems originate, the set of human actives in which object systems are utilised (Gomiero, 2017)". Gomiero (this issue) decides to work with a definition of a tool as "a handheld device that aids in accomplishing a task"("Tool," 2017) which he finds more conducive for his analysis than definitions of technology. From an anthropological point of view however, "technology is not a set of tools, but a form of relation to the world and to others, as it embodies and shapes social relationships. Tools on the other hand are carriers of meaning, reflect power relations, enframe the sphere of actions and collective practices" (Muraca & Neuber, this issue), Heikkurinen (this issue) works with Heidegger's encompassing definition of technology that goes beyond technology being a means to an end and is deeply rooted in ancient Greek philosophy of knowledge and practice.

Contributions to this special issue mirror well the full spectrum from technological enthusiasm to scepticism towards technology (Kerschner & Ehlers, 2016) within Degrowth scholarship and practice. The goal is not to forge a consensus between these different positions. Readers cannot expect to find a conclusive answer to the question "What is a Degrowth technology and what is not?". This in fact we argue would contradict the spirit of Degrowth itself, which is "more an exploratory avenue than a completed and sealed doctrine" (Schneider and Flipo, 2015). Consequently, our special issue has three aims: (1) to invite authors to present their cases, bring different positions to the open and set off discussion among them. , which already started at the special conference sessions; (2) to pave common

ground for the continuation of these discussions and theoretical and practical advancement among the different camps and (3) to provide theoretical and practical substance for visions, imaginaries and narratives that describe the technological future of a Degrowth society. This includes criteria for evaluating the compatibility of technologies with Degrowth principles and procedures for their governance.

In what follows we briefly review the state of the art of technology research and discussions in the Degrowth community – supported where possible by contributions to this special issue. Section three provides a short presentation of every article embedded in the illustrative analogy of a bouquet of flowers in a vase and the four main categories we distilled from all texts (theory, cases, evaluation and governance). In section four we formalize the emerging concepts of "Degrowth Technology" and "Degrowth Society" and suggest avenues for the Degrowth & Technology research agenda. Section five summarizes and concludes.

2. Degrowth and Technology: short history of a love-hate relationship

Technology: a key theme in the intellectual origins of Degrowth

Technology was a central theme for classic authors like Charbonneau[7], Castoriadis, Gorz, Georgescu-Roegen, Illich or Ellul who represent the early intellectual roots of Degrowth from the 1930s onwards (Martinez-Alier et al., 2010). The writings of Georgescu-Roegen and of predecessors of political ecology such as Grinevald (2006, 1975) and Gorz (2007, 1994, 1977) are one of the two streams that inspired Degrowth (Decroissance) at its birthplace in France. The other stream originates in intellectuals criticising 'development', in particular **Ivan Illich**, who wrote extensively on technology, developing the concept of convivial tools (Illich, 1973) He was influenced by Sahlins`s (1972) description of "primitive" societies as beholders of true affluence[8] and Ellul's (Ellul, 1964) criticism of modern technology. Similar to Ellul, Castoriadis and Charbonneau (1969), who saw the "solution" in a society based on solidarity and frugality (voluntary simplicity), Illich promoted a "modern subsistence society". This society lives in a post-industrial world based on convivial technology and is less dependent on markets and the state (see Samerski, this issue). Illich is by far the most

[7] Unfortunately the work of Charbonneau has not been considered by any of the authors of this special issue and remains yet to be explored in detail.
[8] With a few hours of work they satisfy their frugal needs.

cited author of this special issue (for more detail see section 3 and (Bradley; Gomiero; Lizarralde & Tyl; Muraca & Neuber; Samerski; Vetter; Zoellick & Bisht, this issue) (see Figure I below).

Figure I: Word cloud of citation frequencies of individual authors in the texts of all articles. Source: own.

Another popular reference in the Degrowth community is the work of **Ellul** (Ellul, 1964; Ellul & Clendenin, 1989) (in this special issue e.g. cited by (Garcia et al.; Hankammer & Kleer; Heikkurinen; Lizarralde & Tyl; Muraca & Neuber; Samerski; Vetter; Zoellick & Bisht, this issue). He criticises "efficiency" in economic terms, i.e. the maximisation of input/output ratios as the highest goal for human activity (Zoellick & Bisht, this issue). Arguably being a technological determinist (Kerschner & Ehlers 2016)[9], Ellul was convinced that modern technology[10], as the god-like defining force of a new social order (Fasching, 1981) eventually forces humans to subordinate themselves to the rules of efficiency, via the division of labour, mechanisation, individualisation, etc. It does so via seven characteristics that form the centre of Ellul's thesis: rationality, artificiality, automatism of technical choice, self-augmentation, monism, universalism, and autonomy (1964, p.79). It implies also that *technique* decides over winners and losers in society, i.e. those who best adapt to its only principle: efficient ordering (Ellul 1964, p.79).

[9] Whether Ellul can be classified as a "determinst" is debated, however his earlier work does show such traits (see Wyatt, 2008)

[10] He actually used the term 'technique' which he defined as "the totality of methods rationally arrived at and having absolute efficiency (for a given stage of development) in every field of human activity" (Ellul, 1964 p. xxv)

The efficient ordering perspective is compatible with the biophysical sources of Degrowth[11] inspired by **Nicolas Georgescu-Roegen** (cited by e.g. Bonaiuti; Gomiero; Muraca & Neuber; Rommel et al.; Zoellick & Bisht, this issue). Georgescu-Roegen (e.g. 1971) saw technology as the manifest face of economic activity shaped by the exosomatic evolution of humans (Muraca & Neuber, this issue). Technology allowed humans to temporarily overcome the limited (natural) flow rates of low entropy provided by the sun using concentrated past solar energy in the form of fossil fuels. This has led to a temporal escalation in scale of the human population and its irreversible economic processes, thereby interrupting regeneration times of the surrounding environment. Technology in that sense is just a way to access and derive human use from the enormous potentials of (non-renewable) raw materials such as crude oil and iron ore, *i.e.* low entropy. Unequal access to such technologies defines "winners and losers" in struggles over economic, military and political dominance, as suggested by Ellul.

Another key concept for Degrowth & Technology is '**autonomy'**. It links both Ellul and Illich with other classic degrowth authors such as Gorz and Castoriadis, even if the respective use and meaning varies. According to (Kallis et al., 2015) autonomy is not principally a response to biophysical or social limits to growth or moral duties to future generations and nature, but a project of political and social change driven by collective self-limitation. When Illich (1973) argues for convivial tools, which unlike "manipulative tools" support "vernacular" practices, his goal is to re-establish the 'autonomy' of humans from large hierarchical non-democratic techno-structures powered by fossil fuels (Bradley; Muraca & Neuber; Samerski; Vetter, this issue) "A convivial society should be designed to allow all its members the most autonomous action by means of tools least controlled by others" (Illich, 1975, p. 33)

As for (Winner, 1980) technological choices are inherently political for Illich and connected to systemic social changes and negative consequences for the human being and social life. Because Illich appears more optimistic about possibilities to govern technology than Ellul, he is the preferred reference for the comparatively more techno-enthusiastic Degrowth scholars. Ellul instead defines 'autonomy' as one of seven problematic characteristics of technology and argued that "…technology ultimately depends only on itself, it maps its own route, it is a prime and not a secondary factor, it must be regarded as an 'organism tending toward closure and self-determination: it is an end in itself' (Ellul, 1980, p. 125)

[11] Demaria et. al. 2013 divide Degrowth into six *sources* (ecology; critiques of development & praise of anti-utilitarianism; meaning of life and well-being, bioeconomics, democracy and justice).

For **Gorz** (1980) (cited by Gomiero; Likavčan & Scholz-Wäckerle; Muraca & Neuber, this issue) 'autonomy' requires a society freed from wage labour and decoupled from income. He aims to reconfigure the entire industrial model, controlled by "private or state-supported powers, which deny human beings to choose their ways of living, producing and consuming together" (Gorz 1977, our translation). Later Gorz strongly argued against the "monopolisation of knowledge" (Gorz, 2010, p.11) which he saw as a common good par excellence, because it can be easily shared, reproduced or combined, without losing value. It explains the great hopes (Gorz, 2010) had in open-source software and ICT-supported tools for self-production, which he considered a first step towards his vision of a post-capitalistic society:

> *"Local workshops for self-production can be connected on the scale of the planet. They can share or commonly use their experiences, inventions, ideas, and discoveries. Work then becomes the producer of culture and self-production will be a kind of self-development."* (Gorz, 2008, p. 29, our translation)

Although his hopes have not yet materialised, Gorz' main arguments are still valuable for the sharing of knowledge and technologies, in fab-labs , digital commons, peer-to-peer production, etc. (Kostakis et al.; Likavčan & Scholz-Wäckerle; March, this issue; Nierling, 2012).

Closely related to Gorz, **Castoriadis's (Castoriadis, 1998)** idea of 'autonomy' describes collectives of people that can freely decide their common future, without having to subordinate to external pressures such as religion and the market-economy. Castoriadis is best known to the Degrowth community for his work on democracy (Castoriadis, 1986) which could explain why he rarely features in this SI (exeptions include March; Pansera & Owen, this issue). He emphasises technology's capacity to increase power and control, which, however, is never absolute and universal but localised, incomplete and possibly involving conflicting ends. A technology may not be used as initially intended, typically has unwanted side-effects (see Gomiero; Grunwald; Lizarralde & Tyl; Metze; Muraca & Neuber; Strand et al.; Zoellick & Bisht, this issue) and will interfere with other parts of society and nature. Moreover, technological power of some coincides with lack of power of others, which runs contrary to an ideology that technology will bring positive development for all (see also Winner 1979, 1977).

Serge **Latouche** (e.g. 2009), argues for a critique of technology in the pursuit of an autonomous society that is not based on Western humanism. His accounts of "local de-growth initiatives" are full of "technological success stories" based on zero-energy developments, organic farming, public transport and cycle routes, etc... For the Global South he suggests to "(r)ecuperate traditional technologies and skills" (page 58) and identifies "techno-economic bricolage" as an asset in opposition to Western engineering and industrial rationality (page 59). Overall, however, his positions on technology seem inconsistent – maybe a reason why he is only sporadically referred to in this special issue (Ferrari & Chartier; Gomiero; Vetter; Zoellick & Bisht, this issue) On the one hand, he famously proposes a moratorium on technological innovation that assesses and redirects science and development of technology and calls for a ban on certain technologies like GM crops. On the other hand, he seems enthusiastic about technological progress and refers to "undeniable and desirable" (p. 11) technological advances and, in line with ecological modernists (see Grunwald this issue), believes that improved technology will increase capacities of ecosystems and productivity of farmland, fisheries and forest.

Current debates on Degrowth & Technology

The Degrowth community's current quest for a shared technological imaginary reflects discussions during its bi-annual international conferences (Böschen et al., 2017; Eversberg & Schmelzer, 2016). In Paris in 2008, technology was only discussed sporadically and did not feature in the first Degrowth declaration following the conference (Research & Degrowth, 2010). Barcelona in 2010 had one working group on "*new* technologies"[12] and from a Group Assembly Process (GAP) radical proposals of "moratoria" and limits to market and profit-driven innovation emerged. Some already suggested to discuss the democratization of technology, innovation and production (open source ICT, etc.) (Loeper, 2014). However, 2012 in Venice, the idea of moratoria was no longer pursued, but there was one session dedicated specifically to technology, related talks ranging from sustainable consumption to smart grids and two practical workshops on participatory design and wind turbines.

In Leipzig 2014 "convivial technology" was among the three main thematic threads[13] and a very prominent theme of the conference. However, unlike in Barcelona, moratoria and

[12] http://barcelona.Degrowth.org/Results.125.0.html
[13] https://www.Degrowth.info/en/threads/

democratically decided limits were unpopular and controversial, as was the general idea of selective criteria. Those in agreement with (Gorz, 1994) and in favour of democratizing technology such as fab-labs and 3-D-printing (Nierling, 2014) clashed with techno-sceptics inspired by Illich and Elull[14]. Eventually, the controversy was set aside and the dedicated working group focused on more agreeable topics, including access to technological know-how and training, blurring the distinction between producers and consumers, including digital commons (Hankammer & Kleer; Kostakis et al.; Likavčan & Scholz-Wäckerle; March; Morell, 2014; more critically Samerski; Vetter; Zoellick & Bisht, this issue) and by addressing gender imbalances. Non-exploitation of workers employed in producing technological artefacts throughout their life-cycle, was also agreed (participant observation; (Böschen et al., 2017)[15]

Technology is both an important and polemic issue in the Degrowth community. The early intellectual roots, with the exception e.g. of Gorz (2010), clearly criticise technology on ecological, political, social and anthropological grounds, emphasising that (modern) technology is rather an "enemy". More recently, however, the potentials of certain types of (modern) technology attract attention, suggesting that these can be a "friend" if used convivially in the spirit of Degrowth. This collection sheds light on what technologies these may be and on how they could be selected and governed.

3. This Special Issue and its contributions

Images and arts are inseparable from the overall Degrowth message (e.g. Alexander, 2017) so we have chosen the analogy of a vase containing a bouquet of flowers to synthesise this special issue (Figure II. below) and the four main categories we have identified (see Table I. for a full list of all contributions and their respective categories). The vase itself delimits the analytical and normative Degrowth framework. The base of the vase represents (1) theories and concepts that lay the foundations. The bulge in the middle are (2) the cases authors of this SI study from Degrowth perspectives. The opening top of the vase – like an entry barrier – represents (3) evaluation and (4) governance of different technologies. The water that flows in the vase connects these four categories and ensures that they can cross-fertilize each other.

[14] Participant observation by at least one of the editors.
[15] As the GAP process was not repeated at the Degrowth conference in Budapest in 2016, it is not clear whether the general mood changed since then.

Often evaluations, governance proposals and theory are supported or derived with help of case studies (e.g. Ferrari & Chartier; Lizarralde & Tyl, this issue). The synthesis coming out of the vase, being nourished and supported by it, is the evolving shared socio-technological imaginary of the Degrowth community – a feasible, viable, appropriate and convivial bouquet of flowers.

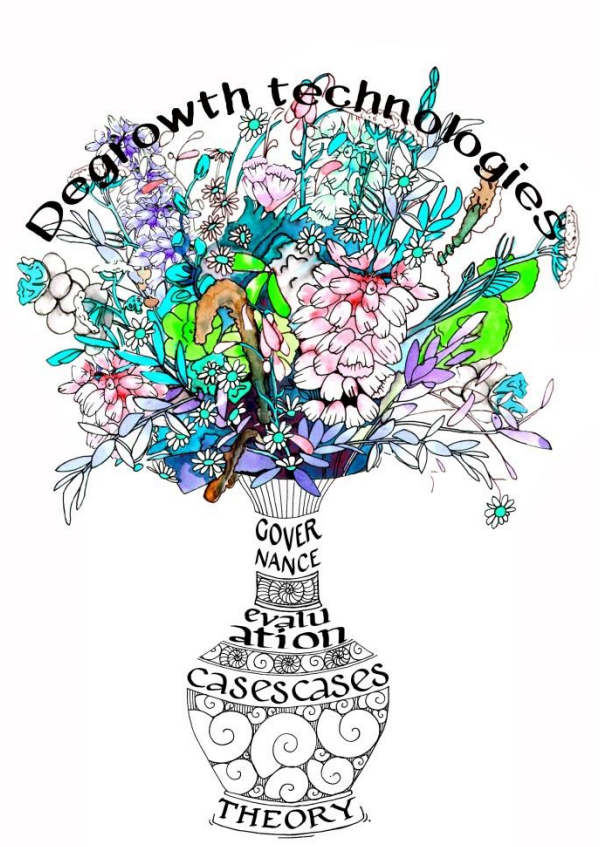

Figure II: Vase and flowers analogy of a shared socio-technological Degrowth imaginary illustrated by Monika Rygálová & Kristýna Krejčová, after a sketch by Christian Kerschner

Contributions to this special issue link technology and Degrowth in diverse ways with some recurring topics, concepts and terms. Criticism of currently dominant growth oriented socio-technological imaginaries (Jasanoff and Kim, 2013; cited by Metze; Strand et al., this issue) or attitudes towards technology (Kerschner & Ehlers, 2016; cited by Garcia et al., this issue) are a typical point of departure in the contributions to this special issue, indicated for example by the relatively frequent use of "growth" as shown in the word cloud below (Figure III).

Figure III: Word cloud representing the frequencies of words in all Special Issue contributions together, excluding references (cut-off at word frequencies below 50, no articles etc. included).

Criticism of dominant socio-technological narratives and imaginaries

Strand et al. (this issue) discuss "the master narrative of innovation for growth" that is based on the "linear model": investment in science yields technological innovation that delivers economic growth that leads to welfare and prosperity (compare Grunwald; Pollex & Lenschow, this issue; Kerschner and Ehlers, 2016; Kerschner and O'Neil, 2015). This narrative firmly guides western capitalist economies, including the European Union (see Pollex & Lenschow, this issue) and also dominates "development" discourses for non-industrialized countries (Pansera and Owen, this issue). Ideological commitment to optimistic expectations about technological progress, to technological determinism (ACATECH, 2015) and productivism (innovation means jobs) (Strand et al., this issue) is at the core of this narrative.

Although debates on finite natural resources challenged these narratives already in the 1960/70s, some of their elements were transferred to the second grand technological imaginary that currently reigns: "technoscience for sustainable growth"(Strand et al., this issue) and "green growth" (Pollex & Lenschow, this issue). Technoscience (bio-, nanotechnology, robotics, etc.) is strongly promoted by the EU (Pollex & Lenschow, this

issue) and promises solutions to the newly identified "grand challenges of society" such as climate change (see also Morozov´s 2015'techno-solutionism', cited by March, this issue). A version of this narrative is eco-modernism, which is a radical counter vision to Degrowth (Grunwald, this issue). Technoscience promises "utopian wonders", justifies risk of technologies in terms of "desperate times need desperate measures" and the finiteness of the planet is interpreted as describable and manageable with "smart" technology, systems science and big data (Strand et al., this issue). Geo-engineering (see Muraca & Neuber, this issue) is one example, where the systems science perspective is justified with urgency.

The dominant neoliberal green growth agenda aims at market expansion, focuses on eco-efficiency, eco-innovation, eco-design (Lizarralde & Tyl, this issue) and "green consumerism" (Haucke, this issue), whilst ignoring rebound effects and 'demand-side' approaches (i.e. reducing material and energy demand) (e.g. Alexander & Yacoumis; Grunwald; Rommel et al., this issue). Consequently, the political and economic status quo (Grunwald, this issue) and high-consumption lifestyles are not challenged, assuming that people need to buy more rather than less things to live sustainably: electric vehicles, solar panels, energy efficient devices, etc. (Alexander & Yacoumis, this issue). Whereas Heikkurinen (this issue) emphasizes that technological practice always increases the throughput of material and energy, dominant imaginaries subscribe to the myth of decoupling (Kerschner and O'Neil, 2015). Ferrari & Chartier (this issue) capture these dominant imaginaries with a concept of technological fetishism, in which technology becomes an end in itself (see also Garcia et al.; Samerski, this issue), because other human needs and desires are concealed from the consciousness of people. The fetish of technological solutions brushes aside problems of unintended side-effects (Grunwald; Lizarralde & Tyl; Muraca & Neuber; Strand et al.; Zoellick & Bisht, this issue)

Dominant narratives and attitudes towards technology (Kerschner & Ehlers, 2016) assume *value neutrality* of technology, while scholars argue that technology and values shape each other (Garcia et al., this isuue). Technology is for example shaped by the maximization of costs vs. benefits ratios (commercial interests) and input-output ratios (efficiency) (Garcia et al.; Zoellick & Bisht, this issue). The problem of value neutrality is also reflected in the Degrowth literature's criticism of the de-politicization of the sustainability discourse (Swyngedouw, 2015; Strand et al., this issue). March (this issue) argues that the assumption of politically neutral technology that is promoted by large international companies in

hegemonic discourses on the "Smart City" shifts urban issues from the political to the commercial sphere (see also Ferrari and Chartier, this issue) Likewise, Wells (this issue) concurs that technological development is increasingly centralised and governed by vested interest. Ferrari & Chartier (this issue) detect moves to maintain the unsustainable features of capitalism in "green energy transitions", because market approaches are used and driven by corporations that promote "false solutions to environmental problems". Capitalism itself is criticised in various ways in this special issue, a core theme being its problematic interdependency with technology (Ferrari & Chartier; Heikkurinen; Likavčan & Scholz-Wäckerle; Pansera & Owen; Wells; Zoellick & Bisht, this issue). However, some argue that a re-appropriation of technology for non-capitalistic Degrowth purposes could break the capitalist technological hegemony (Likavčan & Scholz-Wäckerle; March, this issue). Overall, the contributions tend to see power of technological development and imaginaries as hegemonic outcomes of capitalism and current discourses.

	authors	title
1	**Concepts & Theory**	
1.1	**Samerski, S.**	Tools for degrowth? Ivan Illich´s critique of technology revisited
1.2	**García, J., et. al**	Methodological Luddism: A concept for tying degrowth to the assessment and regulation of technologies.
1.3	**Heikkurinen, P.**	Degrowth by means of technology? A treatise for an ethos of releasement
1.4	**Likavčan, L., Scholz-Wackerle, M.**	Technology appropriation in a de-growing economy
2	**Cases**	
2.1	**Democratisation of technology**	
2.1.1	**Bradley, K.**	Bike Kitchens: Spaces for convivial tools
2.1.2	**Kostakis, V., et. al**	The convergence of digital commons with local manufacturing from a degrowth perspective: Two illustrative cases
2.1.3	**March, H.**	The Smart City and other ICT-led techno-imaginaries: Any room for dialogue with Degrowth?
2.1.4	**Wells, P.**	Degrowth and techno-business model innovation: The case of Riversimple
2.1.5	**Hankammer, S., Kleer, R.**	Degrowth and collaborative value creation: Reflections on concepts and technologies
2.1.6	**Haucke, F.**	Smartphone-enabled social change: evidence from the Fairphone case?
2.1.7	**Pueyo, S.**	Growth, degrowth, and the challenge of artificial superintelligence
2.2	**Energy**	
2.2.1	**Metze, Tamara**	Framing the future of fracking: discursive lock-in or energy degrowth in the Netherlands?
2.2.2	**Rommel, J., et. al.**	Community renewable energy at a crossroads: A think piece on degrowth, technology, and the democratization of the German energy system
2.2.3	**Ferrari, C. A., Chartier, C.**	Degrowth, energy democracy, technology and social-ecological relations: Discussing a localised energy system in Vaxjö, Sweden

2.3	Evaluative Frameworks and Tools	
2.3.1	**Lizarralde, I., Tyl, B.**	A framework for the integration of the conviviality concept in the design process.
2.3.2	**Vetter, A.**	The Matrix of Convivial Technology – Assessing technologies for degrowth
2.3.3	**Zoellick, J.C., Bisht, A.**	Powering and organizing technology from a degrowth perspective.
3	**Evaluation with Biophysical Focus**	
3.1	**Bonaiuti, M.**	Are we entering the age of involuntary degrowth? Promethean technologies and declining returns of innovation
2.11	**Muraca, B., Neuber, F.**	Viable and convivial technologies: Considerations on Climate Engineering from a degrowth perspective.
3.2	**Gomiero, T.**	Agriculture and degrowth: State of the art and assessment of organic and biotech-based agriculture from a degrowth perspective.
3.3	**Alexander, S., Yacoumis, P.**	Degrowth, energy descent, and 'low-tech' living: Potential pathways for increased resilience in times of crisis
3.6	**Zoellick, J.C., Bisht, A.**	Powering and organizing technology from a degrowth perspective.
4	**Governance, Policy and Agency**	
4.1	**Strand, R., et. al.**	New narratives for innovation
4.2	**Grunwald, A.**	Diverging pathways to overcoming the environmental crisis: A critique of eco-modernism from a technology assessment perspective
4.3	**Pollex, J., Lenschow, A.**	Surrendering to growth? The European Union´s goals for research and technology in the Horizon 2020
4.4	**Pansera, M., Owen, R.**	Innovation for de-growth: A case study of counter-hegemonic practices from Kerala, India

Table I: Overview of contributions to the special issue Degrowth & Technology

Note: Contains active links to the papers

3.1 Concepts and theory

One of the goals of this special issue was to cover important scholars working on technology that were yet underexplored in Degrowth. Hence it is refreshing to see so many "new names" in the texts. For instance, Muraca & Neuber (this issue) argue that Marcuse (1964) who criticised the alienating effects of technocracy(Vetter, this issue) alongside Ellul (1964), Anders (1956) and Mumford (1967), is a central author for Degrowth & Technology.

Mumford´s (1967) accounts of the "technological megamachine" (Vetter; Zoellick & Bisht, this issue) closely relate to Elull's influential work, but he also described a harmonious "biotechnic" society (Rommel et al., this issue). Zoellick & Bisht (this issue) use Mumford´s, 1934) early work and also introduce Hannah Arendt´s (1998) positions on 'technological instrumentality', Schumacher`s (1973)notion of 'gigantic technologies' and Marxian perspectives on the separation of ownership and human labour. Marx's importance for

Degrowth is reiterated by Ferrari & Chartier, Likavčan & Scholz-Wäckerle, Pansera & Owen, Pueyo, (this issue).

(Ferrari and Chartier (this issue)discuss the analysis of capital and society devised by Adorno (2005) who, together with Horkheimer, contributed to the expanding critique of modern technology (Grunwald, this issue). Their conceptualisation of ambivalent technology and capitalist production of "technological people" resonates well with (Feenberg, 2001, 1995), who sees technology as a major source of power in modern societies, where technologies are selected to reproduce and conserve hierarchies (see also Ferrari & Chartier, this issue)

Hans Jonas´s (1973) concept of "responsibility" and his call for an ethical system capable of dealing with the challenges of new technology feature prominently in Garcia et al. (this issue) and Grunwald (this issue). Garcia et al. (this issue) find further inspiration in (Borgmann, 1984) to advance (Winner, 1978) "Methodological Luddism". Winner's notion of political agency of technology is also of interest to Haucke, Heikkurinen and Strand et al.(all this issue) His "withdrawal" from technology shares similarities with Heidegger's (1966) releasement, which (Heikkurinen, this issue) integrates into Schatzki´s, (2014) concept of practice to develop a theory of technological practice. On the important issue of agency of technology Heikkurinen (this issue) and particularly Likavčan & Scholz-Wäckerle (this issue) draw heavily on Latour´s (2005) Actor-Network Theory. Both contributions refer to Schumpeter´s (1934) work on "creative destruction" within capitalism that can involve technology (see also Bonaiuti; Pansera & Owen; Vetter; Wells, this issue)

However, even with respect to classic Degrowth authors like Illich, there remains a lot to explore and clarify. For instance ***Silja Samerski (this issue)*** who worked personally with Ivan Illich, suggests that he did not criticise economic growth in relation to environmental destruction. Rather he saw this as a regrettable outcome of the overwhelming power of tools that deconstruct social life and the fragility of human relations. In his later works, Illich pointed to the dangers of "disembodiment" that emerges from strong reliance on technical devices, e.g. computer technology. Samerski argues that his early vision on ITs is unfolding today and challenges those Degrowth proponents who imagine that open source ICT facilitates autonomy and democratic action. She states that Degrowth should take up Illich's critique more carefully and recognise the fundamental difference "between facing each other and communicating through machines" to develop an approach of "technological ascesis" (see

also Heikkurinen, this issue) which should co-exist with the responsible use of digital technologies.

Garcia et. al. (this issue) also draw heavily on Illich and 'conviviality', but focus on Langdon Winner's (Winner, 1978) concept of Methodological Luddism as a rigorous assessment, limitation of and control over technology. Winner called for a reflexive re-politicization and axiology of human relationships with technology and innovation. According to Garcia et al., (this issue) technology should shape our material circumstances to promote Degrowth values such as freedom, sociability and care for the environment. An example methodological Luddite practice is Winners (Winner, 1978) "withdrawal" from technology such as deliberately not replacing the TV once it is broken (compare Heikkurinen, this issue). Such actions can spur creativity and innovation of socio-technical configurations that fill new voids through "creative acceptance" of limits (Mitcham, 2003, p.29, cited by Lizarralde & Tyl, this issue).

Heikkurinen (this issue) argues that Degrowth is only possible through an ethos of releasement (Heidegger's Gelassenheit) in the sense of letting things be, instead of transforming them through technological practice. We should neither try to improve technology, nor consider it in decision-making. Drawing on agency theory (see also Likavčan & Scholz-Wäckerle; Zoellick & Bisht, this issue) and philosophy and sociology of technology Heikkurinen suggests that technological practice increases the utilisation of ever more objects and is therefore incompatible with Degrowth, because it increases cumulative throughput of materials and energy. However, biophysics is only one source of Degrowth (Demaria et al., 2013; Gomiero, this issue). It still needs to be explored what releasement can contribute to other Degrowth aspirations such as conviviality. Some initial guidance can already be found in Garcia et al.; Samerski, (this issue)

Rather than technological releasement or withdrawal (and in-line with 'technological democratisers' see below) ***Likavčan & Scholz-Wäckerle, (this issue)*** theoretically examine the prospect of ideologically reorienting (appropriating) technology to serve Degrowth ideologies. Drawing on evolutionary political economy and actor-network theory they argue that technological and institutional change produces socio-technical complexes such as ICTs that have unspecific ideological orientations. The currently dominant ideology of neoliberalism appropriates technology with an emphasis on profit and efficiency (see also

Garcia et al.; Zoellick & Bisht, this issue), that has to be reversed. The key question is what hegemonies certain technologies tend to support and vice versa (see e.g. Ferrari & Chartier; Grunwald; March; Metze; Pansera & Owen, this issue). This urgently needs further theoretical and empirical work, for example building on Mumford´s (1970) and Winner´s (1980) and understanding that certain technologies, like nuclear power and authoritarian military complexes, mutually support each other. Overall the intriguing analyses of the authors of this section calls for further research into how their proposals could be developed further and applied in practice.

3.2 Case studies of specific technologies and institutional arrangements

The case studies in this collection cover (1) potential role-model Degrowth technologies like bicycles (Alexander & Yacoumis; Bradley; Lizarralde & Tyl; Vetter, this issue); (2) technologies that are seen very critically like fracking (Metze, this issue), geoengineering (Muraca & Neuber, this issue) and GMOs (Gomiero, this issue) and (3) more ambiguous technologies such as ICT, alterative transport and renewable energy. Some focus on potentials (Hankammer & Kleer; Haucke; Kostakis et al.; March; Wells, this issue) of the latter and others on their limitations and dangers (Ferrari & Chartier; Pueyo; Rommel et al., this issue). Rather than technology itself, many discuss conceptual (e.g. the smart city), consumption (e.g. life-style movements), production (e.g. design global and manufacture local,) and institutional arrangements (e.g. community renewable energy) around technology (Bradley, 2016; Hankammer and Kleer, 2017; Haucke; Kostakis et al.; Lizarralde & Tyl; March; Rommel et al.; Wells, this issue) . The case studies of this section are also often evaluative and point at governance issues. However, whenever contributions use cases (only) to develop, test or discuss proposed evaluation and governance approaches these are covered in subsequent sections.

Democratisation of technology

A central theme among more techno-enthusiastic authors of our special issue is ‘democratisation of technology’, including liberation of access to technology in terms of: know-how (open source); necessary skills for production (prosumers) use and repair; income (affordability) and gender. Most “technological democratisers” tend to be inspired by Illich’s “autonomy” (see section 2.1). No one should be excluded from becoming “technologically

autonomous" because of personal wealth, origin, gender and technical abilities. Related concepts are: open-source design (Kostakis et al.; Wells, this issue) prosumers and collaborative value creation (e.g. Hankammer & Kleer, this issue); digital commons and commons-based peer-to-peer production (Hankammer & Kleer; Kostakis et al.; March, this issue).

The assumption behind this trend is that a wider spread of certain (not all!) technologies such as 3D printing, small scale wind-turbines and bicycles can facilitate the move towards a Degrowth society. Technology as an agent of change is expected to support "counter-hegemonic technological practices"(Likavčan & Scholz-Wäckerle; Pansera & Owen, this issue) that can undermine capitalism from within (Kostakis et al.; March; Wells, this issue) Moreover, certain technologies if combined with deliberation and appropriate institutions can re-politicize debates over technology (Bradley; March, this issue) and provide points of entry for Degrowth ideas, including criticisms of technology (Metze; Vetter, this issue). Enthusiasm for particular technologies may be used like Trojan horses to introduce and spread the more general Degrowth message. Nevertheless some Degrowth authors have been sceptical as the following quote illustrates:

> "Degrowth has nothing to do with a simple greening of existing techniques, nor with a ‚democratization`, to make them accessible to all (assuming they are wanted), or merely with the collective self-management of capitalist techniques. Degrowth signals a radical critique of society: it challenges techniques, rather than just calling for their control." (Schneider and Flipo, 2015, p. xxv)

Most technological democratisation proposals in our special issue involve ICT – but not all. For ***Bradley (this issue)*** a bike-kitchen is another example of what democratization of technology could mean in a Degrowth context. Overall she draws attention to the convivial potentials of the do-it-yourself (DIY) culture and the expansion of the collaborative economy. Bike-kitchens are non-commercial shared spaces that liberate people's access to use and repair bikes in a collaborative way (see also Lizarralde and Tyl, this issue). Moreover they provide the infrastructure for cultivating non-capitalist relations and for political engagement. In fact often they may be embedded in larger political movements such as the squatters. Bradley further concludes that the bicycle is exactly what Illich defines as a convivial tool (see section 3 below). However, to avoid commodification of such tools, their conviviality

needs to be cultivated by appropriate institutions such as bike-kitchens and other DIY repair shops and maker spaces.

Kostakis et al. (this issue) present the design global and manufacture local (DGML) model, which links local desktop and benchtop manufacturing like fab-labs and maker spaces with the digital commons of knowledge and design. DGML is portrayed as implying a different political economy than industrial mass production, as for example it discourages planned obsolescence and wage labour exploitation. To support their argument they use cases of prosthetics and small scale renewable energy technology. Modular designs and use of locally available materials enable wider participation in more distributed and collaborative production. It allows greater control of users over the technology, while experiences and design adaptations are globally shared via digital media. This resonates well with Degrowth principles, as Kostakis et al. Kostakis et al. (this issue) claim. However, they also notice that ecological superiority of the suggested technologies and design and manufacturing arrangements over alternatives still require assessment. The DGML model does not yet appear to intrinsically avoid industrious junk production (compare Ariès, 2007 cited by Lizarralde & Tyl, this issue) and waste of material and energy.

March´s (this issue) analysis of the "Smart City" concept on the other hand explicitly thematises the socio-environmental impacts of ICT and the associated dematerialisation myths. Moreover, he criticises the 'technological solutionism' in hegemonic discourses on the "Smart City" that ignore non-technical aspects of urban problems such as equal access to services. Nevertheless he encourages the Degrowth community to appropriate (compare Likavčan & Scholz-Wäckerle, this issue) and critically engage with the opportunities of the „Smart City" concept. In line with Haucke (this issue) and Kostakis et al. (this issue) he sees great potential for improving social equality and ecological sustainability in ICT-enhanced grassroots collaboration. He concurs with Bradley (this issue) and Likavčan and Scholz-Wäckerle (this issue) in that the analysis of a particular technology from a Degrowth perspective is incomplete without considering the associated networks of actors and the rationales behind technologies.

More democratic control over technology is also one of the benefits of the Riversimple Rasa car presented in a case study by ***Wells´s (this issue).*** It combines ‚radical' innovation of (1) technology to reduce environmental impacts (based on hydrogen) and (2) business models

geared away from increasing demand. The design is open-source and the product is a service (mobility) because the cars are let without any maintenance and repair responsibility. This makes planned obsolescence unprofitable and allows the sharing of designs. However, Riversimple still requires engineering specialists and new support infrastructure such as hydrogen supply. This could increase material and energy flows. Moreover the car may lack conviviality (see Samerski, this issue), as buying a service (mobility) without any responsibility for the providing technological artefact could imply further detachment of people from the technology they use (compare Bradley; Garcia et al., this issue). However rather than describing a technology and business model that is "ready" for a Degrowth society, the author stresses its potential to disrupt capitalist logics of the car industry and beyond.[16]

Hankammer & Kleer (this issue) also analyse new production models, focussing on collaborative value creation (CVC) such as crowd sourcing, mass customization and innovation toolkits. In line with Haucke´s, (this issue) material artefacts can help creating identities and form politics. Similar to Haucke, Kostakis et al. and Wells (this issue), they argue that such models could reduce overproduction, increase product lifespan, lower material and energy use and support decentralisation and democratisation of technology. Democratisation is interpreted here as the maximum involvement of consumers in the production process. Hankammer & Kleer, (this issue) find that CVC could fit a Degrowth society, but such models are yet insufficient for the necessary transformation into a Degrowth society. Potentials and limitations of commercial CVC certainly require further analysis. For instance, it is not clear, whether mass customization with its implied ethos of material identity creation could rather reinforce than curtail the currently unsustainable consumer culture.

Haucke (this issue) targets social network sites that facilitate lifestyle movements, as the one around the Fairphone, which challenges consumer culture and economic practices. If technological artefacts have political power (Winner, 1980) then owning and using them is also political, she argues. Her analysis of a quantitative survey of the Fairphone online community suggests that this smart phone is rather a technological artefact to express commitment to sustainable consumption and lifestyles than sustainable consumption itself. The pursuit of a sustainable lifestyle drives involvement in the Fairphone community, but not

[16] At the point of writing Riversimple is launching a pilot series of 20 Rasa cars ("THE RIVERSIMPLE RASA IN BETA TEST: RECRUITING 'TESTERS,'" n.d.)

its ownership, as joint deliberation often suggests it is more sustainable not to purchase a new phone. Haucke (this issue) criticises the Degrowth literature for neglecting technological innovation as an agent of change. Unlike Samerski (this issue) who questions the conviviality of many ICT developments, Haucke argues that lifestyle movements around technological artefacts could be instrumental for Degrowth strategies such as reform, the building of alternatives and oppositional activism (see Demaria et al., 2013).

Pueyo (this issue) focuses on artificial intelligence (AI) and warns about its dangers if combined with neoliberalism: ecological disruption and serious social consequences e.g. automated companies working effectively without humans (see Becker, 2017). According to Pueyo (this issue), a positive future of AI can only be shaped within a Degrowth framework that calls for comprehensive systemic changes including new forms of democratic control of the economy. However, he argues that AI could provide a window of opportunity for Degrowth, because its effects could apply equally to economic elites as "efficient" algorithms could replace managers (compare Ellul, 1964). As for Haucke and Kostakis et al. (this issue), ICTs are promising agents of change towards a Degrowth society, only that in this case agency is exerted in a bogyman type manner.

One widely acknowledged (Hankammer & Kleer; Kostakis et al.; March, this issue; Morell, 2015) weakness of the concept of "technological democratization" is that ecological concerns about reducing materials and energy are less prominent. This may be traced back to Benkler´s (2006, 2002) conception of commons – typically having in mind knowledge-sharing and ICT activities. These often ignore their embeddedness in biophysical realities of direct and indirect material and energy use of hardware and infrastructure. Thus, unlike the traditional conception, one person's use of a part of the common resource does not withdraw it from another person (Ostrom, 2005). The relevance for Degrowth of Benckler's (2006) "commons-based peer production" and Bauwens´ (2009) (2009) "Peer-to-Peer Production" is found in their flat hierarchies (Benkler, 2006) and potential erosion of capitalist modes of production (Bauwens, 2009; Kostakis et al., this issue)

Zoellick & Bisht (this issue) critically examine the alleged conviviality of digital communication platforms, but do not arrive at a general conclusion. Samerski (this issue) on the other hand is clearly sceptical, because digital commons do not directly support what she

sees as important elements of a convivial society such as face-to-face communication, embodied knowing and human action instead of engineered production.

ICT and Digitalisation

Despite a widespread suggestion that ICTs could play an important role in the democratisation of technology, the contributions to this special issue do not provide a unified answer on which, how and to what extent ICTs should be supported by Degrowth advocates. In general the conditions and contexts in which a technology supports Degrowth principles still require deeper investigation (see Haucke, this issue). Overall, a reflective approach (Samerski, this issue) seems appropriate, also because the socio-psychological effects of the increasing prevalence of ICTs in our lives, which Illich for example warned about, are still poorly understood. Strand et al. (this issue) identify a general trend in the dominant socio-technical imaginaries, to place great hopes in ICT-based sustainability solutions (see Pollex & Lenschow, this issue) and hopes to provide conclusive accounts of material and energy needs and rebound effects of the "ICT revolution" using life-cycle analysis.
For Lange (2017) digitisation will inevitably be a part of future technological developments, but he warns about its potential dangers e.g. increasing inequality and material throughput. Nevertheless he argues that the Degrowth community should engage in digitisation to prevent undesirable effects and to foster potentials in renewable energy and the sharing economy. The outcomes crucially depend on whether digitisation is dominated by small-scale projects or by large enterprises.

An important limitation of the ICT- revolution is that unlike "epoch-making inventions" many of the latest ICT applications "eat" human time rather than saving it for other purposes e.g. smartphones and social media (Bonaiuti, this issue). This means they run against an important (often overlooked) biophysical limit: human time. Moreover, if taking a mainstream approach (total factor productivity) as (Gordon, 2012a) then the overall potentials of ICT are already declining and have never been close to matching those of other technological inventions such as indoor plumbing (see Binka, this issue for a review of Gordon, 2017). This contradicts the accelerationists (Srnicek & Williams, 2016), who point at the time requirements of democratic deliberation.

Energy

Energy is a key theme of this special issue (see Figure III above). This section focuses on social research of energy production. Biophysical assessments of technology including resource peaks and the energy return on investment (EROI) of renewable energy sources are covered in the evaluation section below (Alexander & Yacoumis; Bonaiuti; Gomiero, this issue). Social research of technology can uncover and specify the socio-technological imaginaries that guide energy generation activities and mitigation of their environmental impacts. New imaginaries that lend themselves to Degrowth can emerge from discourses around fracking, which itself is typically not associated with Degrowth (Metze, this issue). There seems to be a general imagination that renewable energy technology is compatible with Degrowth. However, in-depth investigations of community renewables unveils some contradictions (Rommel et al., this issue) and a fetish of technology could obscure undesirable side-effects of renewables (Ferrari & Chartier, this issue), which is also evident with climate engineering technologies (Muraca & Neuber, this issue).

Metze (this issue) looks at hydraulic fracturing for shale gas recovery. She analyses respective Dutch media controversies about environmental impacts and potentials as a future energy source. This is important for Degrowth, as the Netherlands enacted an effective moratorium on this technology. Metze found that pessimistic energy futures (i.e. scarcities) are both used to promote and demote fracking. Interestingly, the analysis further suggests that the framings of energy futures that were mobilised in shale gas controversies can open-up debates about alternative energy futures based on different technologies. Referring to attitudes towards technology Kerschner & Ehlers (2016) she found that techno-enthusiasm in general (even for fossil fuel-based technology) made room for future renewable energy framings that have Degrowth attributes. Hence, controversies about (energy) technologies could also provide entry points for more general Degrowth thinking in established discussions.

Rommel et. al. (this issue) critically analyse Germany's energy transition in general and community renewable energy (CRE) projects in particular . They discuss six hypotheses derived from central claims of Degrowth and contrast them with empirical observations, for example whether CRE facilitates sustainable consumption. Alternative business models of CRE projects can support democratic decision-making and collective endeavours are central elements. Further benefits may include capacity building and empowerment of their members – who theoretically could have diverse backgrounds. In reality, however, members are predominately male, well-educated, have above average incomes and "technophile eco-modernist" attitudes towards technology (compare Grunwald, this issue). Photovoltaic CRE

projects tend to be decentralized but wind energy is typically based on large installations, expensive infrastructure and growth-oriented business models. Moreover legal and political changes threaten these projects, for example by favouring "green consumerism" and fewer and larger investors. Thus unlike the promises seen in other technologies (see Haucke; Kostakis et al.; March, this issue). Rommel et al., (this issue) doubt that CRE projects generally facilitate a transition towards a Degrowth society.

Similarly sobering is ***Ferrari & Chartier´s (this issue)*** account of Vaxjö, Sweden, once termed „Europe's greenest city", because of its ambitions to become fossil fuel free. With the help of a novel combination of Degrowth, energy democracy and critical theory of technology and capitalism (e.g. Feenberg, 2001; Horkheimer and Adorno, 1944; Hornborg, 2001) the authors analyse Vaxjö's municipal energy company. They conclude that it moves towards some notions of "energy democracy", but does not respect Degrowth principles, because it is embedded in an eco-modernist (see Grunwald, this issue) techno-fetishist and capitalistic framework that is dedicated materially and discoursively to capital accumulation. Moreover, by-products of unsustainable forestry practices are used as fuel (e.g. small branches), inflating the involved industry and threatening biodiversity. Their analysis thus points at the role of context when analysing empirical cases from a Degrowth perspective. The meaning of technology is contextual, which is why technology is ambivalent (see Feenberg, 2001). It implies that the identification of convivial techno-social imaginaries should focus on conflicts about technology both in material and communicative terms (see Metze, this issue).

3.3 Evaluation of technology

Despite the controversies in the Degrowth community (see section 2), there is a broad consensus for the need to evaluate and select technologies according to Degrowth criteria. (e.g. Latouche, 2004a, b - see Martinez-Alier et al., 2010). The challenge is to identify and agree upon such criteria and procedures. The authors of this collection suggest four main evaluation criteria: conviviality, appropriateness, feasibility and viability.

Conviviality & Appropriateness

Conviviality for Illich, is the "opposite of industrial productivity" (1973, p. 17) and focuses on autonomous individuals satisfying human needs, social solidarity, friendship and mutual giving (Gomiero; Lizarralde & Tyl; Samerski; Vetter; Zoellick and Bisht, this issue). For Illich (1973) it is an intrinsic ethical value, which designates the individual freedom realized in personal interdependence (see Vetter, this issue). Six phenomena threaten conviviality, each of which unsettles delicate balances: (1) biological degradation (human activities vs. integrity of the biosphere); (2) radical monopoly ("what people need to do by themselves" vs. "what they need to obtain ready-made" (Illich, 1973, p. 63) i.e. standardized products only large industrial operations can provide; (3) over-programming (formal education vs. self-initiated learning); (4) polarization (balance of power relations); (5) engineered and planned obsolescence (maintaining the old vs. replacing with new) and (6) frustration over the coincidence of several of the above threats simultaneously. Depending on which direction the imbalance takes, it implies either an under-industrialized society inviting the mutual exploitation of human beings or an over-industrialized society enslaved by its own "manipulative" tools that limit autonomy (see section 2.1 above) and creativity (Illich, 1973; Samerski; Zoellick & Bisht, this issue).

"**Convivial tools**"(Illich, 1973) (and similarly Schumacher's (1973) "intermediate technologies") can help to re-establish the balance (Lizarralde & Tyl, this issue) as convivial tools are those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision." (Illich, 1973, p. 78-79) Departing also from Illich Vetter (this issue) develops the notion of "convivial technologies". This is a narrower concept than Illich's "tools", which include broader rationally designed institutions like schools and bureaucracies. Also, Illich focused on the use of technologies and Vetter (this issue) on the production side of technological artefacts, summarizing in her concept the basic ethical values and resulting design criteria. Zoellick & Bisht, (this issue) also expand Illich`s framework of hand tools and power tools and distinguish tools by their power source. Further development of Illich´s ideas can be found in "convivialisme" which is a social theory that describes under which circumstances conviviality as a practice occurs (Les Convivialistes, 2014; see also Vetter, this issue)).

Similiar to Illich, Schumacher, another classic Degrowth reference, was inspired by Ghandi's and the Indian Economist Joseph Kumarappa's (Pansera & Owen, this issue) call for rural self-subsistence. Schumacher also emphasises biophysical limits in the use of technologies;

criticizes the increasing distance between people and those deciding over large technologies (Zoellick & Bisht, this issue) and sees technology deprived of any self-limiting principle (Zoellick & Bisht, this issue). His concept of "**appropriate**" or "**intermediate technology**" (see Zoellick & Bisht, this issue) has many parallels with Illich's "conviviality", only that it has been conceptualized mainly for "developing" countries (Vetter, this issue) and emphasizes the context, location and time component in evaluating technologies. "Appropriateness" is determined by the values and aspirations of the people involved (Alexander & Yacoumis, this issue) and describes technologies that are developed and maintained with local materials and are repairable and adaptable without the help of external experts (Lizarralde & Tyl; Pansera & Owen; Vetter, this issue). Overall convivial and appropriate tools (and technologies) tend to: support sufficiency and creativity; favour labour-intensive and open source technology; be broadly affordable, durable and repairable; empower the community and are incompatible with "social engineering" (Samerski this issue), support traditional knowledge and local skills and promote decentralized small scale local production and local supply chains.

Feasibility & Viability

Georgescu-Roegen, (e. g. 1986) argued that the temporal disentanglement of economic activity from the limited natural flow rates of low entropy has led to the common cornucopian illusion that technological development will always overcome biophysical limits. However, Georgescu-Roegen (1986) identified most technological innovations as parasitic, as they may be '*feasible recipes*' but are not '*viable*' in the long run. ***Feasible*** means that all specific flow and fund coordinates[17] of a process (recipe) are known and that it is reproducible within the desired time and conditions. For example, iron ore smelting may be feasible but thermonuclear processes are not (Muraca & Neuber this issue). ***Viable*** are only technologies that "…can maintain the corresponding material structure which supports its resource and sink functions and consequently supports human activity indefinitely under current environmental conditions"(Gowdy & O'Hara, 1997, p. 242). For example, the viability of agricultural technologies depends strongly on the metabolic constraints of a particular society as Gomiero (this issue) argues. From a macro-level perspective (1) a conversion to

[17] Georgescu-Roegen's (1971) distinction between flows (inputs, outputs and maintenance flows) and funds (capital equipment, Ricardian land and labour) is one of his most appreciated contributions (see Kerschner, 2010 and Muraca & Neuber, this issue), providing inspiration for today's work on societal metabolism (e.g. (Giampietro et al., 2011).

"traditional organic agriculture" in current Germany is *feasible* i.e. produces more food calories than what is needed by people working in the fields, but (2) hardly *viable* as total supply of calories per unit of time does not match demand of Germany's current population. Bonaiuti, Gomiero and Muraca & Neuber, (this issue) use these criteria for their evaluation.

Georgescu-Roegen (2011) further describes a special case of viable technologies as "promethean techniques or innovations"[18]. Only these permit a (new) qualitative transformation of energy that produces high levels of net energy and allows a leap in scale of the system and its complexity (see Bonaiuti, this issue). According to Georgescu-Roegen, historically there are only three such innovations: the mastery of fire, the adoption of agriculture (see Gomiero, this issue) and the conversion of fossil fuels into mechanical work. Most other technological innovations are just variations of using (or squandering) the large quantities of newly available net energy (see Bonaiuti, this issue).

Apart from the above many more criteria can be found in the texts and could be built upon in the future. For instance Zoellick & Bisht (this issue) consider for their framework Mumford´s (1934) classification of technologies based on the degree of their flexibility, Marx´ analysis of ownership regimes (1962) and Arendt`s categorisation of tools (1998). Garcia et.al. (this issue) put forward "focal things and practices" by Borgmann (1984). Finally following Pansera & Owen (this issue) another popular criterion could be whether a technology is suitable for "counter-hegemonic" practices (see also March, this issue).

Evaluative Frameworks and Tools

While designers and engineers often are deeply implicated in the uncontrolled "junk production" process (Ariès, 2007), ***Lizarralde & Tyl (this issue)*** argue that they can also be core actors in the transformation to a Degrowth society. However, they need appropriate limits and guiding principles such as to avoid Illich's threats to conviviality. The authors evaluate: (1) existing eco-design approaches such as slow design (Fuad-Luke, 2005) and frugal engineering (Hossain et al., 2016) and (2) four case studies on organisations that engage with Degrowth's favourite technological artefact – the bicycle. While some eco-design approaches seem promising, a focus on short-term technological solutions still

[18] Georgescu-Roegen was inspired by his former mentor Joseph Schumpeter's concepts of 'epoch-making innovations' and 'creative destruction'.

prevails. Their case studies agree for example with Bradley (this issue) on the conviviality of bike kitchens, while large scale international bicycle manufacturing runs against that criterion. Along their two-step analysis they developed a framework that provides the foundations for a new "design for conviviality" approach.

Vetter (this issue) also draws heavily on Illich for developing her "Matrix of Convivial Technology"– a qualitative technology assessment tool, based on her ethnographic "convivial research" of various Degrowth-inspired grassroots groups such as permaculture farms and Open Source Ecology Berlin. The five dimensions of her 'convivial technologies' are relatedness, access, adaptability, bio-interaction, and effectiveness They serve as the y-axis while on the x-axis she places four life-cycle stages from material extraction to the necessary infrastructure. The resulting twenty subfields contain antagonistic terms e.g. for access: "elitist" vs. "open to anyone", which can be used by scholars and activists alike to inspire self-reflection and deliberation. In workshops with engineering students, for example, she discovered that the tool could also be used for education, fostering reflection about technologies in general and to disseminate ideas about Degrowth (compare Metze, this issue). Hence not only has Vetter succeeded in putting Illich's abstract concepts into practice, she has also put forward a tool that resonates well with post normal science (see Strand et. al., this issue).

Similar to Vetter and Lizarralde & Tyl (this issue), ***Zoellick & Bisht (this issue)*** also build an evaluative framework from the literature, but they draw on a broad spectrum of authors, from Illich and Elull over Schumacher, Mumford and Marx to Hannah Arendt. Their final framework relies on the categorization of Arendt´s (1998) tools, Illich´s hand tools and Schumacher´s gigantic technologies. They categorise technologies according to their power source: labour tools, electric tools and fossil fuel tool. Zoellick and Bisht's evaluation suggest that labour tools tend to be the most favourable for Degrowth. The identified structure of technologies relies on the prerequisites affordability, small-scale applicability and enhancement of human creativity and ownership. However, the authors admit that the question of technological agency (see e.g. Heikkurinen; Likavčan & Scholz-Wäckerle, this issue) needs addressing in further research.

Evaluation with a Biophysical Focus

Bonaiuti (this issue) argues that "promethean leaps" of a society can be combined into one "great wave" that determines the end of that particular society. This hypothesis is based on Georgescu-Roegen's (2011) definition of "promethean techniques or innovations" and Tainter's (1988) principle of "declining marginal returns": while societies innovate to solve (scarcity) problems, their complexity increases to levels that eventually make costs greater than benefits and lead to collapse[19]. Similar to Gordon (2014, 2012; see Binka, this issue) Bonaiuti uses total factor productivity data to show that the "ICT revolution" led to minimal and short-lived gains of total factor productivity that since then dropped to pre-industrial (!) levels. For Bonaiuti it confirms the presence of a post-industrial "great wave" and the onset of "involuntary Degrowth". In his review ***Binka (this issue)*** praises Gordon's (2017) robust empirical analysis of the main causes of the extraordinary economic growth in the United States which started to fade from the 1970s. The book explains that growth will not continue in the future, because the beneficial conditions on which it depends have already been exploited.

Muraca and Neuber (this issue) provide important inputs for the evaluation of Degrowth technology, both biophysically via Georgescu-Roegen and "socially" via Illich and a highly relevant case study of climate engineering (CE) (see Gomiero, this issue for a similar approach). Using Betz´s (2010) applied ethics theory of dialectical Structures they describe trade-off arguments and conclude that enhanced use of CE technologies (with uncertain success) would lead to fewer efforts in greenhouse gas mitigation. In a next step, the criteria of feasibility and viability (Georgescu-Roegen, 1986) and conviviality (Illich, 1973) are converted into formalized trade-off arguments and applied to three specific CE technologies: sulphate aerosol injection, bio-energy and carbon capture and storage (BECCS), and afforestation. The findings suggest that these technologies are to be rejected, as they risk unforeseen and unintended consequences, may demotivate reduction of greenhouse gas emissions and are neither viable nor convivial.

Similarly to Muraca & Neuber, ***Gomiero's (this issue)*** analysis of farming technologies also relies strongly on Georgescu-Roegens criteria of 'feasibility' and 'viability'. He adds 'desirability' (compatibility with how people *want* to live) and recent advances in societal

[19] Gowdy & Krall (2014) interestingly add that this is what happens under competitive conditions at the societal level, which may suggest that a more collaborative and solidary social order as aspired to by Degrowth may at least partly counterbalance this trend or at least its negative implications for society.

metabolism analysis (Giampietro et al., 2014, 2012) to evaluate the desirability of organic agriculture and biotech-based agriculture in terms of "appropriateness" (Schumacher, 1973) and "conviviality (Illich, 1973). Degrowth proponents commonly favour organic and reject biotech-based agriculture (Kallis et al., 2015; Latouche, 2012) Gomiero concludes that organic agriculture has great potential for meeting "Degrowth criteria", unless it uses large machinery and sophisticated organically certified agro-chemicals and pest-controls. However, it might face viability limitations in densely populated areas, because of lower yields. Contrary to Conway & Shah (2012), who claimed that biotech-based agriculture could be seen as "appropriate (or intermediate) technology" (low cost, simple usage etc.) Gomiero rejects such approaches, as their alleged benefits are controversial, eroding viability, their risks high and as they represent a radical monopoly in Illich's terms.[20] According to Muraca & Neuber's (this issue) reading of Georgescu-Roegen, biotech-based agriculture may currently not even be a feasible recipe, as not all flow-fund coordinates are known.

Alexander and Yacoumis (this issue) finally provide an overdue peer-reviewed[21] evaluation of the enormous household energy-saving potentials (up to 36%) of mostly known and simple technology – very different to those presented in glossy eco-design magazines, including solar shower bags and washing lines for clothes. For each technology, they suggest simple amplifying behavioural changes such as halving showering times. In line with Grunwald (this issue) they argue that such demand-side approaches are completely neglected in current sustainability discourses. Apart from energy savings, mindful 'low-tech' lifestyles (see Haucke, this issue on lifestyles) could also make people more resilient to climate change and Peak-Oil (see Kerschner & Capellán-Pérez, 2017) than 'hi-tech' energy-intensive lifestyles. Alexander & Yacoumis (this issue) suggest more potential benefits of low-tech life-styles, such as improved health and social ties (compare Bradley, this issue).

Alexander & Yacoumis, Gomiero, Bonaiuti (this issue), and to lesser extent Muraca & Neuber, Ferrari & Chartier and Heikkurinen (this issue) follow a biophysical tradition, based mainly on limits to growth, societal metabolism, thermodynamics and Georgescu-Roegen. Some authors in this tradition are critical, yet sympathetic, about Degrowth (e.g. Ramos-

[20] How little agreement there may be over the selection of technologies for Degrowth shows a recent reply to Gomiero (this issue) by Bartkowski (2017).

[21] The interested reader may want to explore the popular semi-scientific online 'low-tech' magazine edited by Kris De Decker, which in many ways could be considered the beacon of related debates: http://www.lowtechmagazine.com/.

Martin, 2016). They see a lack of biophysical analysis, understanding and realism in some Degrowth proposals such as work time reduction (Sekulova et al., 2013 vs. Sorman & Giampietro, 2013) or food self-sufficiency (Gomiero, this issue vs. Latouche, 1993; Pallante, 2011a, 2011b) For instance, Ferrari & Chartier (this issue) reiterate (Quilley, 2013) critique of Degrowth authors like Kallis (2011) for their limited understanding of energy and "thermodynamic price tags" (p. 277). These authors also question the possibility of planning the biophysical decent demanded by Degrowth, as the global socio-economic system is too complex (Sorman & Giampietro, 2013). Hence Bonaiuti (this issue) refers to "involuntary Degrowth"[22], in line with the original meaning attributed to "decroissance" by Georgescu-Roegen (1979); Illich's (1973) theory on counter-productivity and system dynamics (e.g. Meadows et. al., 1972). Some of these criticisms are also raised by Post-Normal Science scholars (see Strand et. al., this issue). Kallis et. al. (2015) on the other hand argue that degrowth supporters are not substantially motivated by biophysical limits or the threat of a system collapse (as in Bonaiuti, this issue), but by prospects of joining a joyful and solidary transformation towards a different society that flourishes within (biophysical) limits. Limits in general are seen as a liberating condition for the good life and a just, environmentally benign and egalitarian society.

Nevertheless Degrowth is a multilevel framework with biophysics being an essential element (Demaria et. al., 2013). Hence, as the contributions to this special issue show, "conviviality" and "appropriateness", with their focus on social and political aspects for selecting technologies, need to be complemented with biophysical criteria such as "feasibility" and "viability" sensu Georgescu-Roegen (1971). In conclusion there are currently four criteria that seem to be the most encompassing and representative for expressing the concerns of Degrowth, but some by drop out or others may be added in the future.

3.4 Governance, Policy and Agency

Proposals for governing technology cover a wide range in our special issue. "Technological democratizers" (see above) and those who are comparatively enthusiastic about technology argue that appropriate institutional settings are needed to allow selected technologies to unfold their convivial potential (e.g. Bradley; Hankammer & Kleer; Haucke; Lizarralde &

[22] "Involuntary Degrowth" and Degrowth in general should not be confused with "negative growth" or GDP decline (Latouche, 2012), which is still quite common (e.g. van den Bergh, 2017, 2011)

Tyl; Rommel et. al., this issue). Some claim (unlike Illich (1973), see Samerski, this issue) that the main problem of technology is not its nature but its appropriation by the growth-oriented capitalistic system from which it needs to be re-appropriated (e.g. Ferrari & Chartier; Likavčan & Scholz-Wäckerle; March, this issue). Other enthusiasts consider certain technologies as agents of change that catalyse the transformation towards a 'convivial society', both, at the high-tech and at the low-tech end of the 'Degrowth technology spectrum'. They expect the properties of a certain technology to trigger the desired change and consequently imply that the right type of technology could mostly govern itself in the right direction and undermine current power structures and capitalism (e.g. Kostakis et. al., this issue). Certain *new* technologies such as digital printing may lead to a more democratic and more equal society, because they liberate consumers from the power exerted by producers such as multinational corporations i.e. they become 'prosumers' (Toffler, 1981)

Similar hopes are also evident in more pronounced techno-utopian visions such as those among members of "Zeitgeist"[23], eco-modernists (see Grunwald, this issue) or accelerationists. The latter claim that accelerated technological innovation facilitates democratic post-capitalism (Srnicek & Williams, 2015). If machines do all the work a liberation of society, especially from wage labour and a collapse of capitalism is expected (Mason, 2015). Such visions are partly compatible with those of Degrowth proponents (e.g. Vansintjan, 2016). Part of the attraction of this vision, as with any "technological fix"(Huesemann & Huesemann, 2011) is the potential revolutionary speed and circumvention of slow and perhaps painful social processes. Strong agency of technology is also assumed by Pueyo (this issue), but with the twist that the dangers of artificial intelligence are expected to make the powerful managers of today allies of Degrowth tomorrow. A more cautious claim is that certain technologies encourage participatory decision-making on production and consumption, although it typically requires alternative governance structures (e.g. Hankammer & Kleer; Haucke; March; Wells, this issue). A "reformist stance" is represented by Haucke (this issue) who argues that existing technological devices (like smart phones) and business model may be transformed into ones compatible with Degrowth.

On the other hand authors who emphasize the dangers (Heikkurinen; Muraca & Neuber; Samerski, this issue) or negative unexpected side-effects and unforeseen consequences (Castoriadis, 1986; Bonaiuti; Garcia et al.; Grunwald; Likavčan & Scholz-Wäckerle; Muraca

[23] https://www.thezeitgeistmovement.com/

& Neuber; Strand et al., this issue) favour more stringent control over technology including moratoria (Latouche, 2009), deliberate withdrawal (Winner 1986 cited by Garcia et. al., this issue), releasement (Heikkurinen, this issue) and decelerated development (Grunwald, this issue).

What remains unclear is whether there can or should be a "black list" of certain technologies that are incompatible with Degrowth as suggested by some authors e.g. nuclear, GMO, nanotechnology, cars, etc. (Latouche 2009; Schneider & Flipo 2015, p. xxv) and whether such a list can or should be juxtaposed with a "white list" of technologies seen conducive to Degrowth like bicycles (Bradley, this issue). Illich for example argued that "certain tools are destructive no matter who owns them… (Illich 1975, p. 39, see Samerski, this issue). Schneider & Flipo (2015) agree that "(s)ome technologies are to be rejected … because they are not amenable to limits, others are acceptable up to certain limits, which should be deliberated by the whole of society"(Schneider & Flipo, 2015, p. xxv). Hence Vetter (this issue) advocates what could be called a "technological alphabetization " – the ability to control the tools we work with rather than being controlled by them. In line with other contributions (e.g. Pansera & Owen; Strand et. al.; Zoellick & Bisht, this issue) she favours bottom-up participation and deliberation in decision-making about technology. Four contributions to this SI prepare groundwork for a new governance of technology that could support Degrowth.

Based on Jasanoff's concept of "socio-technical imaginaries" ***Strand et. al. (this issue)*** argue – in accordance with Grunwald (this issue) – for the development of a "Degrowth narrative of innovation" to challenge traditional narratives. According Strand et. al. (this issue) Degrowth draws heavily on the systems sciences to describe the present state of the world, but when it comes to the descriptions of imagined futures Degrowth combines system scientific arguments with values such as conviviality. Thus, Degrowth needs to clarify how to present itself: as a scientific authority or a political project? When traditional system scientific thinking determines, what technologies are viable and feasible, scope for other Degrowth principles such as democracy to inform sociotechnical imaginaries is constrained. Consequently, citizens can only respond to technology and lack agency to shape it (see Winner, 1986). If, in turn, Degrowth prioritises values such as democracy over science, it needs to accept values that contradict what it sees as facts, such as climate change. Strand et. al. (this issue) suggest that Post-Normal Science offers useful insights into this problem. First,

facts and values are not seen as distinct. Degrowth scholars are therefore learning experts that have some temporary authority on dealing with certain values. Second, the blurred borders between science and society enable creativity and new opportunities in developing technological imaginaries for Degrowth that become counter hegemonies to traditional innovation concepts.

In his contribution, ***Grunwald (this issue)*** deconstructs eco-modernist positions including the eco-modernist manifesto (Asafu-Adjaye et al., 2015) that clearly builds on the growth paradigm, whilst ignoring biophysical limits to growth (compare Bonaiuti; Gomiero, this issue). Eco-modernism is a counter-vision to current Degrowth thinking, because it prioritises technological progress and efficient management in solving environmental problems. Taking the premises of the Manifesto, Grunwald (this issue) uses the ethical perspective of Hans Jonas (1973) combined with the experiences of technology assessment (TA) to deconstruct the eco-modernist's faith in technological optimism that assumes that ecological problems can be solved by "green technologies" alone. Eco-modernism ignores unintended side-effects of technologies (see Strand et. al., this issue), which according to TA experience may always exist (see also the Hydra-effect in Garcia et. al., this issue).

Pollex & Lenschow (this issue) trace evidence of Degrowth concepts in current European research and innovation policymaking. Their document analysis of the Horizon 2020 strategy focuses on three indicators: (1) Evidence for measurement beyond growth, (2) consideration of unintended side-effects (see also Grunwald, Strand et. al., this issue), and (3) broad inclusion of social actors. The authors argue that economic growth and green growth strategies are clearly dominant in the Horizon 2020 program, explained by a path dependency along liberal markets. (see Grunwald, Strand et. al., this issue). Strategies which go "beyond growth" are clearly marginal, even despite former initiatives. Although there seems overall little prospect for a European Degrowth agenda, the authors argue that a "moderate Degrowth discourse" is still needed to "provoke" policy makers to develop future options for social wellbeing in Europe.

Examining the Kerala Science Literature Movement in India, ***Pansera & Owen (this issue)*** argue that the practices of this movement match Degrowth principles, namely in opposing top-down technological modernisation strategies and national political growth agendas. The authors present alternative strategies to use and further develop technologies which are deeply connected to the specific surrounding of people living in Kerala such as the self-production of

soap and biogas plants (compare with 'low-tech' solutions in Alexander & Yacoumis, this issue). They conclude that it is very important to understand and locate technologies in their normative and socio-political context (see Schumacher´s appropriate technology). Cases like theirs can inspire the identification of alternative – Degrowth – innovation strategies also for the Global North.

4. A Degrowth & Technology Research Agenda

Contributions to this SI suggest four main categories for future "Degrowth & Technology" research: Theory, Cases, Evaluation and Governance. In addition we identify seven reoccurring themes which we expect to shape such a research agenda: criticism of current affairs; insights from classical authors; democratisation of technology; ICT and digitalisation; energy, evaluative criteria and frameworks and agency of technology.

Moreover based on the criteria and arguments put forward by the authors of the SI, it makes sense to formally introduce the concept of "**Degrowth Technology**", as in our vase analogy above. This concept summarizes the outcome of Degrowth & Technology research, evaluation and governance. Some already suggest definitions for what makes a "Degrowth Technology" (e.g. Metze; Pansera & Owen, this issue) but it remains to be clarified, if all temporarily agreed criteria and positions are taken into account. Heikkurinen (this issue) for example argues that the practice of technology is incompatible with the narrower biophysical understanding of Degrowth. In fact many of the presented evaluative frameworks are open for deliberation about Degrowth criteria (see Lizarralde & Tyl; Vetter; Zoellick & Bisht, this issue). Open for debate are also "disqualifying" criteria such as profit-orientation (Vetter, this issue). This openness however should not be taken as an invitation to postpone the urgent need to develop a shared Degrowth & Technology vision or imaginary, nor should there be a repetition of mistakes made in the field of Ecological Economics with respect to plurality (Spash, 2012, 2009).

Imaginaries of a "Degrowth Society"

Visions, imaginaries and narratives (see Strand et al., this issue) that clarify the shared goals of the Degrowth community are essential. Previously it was argued that Degrowth was a path that lacked an explicit motivating goal (even if in the form of an "unattainable goal")

(Kerschner, 2010). However, the burgeoning Degrowth literature and vibrant community since Paris 2008 suggests an emergent goal at all levels of a "Degrowth Society". This term is referred to 46 times across 15 contributions of this SI, despite a missing specification in the literature. The usage of this term suggests a linguistic transcendence beyond the negative connotations the term Degrowth has been criticised for (Drews & Antal, 2016; Stirling, 2010; van den Bergh, 2011). On the contrary, the term "Degrowth Society" is increasingly fleshed out with alternative imaginaries and narratives of a prosperous, just, equal, convivial and sustainable society in which Degrowth proponents would like to live in.

Advancing socio-technological imaginaries is key not only for specifying the role of technology for Degrowth, but also for the Degrowth community in general. Imagining a "Degrowth Society", or Grunwald's (this issue) "thinking in alternatives" resonates well with the futurity of technology and the established practice of imagining social futures around technology, for example through technological forecasting (Beckert, 2016). Technology can be a starting point around which imaginable futures can be constructed (Beckert, 2016; Lente & Portela, 2017) for a "Degrowth Society". Technological artefacts and controversies assist in interpretive framing of socio-technological imaginaries, even when the technologies at the core are not associated with Degrowth, because they provide directions for alternatives, for example as futurity framings in opposition to fracking (Metze, this issue). The controversies, artefacts and symbols of technology appear to make Degrowth futures more tangible than visions of happiness, justice and the like. However, this does not mean that such visions can be ignored when thinking about a future Degrowth Society. The task is rather to use socio-technological imaginaries productively in approaching abstract goals such as the "good life" (see also Georgescu-Roegen´s "enjoyment of life" concept 1975, p. 353), within biophysical limits.

When focusing on the "good life", associated and apparently more specific goals typically enter the deliberations, for example the satisfaction of "needs". The relating question is then which needs do people in a Degrowth Society have and how technologies satisfy or erode them. March (this issue) for example cites Castoriadis (1986) to argue for technology based on social needs. This opens a large debate, because these needs are many (e.g. subsistence, identity and freedom) and they are linked in many ways to one another and to other expressions, such as having "tools" (see Max-Neef, 1991). There are also bound to be conflicting views for example about the satisfaction of individual consumer needs (e.g. Hankammer & Kleer, this issue) and collective needs. In the highly creative enterprise of

defining goals for a future Degrowth Society, imagination is not to be misunderstood as fantasy or "fairy tale" but as a cultural resource that "helps to produce systems of meaning that enable collective interpretations of social reality, … the basis for a shared sense of belonging and attachment to a political community" (Jasanoff & Kim, 2009, p.122). Moreover, the construction of socio-technological imaginaries typically involves debates about ends and means together and not separately (e.g. Garcia et. al.; Heikkurinen; Samerski this issue). However, the term "end" in itself is problematic for Degrowth (Schneider & Flipo, 2015; Strand et al., this issue), because when aiming to arrive democratically at imaginaries for a future Degrowth Society, respective deliberation needs to be open to prevent dogmatism and even sectarian or authoritarian developments. Just like the flowers in our vase analogy are not permanent, agreed sets of Degrowth Technologies will need continuous renewal, re-evaluation and replacement. Some technologies may never qualify as "Degrowth Technologies", while others may be accepted temporarily or contextually. Similarly the shape and design of the vase is not unchangeable.

Finally, we have identified the following non exhaustive agenda for further Degrowth and Technology research. Some are derived from contributions, others are areas that we found were not yet covered sufficiently:

1. *New Classical Authors*: Although many new ones have been brought in there are important omissions such as Castoriadis or Charboneau and sporadically covered authors such as Mumford and Feenberg. So far a thorough analysis has only been provided for the work of Illich.
2. *Democratization of Technology*: So far research seems to highlight only the potentials and not the possible threats of broadening access to technology. It is also short on how to avoid democratised technology from appropriation by individuals or groups that intend to inflict harm upon others e.g. 3D printing of weapons or DIY genome editing (Regalado, 2016).
3. *Longitudinal studies* are needed into the relation between society and technology – in particular for ICTs linkages with Degrowth (see e.g. Haucke, 2017).
4. A large area requiring further multi-level analysis (biophysical, sociological, psychological, etc.) are the potentials and limitations of *low-tech and mindful lifestyles* and technological practices as in Alexander & Yacoumis (this issue)

5. What can more "technical" methods to evaluating technological artefacts like Life-Cycle Analysis do for Degrowth & Technology and what are their limitations?
6. People working with new technology "on the ground", especially those in charge of repairing and maintaining, do not seem to have much voice in current research, particularly about issues such as durability, reparability and quality. How does their perception differ from those who develop and use technological artefacts?
7. Several contributions in this collection invite further research into the development of *deliberative formats* to evaluate technology. This includes attempts to put the theoretical approaches discussed in section 3.1 into practice.
8. *Gender and Degrowth Technology* has been touched upon by Vetter (this issue), but it remains underexplored. How does gender for example influence technological choices? How is gender shaped by technology – is there any validity of stereotypes such as "boys love their toys", for example?
9. Experiences of communities in the past and today that already limit technology (e.g. the Amish).
10. What can we learn from technologies that are broadly controversial or rejected e.g. cloning? What makes some technologies a no-go and what does that mean for a Degrowth & Technology "black list", if there can and should be one?
11. *Technology, power, war & violence:* An intimate relationship exists between power relations and technology, which is reflected in the military being at the forefront of technological development. Violent movements also employ technology e.g. the trend to use motor vehicles in terror attacks. What does that mean for Degrowth & Technology research?
12. Finally, *robotisation* e.g. (Labini, 1989) *digitalisation* in general and specific technologies such as "bitcoin", "block chains" ("Disrupting the trust business," 2017) and visons like "Industry 4.0", are in urgent need for analysis through Degrowth lenses – again with respect to both, their potentials and threats e.g. compare China's "Social Credit System" to judge the trustworthiness of its citizens (Botsman, 2017)

Conclusions

The literature on technology and society is vast, so is literature on technology and sustainability. However, with this special issue a new research field is opening: technology for a sustainable society that has liberated itself from the (economic) growth paradigm. Such a

new normative setting raises many new questions that only few have dared to ask so far. To symbolize the components and outcomes of this research agenda, based on the contributions to this special issue we have proposed a Degrowth vase (the normative Degrowth setting) containing a bouquet of flowers consisting of feasible, viable, appropriate and convivial Degrowth Technologies. Together it represents the emerging, dynamic and evolving shared technological imaginary of the Degrowth community and its narratives and visions.

There are four main axis on which perspectives on technology of Degrowth authors (and beyond) can be scaled (1) attitudes towards technology sensu Kerschner & Ehlers (2016), between enthusiasm and scepticism; (2) potentials of technology as an agent of change towards or against a Degrowth Society, between revolutionary and neutral; (3) normative governance, between strong control and laissez faire and (4) controllability (governability) between full autonomy (i.e. determinism) and complete context-dependency of technology that implies that technology is not good/bad per se. So far the most influential "classical" Degrowth authors, tended towards scepticism, strong technological agency working *against* the goal of a Degrowth Society and - if possible, as to many technology is autonomous - a strong need for control. In line with such critical views many authors of the SI highlight the dangers of unintended side-effects of technologies, including unintended ways of deployment such as to exert power over or harm to others. One advocated response is trying to do without or with deliberately less technology (Garcia et al.; Heikkurinen; Samerski, this issue). The resulting void and acceptance of limits is expected to spur creativity at multiple levels to solve problems in non-technological ways.

However, as the content of this special issue shows, this does no longer reflect the full breath of current technological imaginaries and narratives in the Degrowth movement. Technology is a theme of increasing importance and at the same time no other topic currently has more polarizing potential among Degrowth proponents. It tends to bring up divergent and apparent incompatible views along the above-mentioned scales and strongest between enthusiasts and sceptics. However, as suggested by Vetter (this issue), there is a need to go beyond simple dichotomies and to engage in constructive and creative deliberation. We believe that these rough two positions are more like the poles of a magnet and it is not the goal to converge them one common Degrowth view on technology or to decide for either or. This again should not be misunderstood as a call for the continuation of the current situation of peaceful co-existence or "pluralism" based on a lack of mutual engagement and understanding. Rather

there is enormous potential for cross-fertilization, where critics tend to bring in the more theoretical, ethical, social and philosophical aspects and the enthusiasts the empirics and practice. Both poles are needed for defining, refining and developing criteria for the design, evaluation and governance of technology. For instance often people's enthusiasm for technological solutions (many Degrowth affine movements define themselves around technological artefacts) can be a point of entry for a broader Degrowth discourse that includes critical views on technology, that were previously overlooked.

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