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Degrowth by design rather than disaster

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Abstract

It has been fifty-three years since *Limits to Growth* was published with its warning that unless global economic growth is highly limited an overshoot and societal collapse could occur sometime during the twenty-first century. In most developed countries the warning has been ignored. Major developed country governments still promote continued economic growth. However, a looming population decline could promote slow/no/degrowth scenarios. This is not a doom and gloom future, but rather an opportunity to develop a degrowth future with significantly less impact on the surrounding planetary ecosystem. Such a development will require a new mindset that features a gentle interaction with the planet. Engineering should be at the forefront of this movement and the paper describes what this might entail with examples provided of what should begin at this time and a timeline of future developments.

1. Introduction

At the Eleventh International Conference on Engineering Education for Sustainable Development (EESD2023), the opening keynote speaker, Dr. Marcia Bjornerud, a geology and environmental studies professor at Lawrence University, told the audience that they needed to consider much longer timeframes for future design activities than they had in the past. In her book (Bjornerud 2018), she provided examples where timeframes of many thousands of years were necessary. Of course, in work such as providing safe storage for radioactive waste products from nuclear power generation, very long timeframes must be considered, but to date almost nothing has been achieved, and most nuclear waste still resides on the site where it was generated. Are we courting disaster? She also challenged us to move away from the Newtonian causal paradigm towards the Darwinian anticipatory paradigm. Taking Dr. Bjornerud's advice to heart, we decided to anticipate the longer-term implications to engineering education based on a no/degrowth economic and demographic scenario that could occur over the coming couple of centuries. Two centuries is not geological time, but it is a stretch for most engineers to consider.

Growth and Degrowth. Near the end of the eighteenth century, the use of a fossil fuel (coal) and the refinement of the steam engine led to the industrial revolution. At this time, two new formal disciplines came into existence: economics and engineering. Engineering was clearly the 'engine' of economic growth over the following two centuries allowing for an explosion in human population, increasing nearly eight times over this same period. Unlimited economic growth became the mantra of economists, and many feel the same even now, that is, continued economic growth solves all problems from inequality to unemployment. But unlimited growth on a finite planet while providing a fantastic increase in the standard of living for many proved disastrous to planetary ecosystems as evidenced by climate disruptions with disasters occurring all over the world; the loss of biodiversity and biosphere integrity; and ocean, atmospheric and land pollution. As well, inequality, inequity and boom and bust economic cycles plague society. To continue living on a healthy planet, continued economic growth must come to an end by building a better, fully sustainable future. Planned no/degrowth in developed countries would allow growth in developing countries to alleviate global inequality. As well, declining populations in many countries is already in progress in places like Europe, China, Japan, Korea, Canada, and the United States. All the near-term population gains will occur in Africa and southeast Asia and there are indications that even the higher birthrates in these countries will begin to decline to sub-replacement levels by the end of the 21st century. Continued economic growth as country economic policy goals could clash with declining populations leading to disaster. It seems we should rather plan for this degrowth to avoid such disasters. If engineering was the ‘engine’ of economic growth in the past, then engineering should be the ‘engine’ of economic degrowth in the future.

The United Nations (Nations 2024) predicts that the Earth’s population will peak between 2070 and 2100 with a total population of about 10.5 billion. Other groups predict that near that date the Earth’s population will begin its precipitous decline undoing the exponential growth of the previous two and one-half centuries and that the Earth’s population could decline to between one and two billion by the beginning of the twenty-fourth century. That this is currently happening is not in doubt. Already birthrates in countries such as the United Kingdom and the U.S.A. are about 1.6 births/woman; in Japan, Poland and Canada about 1.3 births/woman; in China and Italy about 1.2 births/woman and in South Korea about 0.7 births/woman. Because of China’s one-child policy from 1985-2015, it is estimated that China’s population could fall from about 1.4 billion to 700-800 million by the year 2100, that is, nearly a 50% decline in population in just 75 years. The Figure 1 below illustrates what the population curve might look like over the coming two to three centuries. In the future, this five-century population spike could be called the ‘fossil fuel age,’ a named era in history. Current economists think that the declining population will lead to economic peril. With proper planning, this should not be the case.

Peter Victor and Tim Jackson in Chapter 11 of *Managing Without Growth* (Victor 2019) use standard statistical economic models to model the Canadian economy for a 60-year period to illustrate that a developed nation economy can flourish under no growth conditions. Inequality is reduced, carbon emissions are reduced, working hours are reduced with no change in the standard of living and happiness measures even increase. Over a still longer period, as population further declines the result would be a degrowth economic scenario based upon renewable resource use with environmentally manageable waste processing leading to long term sustainability. As mentioned previously, during this no growth period, Global South countries could continue to develop resulting in global parity before the overall global population begins its decline.

Victor and Jackson (Victor 2019) used a standard statistical model, one that is much more familiar to economists, rather than a systems dynamics model such as World2 developed by Meadows, et al (Meadows, Meadows et al. 1972) and World3, also by Meadows, et al (Meadows, Randers et al. 2004) because the Meadows’s models provoked so much scorn and derision at the time by economists even though as time has passed the results illustrated (Meadows, Meadows et al. 1972, Meadows, Randers et al. 2004) no longer appear to be as outlandish as economists predicted. The Meadows’s major result that unless economic growth is limited, societal collapse will result sometime in the current century, still seems to hold.

Now another group has entered the discussion. Actuaries (Trust, Saye et al. 2025), who do risk assessment in order to make a living, have stated that should the Earth’s temperature exceed the +3° C increase over pre-industrial levels, that humanity could experience four billion excess deaths and a 50% decrease in global GDP in the 2050-2070 timeframe. This is the degrowth disaster.

Disasters. Without adequate planning to manage degrowth, disastrous events could shake the world. Disasters such as pandemics, climate disruptions with increased forest fires, flooding due to extreme rainfall scenarios, much more intense hurricanes, more intense and wider-spread droughts, heat domes, sea level surges, wars and refugee crises could cause untold numbers of deaths, and trillion dollar damages each year. Because of our collective failure to act to this date, and with little hope of upcoming changes, climate disasters will occur even without economic degrowth. However, this does not remove the need for planning. Design opportunities exist to help alleviate property losses and deaths associated with climate disruptions.

The greatest disaster of all would be the extinction of humanity. Bruce Tonn in his book *Anticipation, Sustainability, Futures and Human Extinction* (Tonn 2021) describes in detail how this might come about. His proposals to monitor the possibilities for human extinction probably have much less chance of happening even than how we have undertaken to mitigate climate disaster. Nevertheless, extinction is a real possibility and should not be taken lightly.

Without design and adequate planning, both engineering processes, these disasters could lead to explosive world conditions including nuclear war, even though this scenario has been held at bay for over 75 years.

2. Engineering Education for a Sustainable Society

Engineering plays a major role in several areas that will be impacted in a no/degrowth society. These include sufficiency in energy and material use; waste and pollution minimization, efficiency in the use of materials/energy; renewable resource/energy usage, durable and reparable product design and manufacture; localization of production for shortened supply chains; production for needs satisfaction; appropriate technologies; and many more. All demand a longer-term view of society and a heightened appreciation of planetary well-being. Engineering education should begin by introducing a new mindset among students where we teach the ‘why’ of sustainability by using facts not opinions.

Degrowth education planning - What we need to change. Changes to engineering education for a future of degrowth and eventual steady-state population will impact the curricular content, a shift in focus on who the client is being served, the purpose of engineering efforts, and the competencies required. Table 1provides an overview of potential changes.

Table 1: Changes to inform future curriculum

Content	Client	Purpose	Competencies
• Retrofit -less new construction should be planned, instead, retrofitting existing structures should take on a larger role. • Repositioning existing structures - taking existing structures and remaking them for another purpose • Deconstruction -with declining population, some structures are going to be unnecessary so need to be taking down	• Humans -humans will remain a main client for engineering but no longer at the detriment to other life forms • Nature writ large- design for other animals will become more important, but the temptation to know better than nature needs to be resisted!	Migration • Human -climate change/disruption is going to lead humans to migrate as a reaction to these pressures (Lustgarten 2024) • Other animals -with less human-centric built environment, migration patterns for animals can be opened up	Weik, et al. (Wiek, Withycombe et al. 2011) • Systems thinking • Anticipatory thinking • Normative • Strategic • Interpersonal Utheim (Utheim 2024) • 3Es: Ecological, Economy, Equality • Multidimensional • Interconnectivity • Imperfection • Reflexivity

Future engineering education needs. Degrowth of population will have a significant impact on the role engineering will have in the future. Figure 2, based on a figure by Victor (Victor 2023, page 214, figure 7.22), highlights our projection for how engineering will change as degrowth starts to occur. Victor's figure maps closely to the plot of biomass in a forest, Figure 3, showing signs of significant growth (Davis 2021). This growth in a forest leads to an overshooting of the capacity of the ecosystem, followed by a period of degrowth until a state of equilibrium, based on capacity, is reached. A key to Victor's and our projection is that humans as a species will follow a similar pattern of growth-overshoot, followed by a period of degrowth, eventually reaching a new equilibrium. Consequently, humans are headed to a new capacity-based equilibrium –like all biological systems.

Each of the three phases shown in Figure 2 requires different knowledge, skills, and competencies of engineers. Therefore, engineering education must prepare students differently for each phase.

3. Design Phases

Phase I: Current design. The period of growth that started during the industrial revolution may be reaching a peak. During this phase, growth in population resulted in growth in both the built environment and the many tools that fostered growth in production. We know how to do Phase I design as it is exactly what we are already doing. This phase effectively consisted of designing against the forces of nature to accommodate the desires of human society. The goal was to make nature subservient to humanity. Traditional curriculum focused on building new artifacts.

The curriculum for Phase I generally consists of: physical sciences, engineering sciences, and engineering design. Each of these components must change as we move towards phases II and III.

As we move through the transition phase, and eventually the new steady state phase, new competencies will be required. Wiek (Wiek, Withycombe et al. 2011) developed a list of 5 competencies required for sustainable efforts, Table 1: systems thinking, anticipatory, normative, strategic, and interpersonal. Utheim (Utheim 2024) presents a list that focuses on what he refers to as soft sciences, Table 1: multidimensionality, interconnectivity, imperfection, and reflexivity. Utheim's terms reflect combinations of competencies from three areas, contemplative criticality, comprehensive complexity, and compassionate collaboration. There is significant overlap of Wiek's competencies with competencies in these three areas, but Utheim combines them into his bigger picture terms. The competencies from these two authors present a potential foundation for engineering education starting in the phase II transition, and through phase III -the new equilibrium.

Phase II: Design for degrowth. This transition period has started but remains tied closely to the growth phase -there is a resistance to acknowledging the extent of damage done to the planet. Progress can be seen through the development of many 'green' design approaches, e.g. LEEDS (U.S. Green Building Council 2020), BREEM (BREEAM 2025), Envision (Institute for Sustainable Infrastructure 2021). These must be examined through two lenses: growth versus degrowth, and the balance between *for* and *against* nature. The commitment to growth continues to dominate. While the softening of designing against nature is occurring, the movement still promotes continued growth of the built environment -just in a 'greener' manner. We are still focused on doing the job *right* instead of doing the *right* job. But, even the *right* job still promotes growth much of the time.

During this transition phase the following issues will characterize what engineering education must develop in engineers:

- Retrofit -less new construction should be planned, instead, retrofitting existing structures should take on a larger role.

- Repositioning existing structures -taking existing structures and remaking them for another purpose
- Deconstruction -with declining population, some structures are going to be unnecessary so need to be taken down
    - o For example the removal of dams on rivers (Rivers 2024)
    - o Reuse and recycling of materials will be critical.
- Humans will remain a main client for engineering but no longer at the detriment to other life forms
- Design for other animals will become more important, but the temptation to know better than nature needs to be resisted
    - o For example the addition of wildlife crossings for highways (CDOT 2024) has started to be included in the design of highway systems.

The activities listed above require curricula different from traditional engineering curricula. First, design content needs to now address how to work with existing structures and artifacts instead of always creating new artifacts. This shift must replace the current idea of 'green' new artifacts -what will be needed is less new and more renewed -in fact, less everything is the key. Most engineering faculty are not prepared to discuss these approaches so training will be necessary.

Designing with other lifeforms will also pose a challenge. Most current attempts to integrate biology into engineering curricula starts with basic biological sciences. What is needed is an understanding of ecosystems, wildlife behavior and flora habitat needs. Basic biological science courses will be insufficient.

Strategic thinking will need to be developed in future engineers (Wiek, Withycombe et al. 2011). Anticipatory thinking can support the development of better strategies. (Korte and Chermack 2007) Considering Utheim's (Utheim 2024) competencies, reflexivity will be important. Reflection and reflexivity are closely related (Allen 2024):

> *"Reflection helps us learn from past experiences to improve future practice, while reflexivity keeps us aware of how our thoughts and actions shape outcomes in real time, allowing for immediate adaptation. Together, these practices strengthen decision-making, creativity, and collaboration for individuals, teams, and organisations."*

Reflection is something easily incorporated in engineering education –reflexivity requires more effort. An approach for incorporating reflexivity into political science curriculum is described by Krystalli (Allen 2024). The approach requires students to: "…Reflexive responses are weekly 500-word pieces in which the students connect one concept or idea from that week's readings to one application in their own lives, …" To adapt this for engineering classes, students can be asked to connect class ideas to design situations that require them to build on their own values and assumptions.

Ecological restoration will also be an important task during the transition. Much of the destruction of the natural habitat needs to be reversed as much as possible. While there is some controversy over whether humans have the right to 'restore' nature, others promote it as being necessary. Masarei, et al. (Masarei, Erickson et al. 2021) provide a plan for making ecological restoration happen:

"… We posit that a better meshing of traditional engineering disciplines and ecological restoration science is central to achieving environmental repair at the scale and pace required to combat globally ever-growing, human caused, land degradation and biodiversity loss. Ecological restoration is an increasingly vibrant endeavor supported by diverse fields of research. But there is a rapidly emerging role for traditional engineering disciplines to design and deploy solutions to the challenges regularly encountered in returning biodiverse plant communities across degraded landscapes of varying characteristics. …"

To accomplish this type of meshing of disciplines major change needs to happen with the content of engineering curricula. As noted above, a better understanding of other life forms, e.g. both plant and animal, will be required. A better understanding of animal behavior will be required.

Phase III: Design for post growth. Phase III is the most difficult phase as it requires acknowledgment we need to act more like other biological systems and realize that we need to maintain a new level of equilibrium that is significantly lower than the growth (overgrowth) peak that includes significant overshoot, Figure 2. Many of the educational topics from Phase II will need to continue into Phase III. When this new equilibrium is reached, the need for ecological restoration will shift to ecological management. Now there will be a greater need to design in harmony with nature. As mentioned in the beginning of this paper, engineers will need to focus on providing the necessities of life while minimizing use of resources. A new balance between use of natural resources and regeneration of natural resources will be required.

- sufficiency in energy and material use
- waste and pollution minimization
- efficiency in the use of materials/energy
- renewable resource/energy usage
- durable and reparable product design and manufacture
- localization of production for shortened supply chains
- production for needs satisfaction
- appropriate technologies

Designing with nature is an area where other disciplines are further ahead of engineering (International Living Future Institute 2020). For example, landscape architecture has advanced this approach for over 50 years (McHarg 1994). As part of designing with nature, nature's ability to regenerate needs to be integrated into engineering. (Siller and Johnson 2025) Regeneration has also been suggested as an approach for the transition period so it might be valuable to enter engineering curricula during Phase II. (Hawken 2021) Both designing with nature and regeneration concepts will require greater interdisciplinary efforts in engineering education.

Pedagogy. We have already addressed some pedagogical ideas above. Before finishing we take a quick look at the UN SDGs and how they might be incorporated in curricula. A 2020 report (SDSN 2020) provides guidance on how education can be transformed to better prepare students to work on attaining the UN Sustainability Goals (United Nations 2015). While the SDGs are worthwhile goals, our purpose is more broadly for the long-term development of engineers for a very different future during and after a period of population degrowth. The pedagogical approaches promoted in this report can also be considered useful for our purposes. Here are some of the approaches recommended:

Interdisciplinarity
Action-based learning
Multi-actor involvement
Project-based units
Co-curricular activities

All these activities can play a role in educating engineers for a degrowth world and line up well with the competencies in Table 1. Here are ideas from this report for consideration in engineering education:

> *"…develop new "transformative learning" activities, which employ interdisciplinarity, action-based learning, and multi-actor involvement…"*

"…With these considerations in mind, some of the most common approaches used so by universities for ESDGs are awareness raising, interdisciplinary introductory units, integration into the existing discipline curriculum, project-based units, co-curricular activities, leadership programs, student-led activities, MOOCs and other online content, and sustainable development degrees. …"

As an example of co-curricular approaches, this paper's authors have spent time developing and implementing faculty-led education abroad programs for students focused on the SDGs, including programs in China and Peru. Students find the real-world experiences bring classroom topics to life. The authors have also integrated the UN SDGs into a first-year engineering program through the Design for People design challenge sponsored by EWB-UK. (EWB-UK 2025)

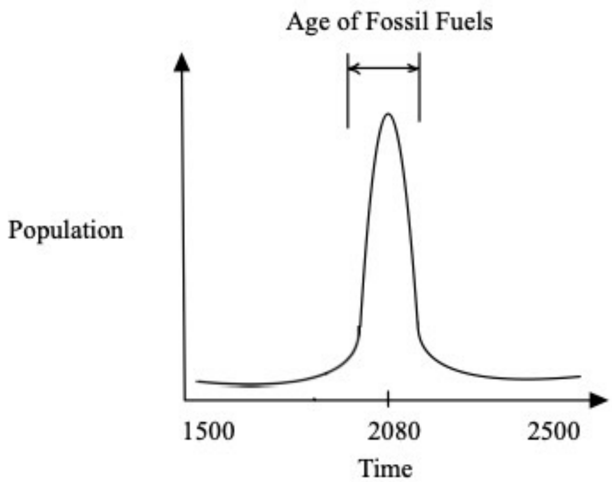

Figure 1: Fossil Fuel Era

4. Conclusion

A smaller future sustainable society should be diverse, dynamic, regenerative and resilient. The economic model should be based on equality without excessive capital accumulation to limit inequality. Regulation through progressive income, wealth, inheritance and corporate taxes with very high marginal rates could be used to keep equality in focus. The ratio of public to private ownership could indicate whether the society is how-socialist or how-capitalist, either might work although a capitalistic society with lots of private ownership might be a stretch, or, an entirely new system might evolve along the lines described in (Buch-Hansen, Koch et al. 2024). Engineering would be required in such a society for reusing, repurposing and recycling nonrenewable materials and resources. Certainly, the engineering curricula would be impacted with a shift in focus from the exclusive attention on engineering new artifacts to developing greater competency on renewal and reuse of existing artifacts. Innovation would be for necessity rather than profit.

Reviewing the changes proposed in this paper leads us to believe that the foundations of engineering and engineering education need to be reformulated as engineering within nature. Degrowth could be the crisis that promotes this reformulation as World War II and the launch of Sputnik led to previous reformulations.

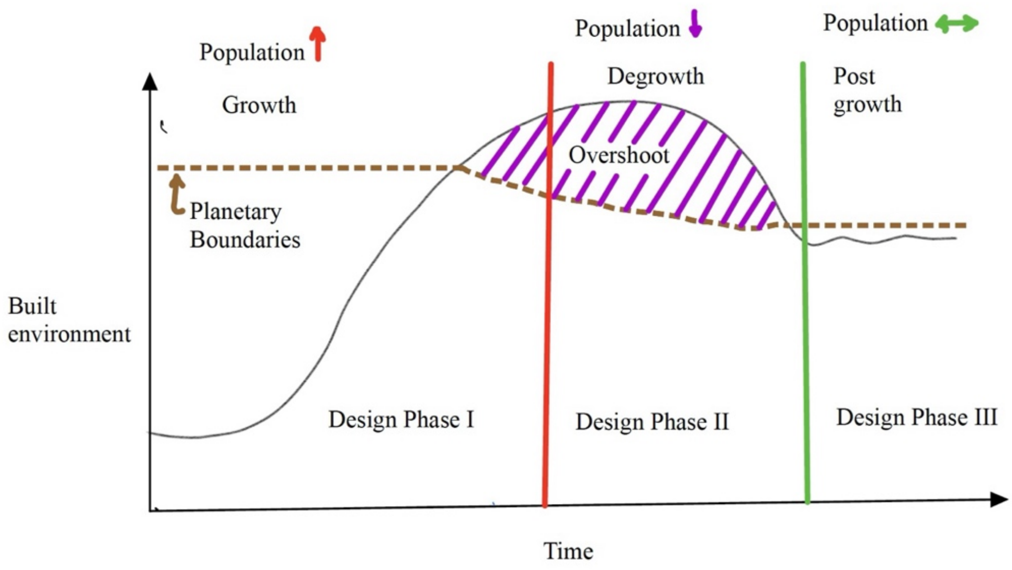

Figure 2: Phases of growth

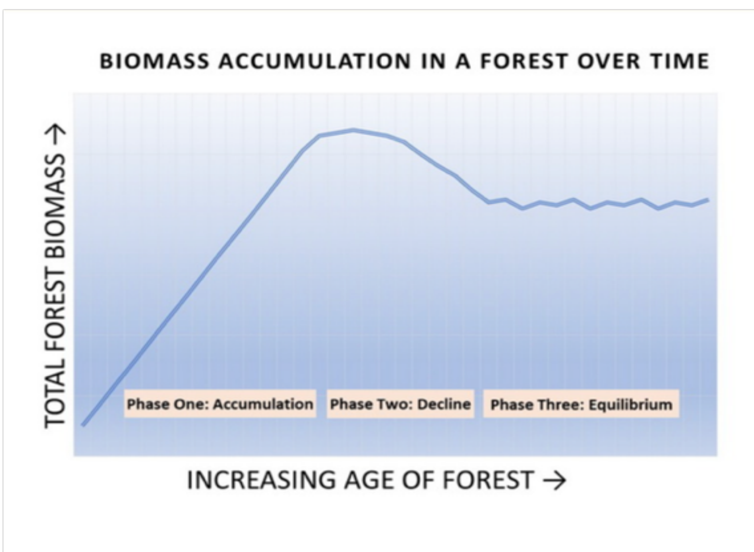

Figure 3: Biomass growth of forests from Davis

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