# Engineering for Social & Environmental Justice: A Design Framework towards a Sustainable Engineering

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# Abstract

This thesis seeks to address the need for a more holistic, environmentally and socially just engineering curriculum by providing a new design framework which incorporates theories of environmental justice. This is motivated by examining other design methodologies which lead engineers to design 'sustainable' technologies. Methods of institutionalizing and incorporating the theories of environmental justice in the engineering program at McGill University are explored. It was found that broadening the engineering curriculum, basing courses on theories of social or environmental justice while providing seminar classes for discussion and well curated design projects which give students the resources and space they require to critically evaluate their actions are actions that can be taken at McGill to provide a more holistic education to engineering students.

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# Introduction

*“Full of merit, yet poetically, dwells man upon this earth”*

*Friedrich Hölderlin*

Martin Heidegger, well-known 20th century German philosopher, draws many of his views about technology from Hölderlin's poetry. While it would not do to try and summarize Heidegger's philosophy of technology in a few sentences, it is worth quoting Bruce Foltz, Heidegger scholar and environmentalist:

“Despite our great cities and transportation systems, our achievements in medical techniques, and our space shuttles and computer chips (“Full of merit, *yet*”), we nevertheless “dwell”... Full of merit, we have devastated the natural environment to a point where responsible scientists and scholars write books of warning and alarm... Yet what is essential is not this at all but rather that we dwell poetically upon the earth.” [1:155].

Dwelling on the earth, says Heidegger, is a “being in” through which we are 'in' the world. The word 'in' here is used in the sense that someone is “*in* a family or *in* love with someone else” [1:157].

How do we create technologies which help us not only to live, but rather, to dwell? It seems that we have lost sight of what technology means, and the places that modern technology is taking us. “What is truly uncanny is not technology as such but the accelerating dominance of technology in our world, together with our inability to confront this transformation reflectively” [1:86]

Today, issues of environmental degradation and the dangers of technology have become fore-running societal preoccupations. Engineers are deeply implicated in these problems, and yet they are often at a loss with how to deal with these issues. Part of the problem stems from the fact that learning institutions, such as McGill University, are still far behind in educating future engineers on the societal, philosophical and environmental issues of the way technology affects the world, or ways to effectively tackle them. Foltz argues that: “The rift between ourselves and the natural environment that has resulted in the environmental crises... cannot be healed by additional scientific research or more efficient technological regulation, but only through a poetic reestablishing of those world regions within whose dimensions we can dwell and be at home”[1:159]. How are we to fit the technology we create to this poetic way of dwelling?

This thesis seeks to address some of these issues pragmatically by proposing a design framework which attempts to integrate theories of environmental justice and the concept of integral communities, while finding ways of implementing them in the university.

## Background

### *Perceptions of engineering*

The role of engineers, along with society's perception of engineers, has changed over time. Engineers, according to the Oxford English Dictionary, were originally the “constructors of military engines” [2].

While some engineers still work solely towards military goals, this definition, which dates back to the fourteenth century, no longer encompasses all that an engineer does. As science and technology have evolved, so has the engineering profession. The word 'engineer' is now often preceded by a distinguishing word, for instance: electrical-, mechanical-, genetic-, *et cetera*.

However, while there exists these distinct engineering disciplines, it is generally true that society and engineers have differing views of the engineering profession. Vesilind notes that “Engineers often consider their foremost responsibility to serve the public good,” however, non-engineers, referred to by Vesilind as “the public”, often see engineers as “tools of the establishment,” “despoilers of the environment,” and the “diligent destroyers” [3].

Herkert explains that even within the engineering profession there are many differing definitions of engineering. One such definition is given by a student: “Engineering is a discipline creatively applying pure sciences, past experiences, and problem-solving skills fuelled by curiosity and the intent to have a positive effect on society.” [4:45] However, while engineers wish to see themselves as having a positive effect on society they often overlook the social and environmental contexts of engineering.

A modern definition of engineering in the Oxford English Dictionary, however, still recounts nothing of the societal outcomes of engineering:

“The branch of science and technology concerned with the development and modification of engines (in various senses), machines, structures, or other complicated systems and processes using specialized knowledge or skills, typically for public or commercial use” [5].

On the other hand, many engineering ethics codes do recognize the importance of technology on society. The opening line of the IEEE Code of Ethics states: "in recognition of the importance of our technologies in affecting the quality of life throughout the world…"[6] The American Society of Civil Engineers labelled engineers for a time as being part of "the people serving profession" [3].

From this, it seems that the goal of the engineering profession is, idealistically, to make the world a better place. However, the outlook of non-engineers shows that engineers may not currently be focusing their attentions in the right places, or solving problems in ways that non-engineers feel is useful.

From society's perspective, the perception of engineers as "unethical, inconsiderate or unresponsive to public need" [4] is not wholly unjustified. The utilitarian nature of many engineering projects, where negative consequences are weighed with positive consequences, can lead to the rejection of engineering solutions by many members of the public. When a utilitarian based cost-benefit analysis of a project is the deciding factor for a project's outcomes, this can be controversial, especially when taking into account ecosystems, traditional lands, and human lives. Who is the engineer to decide the costs or benefits of these?

However, as more and more engineers move into the private sector, with over three-quarters now working for large corporations [4:47], engineers are given less and less agency to shape a project to their ethical concerns. Having been given a commission to a project, engineers are often "somewhat reluctant to criticize the commissioner" [7:199]. Engineers end up being blind followers of the status quo, and are therefore implicated in whatever damages they cause, even if they feel society's concerns to be outside the scope of their work.

For engineers to contribute to the betterment of society, as it seems they wish to do, changes must be made to the way the engineer practices engineering. As will be argued later in this paper, this change must come from the structure and goals of engineering teaching institutions if engineering is to fulfil the goals that society is striving towards.

## Sustainability & Environmental Justice

A relatively new societal goal is that of sustainable development, or 'sustainability'. Since the concept's introduction in the late 1980's, 'sustainability' has become a buzzword and is now devoid of much meaning. Naming a project 'sustainable', without defining the scope of what sustainability means, has allowed the green-washing of many projects, often covering up negative aspects with positive wording.

***Sustainability***

The standard definition of sustainability and sustainable development stems from the report of the World Commission on Environment and Development (WCED), more commonly referred to as the Brundtland report: “We define sustainable development in simple terms as paths of progress which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs” [8]. However, as noted by Holmberg and Sandbrook, there are over seventy other definitions of sustainable development [9]. The word 'sustainability' is used in many different contexts, many of which are not necessarily in the spirit of what the Brundtland report was trying to achieve. This definition is purely a starting point for this investigation.

The Brundtland definition of sustainability puts forth an inter-generational criterion, which acknowledges the power that current generations have over the resources available to future generations. This poses ethical questions – how does one balance the interests of present and future generations [8]?  The definition doesn't give any theories as to what exactly constitutes a human *need*, nor does it give any guidance as to the importance of future generations' *wants*. The needs and wants of future generations are also hard to predict, and are not necessarily an incentive for sustainable business or engineering practices. Indeed, as pointed out by Martinez-Allier: “individuals not yet born have ontological difficulties in making their presence felt in today's market for exhaustible resources” [10]. Governments are also hard pressed to take sustainability into account, especially if this means adversely effecting current voters. One current 'sustainability' policy is to put a price on nature with, for example, carbon credits. However, as Banerjee notes: “sustainable development uses the logic of markets and capitalist accumulation to determine the future of nature” [10]. This has led many environmentalists to have concerns about whether this definition of sustainable development is possible while simultaneously taking into account the seemingly exclusive concepts of economic growth, environmental maintenance and equity. Banerjee makes this distinction: “the greening of industry should not be confused with the notion of sustainable development” [10].

Horror stories of ill-conceived sustainable development projects abound in the media, for instance those of the 'Green Revolution', and the inclusion of terminator technology in seeds. To combat this, a postulate for 'appropriate technology' has been added to that of sustainable development. Appropriate solutions acknowledge that the tenets of western science and the reliance on cutting-edge technology are not the only solutions to all problems, be they sustainability, developmental or desires. Indeed, many cultures were already completely sustainable before they were imposed with a more 'advanced' European way of life. Science and technology seek to understand and control nature. This transforms the idea of 'nature' into the idea of 'environment'. Banerjee notes that “Sustainable development … is about rethinking human-nature relationships, reexamining current doctrines of progress and modernity and privileging alternate visions of the world” [10].

### *Environmental Justice*

The concept of environmental justice tries to tackle some of these issues with the definition of sustainability. Environmental justice movements often follow two main premises:

1. everyone should have the right and be able to live in a healthy environment, with access to enough environmental resources for a healthy life and;
2. that it is predominantly the poorest and least powerful people who are missing these conditions [11].

Environmental justice also tackles the inter-generational issues of sustainability, as injustices to future generations go against the first premise ('everyone' also includes future generations).

Environmental justice removes the requirement for constant economic growth, and instead puts a greater emphasis on giving everyone the resources for a healthy life. The recognition that the poorest are predominantly affected in a more adverse manner by environmental issues requires the evaluation of qualitative aspects of a project. For instance, in a solely qualitative comparison of electricity generation methods, the Canadian Electricity Association shows that wind power has almost no environmental impacts. However, Pierpont mentions that: “to live near one can be hell on earth. So I have been told by countless people who suddenly find themselves grievously ill from the subtle yet devastating infrasonic jackhammer generated by these “clean, green, renewable energy” giants.” [12] Quantitatively, wind power looks perfect. Qualitatively, we see otherwise.

Environmental justice aims to recognize that it is those who are often looked over by society, the least powerful people, who are most often affected the greatest by environmentally damaging practices. For instance, 70% of all electronic waste in New Delhi is dumped there by the global north [13]. In monetary terms, shipping e-waste from the global north to the global south costs less than dealing with it at home. However, this outsourcing of the problems created by the north's technology addiction to the south is obviously a less-than-savoury solution.

## *Outlooks on technology*

### ***Engineering and un-just practices***

As noted before, engineers are often under the leadership of those most powerful in society: governments and corporations. These entities are the ones that look over the marginalized. It has been argued that these organizations require this marginalization in order to keep their power in society. While justifying and examining this claim is outside the scope of this paper, it is important to keep in mind that engineering projects are often complicit in this marginalization. For instance, Lucena, Schneider and Leydens note that in the 19$^{th}$ century: “Engineers were frequently in a position to *socially engineer* communities for the purposes of order and national progress, for example, by relocating them or connecting them in different ways to other parts of the country” [14]. This is not meant as an argument against installing technology within communities, rather, it is insightful to see that the technology is meant as a way of establishing the status quo of government control where it might not otherwise have existed.

### ***Technological Determinism***

According to Lucena, Schneider and Leydens, engineers are often holders of a belief in technological determinism, the belief that technological development occurs on a fixed path which is not influenced by culture, society or politics [14]. This view is often coupled with the view of technology as being value-neutral – the technology created in of itself isn't loaded with any moral value, rather it is society who may choose the moral purpose of the technology. This can remove an engineer from taking the responsibility from the negative consequences of the technologies that they are implicated in, and thus requires no value judgement on their part. Technologies that, at first glance seem to have no negative moral or social consequences, may also be detrimental in ways that can't be measured. Gene Moriarty identifies this problem: “what is locally benign may present serious moral problems in the realms of social justice, environmental sustainability and health and safety of affected parties. The moral assessments of engineers, of engineering and of engineered products require a step back and away from immediate concerns to reflect on the larger picture of the contextually embedded engineering project” [15]. We see within Moriarty's argument the concepts of environmental justice, and he ties this strongly to the ethical dilemmas inherent in any engineering project.

Technological determinism can be held in both an optimistic and pessimistic sense. The Unabomber, Theodore Kaczynski, who was a staunch critic of modern technology held this belief. Kaczynski argued that technology is taking away our freedom, as we are often left without a choice to use it. In the Unabomber Manifesto, he states: “When a new item of technology is introduced as an option that an individual can accept or not as he chooses, it does not necessarily REMAIN optional. In many cases the new technology changes society in such a way that people eventually find themselves FORCED to use it” [16].

Jacques Ellul held a similar pessimistic view of technological determinism. He found that medieval technologies differed from modern technologies as “individuals and local communities were able to influence and shape the technologies they applied”[7]. This was due to the fact that medieval technologies were based on local resources, required well developed skills and were localized solutions to local problems. Modern technology, according to Ellul follows four premises: (1)*Automatism:* technology provides solutions where there is one 'ideal' way to solve a problem which works outside of any social context; (2) *Self-Perpetuation:* technology reinforces the growth of other technologies, perpetuating technology in general; (3) *Indivisibility:* technology must be accepted in full, with all positives and negatives; (4) *Universalism:* technology is omnipresent, both geographically and qualitatively. Ellul, like Kaczynski, thought that technology destroys freedom [7].

***Utilitarianism***

Utilitarianism, an anthropocentric view of the world, is also widely subscribed to by engineers. According to Herkert: “Utilitarianism is an ethical system that judges an action to be morally correct if its outcome results in the greatest good for the greatest number of people” [4]. The concept of greatest good, is of course, a subjective one. Sustainability takes on a different meaning when looked at from a utilitarian perspective - sustainable solutions may not treat the environment or various groups of people with the respect they deserve, even if the overall net gain is positive. Vesilind gives the example: “Utilitarian calculus, so valued as a decision making tool by engineers, is irrelevant to most individual members of society. In a public hearing, therefore, the engineer may announce that the net detrimental effect of the emission from a proposed fossil fuel power plant is to increase cancer deaths by only 1 in a million, and consider this risk to be quite acceptable given the benefit of the power produced. But many members of the public, not appreciating the utilitarian calculus, will see this death as grossly unethical” [3].

Since utilitarianism is often based purely in economics, it is ill equipped to provide sustainable solutions to engineering problems. Sagoff argues that “The reasons to protect nature are moral, religious and cultural far more often than they are economic” [17]. Thus, the structures that engineers currently work within are perhaps ill-conceived to design just solutions.

### *Social Constructivism*

Social constructivism is where “technologies are considered to be social constructions, i.e. technologies have been given shape by the demands of various social groups” [7]. People viewing technology as if it were socially constructed look at how different criteria of the technology affects different groups and stakeholders. For instance, if a certain solution is labelled as being the 'best' solution, a social constructivist would seek to find who defined these criteria. This leaves technology open to development by different groups. Since “different groups attribute different meanings to the same technical artefact” [7], technological solutions may lead to controversy when placed in a different social context. Any news reports on the building of any large infrastructure project will verify this.

At first glance, this seems to be a useful outlook with which to view technology in order to integrate the concepts of environmental justice. However, social constructivism has been criticized for lacking “a good analysis of the interactions between relevant social groups who do not have an equal opportunity to influence the process of technological change” [7]. Influence on various projects is often dependent on the resources (such as money, status, societal position) that the different stakeholders have. Social relations also play a large role in the amount of influence one has on any particular project. Another criticism is that social constructivism neglects the importance of the physical world by over-emphasizing the role that society plays in shaping technology [18].

Traditional engineering outlooks of technological determinism and utilitarianism, while useful for some engineering projects, are not suitable mechanisms to think about engineering projects when striving for justice based solutions.

However, this isn't necessarily the fault of the engineer. In most learning institutions, there is no formal place to explore the ethics inherent in any project. Unfortunately, simply following a prescribed code of ethics, such as those enforced by professional bodies, doesn't always lead to ethical practices. Adherers to an ethical code should understand the nature and purpose of the code. This understanding, however, isn't automatically attained by becoming a member of a professional society, nor by wearing an iron ring. As Ladd explains: “ethics cannot be dictated. In old fashioned terminology, the principles of ethics are “discovered” rather than created by fiat. They are established through argument and persuasion, not through imposition by an external social authority” [19]. Thus, while both the university and the professional bodies give guidelines on the required ethics of engineers, neither the skills nor a forum to evaluate, discuss, or formulate a personal code of ethics are provided to students. Ideally, students would be faced with ethical problems within their design courses and be provided a forum to discuss these with peers and professors. Similarly, within a corporate context, commissioned projects should be evaluated ethically prior to being worked on by an engineer.

## Objectives

The objectives of this thesis are to identify and propose a framework within which engineers can work to orient projects to tackle issues of environmental justice. Particular attention will be taken to ensuring this process can be applied in situations where these concerns are not immediately evident. Ways of institutionalizing this process within a university setting, integral in the success of a work such as this one, will also be provided.

## Hypothesis

In order to provide more holistic, socially and environmentally just solutions to the worlds problems, and in keeping with current societal objectives, engineers should be taught and required to follow a framework that takes into account the needs of both the planet and stakeholders at all stages of a project's design, production, use and post-use.

This will require that engineers are given adequate ownership over codes of ethics, as well as recognize the role that technology has played in further marginalizing the least powerful in society. The multidisciplinary approach to projects that this suggests will require that future engineers are provided with an education that is broader in scope than current university curricula provide. Finally, corporate and government leadership will be required to subscribe to similar goals for this framework to be effective once engineers leave the university context.

# Design Processes

## Why a formalized framework is necessary

There is a stereotype that engineers are in general apolitical [20]. Taking a stance on any justice issue, however, can be seen as a political act, and may be a barrier for engineers who may not wish to engage in this way with a project. Throughout engineering education, systematic, calculative and analytical thinking processes are emphasized, leaving engineers with a particular framework with which to think about the world and to think through problems. Having a procedural method of design is therefore necessary if it is to be accepted within the currently accepted system of problem solving.

A systematic design process "provides an effective way to rationalize the design and production processes. In original design, an ordered and stepwise approach—even if this is on a partially abstract level—will provide solutions that can be used again" [21]. Instead of purely providing recommendations for engineers to follow when carrying out a design, providing a formalized process will be a more effective way of guiding engineers to formulate more sustainable solutions.

## Engineering design, social constructivism and technological determinism

While most people probably hold a view of technology that is somewhere in between technological determinism and social constructivism, they are important models to keep in mind when thinking about a design process, especially in order to avoid the pitfalls that both outlooks fall into. These two schools of thought also provide different ways of thinking about the environment. Determinism sees technology's destruction of the environment as inevitable, or at least, solely fixable by technology itself. Constructivism, on the other hand may provide other solutions to the environmental dilemma that are not necessarily technological in nature.

It is important to acknowledge the fact that both technology and society are not exclusive of each other, that technology is shaped by society, which itself is shaped by technology.

## Creativity in Engineering

Designing for environmental justice is a difficult process without being able to 'think outside the box'. Creativity, an important part the engineering design process is, therefore, of the utmost importance. A definition of creativity is given by Baillie: “Instead of seeking the right answer, one can ask 'Is this the right question?'”[22] As will be noted later in this paper, this is an important way of thinking about designs for environmental justice. However, while it is important to give a systematized design framework, systematizing the creative process may actually stifle creativity. As Baillie mentions “Attempting to provide a framework for the creative process is by no means the ‘same thing as systematizing creativity. There are systematic techniques and non-systematic, random idea-generation methods that work well in different contexts” [22].

## Processes of Design and Innovation

There is no doubt that the engineering design process is highly complex, and there probably exists as many design processes as there are engineering designs. This section outlines some of the basic design models that exist within engineering literature. Of course, this list is by no means exhaustive.

### *Linear Models*

The six-phase linear innovation model described by Mulder, and shown in Figure 1, can be thought of as a simplified model of technology development. Basic models of technology like this were prevalent prior to the 1970's, and shows the relationship between various actors within the technology sector. A model such as this one shows how engineers take basic scientific knowledge and transfer it to a useable product in a market. However, it is highly deterministic, and assumes that given an input of appropriate basic science, usable technology will result. There is nothing here which accounts for the effects that other parts of society have on technological development. Mulder points out that the innovation process is much more complicated than this: “Choices are made continuously between alternative development options. Social factors play an important role in such choices. Feedback loops are important and previous choices often have to be reconsidered.” [7:221]

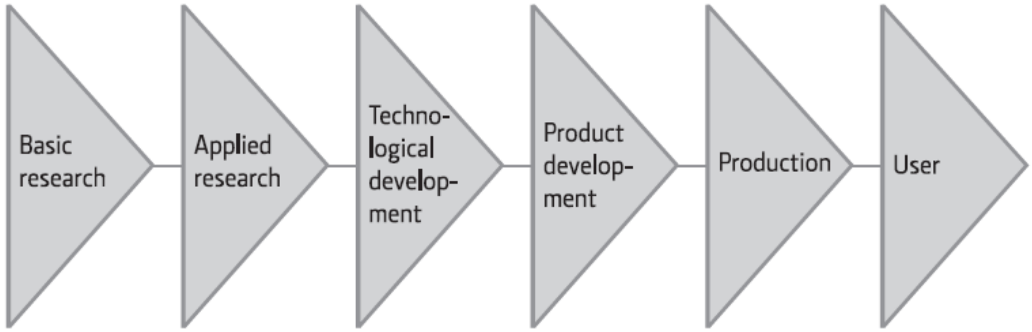


*Figure 1: A Linear model of the innovation process* [7:220]

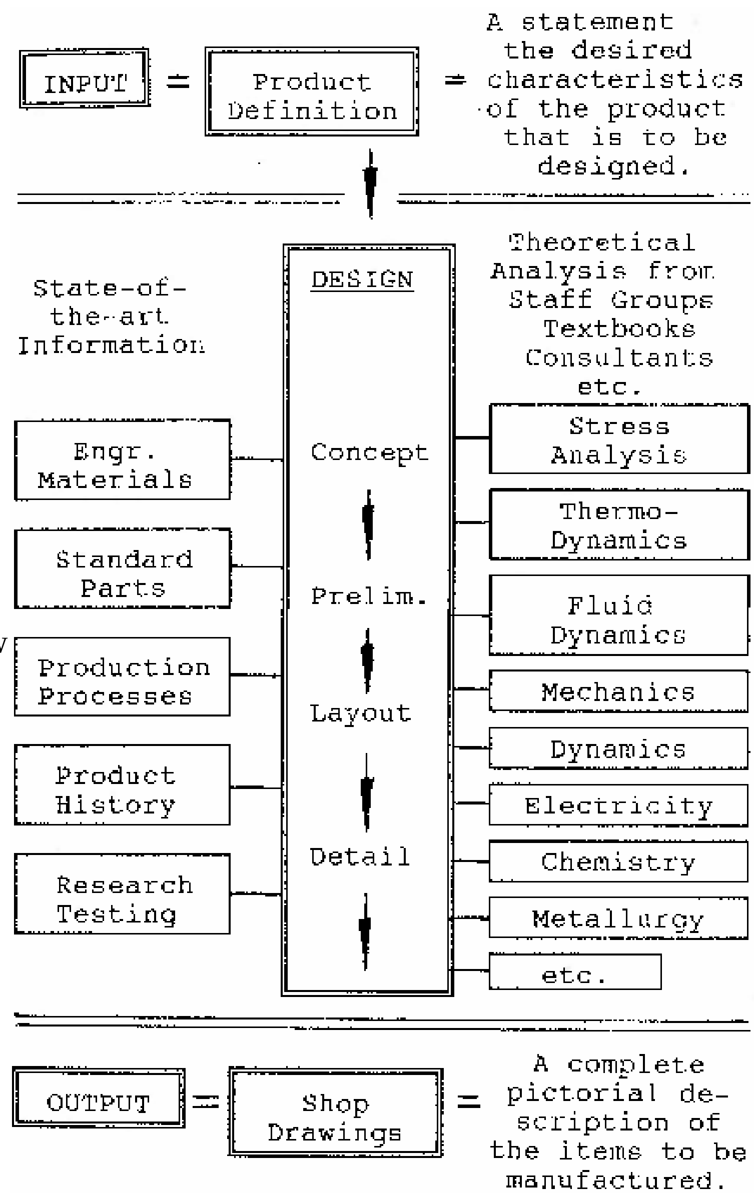


*Figure 2: Hanson's linear design process [23:10]*

The “black box” nature of this model doesn't show the particular steps within each block which produces a technology.

Hanson provides another linear model, geared towards aeronautical engineering, shown in figure 2. This six-step design process–Product definition, concept, preliminary design, layout design, detail design, shop drawings–is also highly deterministic, and does not allow any inputs from societal sources. (Hanson seems to view the engineer in the same way he views the design process – for him, engineering creativity seems to be a natural talent which cannot be provided to graduates.)

Mulder also provides a 'cycle of designing' [7:201], which is less linear than Hanson's model, however, still does not allow for inputs from other people than the engineer. Mulder indicates that within the analysis phase, an engineer may not have much flexibility with the direction of a project they are working on. “The programme of requirements is generally so restrictive that only small product improvements are possible” [7:202]. It is within this analysis phase that the engineer must be critical of a proposal from the standpoint of environmental justice. Having consensus on the direction a product takes at this stage “prevents the design from having to be overhauled at a later stage” [7:202].

Ertas and Jones describe a linear design that is similar, if not a more complex version, of that presented by Mulder [24].

It seems that the traditional linear model leaves much to be desired, even when trying to explain how a design is actually carried out. The descriptions of these models seems to suggest that the engineer traditionally doesn't have much say in the desired outcomes, as this is normally already provided by a contractor. There is little room in these models for an engineer to “ask the right question” [22] and hence - if we take Baillie's view that this is a major component of creativity – the engineer is given limits on their creativity.

These models give an indication of the focus on economics that engineering design is often part of. Engineers working within a corporate context are often required to make decisions based on profitability and economics. Since environmental justice has a different focus than solely economic gains, these models are not necessarily compatible with designing for environmental justice.

Instead, engineering design for environmental justice requires that consideration be given to parties outside of the traditional company and end-user sphere of influence. Some frameworks have been developed to take this into account, especially for large civil-engineering type projects, but also within the realms of computer science.

## *User-Centred Design*

User-centred design (UCD) is a method often employed in fields such as human-computer interaction (HCI). UCD covers a wide variety of design methodologies, all of which have differing levels of involvement with stakeholders. Olson outlines these levels of involvement: “from users as designers and co-designers, through user collaboration and user participation, through continuous user access and user contact, to ending with users represented through personas and designers thinking about users” [25].

However, user-centred design can also be controversial. The term 'user' when used in a design context can strip users of their agency. “This would seem to set these people up in opposition to 'producers', 'developers', 'designers', and those at the core of the designing work. Thus, the term user may foster perceptions of 'us and them'”[25]. On the other hand, some UCD models, for instance one proposed by Norman treat 'users' as being inherently knowledgeable about the products that are being designed for them.

As Light and Luckin describe, there are two main motivations of UCD - the business case, where “there is nothing implicit in UCD that means the design outcomes should be good for society”[25]; and a more social approach since “UCD is regarded as a more equitable as well as informative way of designing” [25] This type of UCD, “has a form of social justice at its heart” [25].

## *Participatory Design*

Participatory design follows from the last motivation of UCD. The department of computer science of the University of Aarhus describe four key principles of participatory design: cooperating, experimenting, contextualizing, and iterating. While a lot of research on participatory design and UCD is mostly done within the context of computer science, we can see how this type of process could be useful to adapt to thinking about environmental justice.

The cooperation principle "stresses two fundamental principles: the"egalitarian" principle which assumes that all stake-holders within a design process are juxtapositioned, all are experts in certain areas and more like novices in others; and the co-working principle which assumes that a design process is a learning process for both computer systems developers and users" [26]  Thus, participatory design advocates for the "establishment of a new work practice" [26] which is more inclusive to the more traditional linear design models presented above.

The principle of participatory design also acknowledges how each person has their own way of making decisions and have their own ways of thinking about a problem. This overcomes some of the issues with UCD wherein users are treated as being less knowledgeable than the designers. This is described as "multi-voicedness" by the University of Aarhus: “In this work practice, a third principle may unfold, the potentials of multi-voicedness, where the participants basically address the same issues, but from very diverse backgrounds and perspectives”[26].

### *Participatory Action Research*

Participatory Action Research (PAR) builds on the ideas of participatory design but puts participants on even footing with researchers. This is seen as “an extreme form of designing with the community” [25]. Krimerman  notes that there are objections from within the scientific community on PAR: one of these is that of the “Popular incompetence or Bias” - this asks the question: “Why involve, in the design and practice of scientific research, those who are inexperienced, if not incompetent, and who have a clear and present stake in the results?” [27], or more simply, should those who are non-scientists be allowed to participate in science. In our case we could ask, should those who are not trained as engineers be allowed to participate in engineering design?

### *Danish Consensus Conference Model*

When looked at in application to engineering, PAR could be seen as finding consensus on the design process, allowing everyone equal say in what comes out of the process. The Danish Board of Technology, the *Teknologirådet*, was created for a similar purpose, albeit for government policy on technology. The consensus conference is “defined as a method of technology assessment organized as a meeting between an expert panel and a panel consisting of concerned citizens- the lay panel” [28]. While the language used to describe the panels ('expert' and 'lay') creates a similar power dynamic between designer and user as does the language of UCD, the conference acknowledges that there is often a difference in goals between 'technologists' and the 'public'. The *Teknologirådet* is counteracting the deterministic view of technology by providing a forum for the social construction of technology. Of course, the consensus conference only deals with technology issues that are: “important, timely, contentious and relevant to policy” [29], but a democratic, participatory model such as this could equally well be applied within the constraints of other design models.

### *Adaptive Management*

Adaptive management is a technique often used in managing water systems where the management process is continuously changed as communities, ecosystems and economics change. As explained by Walters, "[Adaptive management] begins with the central tenet that management involves a continual learning process that cannot conveniently be separated into functions like "research" and "ongoing regulatory activities," and probably never converges to a state of blissful equilibrium involving full knowledge and optimum productivity".

UCD and participatory design follow similar principles, as the internal process for thinking and looking at technology are continuously changing as inputs from different participants are taken into account. The only way that this can happen is for all participants to learn from one another. “Adaptive management is learning to manage by managing to learn” [30].

Adaptive management is therefore a non-linear process which is constantly re-evaluating the ways that it approaches problems. Feedback loops within the adaptive management process are what allow decision makers to learn from experience in a timely manner [31].

## Frameworks for designing sustainable technology

As 'sustainability' is quickly becoming an important goal in society, we find more and more literature on providing sustainable technological solutions. Many of the methods that this literature proposes are geared towards more standard definitions of sustainable development, along the lines of the Brundtland report. Some of these methods, while they are a step in the right direction, unfortunately do not apply principles of environmental justice and therefore often overlook the important societal components that this theory encompasses.

This section outlines some design frameworks which have been proposed in the past.

### *Cradle-to-Cradle*

Cradle-to-cradle (C2C) design, made famous by McDonough and Braungart's book by the same name, attempts to mimic how nature uses resources in product design - where “waste equals food”. They put forth the idea that “less bad is no good”, that instead of being efficient it also necessary to be *effective*. The book itself is printed on a plastic polymer which can apparently be recycled indefinitely - the ink can be washed off in a bath of hot water and reused (which, apparently, doesn't photocopy well!), the 'paper' and cover are themselves waterproof and can be printed on again. Through re-designing paper, they also re-define the design process: they “embrace the challenge of being not efficient but *effective* with respect to a rich mix of

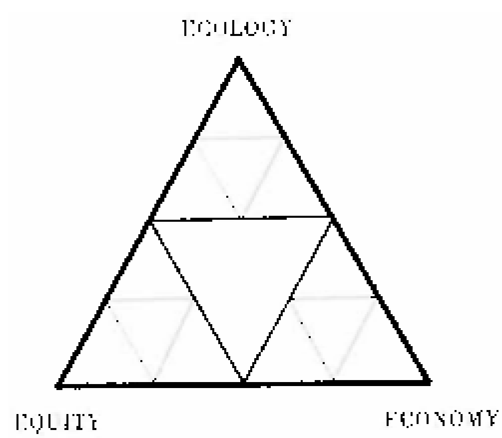

*Figure 3: Cradle to Cradle [32:150]*

considerations and desires.” [32:72].

This process is dubbed “eco-effectiveness” which, in an attempt to bridge the gap that is often present between businesspeople and environmentalists, “celebrates commerce *and* the commonweal in which it is rooted”. They see this as a kind of 'triforce' of ecology, equity and economy, with a trade off in the middle, shown in figure 3.

The last step of the eco-effectiveness process, *Reinvent*, asks designers to “recast the design assignment” [32:178]. The example McDonough and Braungart give is that instead of designing a new car, one should instead “redesign transportation” [32]. This is in line with Baillie's definition of engineering creativity, and of asking the 'right question' [22]. This type of critical thinking of the outcomes of a design are crucial when designing for environmental justice.

C2C seems to be a theory which focuses very much on the materials used in a product, and the effect that these have on the environment. While this process has been seen to be very effective (and popular), it fails to address many concerns that fall under the environmental justice umbrella. The ecology-equity-economy triangle which designers are meant to use oversimplifies the interactions between the the vertexes. This could lead to situations where, for example, someone was trying to design as equitable a product as possible, the bottom left of the triangle. Using the C2C model, this would disregard any economic or ecological factors, which, obviously would not lead to an equitable solution at all.

The C2C design process does, however, provide an interesting way of thinking about the way that products are created. Instead of the design process ending when a product is delivered to the user (or to manufacture) as is the case in all of the frameworks described above, the design process ends when a product returns to its original form again. This is very different from providing recycling mechanisms (in contrast to cradle-to-cradle, this is also known as designing for 'cradle-to-grave'), since recycling often removes value (both material and economic) and can often require more environmentally destructive processing.

### *Life Cycle Assessment*

Life cycle assessment (LCA), is a quantitative method to assess the environmental impact of a design. LCA is a typical example of a utilitarian way of finding a solution to an engineering problem. Also known as 'cradle-to-grave' analysis, LCA quantifies the impact that a certain product has on various parts of the environment. Since everything is converted to standard units (for example, greenhouse gasses are converted to kilogram equivalents of $CO_2$) products can be compared with some ideal product or a bottom-line. LCA scores are calculated based on weightings for each category. Hence, if environmental priorities change, product scores will change.

During an LCA, each phase of a product's life is analyzed, according to Mulder these are: (1)"Raw materials acquisition and refining (e.g. mining, drilling, agriculture, forestry, fisheries); (2) Processing and production of product and production equipment; (3) Distribution and transport; (4) Use, re-use and maintenance; (5) End-of-life -- land-filling, incineration, litter and recycling" [7:206].

LCA is particularly useful when a product is being redesigned, since the analysis can show which parts of a product need work. Once parts of a product have been identified to be changed, a designer can use the LiDS wheel as developed by van Hemel. This gives seven strategies which can help optimize a design according to the characteristics of the LCA. This is shown in Figure 4.

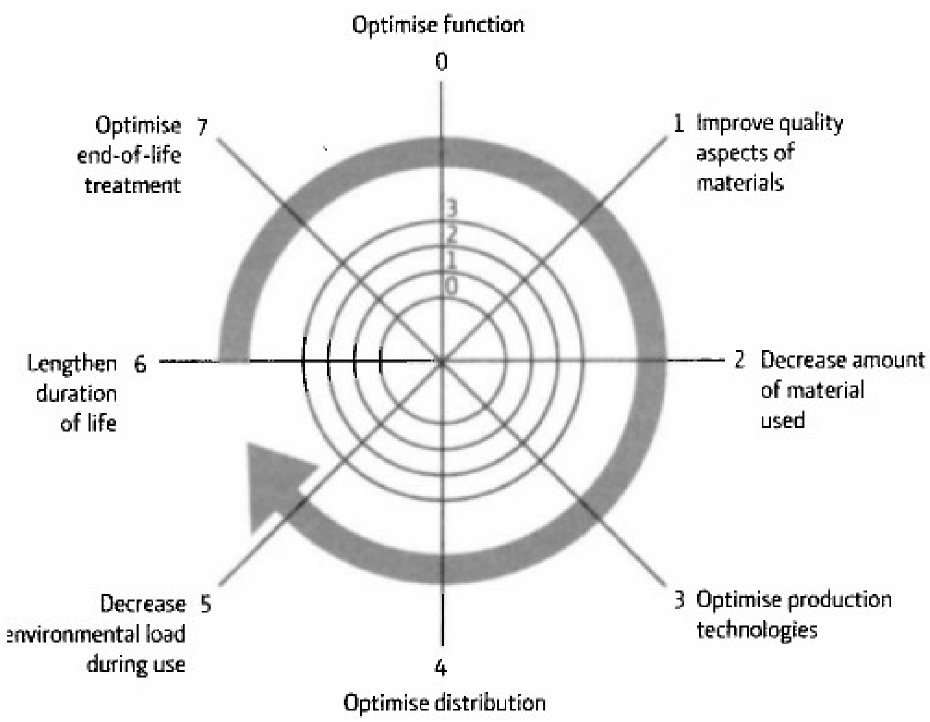

*Figure 4: LiDS wheel [7:212]*

Strategy 0: optimize the way the function is performed, is particularly interesting since this strategy allows us, as Baille suggests we should, to 'ask the right question' [22].

The way that LCA is structured, however, could create a culture where designers are designing for LCA 'points', instead of comprehensively examining the reasons behind them. This also seen in other points based environmental tools such as the Leadership in Energy and Environmental Design (LEED) system, where there are mechanisms where designers are essentially able to pay for certain points.

A quantitative system like this will never be able to provide an accurate depiction of society, nor of products or practices that have unjust outcomes. There is growing backlash against purely quantitative systems of analysis that came about after the European age of enlightenment. Mathematics, the language of reason, is extremely reductive, and disregards other ways of knowing. Therefore, systems of analysis such as LCA are unable to really provide just solutions to problems, as they look at the world through only one frame.

This quantitative way of thinking can also be seen in other attempts at making sustainable design frameworks. Molgat provides a mathematical model of the difference between the classical engineering design process and a design process that also takes into account social and environmental criteria. The traditional design process is modelled as a single value function $A=f(x)$, with x representing the techno-economic criteria that are being used. A broader design process is modelled as $A=f(x)+f(y)+f(z)\ldots$, with y and z being social and environmental issues. Modelling the design process in this way disregards the multifaceted and interrelated nature of all these issues and suggests that they should be looked and solved using similar methods to the traditional linear design process [33].

## *Sustainable Interaction Design*

Sustainable interaction design is interesting as it looks at areas of engineering which are not normally associated with being environmentally destructive, namely software design. Sustainable interaction design attempts to reconcile the fact that software and hardware are “intimately connected to a cycle of mutual obsolescence” [34].

Blevis, who first proposed this framework, essentially calls on interaction designers to integrate the concepts of C2C when writing software. We can see that even designing something physically abstract, like software, has effects on the environment and people, either through the creation of waste, or the obsolescence of certain lines of work, etc. Thus, thinking about environmental justice is also necessary when designing software [34].

*Regenerative Design*

Regenerative design is also heavily based on natural systems. Within a 'regenerative' framework, traditional design systems are seen as linear, with sources such as mines, forests, watersheds etc, and outputs that end up in sinks such as the air, land and water. In this linear model, energy is lost to the environment through entropy. Regenerative design: “means replacing the present linear system of throughput flows with cyclical flows at sources, consumption centres, and sinks” [35].

Regenerative design is has similarities to C2C—instead of promoting recycling, it promotes thinking about how products will be reintegrated into the environment. “A regenerative system provides for continuous replacement, through its own functional processes, of the energy and materials used in its operation” [35:11]. Lyle provides five characteristics which are fundamental to regenerative design:(1) operational integration with natural processes, and by extension with social processes; (2) minimal use of fossil fuels and man-made chemicals except for backup applications; (3) minimum use of nonrenewable resources except where future reuse or recycling is possible and likely; (4) use of renewable resources within their capacity for renewal; (5) composition and volume of wastes within the capacity of the environment to re-assimilate them without damage [35].

In essence, Lyle states that regenerative design “has to do with rebirth of life itself, thus with hope for the future” [35]. Regenerative design is grounded within natural systems, in contrast to other frameworks which are based upon providing material solutions. Lyle expands on this: “It has often been said that solving the environment/resource dilemma is not a matter of technology alone. The human relationship with nature is the core issue” [35].

Regenerative design, is closely linked to designing for environmental justice. Lyle makes the link between society and the environment very clear: “Regenerative systems…are enmeshed in natural and social processes in ways that make their purposes far more complex. While technology remains the means for augmenting nature, it ideally becomes a factor within the larger social and ecological context rather than the engine driving that complex. … Regenerative systems function as integral parts of the communities they serve. This means they necessarily involve those communities in their design and construction" [35:37].

One way that Lyle recommends incorporating communities in the design process is using participatory workshops, similar to the Danish consensus conference model described above.

***Regenerative Design Strategies***

Lyle outlines twelve design strategies for regenerative design. Of particular interest to this investigation are the following steps, as they are directly related to designing for environmental justice:

- *Aggregating, not isolating:* Lyle argues that our increasingly technological world is becoming more and more disaggregated. This requires more energy than if the parts of the system were aggregated. Regenerative design requires the re-aggregation. "In re-aggregating the parts, regenerative design has to be as concerned with the interactions among parts, the connections, as with the parts themselves."
- *Seeking optimum levels for multiple functions, not the maximum or minimum level for any one:* In industrial era technology (what Lyle calls the 'Paleotechnic era', after Mumford), "environmental and social concerns are given low priority or ignored entirely". Having more than one goal is characteristic for regenerative design, to the chagrin, I would imagine, of many engineers: "Regenerative systems always have more than one goal; often they have numerous goals, some of them in conflict with others. In such complex situations, quantification is difficult and almost always imprecise." [35:40].
- *Matching technology to need:* Lyle believes that a lot of technology is over-designed to do a specific jobs, and occasionally, under-designed. This is attributed to economics which, unfortunately, often works against sustainability.
- Using information to replace power: This follows from the previous point, wherein: "given adequate information, we can achieve precise fits between system and function". Power in this case is used in the sense of 'computational power' rather than 'political power'. [35:41]

## *A design algorithm for a morally deep world*

Catalano describes a design algorithm for a morally deep world which “was first developed within the context of environmental ethics. A key element in its development in environmental ethics is the identification of an integral community.” The strong link to the community fits very well with the idea of environmental justice. It is this 'integral community', which “include[s] not only the environment but also other segments of society which have not been included in engineering ethics cases in the past” that allows for a more focused thinking about communities which are most effected by engineering designs [36].

Catalano's design algorithm consists of four steps: “(1)Via Positiva: The problem is identified, fully accepted and broken down into its various components using the vast array of creative and critical thinking techniques which engineers possess. What is to be solved? For whom is it to be solved? (2) Via Negativa: Reflection on the possible implications and consequences for any proposed solution are explored. What are the ethical considerations involved? The societal implications? The global consequences? The effects on the natural environment? (3) Via Creativa: The third step refers to the act of creation. The solution is chosen from a host of possibilities, implemented and then evaluated as to its effectiveness in meeting the desired goals and fulfilling the specified criteria. (4) Via Transfomativa: The fourth and final step asks the following questions of the engineer: Has the suffering in the world been reduced? Have the social injustices that pervade our global village been slightly ameliorated? Has the notion of a community of interests been expanded?” [36:47]

Catalano gives two case studies of how this design algorithm could be used. These examples are insightful since they allow us to see how an extended examination, in this case, from a 'morally deep' standpoint, might be undertaken when thinking about communities during the design process.

The first example is the design of a mechanical fruit harvester. Once implemented, this harvester is set to save a lot of money for the producer, however, it will also put the equivalent of 3600 workers out of work. Catalano asks: "What will become of them? Should we as the engineers who designed, built, tested, evaluated and delivered the harvester care? If we use the code of ethics described by countless engineering societies today, the answer would be no" [36:49]. Catalano suggests that the steps of Via Negativa and Via Transformativa are what allow engineers to act ethically from the standpoint of a morally deep world. Via Negativa allows “careful considerations of the societal and environmental implications of the device.” These two steps, which are additions to the traditional design process, allow products to be designed which are based more directly on morals, rather than on the wills of a contractor.

This design algorithm gives an good basis for an environmentally just design framework. The critical thinking that it requires allows designers to explore many more of the dimensions that a design contains. However, this process also requires a large amount of agency on the part of the engineer to be able to make recommendations on the aims of a project. In a corporate, industrial or military setting, the aims of a project can't necessarily always be changed to have an environmentally or socially just outcome. This is true of many engineering jobs – the largest employer of engineers in the United States is also the largest defence contractor, Lockheed Martin [20]. Therefore, providing engineers with these critical thinking skills prior to their entrance to the job market is necessary for them to make informed decisions on the outcomes of the projects they will be working on.

This section has provided an overview of several design processes and frameworks which have been developed with either the environment or justice in mind. Some of these, such as the life cycle assessment are incompatible with the ideals of environmental justice, whereas others, such as regenerative design and design for a morally deep world can be adapted to our purposes.

# An engineering design framework towards an environmentally just engineering

Thus far we have identified several facets that would contribute to an environmentally just engineering design process. These will be reiterated and expanded upon here in preparation for the framework.

Environmental justice is based on two main premises:

1. everyone should have the right and be able to live in a healthy environment, with access to enough environmental resources for a healthy life and;
2. that it is predominantly the poorest and least powerful people who are missing these conditions. [11]

Environmental justice requires a new outlook on design problems. Qualitative aspects are required to be given as much thought as quantitative aspects. Utilitarian and deterministic outlooks on technology are inappropriate here, as they diminish the importance of the societal consequences and implications of technology. Thinking about the qualitative aspects requires a certain creativity, and requires engineers to 'ask the right question'.

The new framework needs to be circular in nature, with many entry points for both designers and stakeholders. The circularity will be a reminder that a design does not end when it is delivered to a user, the consequences of any decisions have a continued effect even past a product's lifetime.

This framework will attempt to put in place a way of providing regenerative, multifaceted solutions, where technology is matched to need, where technology is an appropriate solution to a problem.

Stakeholders, especially those who are the least powerful, will be at the centre of the framework. Identifying these stakeholders, and involving them in the process will also be one of the more challenging aspects of the process.

While this process is not in any way meant to be prescriptive, these steps will help frame questions with which to approach a design problem.

### *Step 1: Defining Stakeholders*

This is the most important phase of the design process. Stakeholders should be an integral part of every following stage, and there should be opportunities for new stakeholders to join the process. Identifying target groups, or what Catalano calls “integral communities” within varying spheres of influence of the project will help designers realize who they are really designing for, and how far reaching the effects of technologies go. Recognizing that products have a wider effect than solely on the manufacturer, user and person who disposes of the product is extremely important. As tools, engineered devices can often put people out of work, or create situations that are culturally inappropriate that only people directly implicated would be able to effectively articulate. When designing for a specific user base, you are also designing for all of these people.

Borgmann describes a scene where an engineer has designed a new water distribution system in a village where previously people had to obtain their water by going to a well. The technological point of view is that carrying water from a well is merely a way of obtaining water. However, “Rebecca, going to the well, not only found water there but also companionship, news of the village, and her fiancé. These strands of her life were woven into a fabric technology has divided” [37:119]. Rebecca not only relied on the well for water, but also used it as time with her friends. This is one example of a way that stakeholders are affected when new technologies are introduced without their participation.

### *Step 2: Evaluation of need*

In this preliminary phase of the design process the designer/engineer identifies the problem that they are trying to solve. This should be done in complete collaboration with potential users, stakeholders, or any others who might be effected by this product.

Engineering solutions to ‘needs’ can only be effective if the need has been expressed by a stakeholder, especially when designing for other communities. Stories abound of engineering projects that have failed due to misrepresentation or misunderstanding of ‘need’ by a community.

Designing products to satisfy ‘wants’ should be looked at critically to ensure that fulfilling one set of stakeholder’s wants is not causing injustice or suffering to another group.

During this phase, some questions to keep in mind: (1) Are you asking the right question? (2) Are there non-technological solutions that might be more effective? (3) Who are the people who will benefit the most from the outcomes of this project?

### *Step 3: Define Criteria*

This phase takes the information from stakeholders in the previous step. Regular check-ins with stakeholders allow engineers and designers to ensure a consistent design with real requirements of stakeholders. During this phase, designers should be acting as facilitators with stakeholders, as in participatory action research, since stakeholders will know their needs better than a designer ever could. Looking at problems in different ways, from different perspectives will also provide a more holistic solution to problem.

As Lyle suggests, design criteria should be aggregating, not isolating—the theory of Regenerative Design suggests that our ever disaggregated world uses more energy than if it were aggregated. “In re-aggregating the parts, regenerative design has to be as concerned with the interactions among parts, the connections, as with the parts themselves” [35].

Lyle also recommends matching the level of technology to a project [35]. While this is often an economic consideration, designers should keep in mind the effects that economy has on providing both sustainable and just solutions.

The communities and people involved with manufacturing, distribution and disposal should be held with as much importance as users, something that is often missed through methodologies such as user-centred and cradle-to-cradle design.

Questions to keep in mind:
(1) What are the ethical, social, global & environmental considerations of each criteria? (2) Who stands to be affected, and who stands to benefit the most from the criteria that you are putting forth?

### *Step 4: Product/Solution development*

During product/solution development, designers should follow an iterative, community-centric, respectful process which aims to create products with heirloom value.

- *Iterative*: Throughout product development, the design criteria created at the last stage must be constantly revisited, and adapted as a solution is developed. A consistent re-evaluation with stakeholders is important–as a technology is developed it is possible that stakeholders find issue with the direction taken, even if it is consistent with the criteria. This should be carried out with models of participatory design, which provides multi-voiced solutions.
- *Community-centric:* Again, as with criteria definition, communities, especially those of the marginalized and overlooked, should be integral in this phase. Some questions to think about: (1) What will become of the workers? (2) What will become of their families? (3) Are there long-term effects that haven't yet been taken into consideration (usage of materials, etc.)? (4) Are there societal implications outside of the direct sphere of influence of the product you are developing?
- *Designing for longevity & heirloom creation:* End-of-life planning  becoming more and more fashionable. Designing for obsolescence, however, has a considerable economic benefit but obviously does not fit within our sustainability definition. Modular, user-serviceable products with options for re-manufacture should be prioritized. Moving "away from technology novelty and induced consumption, towards an aesthetic of well-cared for systems" [34],  i.e. creating products that obtain heirloom status makes more sense. This works to stem the constant push towards progress (and, hence, obsolescence), by not forcing consumers to seek out the next best thing, but rather to take care of the things they have.
- Respect for diversity: Acknowledging that a 'one-size-fits-all' solution is often non-optimal, especially for different communities in different contexts. A product designed for a farmer in Canada should not be assumed to also be optimal for a farmer elsewhere.

### *Step 5: Redeployment*

Prior steps should hopefully have provided a plan for reusing and refurbishing. Concepts such as 'Cradle-to-Cradle' design are useful here, as it provides a way to start from the beginning again. This can be the most effective when thought of from a 'sustainability' perspective, however, strategies here should also be worked out with stakeholders and others influenced in any way through the disposal or redeployment of the product.

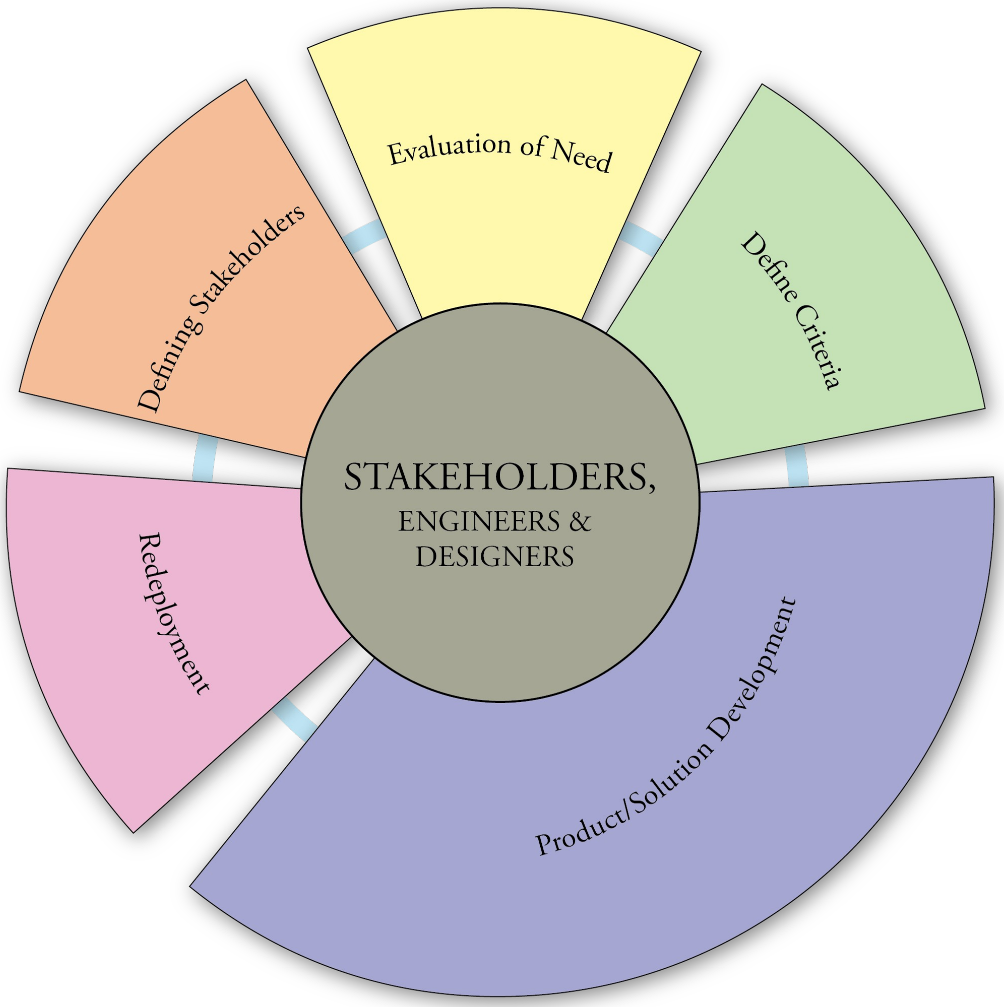


*Figure 5: A new design framework*

# Institutionalization

While the stakeholder design process proposed in the previous section is hopefully a good start when designing with environmental justice in mind, introducing this at an institutional level is important. Within a university, there are many barriers to integrating such a drastic paradigm shift within courses, especially in a discipline such as engineering which is often viewed as a highly technical.

However, this shift is becoming more and more necessary. As Reader has pointed out, engineering students are becoming increasingly unclear about their role in the community [38]. Helgesson, after working with Engineers without Borders suggests that “Many engineering students (and other students for that matter) and professional engineers are frustrated at being tied up with solving problems connected to people in the wealthy part of the world when, at the same time, they are becoming increasingly aware of the poverty that characterizes a majority of the inhabitants in the third world.” [39]. Adding social science material to the engineering curriculum is likely to become a trend in the near future. There are many ways for this to occur, which are explored below.

## Levels of involvement

VanderSteen, whose PhD thesis explores implementing humanitarian engineering concepts in the curriculum at Queens University, outlines five different levels of involvement that respondents gave him when asked about including humanitarian engineering topics in the engineering curriculum [40]. These are useful for examining different ways that justice based topics can be introduced to engineering students and how these might be perceived. The different levels of involvement become more challenging to implement as the list goes on.

1. *A good idea for those who are interested:* For example, a single elective, or a stream only for those people who express interest. This would be equivalent to the system currently in place at McGill where only one or two electives, which are not necessarily directly linked to engineering are available for students if they choose. If a special stream is provided, this could lead to the classification of the rest of the engineering program as being environmentally unjust.
2. *All students should be exposed:* This suggests a mandatory course to ensure all students are exposed to the issues of environmental justice. This would help prevent what VanderSteen calls the 'bore-hole' effect – where students become so immersed in their own area of studies that

they cannot relate to other disciplines. This is somewhat like currently happens at McGill, where a single course on ethics is presented to students.

3. *Broadening the curriculum:* Here, VanderSteen shows that including these topics throughout the curriculum are important to help create more holistic engineers with both objective and subjective tools to solve problems. There are some concerns that including justice-type issues within the engineering curriculum might dilute the important technical skills that engineers need to obtain. However, one respondent to VanderSteen suggests: “We want to be training problem solvers who can be able to identify the problems. You can always pick up the technical skills... I didn't learn any critical skills.”

4. *All curriculum should be built around social impact and community needs:* This would mean that all curriculum would be built on a foundation of environmental or social justice issues. This would help provide students with the skills to see that technology exists in a social context, where technologies always happen within social, political and economic contexts.

5. *Some unlearning is necessary before this curriculum can be effective:* This suggests that a curriculum with goals of social or environmental justice requires students to learn critical thinking skills (currently absent in the curriculum), to be able to see past solely technical solutions to problems: “The engineer's tendency to solve a problem with a technical solution must be counter-acted with the knowledge that the best solution to a problem may not have anything to do with technology” [40]. This also puts into question the currently dominant thinking that people who excel at the sciences and mathematics will be good engineers. This method also requires an unlearning of the dominant ideology of the current political, economic and corporate world order. One respondent to VanderSteen notes: “The engineers are the soldiers of industry. We are soldier/mercenaries. As long as the the captains of industry keep us marching in the directions we are, we can’t help but find ourselves drawn in that direction... I think that if people pursued engineering as people who wanted to live simply, then that is the kind of values that we need to stimulate” [40]. This would be the most challenging structure to implement, because engineering programs are generally administered by people who have succeeded within the current structure.

## Curriculum

The levels of involvement presented in the last section can be applied to different methods of implementation within the engineering curriculum. VanderSteen outlines several ways of including humanitarian engineering at the undergraduate level [40]. These are highly pertinent for engineering for environmental justice.

1. *A module to which all engineering students should be exposed:* Care should be taken to ensure that students take this course seriously, so as to avoid the impression that faculty are purely paying lip-service to important issues. On a personal level, this has been my experience when taking courses aimed at providing social issues to engineering students at McGill – for instance, I found the 'engineering ethics' course which I took in my first semester as simplistic and irrelevant.
2. *New, additional courses for those who want more:* This would require the curriculum to be more flexible to allow students to take courses outside of the rigid engineering structure. From personal experience, the McGill engineering faculty is not open to students taking classes outside of those specified for specific disciplines. Even though I was writing this thesis, on the subject of environmental justice, I was denied the opportunity to count an architecture course (which is still technically within the faculty of engineering) specifically about Sustainable Design. Currently as part of my degree. Professor Adamowski, in the faculty of bioresource engineering is preparing a course entitled "Engineering for Sustainable Development" which covers many aspects of environmental justice [41]. Having these options for every engineering student would help provide a broader education, however, by presenting these issues in a technological context, care must be taken to not create a mentality that technology can solve every problem.
3. *A broader curriculum:* Awareness of social and environmental issues are essential for good problem solving skills. Instead of solely filling student's minds with theory, it is just as important to provide skills for engineers to be able to facilitate their own learning in the future, as well as the critical thinking skills required to develop just design solutions.
4. *Adjusting existing courses:* Moving courses away from discussions about economics, business and industrialization, which do not have to necessarily be the focus of engineering, towards discussions of social and environmental justice. This requires co-operation from professors, as

they would be required to change the focus of their courses.

5. *Seminars:* As previously mentioned, ethics requires discussion to be appropriately adopted by students. Seminar sessions where students can discuss with their peers guided by a professor would be a good place to develop personal ethics of technology.
6. *A capstone project:* Design courses and projects often require closed solutions, especially when working on a project alongside graduate students or professors. I think this is one place where McGill is currently lacking – design projects, especially in electrical engineering tend to be focused either on industrial or academic applications, instead of finding projects applicable to communities around the university. Resources for participating in projects such as these are numerous, at McGill and Concordia there is the *Community University Research Exchange* (CURE) which provides a database of community research opportunities [42].

Points three to six should be carried out together for the most effective way of ensuring students internalize and are able to design according to environmental justice principles.

## Case Studies

Universities throughout Europe have recently started implementing environmental justice concepts within their curricula, to varying degrees of success.

The Royal Academy of Engineering in the UK are actively pushing for the principals of sustainable development to be included in universities. Government policies in the UK also acknowledge the principals of environmental justice [11].

Three example universities are looked at: The University of Surrey, Cambridge University and Delft University. These three have programs and policies in place which provide a broad depth of education to give engineers the skills to critically evaluate the projects that they work on. While none of the programs directly look at embedding environmental justice, the experiences that they had in institutionalizing  multidisciplinary programs in the engineering faculty can be learned from.

### *The University of Surrey*

The University of Surrey (UniS) has implemented a program where they acknowledge that "taught modules and teaching materials for engineering students should include not only technological analysis and economic evaluation, but also environmental and social considerations” [43]. This has led UniS to strive to encourage engineers to “act as social agents, rather than just technicians” [43]. This program also provides a place to explore the ethical implications of environmental impacts. The faculty have attempted to “encourage students to actively analyze and evaluate different ethical perspectives” [43]. Students can enrol in either MEng or BEng programs with a focus on sustainable development. The programs pertaining to sustainable development each have one quarter focused on the general concepts of sustainable development, while the other three-quarters relate this to the students' respective engineering disciplines. The ideas are introduced early in the course of study and are often revisited in future courses.

Two post-graduate programs were also created, the Engineering Doctorate (EngD) in Environmental Technology and the MSc in Environmental Strategies. The EngD provides students with week long taught modules at the university, with the rest of their time spent at a company or organization which is sponsoring the research. The immediate use of the research means that the EngD program “trains students to work on sustainable development issues in an academically rigorous manner but in an industrial environment” [43]. The MSc program emphasizes the multidisciplinary approach that is required of thinking about environmental issues by drawing on the expertise of other corners of the university, including sociology and philosophy.

IT-based sustainable development learning materials were created for the new programs, including case studies which illustrate how the concepts can be used.

This program is based very much on the Brundtland definition of sustainability [8]. While it does acknowledge the multidisciplinary aspects that designing for environmental justice requires, it lacks many of the concepts that we would have hoped.

### *Cambridge University*

Cambridge University currently offers an MPhil. in “Engineering for Sustainable Development”. The main challenge of a program which seeks to “develop 'T-shaped engineers'” with deep problem solving skills and broad problem-definition skills [44] is how to encourage “numeracy-oriented” graduates “to embrace the wider social, economic, environmental and policy issues ” [45] important in practising engineering in a sustainable manner. Undergraduate students are also introduced to the topics of sustainable development through a compulsory first year course - “the engineer and society”. First years are also exposed to exploring ethical issues, current events and research methods through the "Expositions" project. [46]

The process of embedding sustainable development into the curriculum took four academic years [16]. Their process started when the Royal Academy of Engineering (RAE) created a UK Chair in Engineering for Sustainable Development which created an elective course: "Engineering design for sustainable development". Slowly, sustainable development ideas were integrated into all engineering department divisions, through a 'sustainable development teaching group'.

Barriers to implementation included: perceived threats of integrity of subject material, with many professors nervous about the value of subjects based on qualitative knowledge; the rapid change in sustainability issues, compared to the relatively static scientific principles normally taught requires different pedagogical skills. The culture of the organization also presented itself as a barrier: most departments were discipline oriented, and so were not used to interacting with other departments within the academic culture of specialization; professors were sceptical of change as they were already short of time. There is also the perception from faculty that: "well it's a soft, general, non-mathematical topic and so it will be popular with the less bright students,"[46] which, obviously, is problematic and should be quelled at the source.

Through their process of initiating change, researchers at Cambridge acknowledge that a "bottom-up" approach was more effective, along with "top-down" support. Hopefully, this thesis will serve as a "bottom-up" incentive to start change at McGill [46].

### *Delft University*

Delft University in the Netherlands wishes graduates to be "able to contribute to the solutions of societal problems. One of the societal issues is sustainable development" [47]. Delft University adopted a sustainable development plan in 1998. This plan uses many strategies in order to better help engineering students integrate sustainable development concepts into their designs. First year students are required to take a course "Technology in sustainable development" whose ideas are integrated into all other core engineering courses. Interested students are able to specialize in sustainable development further in their studies and can graduate with this specialization [47].

Researchers at Delft University outlined a number of problems that can occur when attempting to integrate the concepts of sustainable development into a university engineering curriculum. Issues that they came across included the organizational, engineering and academic cultures. Academic culture was an issue as the interdisciplinary nature of sustainable development created a barrier with lecturers who perceived the traditionally divided disciplines within the university as being important for scientific progress. The quantitative nature of most engineering courses means that there is an ingrained culture to disregard things which cannot be enumerated within a design. There is also a trend to think about the sustainability of a design in the same way one would think about cost. However, this utilitarian view often reduces the problem of sustainability to one of measurable facets such as 'tons of carbon produced' or 'toxic emissions per unit', instead of taking a broader, more holistic view. Delft University explored ways of tackling these problems, and found that individual interaction with lecturers and involving students were the most effective ways of dealing with the potential resistance from lecturers when including the ideas of sustainability in their classes [47].

## McGill University

The Canadian Engineering Accreditation Board (CEAB) is followed by the faculty of engineering at McGill. While the CEAB does acknowledge that “some areas of study are essential in the education of an engineer” [48], it doesn't put a high weighting on the social or environmental aspects of technology since only one required class, “The impact of technology on society”, touches on these issues. At McGill, this class is often highly theoretical and is seen as irrelevant, as a 'bird course' or too non-technical for engineering students to care. This is in contrast to the Accreditation Board for Engineering and Technology (ABET), used mostly in the United States, whose criterion demands “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”[49]. ABET also require accredited programs to provide students with “an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”[49]. The ABET criterion puts emphasis on applying the principals of sustainability and social issues into designing technology. As it stands, the CEAB model is lacking this.

Since the CEAB requires that universities follow their recommendations in order to be accredited, very few engineering departments at McGill offer classes directly related to the concepts of sustainability or environmental justice. The department of chemical engineering has space for an independent Environmental Research Project where students can work on an environmental topic chosen by consultation between the student and departmental staff. The department of civil engineering, a discipline often more associated with dealing with societal issues has a concentration in 'Environmental Engineering'. Undergraduate civil engineering students are also required to take a class in 'Environmental Engineering'. Even within the civil engineering department there are few courses which touch on social issues.

With course loads already extremely high for engineers at McGill (many engineering curricula suggest 6 courses, or 18 credits, per semester for many degrees) it would be hard to add extra courses, especially if they do not directly help with accreditation. However, learning from the process at Delft and Cambridge, as a starting point, and following from VanderSteen [40], integrating these topics in many different courses, as well as providing places within design courses to undertake projects relating to environmental justice, would be beneficial for students.

### *Integration into design courses*

Throughout the McGill engineering degree, students take many courses with some design component. Most of these currently do not provide the space to think about the outside consequences of a project, and many projects require closed ended solutions which are often predetermined by the course supervisor. The competitive nature of design based classes doesn't foster a culture where students would feel comfortable questioning the nature of their designs as this might jeopardize their own or their team-mates grades. Creating a venue for looking at a project in many different ways, starting with looking at the integral communities or thinking about the array of stakeholders within design courses would be a good way for engineering students to be introduced to the concepts of environmental justice. Using a design process similar to the one detailed in the previous section might be a good starting point.

As VanderSteen points out, there is often no opportunity for students to explore their creativity, especially with time constraints of single semester designs: “One professor said that “creativity is a really tough thing to teach… We need to allow opportunities to explore it, but we don’t give [students] opportunity or time to think about creativity. We give them closed ended problems” [40]. Providing a venue for students to discuss and think about the projects they are undertaking from a societal perspective during the design course, with guidance from professors, may also help students start thinking outside the traditional engineering box.

Integration into design courses is a good starting point for implementing these concepts in the university. However, a continuous process of expansion into other courses is also suggested.

### *Ethics & Professional Practice*

Currently, engineering students are only required to take two one-credit classes on ethics and professional practice. As was argued before, this is not appropriate in creating engineering students with the critical thinking skills required to design with environmental justice in mind. Instead, creating a seminar type class where students are able to form their own definition of ethics and what it means to them. For instance, the current iteration of ARCH 515 – (Questioning) Sustainable Design with Professor Ronald Jelaco would be a great model to follow.

### *Institute for Sustainability in Engineering and Design*

McGill University is currently in the process of setting up a new institute focusing on the concepts of sustainability in engineering design (ISEAD). The goal of this institute is to position McGill as a leader in “teaching, training and research in the principles and practices of sustainability in engineering, design and technology development”[18]. In theory, this institute could fit within our environmental justice framework. However, the institute's mandate explicitly doesn't deal with the societal aspects of 'sustainability' [51] and so might end up being a hindrance to other measures that are more focused on environmental justice, especially if it opposes changing the dominant discourse of economics, business and industrialization within the classroom. Judging by the recent speaker series, it seems that ISEAD is actually promoting these concepts within the engineering faculty, in opposition with what VanderSteen suggests for effectively implementing justice based engineering programs in the university [40].

## Reflections & Conclusions

I started my engineering degree at McGill with the naive view that technology would solve all of the world's problems, and that I would graduate with all of the skills I needed to make the world a better place. I don't think I could consider myself a university graduate without leaving the university with some amount of cynicism and disenchantment towards my initial goals, the engineering curriculum, and the world that I am about plunge into. While I feel I am leaving the university with some amazing hard skills, and the knowledge that pretty much everything is possible as long as you stay up late enough, or try hard enough, I can't help but feel that there is something missing. This thesis was an attempt to bridge the gap between the direction I was hoping my education would take, and the actual place it took me. I am still trying to reconcile those two.

Engineers, I believe, have a great capacity to do good. Many engineers see themselves in this way too–serving the public good, affecting the quality of life of people around the world. While learning institutions provide many of the technical skills required by engineers, my experience has shown me that there was a serious lacking in discussions and knowledge about the people and the environments that are affected by the decisions that engineers make.

The concept of environmental justice takes into account both the environment and the people that are affected by the destruction of the environment, paying special attention to the fact that it is often the most marginalized whose lives are most afflicted. This concept was explored in relation to engineers' common outlooks on technology, especially those brought forth through traditional engineering education: technological determinism and utilitarianism.

Working with the concepts of environmental justice in mind, current design processes were examined, including frameworks for designing sustainable technology. While many of these incorporated some of the ideas put forth by environmental justice, there was often something missing. A new framework, that attempts to provide stakeholders with a central role in shaping the designs that stand to affect their lives, was proposed.

To be effective, this design framework must be implemented within design courses, along with other strategies to sensitize engineers to broader social, cultural, environmental and political issues. Broadening the engineering curriculum, basing courses on theories of social or environmental justice while providing seminar classes for discussion and well curated design projects which give students the resources and space they require to critically evaluate their actions would be great additions to the engineering program at McGill. However, creating a venue for students to look at their design projects from an environmental justice standpoint would be a welcome start, and would hopefully set the ball rolling for the future.

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