

The 22nd CIRP conference on Life Cycle Engineering

Industry-university collaboration in sustainable manufacturing.

Bernard J. Kornfeld^{a*}, Sami Kara^a

^a*Sustainable Manufacturing & Life Cycle Engineering Research Group*

School of Mechanical & Manufacturing Engineering, University of New South Wales, Sydney, 2052, Australia

* Corresponding author. Tel.: +61-407-600-268. E-mail address: bernard.kornfeld@unsw.edu.au

Abstract

A recurring theme in the economics of development is the tragedy of the commons – a situation in which independent actions guided by self-interest result in an outcome that is contrary to the overall and long-term interest of the many. Actors become “locked into a system that compels” them to strive for growth without limit within a finite system. Although some forward thinking companies recognize their role in transitioning to sustainable environmental practices, even the most well meaning may not have the capability to recognize and implement the most appropriate technology. Moreover, that technology might not yet exist in an industrial form and so such steps may well be speculative and risky for little or no return to the business. Polluting is asymmetrically favorable to industry and would rationally suggest inaction. A framework for industry-university partnership demonstrates how new and complex approaches to sustainable manufacturing can be implemented. Governments must support collaborative work with industrial norm entrepreneurs and academia to aid the introduction of technologies that are asymmetrically favorable to the interests of humanity at large and to future generations.

© 2015 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of The 22nd CIRP conference on Life Cycle Engineering

Keywords: Sustainable Manufacturing; Renewable Energy; Industry-University Collaboration

1. Introduction

Throughout the history of human endeavor, driven by rational but independent self-interest, what we call progress or development has almost invariably resulted in unfavorable circumstances for the natural environment. Even as early as the second millennium BCE, Crete and Greece, once covered in forests, were laid bare by the consumption of wood to smelt copper, to build instruments of warfare and to clear the land for agriculture [1]. Our technological and social ability to influence the environment has led to environmental degradation beyond our immediate locale and has resulted in impacts that are contrary to the interests of humanity at large and to those of future generations, in a cycle that is seemingly beyond our ability to control.

As governments struggle to introduce and maintain regulatory and policy structures at national and global levels, the problems continue unabated, leaving individuals and corporations to search for meaningful local solutions.

In this paper we discuss the problem of dealing with sustainability at a global level and argue that a localized approach is also necessary. We then explore how industry and academia can collaborate to achieve their common interests and develop sustainable manufacturing approaches. Finally, we conclude by examining key factors in the success of local collaborative efforts.

2. The Tragedy of the Commons

A recurring theme in the economics of development is the tragedy of the commons – a situation in which independent actions guided by self-interest result in an outcome that is contrary to the overall and long-term interest of the many. Actors become “locked into a system that compels” them to strive for growth without limit within a finite system [2]. In his seminal paper, Hardin noted that this problem is neither amenable to technical solutions nor to legislation but, rather, requires “a fundamental extension in morality” of the actors [2]. We will take a more temperate position and suggest that there are technical solutions to the problems of sustainable manufacturing but that these can only work within a co-evolutionary framework that includes all actors, strategies and practices.

Since the atmosphere and the oceans are immense and without physical borders, they may be jointly consumed or

polluted by many actors operating simultaneously and without regard for one another. They are, therefore, considered to be a public good or a global commons. As no one owns property rights, anyone is free to ignore the global effects of their local actions. As with the tragedy of the commons, each actor stands to gain unlimited incremental utility from production, while the incremental negative utility from polluting is infinitesimal. Moreover, the negative effects are often separated by time and space from the positive benefits of production and growth. Markets have traditionally found environmental impacts difficult to quantify and have therefore treated them as externalities, meaning that actors could ignore environmental impacts, which were instead borne by the many or the future. Therefore such problems have been assumed to be cases of market failure, compelling governments to seek to introduce regulatory frameworks and economic policy instruments to encourage or compel industries to change their behavior.

Governments however find themselves trapped in a deadlock of ‘sustainability’ attempting to satisfice (not maximize) between competing outcomes that may vary from country to country and state to state. This deadlock can be better understood by examining the concept of sustainable development, as defined by the World Commission on Environment and Development:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of ‘needs’, in particular the essential needs of the world’s poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs.” [3].

Although needs form a central tenet to this definition, they are inherently incommensurable and therefore problematic politically. As an example, the Australian Department of the Environment [4] includes the following in its indicators of sustainability:

- “social and human capital (skills and education; health; employment; security; institutions, governance and community engagement)

- natural capital (climate and atmosphere; land, ecosystems and biodiversity; natural resources; water; waste)
- economic capital (wealth and income; housing; transport and infrastructure; productivity and innovation)."

Balancing these disparate needs requires considerable political will (which is difficult to muster and more difficult to maintain) or strong policy frameworks (which are difficult to negotiate, especially across borders). Moreover, on a global level, this is a multiplayer game of incomplete information in which countries argue national interests and industries argue for special consideration. Many countries are therefore unwilling to take the first steps towards sustainable action.

This is exemplified by the responses of the 193 UN member states to the United Nations Framework Convention on Climate Change (UNFCCC), which have been quite varied and it is undeniable that many nations are unlikely to meet their emissions reduction targets. Furthermore, such targets are very difficult to measure and administer, indeed some latest reductions may simply be artifacts of the recent economic downturn.

While global unity is important when dealing with global imperatives, it is clear that this process is long and difficult. For example, although the UNFCCC became effective 21 March 1994, it is still not entirely effective. Moreover, economic and regulatory interventions alone cannot bring about industrial change. Major system change implies that government policy, business strategy, technology, and user practices interact positively to bring about favorable technological substitution as illustrated in figure 1 [5,6].

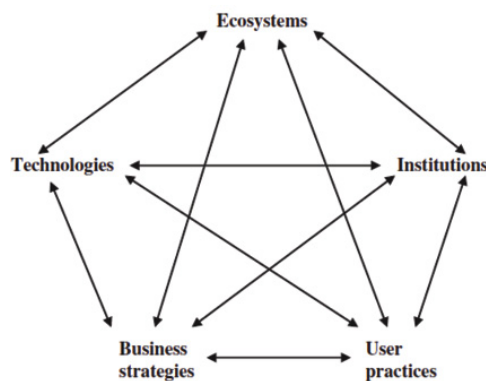


Figure 1: Co-evolutionary Framework [5]

The literature on life-cycle development proposes that major technological changes emerge over time, as dominant design modes develop and supplant the plethora of early variants [see for example 7]. Deisendorf's [8] survey of energy technologies and their stage of maturity suggests that we are yet to arrive at stable, dominant design paradigms for many alternative and renewable energy sources.

Similarly, technology internalization occurs over time. Norms emerge amongst early adopters and gradually gain legitimacy, before becoming commonplace within an organization, as illustrated in figures 2 and 3 [9].

Any model for transition to sustainable energy systems must therefore consider the dynamic roles of various actors and determine an appropriate entry point for initial focus. For example, state and local governments may better positioned than their federal counterparts to address climate change imperatives, inasmuch as they directly control critical infrastructure such as power generation. They may therefore act locally by changing their pattern of infrastructure investment to include or favor renewable energy sources. Similarly, we must identify individual companies that can create an initial foothold for sustainable technologies and nurture relationships with them until a tipping point is reached that will bring about an institutionalization of the new technology.

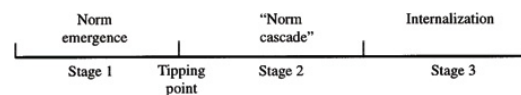


Figure 2: Norming Lifecycle [9]

	Stage 1 Norm emergence	Stage 2 Norm cascade	Stage 3 Internalization
Actors	Norm entrepreneurs with organizational platforms	States, international organizations, networks	Law, professions, bureaucracy
Motives	Altruism, empathy, ideational, commitment	Legitimacy, reputation, esteem	Conformity
Dominant mechanisms	Persuasion	Socialization, institutionalization, demonstration	Habit, institutionalization

Figure 3: Norming Lifecycle [9]

3. Co-evolutionary Development

The success of many organizations comes about through finding solutions that are effective and then reducing risk by minimizing or actively resisting change. Such an approach can also lead to path dependence and bounded rationality in decision-making, which can make it difficult for organizations to find new solutions even when there is an imperative to do so. Moreover, the social, cultural, economic, environmental, and organizational needs of society are entangled within the issue of sustainable development. Such a problem is therefore unlikely to be amenable only to technical solutions, nor is a fundamental extension of morality likely to suffice.

If organizations are to pursue change for the sake of sustainable development, they must recognize that solutions will not necessarily arise from the same thought processes and

practices that created the current business state. Co-evolutionary economics suggests that a pluralist approach, which considers societal, institutional and environmental viewpoints and knowledge, is needed. Furthermore, the other actors will also benefit from such interplay of expertise. For example, it is not possible for universities to fully comprehend the practical needs of industry, if it is not working alongside of it. Also, societal needs will be better understood by industry and be more tempered if the public is engaged in the development of solutions.

While governments seek to transition to a sustainable, low carbon economy at global and national levels through legislation and policy, they also have a role to play at the local and micro levels. Since industry may be expert at generating incremental innovation within their framework of success, the radical innovations required to shift norms are unlikely to be considered. What academia considers novel and worthy of study translates as unknown and risky in the minds of industrialists. Yet, based on the norming cycle, it is imperative that we begin here in order to bring about the requisite knowledge and demonstrated outcomes to create legitimacy and ultimate norming of new technologies. Thus governments have a role in supporting or insulating niches that can provide places collaborative learning, development and socialization of early innovations in this domain.

4. Industry-University Collaboration

Not all organizations are amenable to such early stage interactions. Our collaborative experience suggests that a combination of actor attributes and organizational platforms must all be present for successful early stage collaboration as set out in Figure 4.

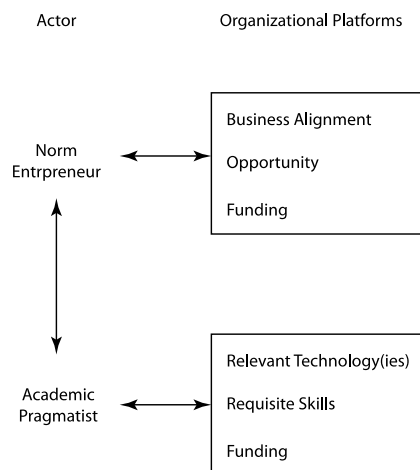


Figure 4: Actor – Organizational Prerequisites

Norm entrepreneurs are individuals who have both the insight and organizational credibility to introduce and promote new technologies within an organization. However, in order to function successfully as a norm entrepreneur, certain organizational platforms must coexist. Firstly, the business within which they operate must be aligned or primed to receive new technologies. Even the most passionate norm entrepreneur will struggle to persuade an organization to try a technology that might place its principles or profitability at significant risk. Those organizations that have sustainability policies, particularly where targets also exist, will often be more amenable to change than those without a policy. Rogers points out that ‘innovations do not sell themselves’ but also require communication channels, time and a social system [10] to foster them.

Even within a receptive organization, technological change may be opportunistic. Opportunities are the result of a confluence of organizational problems (i) that are amenable to accessible technologies (ii) that are of interest to available academics (iii) and which occur at a time when funding and resources are available. Timing and agility to respond are therefore important features of a norm entrepreneur’s success.

The critical axis of Figure 4 is the collaborative relationship between the norm entrepreneur and an academic pragmatist. Industry often considers those technologies that are novel or academically interesting as being too risky to invest their time and money, whereas technology implementation may be trivial or uninteresting to many academics. The actors must collaborate to create circumstances that allow new technology to be trialed and observed in order to demonstrate its compatibility and advantage in the organization [10]. For example, in our research into on-site energy generation [11] we have seen how a mature technology (in our case, Combined Heat and Power or CHP) that has real and immediate impact on business can also provide an important platform for novel research. In this particular case, the technology provides invaluable data at high resolution and poses a number of industrially and academically important questions. For example, how can a manufacturing facility dynamically manage supply across multiple energy sources (such as grid, CHP and photovoltaics) the cost, quality and availability of which will vary throughout the day, in order to most efficiently and effectively meet a dynamic demand profile?

Like the norm entrepreneur, the academic pragmatist is a key actor in norm emergence. This actor must be able to access relevant technologies and requisite skills and bring those to bear to solve industrial issues in a timely and practical manner. Whereas the norm entrepreneur must create credibility within the organization and understand the opportunities for innovation, the academic pragmatist must be able to create academic credibility and demonstrate the value of novel approaches to the organization. Since these opportunities may be speculative and transient, it is likely that this actor will need to work with many organizations in order to deliver a small number of successful technology transfers.

The norm entrepreneur - academic pragmatist axis represents the vital link between university and industry, through which ideas and data flow. In our experience, however, such partnerships form by trial and error and build over time through a process of (i) searching, (ii) trust building and (iii) consolidation.

- i. Searching can be a very inefficient processes as organizations attempt to match the needs of localized problems to a knowledge pool that is global and diverse. However we believe that this could be augmented through the use of network-facilitating websites to bring researchers and norm entrepreneurs together and also by encouraging businesses to act as open technology demonstration sites to other businesses and researchers.
- ii. Trust plays an important role in the formation and maintenance of the relationship and the link may be tenuous as actors change roles or organizational priorities change. Moreover, the role of an internal entrepreneur is often not recognized or valued in an organization and may be stressed by failed projects. Project scope should thus be kept tight to minimize risk, while government funding should target transfer and future practice sharing to foster collaboration.
- iii. Consolidation implies letting go, so that entrepreneurial activity becomes business as usual. For norm emergence to cascade and become internalized, norm entrepreneurs must develop influencing skills and networks, but most importantly must be able to walk away from their investment in order that it may flourish.

5. Conclusion

The environment is a global commons and the consequences of our industrial activities today affect the many and the future. Unlike other areas of industrial development, where individuals and organizations stand to gain asymmetric benefits through research and development, in the case of the environment, the asymmetry generally runs in the opposite direction and thus typically favors inaction by business.

Although some forward thinking organizations recognize their role in transitioning to sustainable environmental practices, even the most well-meaning may not have the capability to recognize and implement the most appropriate technology on their own. Moreover, that technology might not yet exist in an industrial form and so such steps may well be speculative and risky for little or no return to the business.

Governments can and do play a role by implementing national legislation and policy, but these will be ineffectual if the requisite technologies do not yet exist in a form that is readily implementable in industrial settings or seen to be risky. Academia wants to support industry, but without industry investment their work is left unfunded. Therefore, it is important that governments aid and publicize collaborative

sustainability R&D efforts where the outcomes benefit the many and the future.

Large strides can be made at the micro level, given entrepreneurial actors, willing researchers and directed government support. We therefore recommend that governments include support for norm emergence activities to their policy frameworks.

6. References

- [1] Perlin, J. *A forest journey*. Woodstock, VT: The Countryman Press, 2005.
- [2] Hardin, G. (1968) *The Tragedy of the Commons*. Science, New Series. 162, 3859, 1243–1248.
- [3] *Our common future*. Oxford New York: Oxford University Press, 1987.
- [4] Environment.gov.au, 'Sustainability Indicators for Australia', 2015. [Online]. Available: <http://www.environment.gov.au/topics/sustainable-communities/measuring-sustainability/sustainability-indicators>. [Accessed: 14- Jan - 2015].
- [5] Foxon, T.J. (2011) *A coevolutionary framework for analysing a transition to a sustainable low carbon economy*. Ecological Economics. 70, 2258–2267.
- [6] Norgaard, R. (1994) *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future*. Routledge, London and New York.
- [7] Utterback, J. and Abernathy, W. (1975) *A dynamic model of process and product innovation*, Omega, 3, 6, 639–656.
- [8] Diesendorf, M. (2011) *Redesigning Energy Systems*. In, The Oxford Handbook of Climate Change and Society. Oxford University Press. Oxford.
- [9] Finnemore, M. and Sikkink, K. (1998) *International Norm Dynamics and Political Change*. International Organization, 52, 887–917.
- [10] Rogers, E. (1983) *Diffusion of innovations*. New York: Free Press.
- [11] Ghadimi, P., Kara, S. and Kornfeld, B.J. (2015) *Real-Time Operation Management of CHP System in Manufacturing Industry*. Modern Applied Science, 9, 2, 158–174.