Policy Strategies to Catalyze the Energy Technology Innovation System in Wisconsin and the United States

By Gary Radloff
Wisconsin Energy Institute
Director of Midwest Energy Policy Analysis

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Background on Research Award:

The Office of Sustainability is charged with promoting sustainability research and education on the UW–Madison campus and creating intersections between UW–Madison campus operations and the research and education enterprises that promote sustainability. The SIRE awards program was created to support this mission and to stimulate innovation in research and education related to sustainability on the UW–Madison campus. This intent is coupled directly with the campus objective of responsible stewardship of resources, as articulated in the Campus Strategic Framework. The 2014 SIRE-RE seed award focus is Climate Change.

Abstract: A robust energy technology innovation system can help advance United States policy goals to reduce greenhouse gases and develop sustainable clean energy solutions. Current national and state policy may not be adequate to achieve these policy goals. The proposed research will include a robust survey of existing policies impacting the energy technology innovation system. There is valuable existing research documenting the seven functions of completing a "successful" energy technology innovation system including entrepreneurial activities, knowledge development (learning), knowledge diffusion through networks, guidance of the search (sometimes including policy goals and targets), market formation, resource mobilization, and creation of legitimacy (counteraction to change). This project will utilize the seven functions of a successful energy technology innovation system as a way to guide targeted policy and systems thinking to address the overall challenge of advancing energy

technology faster and smarter in these times. The research project will also evaluate energy technology innovation in the context of an evolution that is occurring in the electric utility sector. In the research, one hypothesis is whether electric utilities are a unique class of the eco-system in which energy technology innovation must occur? Finally, consideration will be given to looking at the existing electric utility, industry as a whole, new energy company entrants, all in the context of whether special boundary conditions exists with the intersection of the "seven functions of a successful energy technology innovation system."

The author is responsible for any errors or omissions in the report. All opinions in the report are solely the authors. For more information contact the primary investigator of this report, Gary Radloff at the address or numbers below:

Gary Radloff
Director of Midwest Energy Policy Analysis
Wisconsin Energy Institute
2123 Wisconsin Energy Institute
1552 University Avenue
Madison, WI 53726

(O) 608-890-3449
(M) 608-347-9681

gary.radloff@wisc.edu

http://energy.wisc.edu

Table of Contents: *Policy Strategies to Catalyze the Energy Technology Innovation System in Wisconsin and the U.S.*

Executive Summary

(1.0) Introduction to the Energy Technology Innovation System (ETIS)

(1.1) Sectors Are Important and Can Be Different

(1.2) Joining Up Policy to Advance Energy Technology Innovation

(1.3) The Seven Functions of the Energy Technology Innovation System

(1.4) Logic for Technology Innovation

(1.5) Barriers to Clean Energy Technology Innovation and the “Carbon Lock-In” Policy Paradox

(1.6) International Agencies Call on Expediting Energy Technology Innovation System to Achieve a Clean Energy Economy

(2.0) Are Recent Solar Market and Wind Market Trends in the United States a Harbinger of Energy Change?

(2.1) Electrical Utility Industry Other Changes on the Horizon

(2.2) Problems with the Existing Electric Utility Model Constrain Innovation

(2.3) Utilities May Be Unique Actors in the Energy Technology Innovation Ecosystem

(2.4) It Will Take A Sustainability Ethos to Make the Energy Sector Sustainable

(2.5) The Dynamic Distribution System Business Model

(2.6) Public Utility and the Low-Carbon Future

(2.7) Networks Are the Engines of Innovation

(3.0) Case Study: Biogas in Germany v. Biogas in Wisconsin
A Case of How the ETIS Can Achieve Success Compared to How It Is Missing in Wisconsin

(3.1) Case Study: Midwest Energy Research Consortium (M-WERC)
Poised for Innovation Leadership in the Midwest

(4.0) Sustainable Innovation Strategy Units and Sustainable Innovation Incubators

(4.1) Policy Windows and Niche Markets

(4.2) Public-Private Partnerships

(4.3) Forms of Stakeholder Participation

(4.4) Integrated Mix of Policy Instruments

(4.5) Accelerating Climate Policies Through Innovation Advances

(4.6) Policy Menu

(4.7) Energy Technology Innovation Advisory Council (aka Sustainable Innovation Strategy Units)

(4.7) Conclusion

(5.0) Appendix

(6.0) Bibliography

Executive Summary

Committing to a continuous energy technology innovation cycle in the United States, and more specifically in Wisconsin, could stimulate economic growth and job creation, transform the electric power sector into a more efficient and resilient system, and promote a clean, healthy environment. Our society can have it all with a strong commitment to evolve and adapt our energy system and this paper will discuss how a sustainable energy technology innovation system can help guide the way through challenges and make them economic opportunities. The challenge is much deeper than simply increasing our use of clean energy and improving energy efficiency – though these are very important. Even energy industry skeptics are acknowledging that change in their sector is occurring, or at least coming.[1] Several key questions are posed in this paper to consider:

- How disruptive is current energy sector change, and is it a revolutionary or evolutionary change?
- Is energy-sector change systemic and can only a systems change create a sustainable energy future?
- Can continuous energy technology innovation be built into the system?
- Finally, from an environmental needs and public health perspective, is the energy system change moving fast enough to address global societal sustainability?

The energy technology innovation system (ETIS) is used in this paper as framework for evaluation and analysis of recent energy-sector trends and policy effectiveness in advancing this economic opportunity. "The ETIS is a systematic perspective on innovation comprising all aspects of energy transformations (supply and demand); all stages of the technology development cycle; and all the major innovation processes, feedbacks, actors, institutions, and networks."[2] The electric utility energy sector is scrutinized to understand whether existing infrastructure, business models, and networks need to change to better advance the ETIS. Looking at the robust research on ETIS, especially in Europe, the Wisconsin energy technology ecosystem is evaluated, specifically the public-private partnership of the Midwest Energy Research Consortium (M-WERC) and the technology of biogas plants operated by anaerobic digesters, in attempt to measure challenges and opportunities for the state. Finally, a menu of policy options is suggested for advancing U.S. and Wisconsin energy innovation.

Robust research documents the seven functions of completing a "successful" ETIS implementation. The seven ETIS functions are:

- entrepreneurial activities,
- knowledge development (learning),

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[1] Lundin, B.V., (2015). Majority of energy execs reporting changes to their business model. May

[2] Gallagher, K.S., Grubler, A., Kuhl, L., Nemet, G. and Wilson, C. (2012). The Energy Technology Innovation System. Annual Review Environmental Resources 2012. 37:137-62.

- knowledge diffusion through networks,
- guidance of the search (sometimes including policy goals and targets),
- market formation,
- resource mobilization,
- and creation of legitimacy (counteraction to change). [3]

Research, particularly throughout Europe, documents that countries and states that have fully implemented the ETIS seven functions have greater success in energy technology innovation development, and typically, broader and more rapid deployment. The paper fully discusses the seven functions of the ETIS and utilizes them as a critical analytical tool and measure.

The recent rapid rise of distributed energy resources (DERs) is disrupting the energy market place – possibly in revolutionary ways. These disruptive DERs include end-use energy efficiency (EE), demand response (DR); distributed generation (DG) sources such as combined heat and power (CHP), solar photovoltaic (PV), wind, and distributed energy storage. The initial driver of what some term “creative destruction” in the energy space was the dramatic fall in price of solar PV in recent years and now the trailing action of falling prices for energy storage. Further market growth of DERs could result in “creative destruction” of legacy energy incumbents because the current value of regulated utility assets, as well as the need for future assets, undermines the traditional financial model of the existing sector. The regulated electric utility is already suffering a crippling blow from energy demand decline. (see Section 2.1).

For regulated utilities some of the existing laws, administrative rules, and rate-setting policies from public utility commissions (PUCs) may constrain their latitude to invest in research and development (R&D) and advance energy technology innovation. The utility business model has not changed a lot in during 100 years of regulation, a system that encourage them to invest in large capital-intensive equipment, mostly energy generation and transmission equipment, and get a return on their investment set by the PUC. To put it simply, utilities do not necessarily profit from energy technology innovation and are happy with the status quo business model. Yet, as more distributed generation options advance and energy efficiency advances lessen overall electricity demand, some utilities may be more receptive to adapting their business model. Promoting an energy technology innovation system agenda might present utilities with new pathways to new services and products.

This report highlights how actors in the existing electric utility structure, especially government-regulated monopolies, may play a unique role in the energy technology innovation system (see Section 2.3). Further, the policy paradox created by “Carbon Lock-in” (see Section 1.5) in addition to the current utility regulatory constraints on how the energy market functions, specifically some states restrictions on third-party companies competing in energy markets, means

[3] Negro, S. and Hekkert, M. Technology Analysis and Strategic Management.

that without reforms utilities are more likely to be barriers to energy innovation than part of the solution. That can be changed by either regulatory flexibility (allowing utilities to invest more in R&D and play a bigger role in innovation research); new utility business models that allow utilities and a broader range of energy businesses to compete in the marketplace (See Section 2.5); or complete market deregulation and elimination of government-sanctioned energy monopolies. Options are available to let utilities be a part of the solution, but only if they are willing to adapt to and evolve toward a more distributed system and a more transparent open competitive energy market.

Another way for utilities to provide creative market solutions in place of energy technology innovation barriers is in the legal and philosophical move back to the original concept of the "public utility." (see Section 2.6). This core idea is that a public utility is an "undertaking" with a robust public dialogue shaping a rethinking of public goals and private industry and moving toward a common sustainable solution. Our society has somehow drifted away from the original vision of a public utility and ended up with a dominant conceptualization of an "investor owned utility" (IOU) that is a manifestation of the public utility, according to the author William Boyd. Perhaps it is too idealistic in this cynical day and age of polarized politics and profits over people, environment, and health, but Boyd states that the utility can become an "instrument of the commonwealth." Specifically, the utility could remain a business with profits, but refocus its mission on sustainability and the public good. [4]

What are some of the key requirements for a future energy marketplace?

- Unlock markets to allow for greater experimentation
- Spur innovation (a continuous cycle)
- Harness competition (welcome new energy partners/Third Parties)
- Reward efficiency (short-term use of performance-based rates)
- Reward clean technology (short-term use of performance-based rates)
- Allow greater R&D investment (potentially off the regulated utility existing rate cases)
- Plan for change (Advanced Planning and greater regulatory flexibility)

Opportunities abound for the United States, and the State of Wisconsin, to be leaders in energy technology innovation, if the barriers can be over come and the research and entrepreneurial spirit unleashed. In two cases studies described in the paper, the technology of anaerobic digesters is identified as a strong market niche for Wisconsin, with the organization of the Midwest Energy Research Consortium as a likely leader for catalyzing energy technology innovation in the region. If all seven functions of the ETIS were put on full bore for research and market penetration of anaerobic digesters, Wisconsin could replicate (on a

[4] Boyd, William. (2014) Public Utility and the Low-Carbon Future. UCLA Law Review. 61 UCLA L. Rev. 1614 (2014).

smaller scale) the success story of Germany where around 9,000 biogas plants produce clean energy from waste. (see Section 3.0). In Wisconsin and the Midwest region, M-WERC has already shown great leadership in advancing the energy-power-control (E-P-C) economic sector and promoting research leadership advancing energy technology innovation. The ETIS functions for which M-WERC could further strengthen its hand include a revitalization of its policy committee to play a greater role in *guidance of the search* (F4) and *advocacy coalition* (F7) that specifically includes advancing government policy in market push and pull, and providing direction in energy technology innovation with the best opportunities for moving into the marketplace. A model for the Midwest region includes the concept of "sustainable innovation policy" that links new policy ideas and creative partnerships of "actors" in the ETIS pushing for continuous energy technology innovation. M-WERC can build off its founding of the Energy Innovation Center and its recently launched WERCBench Labs program to better understand not only which technologies and innovations have the best chance of success, but also start-up companies and incumbent E-P-C industry leaders who might partner for sustainable energy solutions. The policy strategy proposed in Europe, called sustainable innovation strategy units, create a public-private advisory group to guide government programs and policy that help energy technology innovation companies through the valley of death – and provide the economic bridge so that new technologies and new start up companies have at least a fighting chance of getting to the energy marketplace (see Section 4.0 through 4.6). It is suggested in this paper that the organization be rebranded as the Energy Technology Innovation Advisory Council and its potential organizational focus is discussed in Section 4.7.

The overall goal is to establish a more adaptive policy making approach in order to respond quickly to future energy technology innovation and allow of policy learning going forward. One important requirement for a sustainable innovation policy strategy is recognizing that a balance must exist between the fundamental economic growth imperative driving most innovation policy and a model of growth that limits negative environmental and societal impacts. Combining the critical functions of the ETIS and the sustainable innovation policy thinking, a process of driving new technology towards "niche markets" will allow for the nurturing of the new technology to reduce costs and improve performance as it prepares to compete with existing technologies. In building this sustainable innovation policy regime to include a strategic clustering of opportunities linking technology innovation and policy, the role of robust public-private partnerships is considered a critical dimension. Finally, this paper suggests a methodology for creating an integrated mix of policy to advance a continuous innovation cycle. [5] The end of this paper includes a policy menu although specific steps or combinations are not endorsed and each state should select what best works for their needs.

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[5] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

These are some of the key findings in this paper:

a) The ETIS provides a framework and lessons for understand how to achieve a continuous innovation cycle. A discussion of two cases studies, one with a technology of biogas development in Wisconsin and another with the organization the Midwest Energy Research Consortium, shows how using the seven functions of ETIS can result in the success and failure of technology advancement.

b) A systems approach is needed for innovation and policy. Details in the papers show a systems approach to policy design and continuous evaluation to advance the innovation cycle.

c) A sustainable innovation policy strategy is recommended for U.S. and Wisconsin. Lessons from Europe can assist in developing a framework for policy development to address sustainable innovation steps.

d) The Midwest Energy Research Consortium is a key player in this innovation eco-system, specifically for Wisconsin and the Midwest.

e) Wisconsin and Midwest states should utilize the model of linking innovation centers and public-private partnerships through the sustainable innovation strategy unit (see Section 4.2) and rebranded for Wisconsin as the Energy Technology Innovation Advisory Council.

Here are some suggested action steps for Wisconsin going forward:

1) Convene a stakeholder meeting to discuss the Wisconsin idea for the energy system of the future.
2) Convene a working group discussion on the policy framework necessary to advance a continuous energy innovation cycle in the Midwest region.
3) Continue to identify gaps in the path of energy innovation ideas to the marketplace and how policy along with organizational partnerships can fill the gaps.
4) Continue to identify areas of research focus in energy technology innovation and energy policy.

(1.0) Introduction to the Energy Technology Innovation System

United States and Wisconsin policymakers, business leaders, and citizens in general should care about innovation because it is the principal source of economic growth[6] and can be the link to new job opportunities in the state. Innovation systems provide a framework for developing new technologies creating these economic opportunities. Bengt-Ake Lundvall in "National Innovation Systems: Towards a Theory of Innovation and Interactive Learning" defines an innovation system as: "the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge."[7] Steps in this process include basic laboratory research, development of market ideas, learning and information exchange, and commercializing new technology.

There are three main elements of technology innovation systems to consider when reviewing impacts. These three elements are:

1) **Actors** (and their competencies), including firms, users, suppliers, investors, and other organizations.
2) **Networks**, defined as the channels for the transfer of tacit and explicit knowledge.
3) **Institutions**, being the entities that govern and dictate the environment within which all actors operate.

When advancing energy technology innovation it is important to clarify that it is necessary to have more than just a better R&D pipeline. Robust research documents the seven functions of completing a "successful" energy technology innovation system including:

- entrepreneurial activities,
- knowledge development (learning),
- knowledge diffusion through networks,
- guidance of the search (sometimes including policy goals and targets),
- market formation,
- resource mobilization, and
- creation of legitimacy (counteraction to change).

Many actors, networks and institutions are simultaneously active in the energy technology innovation systems and will ultimately play a critical roles in taking clean energy technologies to full market success. This research project will utilize

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[6] Mokyr, J., (2002). Technologies and institutions. In: Steil, B., Victor, D., Nelson, R. (Eds), Technology Innovation and Economic Performance. Princeton University Press, Princeton, NJ.

[7] Lundvall, B-A., (1992) National Innovation Systems: Towards a theory of innovation and interactive learning. Pinter, London. And Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D., (2005). UK innovation systems for new and renewable energy technologies: drivers, barriers, and system failures. Energy Policy 33(6), 2123-2137.

the seven functions of a successful energy technology innovation system as a way to guide targeted policy and systems thinking to address the overall challenge of advancing energy technology more quickly and effectively in these challenging times.

Looking at the seven functions has the potential to enhance our understanding of the process of, and drivers behind, the emergence and transformation of energy innovation systems. Many believe that using this innovation system framework for analysis, especially in the context of sustainability transitions (such as is occurring in the energy technology system), allows for policymakers to identify system weakness.[8] More specifically, using these analysis tools can help us to identify policy interventions that could solve a problem in the technology innovation system or influence technology success.

Some new thinking may be necessary when considering the modern interface of the innovation system and policy. Historically, the innovation technology system perspective has been characterized supportive policy in a traditional linear model creating market push and pull – meaning a policy that creates a technology push into the market place or a policy that creates a demand pull on the market. Pull policies are incentives or regulations that are intended to attract private and/or public sector activity in developing "projects." Pull policies are often referred to as 'market makers.' "The process of changing from fossil fuel-based energy systems to more sustainable ones can be seen as a long-term process of technology change, the analysis of which is the prime focus of innovation studies. When observing the policy-making front however, it appears that innovation and sustainability issues have, until quite recently, been addressed through separate policy regimes that are based on distinct rationales for policy intervention."[9] Another dimension of this traditional innovation technology system perspective is that in cultivating R&D there are steps of basic research, applied research, and product development and diffusion.

Renewable energy solutions may differ from recent thinking about innovation technology systems when short-term government may appear to be 'picking winners' with current technology while maintaining an environment for adaptive innovation. That is why some policy solutions, like advanced renewable tariffs, may be more attractive to create a catalyst for investment while trying to avoid technology solution lock-in. Systems theory has been used much longer in the natural sciences than the social sciences, but a combination with technology

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[8] Jacobsson, S., Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. Environmental Innovation and Societal Transitions 1 (1), 41-57.

[9] Al-Saleh, Yasser M. (2010). Systems of innovation as a conceptual framework for studying the emergence of national renewable energy industries. World Journal of Science, Technology and Sustainable Development, Vol. 7, No. 4. P. 309-334.

innovation systems may strengthen this analytical approach.[10] With today's focus on job creation and revenue growth these innovation systems are important to advancing technology.

(1.1) Sectors Are Important and Can Be Different

Another area where some differentiation will help in understanding innovation systems is the recognition that specific sectors are important and are different from each other. For example, the innovation process may differ greatly from sector-to-sector in terms of development, rate of technology change, linkages with the sector and the related access to knowledge, as well as the broader areas of organizational structures and institutional factors. Some sectors are characterized by rapid change and radical innovations, other sectors by smaller incremental changes. It is for this reason that related analysis such as carbon lock-in in the energy sector and the unique subsystem of energy electric utilities will be considered in this paper.

Further, using the energy technology innovation system framework could help in providing a methodology for the analysis and comparison of sectors in terms of sector transformations, structure, and boundaries. With the help of the energy technology innovation system framework it is possible to consider the issue of systemic failures. Systemic failures can be typically grouped into the following broad categories: infrastructural, (related to actors and artifacts): interaction, (related to networks): and capabilities, (related to actors). On the more positive side, using the energy technology innovation system framework, it is also possible to identify the system builders necessary for success. "In effect, system builders comprise a set of actors who are technically, politically, and/or financially powerful enough to strongly influence the development and diffusion process of technologies." Finally, there is value in considering a subcategory of evolutionary theory. The evolutionary process involves actors not solely driven by profit. Evolutionary economics considers variation and selection to be central mechanisms for explaining innovation and technology development.[11]

(1.2) Joining Up Policy to Advance Energy Technology Innovation

While this technology innovation analysis framework has a more limited application in environmental innovation, a smaller body of knowledge is emerging in this area. When looking at environmental innovation, and in this case a sustainable transition in the energy technology system, it is important to recognize the diversity of the technologies and how the challenges are different

[10] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.
[11] Al-Saleh, Yasser M. (2010). Systems of innovation as a conceptual framework for study the emergence of national renewable energy industries. World Journal of Science, Technology and Sustainable Development, Vol. 7, No. 4. P.324.

for each. As Simona Negro and Marko Hekkert explain, "It is thus important that policy is 'joined up' and supports innovation through the various stages, targeted if necessary to address specific barriers in the innovation cycle."[12]

(1.3) The Seven Functions of the Energy Technology Innovation System

Below are seven key functions involved in energy technology innovations, as summarized from a list found in Simona Negro's and Marko Hekkert's article in *Technology Analysis & Strategic Management* [13]:

Function 1 (F1): Entrepreneurial activities

It is the entrepreneur who plays the key role in the innovation system. Entrepreneurs, as the cornerstone of innovation systems, can be new businesses entering the marketplace or existing businesses wanting to diversify their portfolio to take advantage of new market opportunities. The role of the entrepreneur is action-oriented and involves taking new knowledge, and technology and dealing with uncertainty in the marketplace by moving the knowledge forward toward a commercial viability. Projects with a commercial aim or demonstration are an example of this function.

Function 2 (F2): Knowledge development (learning)

New knowledge is fundamental to technology development. The new knowledge whether adapting existing technology or creating something new, is applied to a currently unaddressed problem in the modern economy. The knowledge base and learning aspects of an innovation system can come from basic R&D, search and experimentation, learning-by-doing, and hybrid models that combine older existing understanding or technology and adaptions of recent innovations. Learning is at the heart of evolution-based systems innovation approaches.

Function 3 (F3): Knowledge diffusion through networks

The exchange of information occurs through networks. This is called the diffusion of information and makes new knowledge accessible to both market participants and a wider audience. "For instance, when discussing the prospects of establishing renewable energy industries, one could argue the importance of a widespread knowledge of renewable energy technologies as

[12] Negro, S., Hekkert, M.P., (2008). (Ibid)
[13] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.

well as the awareness of recent energy and environmental concerns."[14] For example, as more individuals in society recognize the need for sustainable solutions through renewable energy versus legacy high-carbon energy sources, the R&D agenda starts to change. This system function relates to such knowledge exchange activities as conferences, workshops, and alliances among actors in the ETIS.

Function 4 (F4): Guidance of the search

Public policy can play a large role in this "Guidance of the Search" through implementation of Renewable Portfolio Standards (RPS), Renewable Fuel Standards (RFS) and other forms of energy source generation targets or goals. These can be the activities within the innovation system that can positively affect the visibility and clarity of specific needs among technology users in this area.[15] This is important for sending a government market signal that the technology and research has credibility and legitimacy and is a step toward achieving a goal. Sometimes the actors are more likely to search for new knowledge or technology within their current business paradigm.[16] This explains, in part, why fossil fuel based energy business is drawn to hydro-fracture drilling technology (aka fracking) for natural gas versus new renewable technology. Borrowing from the terminology of evolutionary economics, it could be suggested that if *knowledge creation* (F2) is concerned with variety, then this function represents the process of selection.

Function 5 (F5): Market formation

As has been seen in the early stages of renewable energy technology development, it is often the case that new technologies often have difficulties competing with deeply entrenched technologies (fossil-fuel sourced energy). Therefore, the likelihood of technology success is improved if protected spaces are created for these new technologies. One possibility is the formation of temporary niche markets for specific applications of the technology.[17] Another possibility is to create a temporary competitive advantage through favorable tax regimes or minimal consumption quotas.[18]

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[14] Al-Saleh, Yasser M. (2010). Systems of innovation as a conceptual framework for study the emergence of national renewable energy industries. World Journal of Science, Technology and Sustainable Development, Vol. 7, No. 4. P. 309-334.

[15] Hekkert, M.P., Suurs, R., Negro, S.O., Kulmann, S., Smits, R.E.H.M., (2007). Functions of innovation systems: a new approach for analyzing technology change. Technological Forecasting and Social Change 74)4), 413-432.

[16] Dosi, G., (1982). Technology paradigms and technology trajectories. Research Policy, Vol. 11, No. 3.

[17] Schot, J., Hoogma, R., and Elzen, B. (1994) Strategies for Shifting Technology Systems: The cast of the automobile system. Futures 26(10)

[18] Hekkert, M.P., Suurs, R., Negro, S.O., Kulmann, S., Smits, R.E.H.M., (2007). Functions of innovation systems: a new approach for analyzing technology change. Technological Forecasting and Social Change 74)4), 413-432.

Market complexity is increased by the fact that societal costs, sometimes called externalities, are often not reflected in the economy. For example, burning coal and petroleum causes many public health issues that society pays for in health care costs. The energy prices of renewable generation sources can look higher than fossil-fuel-based sources such as coal and petroleum because the externality costs are not reflected in the energy purchase price contracts. This function could include activities such as taxes, tax exemptions, and regulation to create niche markets. According to the European Commission, "the cost of producing electricity from coal or oil would be double…if the external costs such as damage to the environment and to health were taken into account."[19]

Function 6 (F6): Resource mobilization

Material and human factors are necessary input for all technology innovation system developments. This system function can be fulfilled by entrepreneurial investment or through government support programs. A broad array of resource mobilization is necessary for a successful innovation system including both finance and human capital. More specifically, resources also include services and network infrastructure that, to the advantage of incumbent generation with coal, are abundant in the existing energy system. For a biomass technology the availability of biomass feedstock is also a resource mobilization criteria.

Function 7 (F7): Advocacy coalition (creating legitimacy to counteract resistance of change)

Advocacy coalitions can function as a catalyst, as they can put new technologies on the policy agenda. This advocacy coalition function is typically performed by non-governmental organizations (NGOs) or industrial interest groups. For a new technology to develop effectively it needs to become a part of the incumbent business model or change it significantly. Parties with a vested interested in the status quo business model typically oppose the new technology if it threatens their profit structure. "In such a case, advocacy coalitions can function as a catalyst; they put a new technology on the agenda (F3), lobby for resources (F6), favorable tax regimes (F5) and by doing so create legitimacy for a new 'technological trajectory.' [20]

[19] Milborrow, D., (2002). External Costs and Real Truth. Windpower Monthly, 18(1), 32.

[20] Sabatier, P.A., (1988). An advocacy coalition framework of policy change and the role of policy-oriented learning therein. Policy Sciences 21, No. 2-3: 129-68. Also in Sabatier, P.A., and Jenkinssmith, H.C., (1988). Policy change and policy oriented learning—exploring an advocacy coalition framework—introduction. Policy Sciences 21, no. 2-3: 123-27. Also in Sabatier, P.A., (1998). The advocacy coalition framework: revisions and relevance for Europe. Journal of European Public Policy 5, no.1: 98-130.

(1.4) Logic for technology innovation

“The incentives to invest in innovation are less a function of risk or even scale and more a question of appropriability,”[21] claims David Victor, the author of *Global Warming Gridlock*. Victor defines appropriability as the extent to which investors can internalize the value that arises if the innovation idea proves useful. In this innovation space, the author believes achieving value can frequently be attributed to the fact that market failures are few or easier to fix. A second consideration for determining innovation success is dealing with lock out – which is especially prevalent in networked systems such as the electric grid and other infrastructures. Innovation technologies with high appropriability and low lock out are most likely to succeed in the market without the need for policy support. One challenge with networks is that they require standards to function and yet the benefit of standards can also be a barrier to radical or changing types of innovation.

Historically, energy technology often falls into a low appropriability and high lock out situation creating barriers to innovation and technology change. Profit oriented companies may shy away from investment in innovation technology due to the high lock out and low appropriability. Victor states that the energy industry has been among the lowest investors in radical innovation. He also notes that electric utilities invest less in R&D than any other major segment of industry and are closely followed by the petroleum industry as a low spender on new technology.[22] Today, electric utilities spend only about 2% of their revenues on research and development (R&D). The rate of utility spending on R&D is less than one-tenth the average rate for all sectors of the U.S. economy and a much smaller fraction of the rate in the most productive sectors. On a slightly more positive note, innovation in the electricity industry is more likely to come from equipment suppliers to the industry. The block to radical ideas is that the improved equipment coming from suppliers is confined to the existing electric utility network versus alternatives. If new equipment is better than existing equipment used in the existing network, it has a chance for success. Other more innovative technologies can face significant barriers. “Technologies that require new standards, a reorganization of the energy infrastructure, or long gestation periods find it extremely difficult to gain market share and are unattractive to private investors to support,” according to Victor.[23]

Another well-documented challenge to technology innovation of any kind is crossing what is called the “valley of death” – the development of an idea or technology to the financing stage necessary for robust market deployment. Victor refers to the combination of low appropriability and the financing across the

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[21] Victor, D. (2011). Global Warming Gridlock. Cambridge University Press.
[22] Victor, D. (2011). Ibid.
[23] Victor, D. (2011). Ibid.

valley of death – as “the innovation trap.”[24] With a large societal challenge such a climate change, and the need for advancing more clean energy technology at a faster rate, there is an incentive to invest in new technology. The problem is that, if most of the need falls into the category of addressing the public good or public benefit, it can be difficult for private businesses to pay for those externality costs in addition to the broad challenge of funding a new idea or product in the marketplace. For some 30-years government funding of research and private entrepreneurial activity has been used to advance and improve solar photovoltaic components. During this lengthy research and development phase the cost of solar panels has gone down by an estimated 90 percent, but most of the price decline came in recent years as technology deployment started to climb. The biggest cost reductions came in the last five years as deployment grew. This documents the interplay of innovation and technology deployment. It also documents the value of supportive policy to advance a technology; solar technology has benefited from policies including the investment tax credits, the state mandates of renewable energy through renewable portfolio standards, and other state incentive programs.

Consequently, an important consideration in determining the best policies for advancing the energy technology innovation system is when the government’s role in supporting innovation starts and stops and when the private sector’s role should increase or take over? In the early basic research stage, government research support for universities is critical. This pre-commercial research is well established at universities and many universities have formed collaborative partnerships with private companies to better understand what are the science and technology needs of the commercial pipeline. Traditional energy research areas have broadened greatly and now more than ever new innovation will likely come from scientific disciplines and areas not commonly associated with the energy sector. “Already the fields of interesting ‘energy’ innovations span the frontiers of genomics and biology (biofuels), mathematics (systems controls), materials (turbine blades and battery designs), chemical engineering (low emission combustion of coal), nanotechnology (solar cells and batteries), and sundry other areas that are more traditionally the province of energy research, such as electrical and mechanical engineering.” [25]

In the private sector side, a policy such as a research and development tax credit can help some businesses to increase work in risky research that might not lead to immediate commercialization. Where government policy can play a more important role is in the market push and pull types of policies that can get new ideas and products into the commercial sector. Good examples of these policies include the federal production tax credit (PTC) and the investment tax credit (ITC) that are tied to the growth of distributed energy generation wind power and solar photovoltaic in the United States. Along with complementary state policies

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[24] Victor, D. (2011). Ibid. p. 139.
[25] Victor, D. (2011). Ibid. p. 144.

such as renewable portfolio standards, these tax credits lead to significant renewable growth in U.S. wind and solar deployment. (see Section 2.0).

For regulated utilities some of the existing laws, administrative rules, and rate-setting policies from public utility commissions may constrain their latitude to invest in R&D and advance energy technology innovation. The utility business model has not changed a lot in about 100 years of regulation. It is a system that encourages utilities to invest in large capital-intensive equipment, mostly generators, and get a return on their investment set by the public utility commission. To put it simply, utilities do not necessarily profit from energy technology innovation and are happy with the status quo business model. Yet, today, some utilities may be more receptive to adapting their business model as more distributed generation options advance and as energy efficiency advances lessen overall electricity demand. Promoting an energy technology innovation system agenda might present utilities with new pathways to new services and products.

Despite institutional barriers to disruptive energy technology innovation, recent years have seen a chipping away at the legacy electrical energy system with the advancement of distributive energy resources (DERs) including end use energy efficiency (EE), demand response (DR); distributed generation (DG) sources such as combined heat and power (CHP), solar photovoltaic (PV), and small wind, and distributed energy storage. Microgrids, a technology defined as a group of interconnected loads and distributed energy resources within a clearly defined boundary (exp. campus or single building) that acts a single controllable entity with respect to the grid, can also change the energy future. Microgrids are being driven by a combination of factors including resiliency from energy disruptions, integration of clean energy technologies, and other customer side energy management issues. A microgrid can connect and disconnect from the grid, which enables it to operate in both grid-connected and island mode. This advancement of microgrid and DERs creates an opportunity for major changes at the distribution level of the existing energy system network (see Section 2.5). Yet it is safe to say even with these new energy technologies entering the market that the energy system is deeply constrained for continuous energy technology innovation due to tight regulatory structures and rules and standards favoring the status quo models.

One criticism of governmental policy and investment in energy technology innovation is the concept of “picking winners” for a specific technology. Although there is limited evidence of the government picking winners, there are steps to try one can follow to avoid the practice.

1) First, it is important for government to stay focused on the central purpose of policy in this area: demonstration of the technology.
2) Second, it is essential to provide reliable support signals.
3) Third, strategic decisions about funding and organization must stay connected to expert assessment of technology performance.

4) Fourth, valley-crossing investments should be evaluated continuously against not only just their own goals but also, their role in a larger portfolio of low-emission technologies.[26]

(1.5) Barriers to Clean Energy Technology Innovation and the "Carbon Lock-In" Policy Paradox

Since 2000 a slow but steady advancement in non-carbon energy generation has been occurring in the United States with a slightly more rapid speed up in deployment since 2012. Whether due to the mainstream news media or long-time policy wonks a clear "climate policy paradox" exists in which science has demonstrated a present and long-term danger to society from greenhouse gas emissions coming primarily from the energy sector and yet there has been only slow progress in meaningful energy policy changes. One explanation of the paradox comes from what is labeled the "Carbon Lock-In" an interlocking set of technological, institutional, and social forces that create inertia to implement critical energy policy change.[27] The question is this: If the technology exists for change, then why haven't the technologies been diffused more rapidly? Gregory C. Unruh in two important papers, "Understanding Carbon Lock-In" (2000)[28] and "Escaping Carbon Lock-In" (2002)[29] explains that industrial economies became locked into fossil fuels through a process of technological and institutional co-evolution as well as the economies of scale in energy economics. A combination of energy infrastructures, organizations, institutions, networks and players in this area both benefit from the status quo energy economy and energy users dependent on this system for economic stability were likewise reluctant to embrace change. In explaining carbon lock-in, Unruh said it was not necessarily a permanent condition, but rather a persistent state that creates systemic market and policy barriers to alternatives.

Solving climate change through policy will be very difficult given the carbon lock-in dimensions in the energy sector and throughout society. Unruh states that the technological systems in the electricity generation and transportation sectors are so integrally tied with other consumer products, goods, and services that resistance to change and a variety of institutional factors block creative problem solving. More importantly, he points to the strong integration with government institutions for policy reasons including national security, universal service, and natural monopoly structures that create what is termed "a techno-institutional complex." Unruh provides a complex interconnecting list of sources of lock-in:

"Technological: Dominant design, standard technology architectures and components, compatibility.

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[26] Victor, D. (2011). Ibid. Pages 147-149.

[27] Unruh, G.C. (2000) Understanding Carbon Lock-In. Energy Policy 28 (2000) 817-830.

[28] Unruh, G.C. (2000) Ibid.

[29] Unruh, G.C. (2002) Escaping Carbon Lock-In. Energy Policy 30 (2002) 317-325.

Organizational: Routines, training, departmentalization, customer-supplier relations.
Industrial: Industry standards, technological inter-relatedness, co-specialized assets.
Societal: System socialization, adaptation of preferences and expectations.
Institutional: Governmental policy intervention, legal frameworks, departments/ministries." [30]

In may be too early to tell exactly how change in the energy sector will evolve over time. Unruh states it may be a combination of a blend of continuity and discontinuity pathways. He correctly projected that wind turbines and photovoltaic rooftop panels could be integrated into the existing electric utility structures as a part of a continuity approach. At the systems level, the electric utility may survive relatively intact as the hub of the large-scale electric grid and source of bulk power for those users needing it. At the sub-system level change may likely occur as the utility business model is not well-structured for distributed energy resources (DERs) including energy storage, distributed generation, and demand response tools, combined with microgrids and greater overall energy efficiency. The problem is that this combination significantly erodes traditional utility business market share and the current business model will need to adapt or change. Further, in the transportation sector the likely scenario of larger deployment of plug-in electric vehicles requires a clean energy grid to significantly reduce greenhouse gases. This means a much higher adoption of distributed energy resources and clean energy generation. For the utility sector to move significantly toward distributed generation means the business model must adapt. One scenario would be a focus on changing the utility model at the distribution level -- specifically at below the existing electric utility substation level (as discussed in greater detail in Section 2.5 of this paper).

(1.6) International Agencies Call on Expediting the Energy Technology Innovation System to Achieve a Clean Energy Economy

Two recent reports by international agencies clearly state that governments must expedite energy technology innovation to meet the world's greenhouse reduction goals. Both reports from the International Energy Agency (IEA) and the United Nation Environment Program (UNEP) stress a degree of urgency in creating both government and private-sector directed energy innovation steps more rapidly than in the past. IEA Executive Director Maria van der Hoeven stated that:

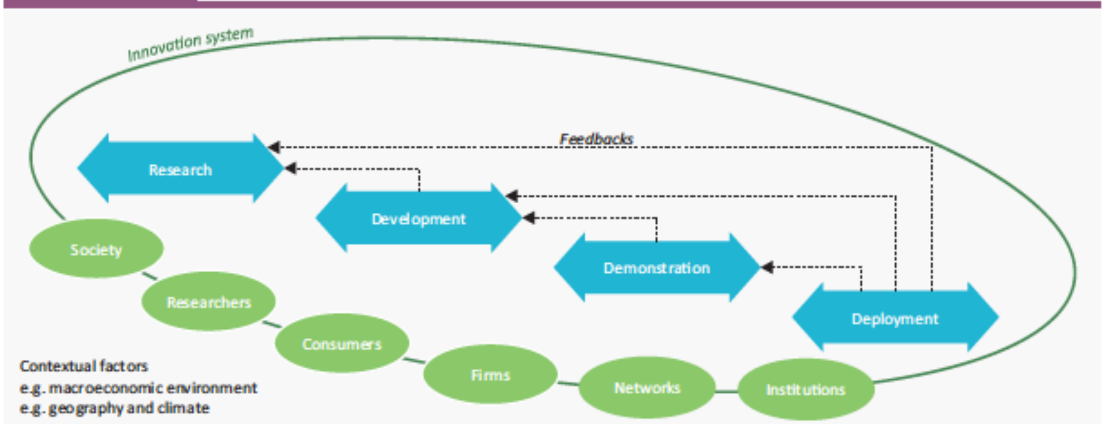
"Governments must do much more to stimulate the uptake of clean energy and energy efficiency technologies." … The world's energy system is gradually being decarbonised, she said, but not fast enough." Later Director Van der Hoeven added in published comments, "It is now crucial for governments and other stakeholders to take effective decisions for energy sustainability. This will not be

[30] Unruh, G.C. (2002) Ibid.

possible by relying on yesterday's technology and policies. It is clean energy innovation that will get us on the right path."[31]

The IEA report, *Energy Technology Perspectives 2015*, discusses how both incremental and radical innovations will be necessary in order to de-carbonize the global energy system. The report points to the need for innovation at a systems level and spells out steps to achieve that goal. It calls on government and private-sector stakeholders to collaborate more in determining what are the most promising technologies. Governments in particular will need to look at methods for supporting these energy technologies across all paths from idea to deployment. This process is characterized as an "interactive innovation process" that involves energy stakeholders capturing a feedback loop that support "learning by research" and "learning by doing." The authors discuss the learning process as necessary to support technology innovation with strategically aligned policy and market frameworks that reflect the level of technology maturity. [32]

Figure I.2 Systems-based interactive innovation



Sources: GEA (2012), *Global Energy Assessment: Toward a Sustainable Future*, Cambridge University Press, Cambridge, United Kingdom and New York; the International Institute for Applied Systems Analysis, Laxenburg, Austria.

A more refined strategy suggested in the IEA report calls for looking closely at policy tools that can best address the different stages of maturity of a new technology. These policy tools need to be part of a short-term and long-term look at the opportunities and challenges in the innovation system. The reason for a two-pronged approach is to rapidly deploy technologies that can immediately provide emissions reductions in the short-term. These short-term energy efficiency steps included many that could be rapidly adopted. The key in times of

[31] International Energy Agency (IEA) (2015) Energy Technology Perspectives 2015. Executive Summary. www.iea.org/etp2015. Accessed on 05/06/2015. IEA Executive Director Maria vad der Hoeven comments at http://www.iea.org/newsroomandevents/speeches/150504_ETP.pdf

[32] International Energy Agency (IEA) (2015) Energy Technology Perspectives 2015. Executive Summary. www.iea.org/etp2015. Accessed on 05/06/2015.

limited financial resources is to prioritize government allocations to support these short-term renewable energy steps and energy efficiency steps, while having a long-term research and development plan to maintain a portfolio of solutions. The authors state that ongoing research and development support is needed for technologies that show long-term potential but still require efforts to reduce costs, carry out large-scale demonstrations, or achieve performance improvements for market entry. [33]

The UNEP report done in collaboration with the Frankfurt School and Bloomberg New Energy Finance is an in-depth review of global investment trends in energy along with recommendations for improvements in the energy innovation space. On the positive side, the report found that global investment in renewable energy sources in 2014 rose almost 17 percent to $270.2 billion. This broke a two-year cycle of decline in renewable energy investments globally. Equity raising by renewable energy companies in public markets increased more sharply, by 43 percent to $15 billion, which is the second highest annual figure since these organizations started tracking this data. In global markets the asset finance of utility-scale renewable energy projects was up 10 percent to $170 billion. In contrast, investment in small-distributed capacity, largely rooftop solar, was 34 percent higher than the previous year at $73 billion. Solar and wind were the largest category of investments globally totalling $249.1 billion. [34]

(2.0) Do Recent Solar Market and Wind Market Trends in the United States (2014 and 2015) Indicated a Harbinger of Energy Change?

From 2009 through 2015, U.S. solar PV installations grew at a compound annual growth rate of over 60%. This resulted in a 2014 market that was 12 times larger than a decade prior. Solar made up over 30 percent of new generation capacity in 2014, up from just 10 % in 2012. According to the Energy Information Agency (EIA), there are 9.6 gigawatts AC of non-solar projects with regulatory approvals slated for 2015 completion. [35] Based on GTM Research for the solar market in 2015 they predict that solar will make up over 40 percent of new generation capacity in 2015 – a new record. More than 250,000 solar projects will be completed in 2015, according to GTM Research. Installers completed nearly 200,000 solar projects in 2014, up from 145,000 the year before. This growth brings within striking distance of one million solar installation in the U.S. by 2015 or early 2016. [36] It is worth noting that the U.S. Energy Information Agency (EIA)

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[33] International Energy Agency (IEA) (2015) Energy Technology Perspectives 2015. Executive Summary. www.iea.org/etp2015. Accessed on 05/06/2015.

[34] United Nations Environmental Program (UNEP) and Bloomberg New Energy Finance. (2015) Global Trends in Renewable Energy Investment 2015.

[35] Energy Information Agency (EIA). (2015). Short-Term Energy Outlook of May 12, 2015.

[36] Energy Information Agency (EIA). (2015) Short-Term Energy Outlook of May 12, 2015.

does not include solar power projects smaller than 1 megawatt in size, but has stated that it may in the future try to find methods to include smaller-scale solar in its projections.

Therefore it is necessary to examine solar growth data from trade associations. According to the Solar Energy Industries Association (SEIA), the growth of solar has continued at a record pace, with a new record of 6.2 gigawatts installed in the United States in 2014. Equally of interest is the persistent growth of small-scale solar, on residential and non-residential rooftops. These projects, a megawatt or smaller, contributed 13% of new power plant capacity in 2014, also a new record. The Solar Energy Industries Association (SEIA) estimates that residential solar alone will represent 45% of the solar market from 2017-2020. Combined with non-residential solar, distributed solar is expected to be nearly 75% of the solar market. [37]

Another organization tracking domestic and global energy trends is Bloomberg New Energy Finance. In a Bloomberg White paper issued April 8, 2015 the authors discuss how the shift toward more renewable energy sources and away from high carbon energy sources may be occurring faster than some official government agencies report. [38] If the current trend with renewable energy growth stays coupled with more base load coal plant retirements that expedites the shift away from high carbon energy generation. In addition, the expanded growth in fuel switching from coal to natural gas is a part of the calculations. Current state and federal policy may be what changes the equation because, at this time, the successful Investment Tax Credit (ITC) has been a key driver for wind installation growth and the ITC is in a phase-down from a 30% credit to a 10% percent credit. In a similar fashion the Production Tax Credit (PTC) – which has been a key to wind installation growth – will no longer be available to projects by the end of 2017. Finally, many states have Renewable Portfolio Standards (RPS) that are starting to be met, modified, or phased out. Drivers that may eventually increase renewable power usage include the Environmental Protection Agency (EPA) Clean Power Plan with final rules coming in the summer of 2015 but full implementation may be delayed with legal challenges to the rule.

US Wind Power

The U.S. Department of Energy believes that wind power can provide 20 percent of U.S. electricity by 2030 and suggests that 35 percent wind electricity generation is possible by 2050, according to its Wind Vision report issued in March 2015. The DOE report also provides a roadmap for U.S. wind power growth. One key to achieving these goals will be continued technology improvements in wind turbines, towers, and component equipment. The cost of operating a wind farm in states like Iowa and South Dakota dropped by more

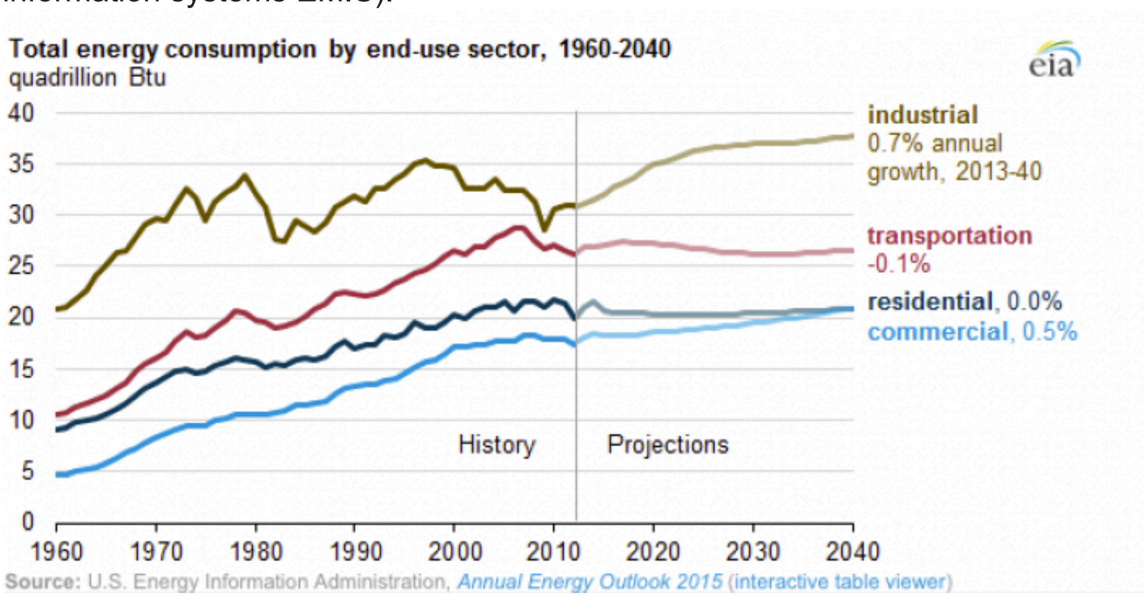
[37] Solar Energy Industries Association (SEIA). 2015.

[38] Bloomberg Financial. (2015) Medium-Term Outlook for US Power: 2015 Deepest De-Carbonization Ever. BNEF White Paper. April 8, 2015.

than one-third to $45 per megawatt-hour in 2013 down from $71 per mega-watt hour in 2008. The 4,854 megawatts of wind capacity added in 2014 was more than four times the amount installed in 2013. [39] There are more than 12,700 megawatts of wind capacity currently under construction in the U.S., according to the American Wind Energy Association (AWEA). [40] The growth of distributed energy solar PV and wind power is a contributing factor to the new pressure on electric utilities to change or evolve their business model.

(2.1) Electrical Utility Industry More Changes Coming

New pressures in the electricity sector are leading to considering a redesign – or what some may term an evolution – of the distribution sector to better accommodate the integration of distributed energy resources. Dramatic advances in distributed energy resources technology and plummeting costs are leading to staggering growth trajectories for distributed generation (DG) such as solar photovoltaic (PV), automated demand-response to electric vehicles (EV), energy storage and complementary technologies such as microgrids, smart controllers and other data management automation (energy management information systems EMIS).



New data from the U.S. Department of Energy shows that overall U.S. energy consumption is slowing and is not expected to grow much at all over the next 25 years despite both a growing economy and population. Overall, U.S. energy consumption is expected to grow 0.3 percent annually between now and 2040. That's half the expected U.S. population growth rate and dramatically less than the 2.4 percent projections for U.S. economic growth through 2040. Greenhouse gas emissions from burning energy are expected to grow 0.1 percent in that time.

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[39] Solar Energy Industries Association (SEIA). 2015.

[40] American Wind Energy Association. 2015.

With more U.S. businesses and residence embracing energy efficiency, residential energy consumption won't likely grow at all over the next 25 years.[41] For these reasons the distribution system and related energy markets may need reform or change.

(2.2) Problems with the Existing Electric Utility Model Constrain Innovation

Traditional cost-of-service regulation was originally designed in an era of significantly increasing sales and decreasing marginal costs, where the primary decisions required by utilities were related to how much and what type of generation and transmission to build to meet growing customer demand, and where the main goal was to ensure just and reasonable rates. The conditions currently facing the utility industry have changed considerably, for instance:

- Retail sales are increasing at much lower levels than in the past, and some utilities are experiencing declining sales. Sales may drop even further as customers adopt more demand side measures, especially energy efficiency, distributed generation, and storage technologies. On the other hand, electric vehicles and other forms of electrification could lead to increased sales.

- Many utilities are facing the need to replace aging infrastructure, which may require significant capital investments that will not necessarily lead to reduced costs or increased sales.

- Utilities have many more options to choose from, in terms of generation, transmission, and distribution technologies, as well as more ways to address customer needs through resources on the customer side of the meter (including energy efficiency, demand response, distributed generation, automated metering technologies, and customer-facing smart grid options).

- Regulators have established a variety of public policy goals beyond simply maintaining just and reasonable rates. These include goals related to consumer protection, promoting competitive markets, encouraging and implementing demand-side resources, encouraging and implementing renewable resources, improving responses to major outages, and meeting carbon and other environmental constraints.

Some states are finding that traditional cost-of-service regulation may not provide

[41] U.S. Energy Information Administration (EIA). (2015) Annual Energy Outlook 2015.

utilities with the financial incentives to respond effectively to all of these developments. In some cases, traditional regulatory practices may provide financial incentives that hinder utilities from addressing these challenges. Consequently, performance metrics and incentives may provide an opportunity to better align utility incentives with evolving regulatory goals and the public interest in general. But it is worth considering some possible unique factors for electrical utilities in the innovation space.

(2.3) Utilities May Be Unique Actors in the Energy Technology Innovation Ecosystem

There are several ways that utilities might be a unique actor in the energy technology innovation system. Below are five factors to consider:

Utilities may have multiple roles: Utilities can be characterized as having multiple roles because it might be a customer for a new technology or innovation or they could play a role in developing a new technology. Utilities might also be isolated or even consider adversarial in the energy ecosystem because they have such a big effect on the “rules of the game” in the policy world and that their actions affect everyone else in the energy technology innovation system in a positive or more likely negative way. (i.e. as described in the carbon lock-in section of this paper, the regulated monopoly have a strong impact on the rules written to advantage them can and, therefore, may shut out competition and innovation for everyone else).

Utilities may not have the appetite for risk: 1) New technology has the potential to fail, and utilities must be prepared to handle that risk. 2) The technology, e.g. energy storage today, may be more expensive. 3) People may not like the new technology. In the past (and present) utilities have always been able to insulate itself from risk. Going forward, So how do we help utilities manage risk?

Utilities may be subject to external pressures: First, utilities are influenced and to a degree run by the legislature and Public Utility Commissions. If the utility is an investor owned utility (IOU), then shareholders and boards also influence the utility actions. Although some observers argue that the utility, with its substantial political and financial clout, has more influence on policymakers, regulators and shareholders than the reverse.

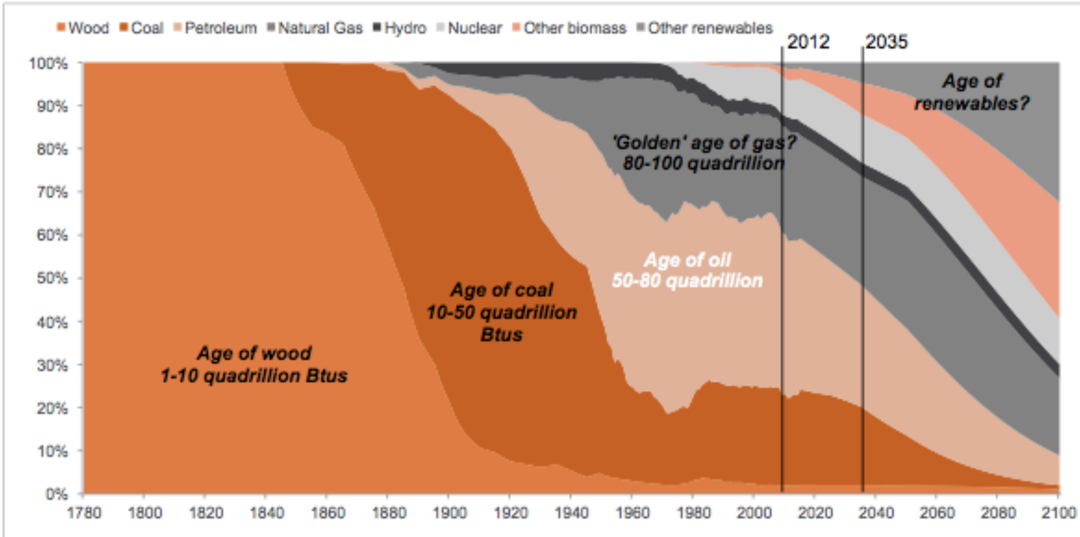
Utilities may have minimal experience working with parts of the innovation financial structure: Financing innovation relies, to some degree, on venture capitalist, angel investors, and entrepreneurs, who may not historically have worked with or interacted with utilities. Investments in innovation are sometimes local or regional and it is helpful to have investors close to where the invention occurs.

Utilities may have legal and financial constraints on their research and development investment: The literature and research seems to indicate that utilities invest relatively small amounts of their revenue in research and development activities. Regulated utilities will argue that public utility commissions give them little latitude to make investments in research and development since these investments could adversely impact ratepayers. The policy question to ask, then, is whether these funds for research and development or investments in new energy technology innovation could be done outside of the rate structures.

(2.4) It will take a sustainability ethos to make the energy sector sustainable

A unique combination of new technologies, financial innovation, and broader environmental and societal trends can lead to a new era of consumer choice and control in the power sector, or a devastating political schism over the management of electrons. A collaborative dialogue is required between the existing electric utilities, regulators, new third-party energy businesses, and the emerging energy prosumer and the legacy energy consumer, to shape the necessary changes in public policy, business arrangements, and the balance of power necessary for energy sector sustainability. The business as usual option in the energy sector has many high-scale risks and an eroding set of benefits. A critical question going forward is what remains of the legacy energy sector and what must change and evolve on the path to sustainability. There may not be easy answers or even clear common ground solutions. Likewise, there may be no choice but to maintain an inefficient but changing legacy energy infrastructure while at the same time evolving the eco-system to create the opportunity for a continuous energy innovation cycle. How did the energy sector get to this state?

Figure 4. The ages of energy: History suggests a process of substitution



Source: IEA, EIA, Citi Research

The driving factor has been the growth of rooftop solar PV although advances in technology with microgrids, energy storage, smart inverters and controllers, and electric vehicles are fueling further changes. Two reports that came out in the fall of 2013 addressed the issue of changing electric utility sector in different ways. The U.S. Department of Energy (DOE) put out a report with the somewhat surprising title "Revolution Now. The Future Arrives for Four Clean Energy Technologies."[42] The report says that the four technologies of onshore wind power, polysilicon photovoltaic modules (PV), LED lighting, and electric vehicles (EV) have advanced to stages that they can revolutionize the energy sector. "In the last five years they have achieved dramatic reductions in cost and this has been accompanied by a surge in consumer, industrial, and commercial deployment," the report authors state. A significant factor in the findings of the report is the linkage between energy technology innovation, the drop in price of products and increase deployment. There is a cycle that can contribute to the goal of continuous innovation between deployment-price-innovation. About the same time the DOE paper came out a different report from The Citi Group, a division of Citibank, titled "Energy Darwinism. The Evolution of the Energy Industry." [43] While the words revolution and evolution both mean change, the contrasting part of their definitions comes from evolution as a gradual process of change and revolution as sudden change or movement. While the speed of change to the energy sector can be debated, that fact of its occurrence cannot be disputed. Select technologies can indeed have a revolutionary effect, and yet transforming the entire electric utility sector is more likely to be a slower or more evolutionary process.

[42] U.S. Department of Energy (DOE). (2013) Revolution Now. The Future Arrives for Four Clean Energy Technologies.

[43] The Citi Group. Citibank. (2013). Energy Darwinism. The Evolution of the Energy Industry.

History suggests that this kind of power system transformation won't be easy or happen quickly. Again, the "iron-triangle" of the carbon lock-in structure slows change. One of the problems is that legacy coal plants represent a substantial financial investment from electric utilities. The life cycle of a base-load coal generation plant is often close to 50 years. Expensive equipment to clean air emissions from these plants may not make sense depending how long the plant has been operating and with strong regulations closing aging plants. Further, declining customer demand for energy due to improved energy efficiency and increasing self-generation of energy from customer rooftop photovoltaic erodes utility revenues. These events can lead to what are termed "stranded assets" for the utilities. Whether the customers, the utilities, the shareholders (for investor owned utilities), and/or the government will pay for stranded assets is likely to be a vigorous public policy debate if these trends continue on coal plant closures continue.

The next changing factor centers on environmental and societal change. For years the energy sector has been allowed to release harmful greenhouse gases without economic consequences. Not monetizing the broad societal impact of air pollution, and specifically greenhouse gases into the atmosphere creates huge barriers to new technology. As discussed earlier, this problem of not maintaining environmental responsibility in the energy sector is broadly captured in the carbon lock-in definition. The status quo structure is protected by the business risks of innovation for new products and ideas, the cost advantages of existing infrastructure supports, and a policy environment that maintains the incumbent systems. It is not cost effective merely to integrate clean energy solutions such as wind, solar, biomass, and others. It will instead be necessary to transform at least parts of the energy infrastructure. A study released by the International Energy Agency (IEA), "The Power of Transformation – Wind, Sun and the Economics of Flexible Power Systems," says that to achieve high penetration of the clean energy generation options will require a transformation of the energy system. [44]

"Integrating high shares of variable renewables is really about transforming our power systems," said Maria van der Hoeven, IEA Executive Director with the release of the report. "In the classical approach, variable renewables are added to the existing system without considering all available options for adapting it as a whole. This approach misses the point. Integration is not simply about adding wind and solar on top of 'business as usual'. We need to transform the system as a whole to do this cost-effectively." [45]

Across the country, utilities are beginning to confront the most dramatic

[44] International Energy Agency (IEA). (2015). The Power of Transformation – Wind, Sun and the Economics of Flexible Power Systems.

[45] International Energy Agency (IEA). (2015). The Power of Transformation – Wind, Sun and the Economics of Flexible Power Systems.

transformation of their business in the past century. They face challenges from customer-owned distributed energy resources (DERs), as well as opportunities in the form of smarter distribution grid technology and analytics, both of which lead to new models for electricity delivery and consumption.

(2.5) The Dynamic Distribution System: An Alternative Business Model

It is time for the United States to re-think its electric and thermal energy distribution system. To efficiently and effectively integrate necessary larger amounts of intermittent solar, wind, as well as geothermal and biomass power that can reduce dependency on high carbon coal, oil, and natural gas energy, new business models, different infrastructure build outs, public policy changes, and systems-thinking designs are all needed. The existing central generation electric utility business model was sculpted by a century of regulation.

A) Dynamic distribution is an energy and power system founded on principles that are emerging from the latest in power systems control theory, microgrid research and implementation, grid automation experiences, dynamic market models, and ethernet, to produce dynamically adapting networks.
B) As conceived, the dynamic distribution system uses local sources to track loads, stabilize voltage and frequency, and smooth intermittent renewable energy generation providing a predictable, constant load profile to the utility.
C) The primary purpose of the dynamic distribution system is to allow for integration of thousands of distributed energy resources (DERs), defined as power generation and/or storage systems (including electric vehicle batteries), that connect directly to the distribution network or connect on the customer side of the meter, including photovoltaics (PV), internal combustion engines, gas turbines, fuels cells, wind turbines, biomass anaerobic digesters, heat pumps, combined heat and power facilities, and microgrids.
D) This new dynamic distribution system connects central and local electricity generation with a marketplace that enables energy transactions, such as payments passing between buyers and sellers of energy at the local distribution level. This new system provides a promising framework for (DERs) to deliver the same services at a better price, with decreased power losses, decreased emissions, and better reliability. [46]

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[46] Beihoff, Bruce, Jahns, Tom, Lasseter, Robert, and Radloff, Gary. (2014) Transforming the Grid from the Distribution System Out. The potential for dynamic distribution systems to create a new energy marketplace. Wisconsin Energy Institute. http://energy.wisc.edu/news/transforming-grid-distribution-system-out

Key Dynamic Distribution System Features:

- Emphasize plug-and-play functionality with the distribution region.
- Promote peer-to-peer model among DER sources (no Master Controller is required for dynamic control of the distribution system).
- Encourage fast autonomous control for load tracking, voltage and frequency control.
- Enable market participation by all sources.
- Localized control is exercised to implement balancing authority and market provider responsibilities.[47]

The dynamic distribution system approach is to create smart local distribution centers run by Distribution System Operators (DSOs).[48] Local group users, third party companies, utilities, and combinations of these entities could compete in the marketplace overseen by the DSO. The DSO and the dynamic distribution system forms an adaptive and self-optimizing system for best solving the interactions of reliability, efficiency, total economy, and total sustainability.

The short-term challenge is getting the electric utility sector open to evolving its business model. In states such as New York, California, Hawaii, Minnesota, Massachusetts, and Colorado, robust public discussions and actions are taking place to change the electric utility sector. Moving this discussion to a more widespread national movement toward change will require electric utility operators to move beyond a sole focus on moving electrons in favor of managing the goals and purposes of the distributed energy system for the benefit of the society. A wide variety of papers outlining new energy utility business models can be found at the Web Site http://sepa51.org.

(2.6) Public Utility and the Low-Carbon Future

Transitioning from a legacy high carbon energy economy to a clean energy economy has numerous challenges. These include securing new financing for projects, creating policy reforms, and advancing an energy technology innovation system for continuous improvement. Research by law professor William Boyd documents how a revitalized and expanded notion of the public utility could play a key role in efforts to decarbonize the power sector in the United States. Boyd looks back to the original, more expansive concept of the public utility as articulated by Progressives, legal realist, and institutional economists in the early twentieth century. Somehow this understanding and definition of a public utility was seriously eroded in the 1960s by what he characterizes as a "sustained

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[47] Beihoff, Bruce, Jahns, Tom, Lasseter, Robert, and Radloff, Gary. (2014) Transforming the Grid from the Distribution System Out. The potential for dynamic distribution systems to create a new energy marketplace. Wisconsin Energy Institute. http://energy.wisc.edu/news/transforming-grid-distribution-system-out

[48] Kristov, L. and De Martini., P. (2014) 21st Century Electric Distribution System Operations. http://resnick.caltech.edu/docs/21st.pdf

intellectual assault" by economists and lawyers that resulted in a distorted view regarding the role of markets and disruptive technologies in the energy sector. This resulted in our current dominant conceptualization of the "investor owned utility" (IOU) which is a manifestation of the public utility, according to Boyd. [49] Yet, the author argues a return to a broad concept of the public utility can facilitate the planning and coordinated investment for a low-carbon energy economy and help manage a system of increasing complexity in the energy sector.

The origins of the public utility and the granting of government sanction monopoly utilities territories was an experiment to harness the energy of private enterprise towards a public end. A product of the Progressive Era, according to Boyd, this has been termed a distinctly American approach to the "social control of business." In American law, the public utility was a legal innovation linking private business and public regulation to provide for the building and managing network industries (i.e. railroads, telephone, natural gas, electricity). [50]

Economist Harry Trebing writes, "Public utilities are network industries that are an integral part of society's infrastructure. This infrastructure, in turn, serves as a platform for promoting growth in productivity and gains in real income. It cannot be assumed that oligopolistic market structures will automatically culminate in the realization of these gains to all sectors of the economy."[51]

It is important to think of electricity as an infrastructure and less as a commodity and its benefit as producing economic activity and not solely for the profit mode of the investor or owner of the power company. Boyd advances the idea of the public utility as an "instrument of the commonwealth." Taken further this defines the actions of the public utility as services and activities in a networked economy.[52]

A primary framework in Boyd's case is that the public utility can play an important role in transforming a high carbon energy economy to a low carbon energy economy by enhancing levels of planning, investment, and coordination across multiple scales. This engagement of the public utility to move into a solution mode for climate change is tied to the importance of encouraging continual technology innovation. The timing of this change could allow for strategically phasing out of large fixed assets such as baseload coal plants in a strategic manner. Further it is recognized that the intermittency of the existing clean energy technologies of solar PV and wind require a balancing of energy resources. Boyd does note that the increase in distributed energy resources (including distributed generation, demand response, and energy storage) allows

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[49] Boyd, William. (2014) Public Utility and the Low-Carbon Future. UCLA Law Review. 61 UCLA L. Rev. 1614 (2014).

[50] Boyd, William. (2014) Ibid.

[51] Trebing, Harry found in Boyd, William. (2014) Ibid. See citation 38 on p. 1628

[52] Boyd, William. (2014) Public Utility and the Low-Carbon Future. UCLA Law Review. 61 UCLA L. Rev. 1614 (2014).

for more and more households and businesses to become an integral part of the new energy infrastructure. “It also deepens rather than diminishes the collective nature of the system, as passive consumers become more active participants on the grid.” [53]

According to Boyd, if utilities cannot see the new value proposition under something like the dynamic distribution system, then society has the right to force the issue. An electric utility and a public utility commission earns’ its social license. Neither the utility or regulatory commission has a right to its authority. Boyd goes on to highlight some steps toward recapturing the public utility ideal:

- Restore the working concept of “public utility” that to make an effective and efficient transition to a new energy economy.

- A public utility is an “undertaking” a rethinking of public goals and private industry toward a common sustainable solution. (i.e., We are in this together).

- Utilities can no longer look at the public as a obstacle, but rather as a source of promise.

- Likewise, the public can no longer see utilities as a obstacle to markets and innovation that could secure a low-carbon energy future.

- An “instrument of the commonwealth” must be built into the notion of a public utility. It can remain a business with shareholders and profits, but only after a refocusing on sustainability and the public good. [54]

(2.7) Networks Are the Engine of Innovation.

Energy technology innovation going forward must address the interaction of networks for sustainable solutions and continuous success. New energy companies will need to leverage these networks, develop service platforms, take the most robust, timely data available, and take the best and latest technology available to facilitate action in markets. Energy companies will need to match services to their customers by using data analytics, intelligent devices, and an integrated network perspective. Energy companies will also need strategic planning that recognizes the traditional economic network, the traditional power network, the gas infrastructure network, and further adding an understanding of the water network, the telecommunications network, the transportation network, and most importantly the environmental network. Further, it will involve:

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[53] Boyd, William. (2014) Public Utility and the Low-Carbon Future. UCLA Law Review. 61 UCLA L. Rev. 1614 (2014).
[54] Boyd, William. (2014) Ibid.

1) Using the best of the digital age (intelligence),
2) Linking physical, digital, and social networks
3) Creating platforms for new business models that leverage the networks and the intelligence.

The energy network model described above, along with the dynamic distribution system (section 2.5), can form the framework of a future energy business model.

(3.0) Case Study: Biogas in Germany versus Biogas in Wisconsin. A Case of How the ETIS Can Achieve Success and How it is Missing in Wisconsin

Unlike renewable energy sources such as wind and solar, which are intermittent –meaning power can only be generated when the sun shines and the wind blows – biogas could provide the juice for energy generation anytime of day and potentially all the time. Further, biogas from anaerobic digester technology provides a low-carbon energy source that takes a waste product and converts it to something useful; heat and power. Finally, anaerobic digesters with agriculture approaches provide multiple co-benefits such as order reduction, residues streams that make on-farm nutrient management easier and co-products such as bedding or use in producing plant nutrient products.

Biogas is produced by the decomposition of organic matter in the absence of oxygen. For typical biogas systems, this organic matter can include manure or plant substrates such as crops or food waste. These inputs are then fed into an anaerobic digester where microbes in the presence of heat and absence of oxygen break down the organic matter, producing biogas (which is composed of methane and other gases). In addition to biogas, the solids that have been digested are also a product of anaerobic digestion.

The biogas produced from this process can be combusted for electricity and heat, or can be used directly by upgrading the gas to pipeline quality or upgrading it further for use as a transportation fuel. The digested solids can also be utilized as an organic fertilizer or as animal bedding. Biogas is thus a versatile energy source.

One of the big advantages of using anaerobic digesters for biogas energy is the versatility of end uses. Whether the anaerobic digester is placed on a dairy farm or industrial site it can reduce Wisconsin's dependency on energy from outside the state. Biogas energy uses include:

- **Electricity**: This is the most common conversion of AD biogas are connected with a genset (electrical generator) to make electricity for the electrical grid. It can also produce electricity for "off-grid use." If electricity is sold to a utility it is subject to negotiated buy-back rates. This baseload renewable power is also scalable and can be competitive with other renewable energy options.

- **Heat:** To maximize statewide efficiency, the heat generated by an anaerobic digester is often used on-farm or in-plant. If there is a nearby industrial space or facility, like a greenhouse, that needs heat, an anaerobic digester can be used in tandem to generate electricity and provide heat.
- **Co-generation**: A combined heat and power facility operates at a high efficiency rate and where there is shared user demand makes a great partnership with anaerobic digesters.
- **Vehicle Fuel**: Combining an anaerobic digester with equipment to clean and compress can produce a vehicle fuel of compressed natural gas (CNG). This renewable fuel can power a CNG vehicle, currently more common in fleet vehicles. In Wisconsin, the School District of Cadott has been running a CNG fleet of school buses for 20 years. More recently, the Dane County landfill has used an anaerobic digester and conversion equipment to run approximately 20 county vehicles on CNG with plans to expand to 30 vehicles.
- **Renewable Natural Gas**: Another emerging opportunity is to take methane from an anaerobic digester and clean it to pipeline-quality renewable natural gas. This process is more common in Europe, but could be attractive at some U.S. locations with existing gas pipeline structures.

Studies indicate biogas energy could have a much bigger market share, for example one study modeled an opportunity a 3% to 5% share of the natural gas market from biogas at a projected price of $5-$6/MMBtu.[55] For a state more than 200 anaerobic digesters could be added under the right policy environment. [56] Yet, today throughout the United States biogas use for energy remains a relative small part of the energy marketplace. The EPA AgStar program says that more than 2,000 anaerobic digesters are producing biogas nationally and 35 on-farm systems are operating in Wisconsin. A Biogas Roadmap produced jointly by the U.S. EPA, USDA, and DOE projects more than 11,000 biogas systems could be deployed in the U.S. In contrast, biogas markets in the European Union have been fostered and are growing with about 2% of gas consumption coming from biogas. In Europe some 12,000 operating biogas plants were documented in an International Energy Agency (IEA) report. Wisconsin could potentially add 250 anaerobic digesters based on the feedstock opportunity. [57] But what are some of the key differences in Europe's biogas market versus the United States?

The literature on renewable energy technology has clustered barriers to the diffusion of new energy technologies and potential solutions to the problem. Eight potential barriers to new lower carbon renewable energy solutions include;

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[55] Murray, B., Galik, C.S., and Vegh, Tibor. Duke Nicholas Institute. (2014) Biogas in the United States. An Assessment of Market Potential in a Carbon-Constrained World.

[56] Radloff, Gary. Runge, Troy, Du, Xiaodong (Sheldon), and Porter, Pam (2012). Wisconsin Strategic Bioenergy Feedstock Assessment. A report to the Wisconsin State Energy Office. Wisconsin Bioenergy Initiative. http://energy.wisc.edu/about/people/radloff

[57] International Energy Agency (IEA). 201x.

regulatory, technology, cultural, demand, production, infrastructure, socio-environment, and economic, according to Tsoutsis and Stamboulis (2005). [58] Using the language of the energy technology innovation system, Jacobson and Johnson (2000) categorize the barriers by actors and markets, networks and institutions. [59] These authors put the first barriers more in the category of market failures where biogas is up against incumbent energy generation sources of coal plants and natural gas plants where existing infrastructure and price keep biogas to a small share of the market. In the network category biogas may either lack its own strong linkage between producers and users or carbon technology lock in will again maintain the status quo generation options over biogas. If anaerobic digester deployment started to grow in deploy then a strong network could provide a more rapid pathway to larger scale use. The category of institutions captures a variety of potential barriers including lack of education about the use of anaerobic digester technology, as well as financial institutional barriers where lenders are reluctant to provide capital for a technology the market for which they are less acquainted with in the market. Finally, institutional failures may also include favorable policy to help biogas generators getting into the existing energy markets.

The energy technology innovation system process can shed some light on the biogas growth. One study specifically looked at the biogas success story in German using the ETIS measurements. Negro and Hekkert used the seven functions of the ETIS to show how Germany advanced over 7,000 biogas plants into the energy infrastructure. Their research looked at a historical overview of the evolution of German biomass digesters from 1990-2006. The work noted some very early key developments including 15 pilot farm-scale plants between 1980-1990 for testing the technology. Then, early policy such as the Electricity Feed Act in the early 1990s that including taxing fossil fuels and promoting renewable energy options, also contributed to growth. “As a result of the introduction of these regulations the expectation among engineers and entrepreneurs have increased that biomass digestion technology could become a promising energy conversion technology for electricity production,” the authors noted. [60] Then in 1992 a German Biogas Association was formed and fulfilled two important ETIS functions with (F3) *knowledge diffusion* and (F7) *advocacy coalition formation*. Putting biogas on the Germany’s political agenda and exchanging knowledge and experience of anaerobic digester technology expedited technology growth. Next unique engineering niches and assistance in developing, planning and constructing biomass plants lead to the formation of four companies who advanced market deployment. Finally, there was more

[58] Tsoutsis, T.D., and Stamboulis, Y.A. (2005). The sustainable diffusion of renewable energy technologies as an example of an innovation focused policy. Technology 25 (2005) 753-761.

[59] Jacobson S. and Johnson, A.. (2000). The diffusion of renewable energy technology: An analytical framework and key issues for research. Energy Policy 2000:28: p.625-640.

[60] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.

government assistance in the form of workshops on operation, financing, and environment benefits of the technology. The government also encouraged Germany's robust network of research institutes to look into technology improvements to encourage greater efficiencies and help bring down costs. These early steps were critical in the formation of niche market for anaerobic digesters and the development of local biogas plants in Germany.

The early 2000s saw several more significant steps toward advancing the biomass and biogas development. Foremost, was that the German government encouraged the liberalization of energy markets and increase renewable energy buy-back rates for energy production businesses through the use of the feed-in tariffs. Where as in 1998, about 150 biomass plants were built, then by 2000 and 2001 more than 200 biomass plants where added each year as project financing became easier with the favorable energy buy back rates. The feed-in tariff was a long term energy purchase agreement over 15 and 20-year periods and banks were willing to lend money to developers with the guaranteed cash flow for energy generation. From about 2000 to 2006 the biomass plant growth curve completely took off and the number of plants reached over 4,000 by year 2006. Another important factor was that farmers in Germany, especially in the South and Southwest regions where animal agriculture was present saw that farmer cooperatives, especially the U.S. equivalent of farm implement dealers, became involved in anaerobic digester technology marketing of equipment and supportive services. The authors note that alignment of ETIS functions of market formation, knowledge diffusion and then institutional conditions allowed for this continued growth of biogas plants. The coalition of agriculture supporters and environmentalists led to even more favorable policy in 2004-2006 including improvements in energy payments and facilitation of expedited permitting of biogas plants. [61]

In March of 2007, the European Union as a whole took an important policy step to advance renewable generation of energy by adopting its 2020 climate and energy package. The package was a binding set of goals to reduce European Union greenhouse gas emissions, but gave individual countries the latitude to take individual steps to meet the targets. The targets were specifically:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewables to 20%; and
- A 20% improvement in EU energy efficiency.

The European Union stipulated that the three targets to be achieved by 2020. The EU also created a set of national targets that were differentiated according to the countries wealth. Modifications were made in the EU Emission Trading System. The German government, whose carbon emission policies were already

[61] Negro and Hekkert. (2008) Ibid.

in place, took the EU action as a green light to strength its climate reduction and energy policies. The German policy was praised by European Union evaluation, “it turned out to be the most efficient and convenient method to support the development and diffusion of renewable energy, as can be seen from the high diffusion of biogas plants, but it also provided 120,000 jobs, a turnover of 6 billion (Euro dollars), and a reduction of 35 million tonners CO2-equivalent (2001).” [62]

The authors Negro and Hekkert stated that in their research that using the energy technology innovation system functions as their metric for evaluation worked well. “The dynamic analysis of biomass digestion in Germany shows that positive functional patterns occur. All systems functions are present, fulfilled and interact with each other, leading to the build-up of a well-functioning innovation system.” [63]

A U.S. and Wisconsin Technology Opportunity with Biogas Not Realized

In looking at the relationship between the energy technology innovation and policy, it is important to consider specific technologies. In the United States and state of Wisconsin, the technology of anaerobic digestion has been relatively aggressively promoted as a clean energy solution, a waste management and reuse solution and, for agriculture, a part of a nutrient management solution. In Wisconsin, for example, several high profile events and other efforts have tried to rally policy support and economic investment in the anaerobic digester technology. These events included:

- Wisconsin Biogas Opportunity Stakeholder planning meeting attended by about 75 diverse stakeholders on October 15, 2010. This meeting produced the paper, the Wisconsin Biogas Strategic Plan
- A Biogas Informational Symposium at the State Capitol building on Feb. 15, 2012. The event was co-sponsored by the Wisconsin Department of Agriculture, the State Energy Office, and the Legislative Council – a researcher and attorney staff that serves and advices state legislators. Businesses selling anaerobic digester technology provided presentations and more than 85 people attended the event, including 11 legislative office and the Governor’s office
- A nationwide webinar and town hall conference sponsored by the United States Department of Agriculture (USDA), Office of Rural Development, the Environmental Protection Agency (EPA), AgSTAR Program, the Farm Foundation, the Innovation Center for U.S. Dairy, and the University of Wisconsin-Madison, Wisconsin Bioenergy Initiative took place on the

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[62] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.

[63] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.

University of Wisconsin-Madison campus on March 14, 2012. It included 100 stakeholders onsite and several hundred more viewing the webinar.

- The Midwest Bio Energy Potential sponsored by the Mid-West Energy Research Consortium took place on January 22, 2015 in Milwaukee, WI. Attracting somewhere between 75-100 people. The promotional materials for this meeting stated that:
  "The meeting will explore the utilization of organic waste streams from farms, food processing facilities, municipalities, and wastewater treatment plants, among others, to produce electricity and thermal energy. Presentations will discuss innovative technologies and best practices to turn organic waste into energy, and policies that create new jobs and facilitate rural development by providing additional income streams for local communities, farms and businesses."

During the approximately five years span that elapsed between these meetings there were other biogas meetings and other policy activities in Wisconsin. But during those five years, the growth in deployment of the anaerobic digester technology in Wisconsin and the United States was modest, at best. Wisconsin went from about 22 on-farm anaerobic digesters in 2010 to the current 34 on-farm anaerobic digester, with an average of about two added a year (note: some older digesters went out of operation so the numbers would not indicate that change). Nationally, the U.S. now has approximately 239 on-farm anaerobic digesters and added 151 on-farm digesters in 2010, adding about 17-18 a year during this five year period.

Using the seven functions of the energy technology innovation system Wisconsin appears, at times moving forward in the biogas market, and at times running in place and at times falling backward. On the positive side, Wisconsin has attempted to look at anaerobic digesters *knowledge development* (F2) and *knowledge diffusion* (F3) through the meeting described in this paper and work of the University of Wisconsin-Extension, which has targeted current and potential future operators of the anaerobic digester technology. Likewise, the support in Dane County of two community digesters projects would support elements of (F1) *entrepreneurial activities*, (F2) *knowledge development*, and to some degree (F4) *guidance of the search*. State government policies and programs have been in adequate to date in (F4) guidance of the search, although the state Renewable Portfolio Standard (RPS) did for a couple of year initially encourage utilities to advance on-farm biogas production with improved energy buy-back rates, even briefly some feed-in tariff-like programs. These utility programs, however, were very short-term and since now the utilities have largely complied with the 10 percent renewable mandate in the state RPS, the biogas buy back rates are not offered or at least are not competitive enough to secure project financing. In a minor attempt at (F5) *market formation* the legislature passed a property tax break on the anaerobic digester equipment, but that program does not appear to have done much to stimulated the market.

With the help of the energy technology innovation system framework it is also possible to consider the issue of systemic failures. Systemic failures can be typically grouped into the following broad categories: infrastructural: (related to actors and artifacts), interaction: (related to networks), and capabilities: (related to actors). A big failure in the Wisconsin biogas sector has been (F6) *resource mobilization* and to some degree (F5) *market formation* because most anaerobic digester projects in the state can secure financing to cash flow a project. Two state organizations that could have provided more leadership, as was seen in Germany, are the Wisconsin Farm Bureau and the Federation of Cooperatives. Neither organization, both of which policymakers look to as key voices in the agriculture sector, has warmed up to bioenergy opportunities, especially promoting biogas plants in the state. (One notable except in the cooperative world in promoting renewable energy and anaerobic digester growth in Wisconsin is the Dairyland Cooperative and its co-op membership, this organization is a true leader in farmer owned and generated energy throughout its market). In Germany, cooperatives have been very successful leaders in biogas plant development, knowledge diffusion, advocacy and policy promotion.

A contrast can be drawn with Germany where from 2005 to 2010 the number of biogas plants using anaerobic digester technology doubled from 2,600 to 5,300. Today, Germany has about 9,000 biogas plants using anaerobic digester technology. A combination of cultural and political factors were drivers for Germany in advancing anaerobic digester technology growth including a strong populist opposition to nuclear power, a general public and policymaker desire to avoid dependence on Russian natural gas, and a strong commitment to greenhouse gas reduction. The German government also has more than 20 years of policy designed to assist in an energy sector transformation, predominately using feed-in tariffs to pay for renewable energy investment and growth. Thus the combination of a strong, supportive policy and public support for the German government's goals to advance renewable energy combined to catalyze the marketplace. Policy helped the innovation system work in Germany, a critical contrast to what has happened in Wisconsin and the United States. [64] Wisconsin could be a global leader in biogas development with a commitment to implementing the seven ETIS functions and a more favorable policy environment.

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[64] Negro, S., Hekkert, M.P., (2008). Explaining the success of emerging technologies by innovation system functioning: the case of biomass digestion in Germany. Technology Analysis and Strategic Management 20(4), 465-482.

(3.1) Case Study: Midwest Energy Research Consortium (M-WERC)

Wisconsin could potentially be very well positioned to be a leader in energy technology innovation. The state has many industry leaders in what is called the energy, power and control (E-P-C) space. Further, many of these companies are already organized under the Midwest Energy Research Consortium (M-WERC) a group formed in 2009 to coordinate, initially a Wisconsin-based and later (July 2013) became a Midwest footprint of the existing industry cluster in the E-P-C space (membership listed in appendix 3). M-WERC which is a collaboration of universities and industrial companies began its research and technology focus in the areas of distributed energy resources (DERs) including microgrids, building efficiency, energy storage, biofuels, renewable energy, and the energy-water nexus. The stated goal of M-WERC is to make the Midwest region the leader in energy, power and control and it defined this industry to four major sectors, generation and transmission, distribution and storage, automation and conversion, and efficiency and conservation. M-WERC is organized around five mission activities and committees including technology innovation, market and industry expansion, public policy support, workforce development, and organization development and strategic collaboration.

ETIS Analysis of M-WERC

Using the energy technology innovation systems seven functions to guide an assessment of M-WERC is helpful to understanding strengths and weakness for Wisconsin in this space. The mission of M-WERC, which is to perform collaborative research and drive strategic collaboration of interest to its members, forms a solid linkage to the ETIS functions.

Entrepreneurial Activities: With the opening of the M-WERC, Energy Innovation Center, the organization is now fostering entrepreneurial activities. Specifically, a new initiative called WERCBench Labs is an immersive-program for technology innovators. Between 10 and 15 start-up teams and early-stage companies a year will be a part of a three-month mentor-driven program that includes access to high-performance computing, rapid prototyping facilities, small-scale production and testing equipment. This is a grant program is for start-up companies and includes business planning and development. The program's first cycle of this work began in the summer of 2015.

Knowledge Development: M-WERC funded seven seed research projects, each at the $100,000 level or greater in their first year. This is shared, early stage research, and more than dozen research projects have been completed including New Energy Storage Technologies and Power Converter Topologies for Wind Turbines and Ultra Efficient Nanowire Thermoelectric Materials for Converting Waste Heat to Electricity (full listing in appendix 4).

On a different track of work MWERC has completed two market analysis and development road maps in distributed energy resources (DERs) (with a focus on microgrid technology), and energy efficiency. The organization has begun work on a energy storage roadmap and next up will take on a broad range of opportunities under the umbrella of the energy water nexus. For illustration purposes consider the findings of the M-WERC industry roadmap of Energy Storage Systems (ESS). This industry roadmap included 6 years of historical date and 10 years of forwarding looking forecasts on the ESS – noting that the market will grow by approximately 400 percent by 2024. Further, the ESS industry road map examined all the existing energy storage technologies and added some new technologies including biodigesters and thermal storage for gas turbine inlet chilling. The report also includes a proposed action plan for eah of the M-WERC mission committees.

Knowledge diffusion through networks: One of M-WERC's strengths has been its commitment to disseminate what is learned through its funded research projects and roadmap development. Through a regular process of meetings open to the public, researchers have been allowed to present the findings of their work and post project summaries at the M-WERC Web site. In a similar fashion, half-day presentations on the roadmap findings were held with industry experts leading the discussion. A series of member sub-committees assist in coordinating the research and roadmap development activities. In more recent years, M-WERC has enhanced public dissemination of its meetings and activities by bring on-board a Director of Public Affairs to put out periodic press releases and cultivate mainstream media news coverage of its research and work. To further enhance outreach the organization has also created a newsletter and a blog.

Guidance of the Search: M-WERC does have a policy subcommittee, but this does appear to be an area for general improvement in this organization. To date, M-WERC has done limited policy development or advocacy for the energy-power-control space. Some policy suggestions are included later in this report.

Market Formation: This is an area that is a little more difficult to measure since the member companies are already in the market, small and large, and how much advocacy goes to niche market creation is not highly visible. Another dimension of this function would include advocacy for tax exemptions or incentives that have not been aggressively sought at this time.

Resource Mobilization: To the extent that M-WERC is now trying to foster entrepreneurial activity the organization is playing some role here. Yet, this function is more focused on the financing side of entrepreneurial activity and new start-ups. Government and other individual businesses are likely to seek investments or subsidies for new business.

Advocacy Coalition: On the one hand M-WERC appears a tireless advocate for advancing business in the energy-power-control space, and on the other hand the organization smaller role in policy advocacy would indicate this is an area for growth and expansion. M-WERC is very well position to be a neutral part in bridging the gap between incumbent energy business and new start-up challengers to the status quo energy business.

An example of how M-WERC and its partners are taking energy innovation to the next step of implementation is the announcement (05/26/2015) of microgrid development as a critical component of the Century City Business Park in Milwaukee. The University of Wisconsin-Madison, the local utility We Energies, the Wisconsin Economic Development Corporation, UW-Milwaukee, Wisconsin Energy Conservation Corporation, City of Milwaukee, and other M-WERC partners will evaluate microgrids in an economic and technical feasibility study. Project developers believe the microgrid can increase reliability and creating energy savings for the customers. The business park development will include other energy and water nexus planning in early stages of the project.

Overall, M-WERC has provided state and regional leadership in advancing research and development and innovation in the energy-power-control space. The organization has been a leader in ETIS areas of *knowledge development* (F2) and *knowledge diffusion* (F3) for its members. The opening of the Energy Innovation Center and the newly launched WERCBench Labs program place the organization at a key focal point for fostering and encouraging *entrepreneurial activity* (F1) and touches on dimensions of *market formation* (F5) and resource mobilization (F6). If M-WERC were to revitalize its policy committee it could play a greater role in *guidance of the search* (F4) and *advocacy coalition* (F7). Going forward M-WERC could play a role in all seven ETIS functions by looking to the public policy concept sustainable innovation strategy units. This seems to be a logical extension of the Energy Innovation Center and WERCBench Labs program to better understand which technologies and innovations have the best chance for advancement. The sustainable innovation strategy units are intended to play an advisory role to government programs and policy that can help new ideas and new companies bridge the valley of death from innovation to commercialization. Much promise remains with M-WERC and the growth of the energy-power-control segment of the economy.

(4.) Sustainable Innovation Strategy Units and Sustainable Innovation Incubators

The United States and Wisconsin will need steady and continuous energy technology innovation to adapt to a changing environment. Currently, both the U.S. and state government policy and the existing energy utility sector commitments to innovation are weak at best. This policy inertia is holding back global economic growth opportunities for the U.S. and Wisconsin due to legacy high carbon energy structural lock-in (section 1.5). Yet, in recent years the growth of distributed energy resources are starting to disrupt the energy financial market place and may lead to a break in the existing bottlenecks. Recent improvements in federal government research investments, coupled with private entrepreneurial activity in clean energy development provide a ray of hope that the energy technology innovation system in the U.S. can be sustained. The lingering question is whether the global community can expedite policy to catalyze energy technology innovation in order to achieve meaningful greenhouse reductions to save the planet from pending environmental degradation and public health disasters. This final section of the paper will spell out a strategy for designing sustainable innovation policy.

Linking up the advancement of a continuous energy technology innovation cycle and policy requires new approaches and new partnerships. These are some key steps towards what is being called, "*sustainable innovation policy*," [65] and include:

a) Developing critical public-private partnerships,
b) Including a more robust and democratic stakeholder involvement,
c) Utilizing a mixture of policy instruments.

The overall goal is to establish a more adaptive policy-making approach to be able to respond quickly to future energy technology innovation and allow policy learning going forward. Researchers have looked closely at case studies in countries around the world to find pathways for successful sustainable innovation policy. Building on this body of knowledge and utilizing with the framework of the energy technology innovation system (ETIS) is helpful in making the connections to future policy. A starting point is seeing the challenge of creating sustainable innovation policy; "The challenge of *sustainable innovation policy* is thus to develop enabling policy frameworks, strategies and processes that support technological and institutional innovation in ways that encompass the economic, environmental and social dimensions of sustainability and that lead to the development of better mixes of policy instruments that promote sustainable innovation." [66]

It will take a systems approach to address integrating continuous energy technology innovation and sustainable innovation policy. Typically, advancing innovation and creating policy are address separately in the policy space. Moving forward, policymakers must consider – all together – energy technology innovation, economics, environmental issues, and policy. This systems approach is necessary, in part, because of the previously discussed carbon lock-in keeping

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[65] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

[66] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

the carbon-based energy system intact and increasing the uncertainty about alternatives in the clean energy technology area. One area of opportunity is to look at systems failures – a problem area where market mechanisms fail to achieve objectives and, for example, where policy interventions could address negative environmental externalities not addressed in the market. The current energy system has three areas creating barriers to sustainable innovation policy including:

a) the energy systems places a low priority on long-term social and environmental problems,
b) the problems are complex due to the inter-related nature economic, social and environmental factors,
c) the goals of a sustainable energy are contested by incumbents. [67]

One important distinction of a sustainable innovation policy strategy is a recognition that a balance must exist between the fundamental economic growth imperative driving most innovation policy and to a model of growth limiting negative impacts on the environment and society. Finding this new model of economic growth that takes into account the environment and other societal dimension will be challenged by energy system incumbents unless a convincing new value proposition is advanced and allows for greater evolution of energy production institutions. Several international and U.S. reports recognize this need to reconcile traditional innovation policy and environmental/sustainability policy including "Blueprints for an integration of science, technology, and environmental policy,[68] U.S. Technology and Innovation Policies: Lessons for Climate Change,[69] and the Organization for Economic Co-Operation and Development (OECD), Governance of Innovation Systems, Vol. 1:Synthesis Report.[70] These reports also discuss the importance of learning and improvement of the policy evaluation processes.

(4.1) Policy Windows and Technology Niche Markets

Classic public policy literature, such as John Kingdon's "Agendas, Alternatives, and Public Policies," discusses the value of positive feedbacks in the policy-making processes. [71] Kingdon's research documents how the typical steps in the

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[67] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

[68] Rennings K., Kemp, R., Bartolomeo, M., Hemmelskamp, J., Hitchens, D. (2003) Blueprints for an integration of science, technology and environmental policy. Final report of 5th Framework Strata Project.

[69] Alic, J., Mowery, D., Rubin, E. (2003) U.S. Technology and Innovation Policies. Lessons for Climate Change. Pew Center on Global Climate Change.

[70] Organization for Economic Co-Operation and Development (OECD), Governance of Innovation Systems, Vol. 1:Synthesis Report. Remoe S-O, editor, Paris: OECD.

[71] Kingdon, John W. (2011). Agendas, Alternatives, and Public Policies. Longman Publishing.

policy-making process involve perceived problem, proposed solutions and opportunities for action, giving rise to what he terms “policy windows” – which means the timing is right to advance a new policy or program to address a problem. Applying Kingdon’s thinking and a systems approach to sustainable innovation calls for creating more “regularized policy windows” using a three stepped approach of policy review, long-term planning and institutionalized policy learning. [72] Further enhancement of this approach called for a strategic approach to technology development that follows what the authors termed, “window preparation”, “window creation” and “window utilization” as an integrated sustainable innovation policy process. In a similar manner, combining the critical functions of the energy technology innovation system and the sustainable innovation policy thinking could result in a process of driving new technology towards “niche markets.” This niche market allows for a nurturing of the new technology to reduce costs and improve performance as it prepares to compete with existing technologies. Likewise, during this time of a technology development through niche markets the knowledge networks are built and diffusion of the knowledge can occur.

(4.2) Public-Private Partnerships

In building this sustainable innovation policy regime to include a strategic clustering of opportunities linking technology innovation and policy the role of robust public-private partnerships is considered a critical dimension. In this public-private partnership linkages of technology information gathering, pilot projects, research and development and knowledge dissemination can be strategically coordinated. Researchers for the European Union and individual countries suggest the public-private partnership could have what they named a, “Sustainable Innovation Strategy Unit” for the purpose of mitigating new technology risk and uncertainty as well as addressing the fear of “government picking winners” in the new technology advancement. [73] In essence, the Sustainable Innovation Strategy Unit would allow for a vetting process between business and government public-private partners to inform government assistance with research and development funding, pilot programs, and other policies that might impact traditional market push and pull measures. The Sustainable Innovation Strategy Unit provides a sort of a check and balance system for moving ahead technology clusters in early stage development and minimizing risk in picking the wrong technology. Finally, the Sustainable Innovation Strategy Unit will allows states the ability to adapt policy more quickly

[72] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

[73] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

to the potential rapid development of new and improved technology. An organization such as the Midwest Energy Research Consortium (M-WERC) could serve as the governments Sustainable Strategy Unit for Wisconsin and other Midwest states.

The researchers of sustainable innovation policy also believe that a strong linkage to Sustainable Innovation Incubators provide a perfect complement to the work of the Sustainable Innovation Strategy Unit. The idea is that the Sustainable Innovation Incubators target small firms and enhance the entrepreneurial spirit in the market to help new technology during the critical early stages of development. A good example would be the Midwest Energy Research Consortium (M-WERC) development of the Innovation Center at Century City Tower in Milwaukee. The Sustainable Innovation Incubators combined with the work of the strategy unit could enhance the advancement of local or regional clusters of innovative firms, stimulate knowledge sharing and promote the development of networks and infrastructures to complement new technologies. [74]

(4.3) Forms of Stakeholder Participation

Another recommendation from researchers advancing the Sustainable Innovation Policy concept is the importance of broad stakeholder participation in this space. The participant mixture should include consumers, industry, non-government organizations (NGOs), investors, commercial downstream users, and interested citizenry in shaping sustainable innovation policy. (note that this complements the rethinking of the public utility described in section 2.6 of the paper). The broad stakeholder participation will enhance public support for innovation policy and investments, according to the authors, and provide a “counterbalance to the prevalence of unsustainable technology systems.” One of the manifestations of carbon lock-in is that incumbents in the dominant technologies “may exert disproportionate control” of rules and regulations governing energy systems and limit opportunities for new technology advancement. These researchers again advance the idea of using new technology niche development and “greater democratization of decision-making processes” to address the problems associated with the carbon lock-in of incumbent energy industry. [75]

(4.4) Integrated Mix of Policy Instruments

The mixture of policy instruments needed for sustainable innovation must address each step of the innovation process. Traditional innovation policy includes research and development support such as tax breaks or credits, market push tools such as technology specific investment credits, and market

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[74] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

[75] Unruh, G.C. (2000) Understanding Carbon Lock-In. Energy Policy 28 (2000) 817-830.

pull tools such a mandatory goals as used under Renewable Portfolio Standards and government agency clean energy purchasing requirements. Researchers on the sustainable innovation policy suggest policy and focus on three methodological considerations:

- *Apply sustainability indicators and sustainable innovation criteria;*
- *Balance returns on investment/economic efficiency with sustainability gains;*
- *Utilize a dedicated Sustainable Innovation risk assessment tool in developing policy support instruments*.[76]

This paper suggests that the methodological process be used by policymakers, or even a newly created sustainable innovation strategy unit, to pick and choose policies including those listed in Appendix One.

(4.5) Accelerating Climate Policies Through Technology Innovation Advances

Another perspective on linking innovation measures and policy comes from researcher Martin Janicke, whose work examines the dynamics between technology innovation and energy and climate policy. His research looked at renewable energy policy and energy efficiency policy in China, India, Germany, Denmark, Japan, Great Britain, and Ireland to highlight 10 successful policies that rapidly advanced diffusion of climate-friendly technologies. This research documents a process Janicke called "the triple cycle of innovation" that created policy acceleration. The triple cycle of innovation has three implications; "firstly, policy influence on market development; secondly, the effects of the induced market dynamic on the development of secondary innovations, and thirdly, the feedback of the market and innovation dynamic on the policy process."[77] This cycle is illustrated in image on page 50 of this report.

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[76] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

[77] Janicke, Martin. (2012). Dynamic Governance of Clean Energy Markets: How Technical Innovation Could Accelerate Climate Policies. Journal of Cleaner Production 22 (2012) 50-59. Janicke, Martin. (2010). Dynamic Governance of Clean Energy Markets – Lessons from Successful Cases. Paper presented at the IPCC Symposium in Toyko.

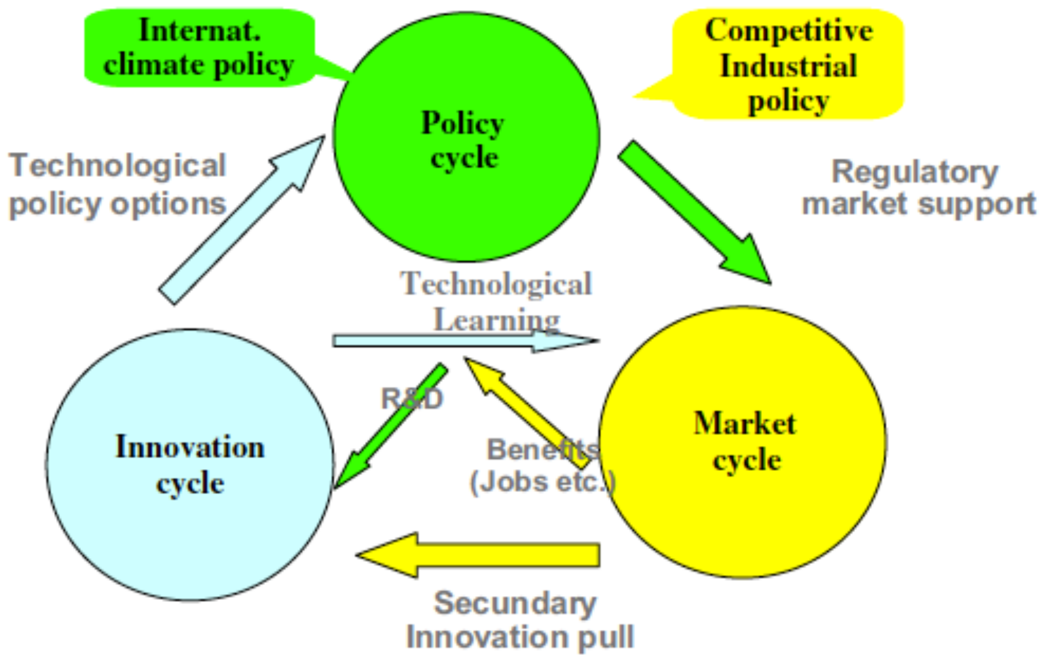

Image from – Janicke 2010. Policy Acceleration – the triple cycle of innovation.

(4.6) Policy Menu by Stage of Innovation

Below is a list of policy options in the more tradition supply push and demand pull method. Also noted are the state of innovation the policy might best applied. Although the list is not exhaustive a state could pick and choose combinations.

a) Research and Development Grants: Supply Push Policy – *Basic Research and Development, Applied Research.*
b) Government and University Research: Supply Push Policy – *Basic Research and Development, Applied Research.*
c) Government Funded Venture Capital: Supply Push Policy – *Basic Research and Development, Applied Research.*
d) R&D Investment Tax Credits: Demand Pull Policy – *Basic Research and Development, Applied Research, Commercialization.*
e) R&D Tax Waivers: Supply Push Policy – *Basic Research and Development, Applied Research.*
g) Government and/or Private Innovation Prize Competitions: Supply Push Policy – *Basic Research and Development, Applied Research.*
h) Public-Private Partnerships for Technology Incubators: Supply, Demand and Other – *Applied Research.*
i) Demonstration Grants and Projects: Supply Push Policy – *Demonstration*.
j) Development Zones: Combination – *Demonstration and Commercialization*.
k) Loan Guarantees: Supply Push Policy – *Demonstration and Commercialization.*

l) Price Supports including Feed-In Tariffs, Reveres Auctions: Combination – *Commercialization and Deployment in the Market*.
m) Quantity Mandates including RPS, RFS, LCFS, etc.: Combination – *Commercialization and Deployment in the Market.*
n) Performance-Based Incentives: Combination – *Commercialization and Deployment in the Market.*
o) Carbon Pricing: Combination – *Commercialization and Deployment in the Market.*
p) Consumer Rebates: Combination – *Commercialization and Deployment in the Market*
q) Producer Rebates: Supply Push – *Demonstration*, *Commercialization and Deployment in the Market*
r) Accelerated Depreciation: Supply Push – *Commercialization and Deployment in the Market*, *Commercialization and Deployment in the Market*
s) Green Bond Programs: Supply Push – *Commercialization and Deployment in the Market*
t) Regulatory Revisions: Combination – *Demonstration, Commercialization and Deployment in the Market*
u) Removing Subsidies to Legacy Technologies: Combination *Commercialization and Deployment in the Market.*
v) Government Initiated Knowledge Diffusion: Combination – *Research, Demonstration, Commercialization and Deployment in the Market.*[78]

(4.7) Energy Technology Innovation Advisory Council (aka: Sustainable Innovation Strategy Units

Wisconsin policymakers should consider creating a Energy Technology Innovation Advisory Council – a renamed version of the Sustainable Innovation Strategy Units described in section 4.0.

The council would advise government agencies, policymakers, stakeholders and others on new trends, ideas and opportunities in energy technology innovation. The purpose of the council is not to pick winners in energy technology, but rather advise on an energy technology portfolio management. The primary goal of the Energy Technology Innovation Advisory Council is to allow the energy innovation ecosystem to grow. Because innovation is constantly evolving the council can provide perspective on generational thinking in energy innovation and how to plan both short-term and long-term. Each new idea and the entrepreneur or companies behind the idea may be at a different stage of product or service development. The council can manage the energy technology innovation portfolio by guiding new companies and potential large company partnerships into

[78] Policy Menu is modified and adapted from multiple sources. Among those sources include: Nelson, D. and Vladeck, T. (2013). The Climate Policy Initiative. www.ClimatePolicyInitiative.org

strategic alliance or guiding them to potential funding sources. Another council goal is to identify gaps in the energy innovation space and potential ideas that address the gap. Further, the goal of the council must always be to constantly improve the adaptability of the energy innovation ecosystem. An organization such as the Midwest Energy Research Consortium utilizing its Energy Innovation Center and WERCBench Labs program can provide input to the Energy Technology Innovation Advisory Council. University research organizations and private sector research and development teams can partner with the council on identification of gaps and solutions in the energy technology innovation space.

(4.8) Conclusion:

President Barack Obama has set a goal for an 83% reduction in GHG emissions by 2050 in the United States. While many promising clean energy generation options are slowly gaining a market hold, e.g. solar PV and wind turbines, these distributed generation (DG) options are probably not adequate to achieve the necessary GHG reductions in the energy power sector. Therefore, the United States and specifically Midwest states, including Wisconsin, need more sophisticated energy technology innovation policies. The model suggested by author Tim Foxon titled, “sustainable innovation policy” is a logically starting point for the U.S. and Wisconsin. This framework for a policy process should aim to do the following:

1) “Stimulate development of a sustainable innovation policy regime, by bringing together the innovation and environmental policy regimes and improving the rationale for public policy interventions to promote sustainable innovation;

2) Apply systems thinking, by engaging with the complexity and systemic interactions of innovation systems and policy-making processes;

3) Advance the procedural and institutional basis for delivery of sustainable innovation policy aims, including improved strategies for stakeholder engagement;

4) Develop a more coherent and integrated mix of policy instruments to promote sustainable innovation;

5) Improve policy review, correction and learning mechanisms for adaptive improvement to sustainable innovation policy processes.” (Foxon, 2004, p.3) [79]

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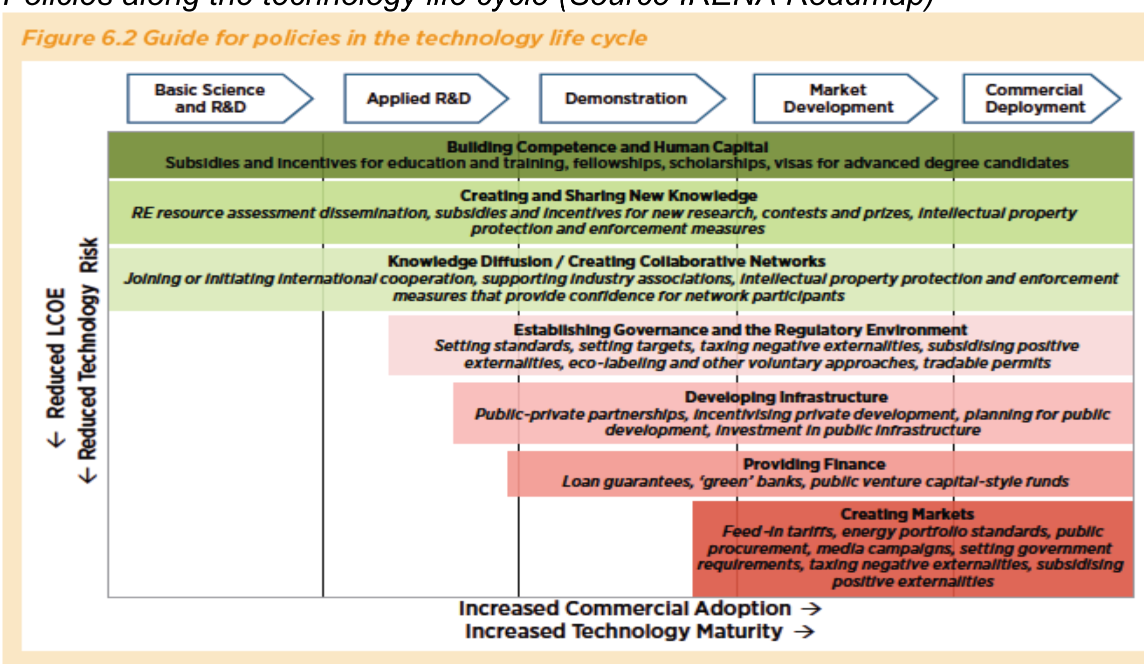
[79] Foxon, Tim and Pearson, Peter. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: some features of a sustainable innovation policy regime. Journal of Cleaner Production 16S1 (2008) S148-S161.

One question in this paper asked, ‘is from an environmental needs and public health perspective, is the energy system change moving fast enough to address global societal sustainability?’ Because it is likely an evolutionary change, the answer may be that change is not fast enough to achieve the greenhouse gas reduction goals set by President Obama for 2050. One-way to measure is a comparison to the innovation timelines in pharmaceutical software and IT, done by the International Renewable Energy Agency. In their analysis it takes 10-15 years for commercial readiness of energy technology innovation compared to 1-5 years in the telecommunications sector. Therefore, to achieve clean energy goals by 2030 means the innovation cycle work must begin right now. [80] An energy technology innovation policy agenda is likely to be the only way to achieve a sustained reduction in GHG emissions from the energy sector. If Wisconsin and the United States want to achieve continuous energy technology innovation then it will be necessary, going forward, to have the proper combinations or sets of policies, including new and additional policy measures in place. When advancing energy technology innovation it is important to clarify the necessity to have more than just a better R&D pipeline. It is recommended that more strategic energy system thinking be applied to programs and policies in the U.S. and Wisconsin and that regular evaluation of these policies and programs take place.

Policies along the technology life cycle (Source IRENA Roadmap) [81]



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[80] IRENA – International Renewable Energy Agency (2014) Remap 2030 –A Renewable Energy Roadmap. June 2014.

[81] IRENA – International Renewable Energy Agency (2014) Remap 2030 –A Renewable Energy Roadmap. June 2014.

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(5.0) Appendices

Appendix 1

The authors William B. Bonvillian and Charles Weiss, in an online publication titled, “The Road to a New Energy System: Stimulating Innovation in Energy Technology,” modified from the *Issues in Science and Technology*, provide a detailed list of energy technology pathways and a second list of policies to match the growth of pathways.

“A complex sector such as energy is home to a great range of established and potential technologies in a variety of separate or connected market sectors. Each technology will follow a different route to emergence at scale, but some may share common features. Categorizing common technology-emergence pathways allows the design of support instruments appropriate to each category; without rigorous and careful categorization, workable support mechanisms will simply not emerge, and gaps in and barriers to implementation are inevitable. With this in mind, we have identified the following energy technology pathways:

- ***Experimental technologies***. This category includes technologies requiring extensive long-range research. The deployment of these technologies is sufficiently far off that the details of their launch pathways can be left to the future. Examples include hydrogen fuel cells for transport; genetically engineered biosystems for CO2 consumption; and, in the very long term, fusion power.
- ***Potentially disruptive technologies***. These are innovations that can be launched in niche markets that are apart from established systems. In these markets, such innovations face limited initial competition, may expand from this base as they become more price-competitive, and can then challenge established incumbent or “legacy” technologies. Examples include wind and solar technologies, which are building niches in off-grid power and LED lighting.
- ***Secondary technologies (uncontested launch)***. This group includes secondary (component) innovations that will face market competition immediately on launch from established component technologies that perform more or less the same function. These innovations can be expected to be acceptable to recipient industries if the price is right. On the other hand, they must face the rigors of the tilted playing field, such as a competing subsidy, or the obstacle of a major cost differential without the advantage of an initial niche market. Examples include advanced batteries for plug-in hybrids, enhanced geothermal, and on-grid wind and solar.
- ***Secondary technologies (contested launch)***. These are secondary innovations that in addition to facing the same barriers as the uncontested technologies have inherent cost disadvantages and/or can be expected to face economic, political, or other nonmarket opposition from recipient

industries or environmental groups. Examples include carbon capture and sequestration, biofuels, and fourth-generation nuclear power.

- ***Incremental innovations in conservation and end-use efficiency***. The implementation of these innovations is limited by the short time horizons of potential buyers and users, who typically refuse to accept extra initial costs unless the payback period is very short. Examples include improved internal combustion engines, improved building technologies, efficient appliances, improved lighting, and new technologies for electric power distribution.
- ***Improvements in manufacturing technologies and processes***. These are improvements in the ways in which products are manufactured that can drive down costs and improve efficiency, enabling the new products to compete in the market more quickly. These investments are likely to be inhibited by the reluctance of cautious investors to accept the risk of increasing production capacity and driving down manufacturing costs in the absence of an assured market.

The second step of our analysis requires classifying support policies for the encouragement of energy innovation into technology-neutral packages and matching them to the technology groupings developed in the first step. In other words, once we have identified the different launch pathways by which new technologies can arrive in a market at scale, we can match them with the best support policies. The policy elements include:

- ***Front-end technology nurturing***. Technology support on the innovation front end, before a technology is close to commercialization, is needed for technologies in all six categories above on the technology-launch pathway. This includes direct government support for long- and short-term R&D, technology prototyping, and demonstrations.
- ***Back-end incentives***. Incentives (carrots) to encourage technology transition on the back end as a technology closes in on commercialization may be needed to close the price gap between emerging and incumbent technologies. Whereas experimental technologies are in too early a stage to need incentives, and many disruptive technologies may be able to emerge out of technology niches into a competitive position without further incentives beyond R&D support, other categories will probably require carrots. These include secondary technologies facing both uncontested and contested launch, incremental innovations in technology for conservation and end use, and technologies for manufacturing processes and scale-up. Carrots may also be relevant to some disruptive technologies as they transition from niche areas to more general applicability. These incentives include tax credits of various kinds for new energy technology products, loan guarantees, low-cost financing, price guarantees, government procurement programs (including military procurement for quasi-civilian applications such as housing), new-product

buy-down programs, and general and technology-specific intellectual property policies.

- ***Back-end regulatory and related mandates***. Regulatory and related mandates (sticks), also on the back end, may be needed in order to encourage component technologies that face contested launch and also some conservation and end-use technologies. These include standards for particular energy technologies in the building and construction sectors, regulatory mandates such as renewable portfolio standards and fuel economy standards, and emission taxes." [82]

Appendix 2

Policy initiatives designed to facilitate the adoption of cleaner energy technologies should be based on three basic priorities:

- Invest in niche markets and learning, in order to improve technology cost and performance;

- Remove or reduce barriers to market development that are based on instances of market failure;

- Use market transformation techniques that address stakeholders' concerns in adopting new technologies and help to overcome market inertia that can inhibit the take-up of new technologies.

Specific points, based on case studies for a number of technologies and countries, include:

- Deployment policy and programs are critical for the rapid development of cleaner, more sustainable energy technologies and markets. While technology and market development is driven by the private sector, government has a key role to play in sending clear signals to the market about the public good outcomes it wishes to achieve.

- Programs to assist in building new markets and transforming existing markets must engage stakeholders. Policy designers must understand the interests of those involved in the market concerned, and there must be clear and continuous two-way communication between policy designers and all stakeholders. This requires assignment of adequate priorities and resources for this function by governments wishing to develop successful deployment initiatives.

- Programs must dare to set targets that take account of learning effects, i.e. go

[82] Weiss, Charles, and William B. Bonvillian. (2209) "The Road to a New Energy System: Stimulating Innovation in Energy Technology." Issues in Science and Technology 26, no. 1 (Fall 2009).

beyond what stakeholders consider is possible with present alternatives.

• The measures that make up a program must be coherent and harmonized, both among themselves and with policies for industrial development, environmental control, taxation and other areas of government activity.

• Programs should stimulate learning investments from private sources and contain procedures for phasing out government subsidies as technology improves and is adopted by the market.

The report concludes that it is the combined effect of technology potential and customer acceptance that makes an impact on markets and hence on energy systems. Developing a deeper understanding of both, including how they are influenced by government, is an essential ingredient of effective technology development and deployment policy.

From IEA Report "Creating Markets for Energy Technologies."

Appendix 3

Midwest Energy Research Consortium Membership

- Alliance Federated Energy
- American Transmission Company
- AO Smith
- The Boldt Company
- Briggs & Stratton
- DRS Power Technologies
- EME Associates
- Franklin Energy Services
- Gateway Technical College
- General Capital
- General Compression
- Godfrey & Kahn
- Graef Engineering
- Greenfire
- Johnson Controls
- Jonco Industries
- Kohler Power Systems
- LEM
- Manufacturing Diversity Institute
- Michael Best & Friedrich
- Miron Construction
- Odyne Systems, LLC
- Regal Beloit
- Rockwell Automation

- S & C Electric
- TM3 Systems
- Vizn Energy Systems
- Whyte Hirshboeck Dudek S.C.
- Wisconsin Manufacturing Extension Partnership
- ZBB Energy
- University of Wisconsin-Madison
- University of Wisconsin-Milwaukee
- Marquette University
- Milwaukee School of Engineering
- Gateway Technology College
- Milwaukee Area Technology College
- Northeast Wisconsin Technical College
- Waukesha County Technical College

Appendix 4

Midwest Energy Research Consortium Recent Research

1. Enhancements of Fiber Optics Current Sensors for Metering Applications – Chiu Tai Law, University of Wisconsin-Milwaukee

2. Distributed Power Conversion Architecture for Microgrids and Integrations of Renewable Energy Sources – Yehui Han, University of Wisconsin-Madison

3. Planning and Design of Advanced Microgrid Test-bed Facilities in Milwaukee and Madison – Adel Nasiri, University of Wisconsin-Milwaukee, Tom Jahns, University of Wisconsin-Madison

4. Integration of Second-Life Batteries into an EV Charging Station with Renewable Energy Sources – Adel Nasiri, University of Wisconsin-Milwaukee

5. Graphene-Tin Hybrid Nanomaterials for High-Performance Lithium-Ion Batteries – Junhong Chen, University of Wisconsin-Milwaukee

6. Virtual Retrofit Model for Aging Commercial Buildings in a Smart Grid Environment – Jeong-Han Woo, Milwaukee School of Engineering

M-WERC Completed Research Projects

- DC Distribution for Wind Farms to Achieve Higher Efficiency and Reliability and Lower Cost
- Current Sensors for Smart Grid Applications

- Novel Protection Means for PM Machines in Wind Energy Generation and Hybrid-Electric Vehicle Applications
- Condition Monitoring and Predictive Diagnostics for Wind Turbine Blade Pitch Control Systems
- New Energy Storage Technologies and Power Converter Topologies for Wind Turbines
- High Capacity Li-Ion Batteries Based on SnO_2Nanoparticles
- CO_2 Recycling and Sequestration via Algae Grown with Coal-Fueled Power Plant Flue Gas
- Ultra Efficient Si/SiGe Nanowire Thermoelectric Materials for Converting Waste Heat to Electricity
- Developing a Business Case for Sustainable Asset Renewal of Existing Buildings
- Probabilistic Methods for High Wind Penetrated Power Systems Design of Cost-competitive, Fuel-flexible, Low NO_X Burners with a Range of Firing Rates

Appendix 5

M-WERC Technology Focus

M-WERC has defined primary EPC technology focus areas of interest;

An initial focus on the two with greatest potential - Utility and Customer Microgrids & Building Energy Efficiency Distributed Energy Resources & Systems.

- Market is emerging rapidly and requires technology development in areas aligned with M-WERC's strengths

- M-WERC's Midwest Region has strong potential to lead the microgrid market due to CERTS, strong research capability, and required power and control product technologies

Building Energy Efficiency

- Microgrid technology will be the next big wave to accelerate growth of the building energy efficiency (BEE) market.
- Microgrid and BEE markets will likely converge, providing a huge opportunity for the M-WERC and the Midwest Region to provide leadership & innovation in both areas.

Energy Storage

- Excellent fit with regional battery, power and control competencies; microgrid and building energy efficiency

Biofuels

- Excellent fit with the strong biomass potential of the region; power and control for biomanufacturing

Renewables

- Expanded M-WERC Midwest Region region offers a strong home market for wind (IL, MN, IA, IN)
- Potential linkage with future BEE and microgrid market opportunities
- Solar power is emerging and will be driven/linked with future BEE and microgrid market opportunities

Energy-Water Nexus

- Natural fit for the Midwest Region; Siginificant opportunties and leverage when combining regional strengths in both technology areas. (From M-WERC Web site) [83]

Report graphics and illustrations

Figure 1.2 -- Systems-based interactive innovation (p.22)

Total Energy Consumption by End-Use Sector, 1960-2040 (p.25)

Figure 4 – The age of Energy. History suggests a process of substitution (p.29)

Policy Acceleration – the triple cycle of innovation (p.50)

Policies along the technology life cycles (p.53)

[83] Midwest Energy Research Consortium Web Site. (2015). Accessed on May 28, 2015.

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