Technology Evolution

SunShot
U.S. Department of Energy

Introductory question

- What is a question we could ask about technology evolution, which when answered could yield deep insight into how to spur innovation?

  1) **Collaboration**: How do we create an environment that fosters collaboration?
  2) **Incentives:** What are the incentive structures for innovation? How do we incent individual innovators? (ties directly to creating an environment conducive to collaboration)
  3) **Feedback:** What types of feedback do we need to better understand how information is transmitted to innovators?
  4) **Motivation:** What is the primary motivation for the innovator?
  5) **Time Horizon:** How far ahead (time horizon) does one need to look to better understand technology evolution?
  6) How can the academic and research community learn from the critical market actors (integrators/sales/contractors)? (depends, in part, on time frame but also on tools/methods/understanding)
  7) How do we verify that the inputs to models are the BEST inputs?
  8) Research: How do we foster collaboration across disciplines and sectors in a way that is organic? Cross-disciplinary research is beneficial, but not useful when forced.
  9) **Technological compliments**: How do we coordinate synergies amongst technologies?
  10) **WHY:** Why is technology evolution significant?
  11) **Mindsets:** How do norms and ecosystems affect innovation/development/idea sharing?
  12) **Mobility:** How do we increase "flow" of expertise from company to company and sector to sector?
  13) **TRUST→ ex) utilities vs. solar installers**

Introductory question

- **What is a question we could ask about technology evolution, which when answered could yield deep insight into how to spur innovation?**

- How does cost/performance scale with production and time?
- What is the overall learning rate, and what are the locations of learning? Global, state? Clustered ecosystems?
- How do we separate effects? Very difficult to control for the effect of a particular variable. Cause and effect.
- What are the different influences effecting the transformation: regulators, legislation, (related but different), carrots and sticks? Implicit assumption – can't rely on the private sector to track the evolution of a technology, government has a role
- On the non-hardware side (soft cost side) has been more touchy feely. How can we leverage new datasets on behavior to model and understand how soft costs can be reduced?
- Can we identify general design features of technology that lend themselves to rapid innovation? Across many different technologies. The behavioral part is also important, but don't forget the tech.
- Better understand from a customer behavior perspective what are barriers to adoption from tech point of view (hurdles: financing,, etc). How big is that market?
- When market gets more efficient, soft costs go down but what are the mechanisms for that? Look at Germany and see what did it.
- Many orgs follow design for six sigma; for module we understand this pretty well, inverter as well. If we come up with similar tools, what would we put as the customer requirements for each tech on the supply chain.
- How do you model the interaction between innovator and consumer? Or an interaction involving a manufacturer, installer and end user? How do we make this quantitative rather than just stick figure diagrams?
- Most important missing piece: quantifying spillover effects. Solar was enabled by advances in IT, semiconductor industry. Subsequently, how do you make effective spillovers happen?

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Technology Evolution: Discussion Questions

Network of innovators

- What questions can we ask about the structure and dynamics of the network of innovators/discoveries that could provide insight into how to better foster discovery?

- On datasets: its hard to know what data would be most useful.

- Lots of work has been done analyzing patents, and this will go forward. If you change the network, how does it change the innovative activity?

- Technology roadmaps have enabled/fostered collaborations.

  - Sematech consortium in NY.

  - Can you do these roadmaps/consortiums on the non-technical side.

- Did the number of patents go up for researchers who joined a hub?

- Could start with patent data, look at collaboration between nodes, see if that led to a research innovation acceleration. Cross reference with some assessment of which projects were successful.

  - Doubt that there is a lot of collective memory on past projects and practices. Hard to find out what has been attempted in the past and what has worked.

- HUBS are like an artificial experiment.

- Humans learn from success or failure, failure and iteration is almost always a part of the process to success. So you shouldn't overly penalize "failure".

Technology Evolution: Discussion Questions

Network of innovators

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- <u>CHALLENGES (specific to solar)</u>

- Clear market for something like a module, no dataset for what the non module costs are.

  - Not sure this is a network of innovators challenge.

    - This is a motivator for the network to innovate.

  - There may not be a market signal to innovate on the BOS side.

- Involvement of more fundamental academic conferences on photovoltaics, a lot of communication and information sharing. This means that there is an existing framework for dialog that may enable the creation and improvement of this network.

- Networks for this could be more disaggregated than one where there is a smaller community with larger barriers to entry. Participants can be segregated.

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Technology Evolution: Discussion Questions

Human-technology interface

- How can we better understand/conceptualize the connection between users and innovators and use this understanding to accelerate the innovation process?

→ How analytical can we be? How quantitative can we be?

Surveys as a means to feed info back to innovation network.
Gap between innovator and consumer similar to gap between engineers and scientists

- Apple model: if we build it they will come, may not necessarily apply to solar. A one time decision. HOWEVER, Apple did invest in understanding consumer preferences.

- Technology decision: capture information on the NON-adopters. Let us better understand why people choose NOT to invest in solar. The biggest dynamic improvement is linked to financing mechanisms. What other innovation can be spurred. Advanced metering infrastructure as a means to collect data.

- How do we predict what consumers want?

- Closing thoughts: Need to capture market segments that are not early adopters,

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- You can create a very functional product, but is this what drives adoption? Are there aesthetic issues? Are scientific innovations required to enable the relevant functionality?

- In energy efficiency, the developers often test early products on potential adopters to iterate at an early stage. This is followed by pilots and demos. There is a natural process for doing this.

- Prior to a couple years ago, almost every job was a one-off custom project. That layered on a whole bunch of costs. Third party ownership scenario may make this better.

- Understanding what limited, manageable subset of choices the customers are willing to tolerate may be an important area of research.

- Understand what performance targets are needed in different circumstances. Can we think about performance targets that would allow us to capture portions of the market.
    - Not tailored to each individual consumers, but classes of consumers.
    - Ease of installation, usability could be possible wants to analyze.

- 3M: They drove innovation by having the people in the lab out talking to customers.

- Is there an example within solar of product development coming out of such interactions:
    - Microinverters.
    - Some innovations come more from the manufacturer <-> installer interaction not the manufacturer <.> customer.
    - Sometimes it is the customer, (don't like the big inverter box).

- What about the apple model "It is not the consumer's job to know what they want"

- Trouble with PV is that it largely provides an already existing product: electricity. It is hard to differentiate for the customer from what they already have.

- Innovations are not just what does the thing look like: more important may be: financing, third party ownership, how does it effect your bill etc. Interfaces also important.
    - Dashboards in your home, saying how much potential savings they would get with PV in there home.

- Decisions in the lab will influence how consumers perceive the technology. New insights to be had from developers interacting with consumers and installers, even at the fundamental level of materials design.

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- How can we better understand/conceptualize the connection between users and innovators and use this understanding to accelerate the innovation process?
- We are finding the customer experience and reactions are more than just the system itself, but also the energy monitoring.
    - One of the biggest levers might be combining PV and energy efficiency with advanced interfaces to make it exciting.
- (anonymous) haven't been sold because it seems like innovations in technology and financing are happening which might make it more profitable to install it later rather than today.
- What potential is there for using datasets and being quantitative
    - Four community groups
        - Researchers
        - Module producers
        - Installers
        - Customers
    - Make sure that researchers are still linked to the customer needs.
    - Differing timescales between how long research takes and how quickly customer preferences can change.
- Time series of cost of electricity changes in different regions to look at competitiveness of wind and solar.
    - (we have this data, so we use it)
- Can DOE play a role in setting forth a set of experiments in different places that lead to very systematic datasets. This will be expensive, but it is a dataset that will enable a lot of research that could not be obtained otherwise.
    - Would be great to have data that can be shared.
    - Smart meter ARRA funding: Each of these projects there is a technical review committee look at social science issues to learn how the customers are behaving. May be a mechanism to do this as well.
- Have other countries been doing "soft side" analysis. See if you can get their datasets.
- Is this an innovation problem or is it an institutional problem. In Germany in certain situations you don't need a permit, no interconnection, financing provided by state bank. Are these the things that matter more?
- Access to information about these differences in soft costs could drive innovation to solve the problem.
- Wouldn't it be nice to have a national clearing price to find out how much other people are paying. Make it a requirement of getting an ITC that you have to submit this data.
- Bay area study of disparity of permitting costs shamed people into lowering their costs.

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Targeting intervention
- What conceptual/analytical models for how a technology evolves exist or need to be developed to inform how we can accelerate the rate of technological progress?

Consumer preferences require design change and potentially new breakthroughs in science. Design and science operate on different time scales. (competing time scales).

Which subsets of technology warrant innovation?

LEARNING CURVE→ what speeds/accelerates the learning curve? Why 20%? If something becomes wildly popular and production increases, costs decline. What dictates the slope? Let us try to understand the conceptual/analytical frameworks for technologies.

Business models as a form of technology → impact learning curve
Improvement in efficiency as a result of experience

Technology deployment barriers:
1) How much are installers spending to overcome barriers to acceleration? Such as permitting, installation, financing, etc.
2) Consumers linking back to innovators.

Improved installer learning curve→ increased deployment→ feedback loop to declines in costs and learning curve improvements for R&D

Summary points

Network of innovators

- What questions can we ask about the structure and dynamics of the network of innovators/discoveries?
  - How do we understand spillover processes and devise systems to maximize their impacts?
  - How can actively change the network of innovators by making new connections to maximize developments?
  - What data exists vs. what data would we like to have? Then, what could we do with it?
    - Advantages and disadvantages of different datasets (e.g. IP)
  - PV has extensive information sharing network between different stakeholders already, How could it be tweaked? Are certain parts of the supply chain focusing too narrowly on cost?

Human-technology interface

- How can we better understand/conceptualize the connection between users and innovators?
  - Have to overcome lack of product differentiation of providing electricity – something customer already has:
    - You can package PV and Energy Efficiency and how those savings are presented to the customer
  - Innovations can be outside of just technology: could also include financing mechanisms, third party ownership, aesthetics.
  - What can be done from a standardized dataset to give insight.

Other

- What is the specific technology evolution strategy as related to soft costs?
- Can we identify general design features of technology that lend themselves to rapid innovation? Across many different technologies. The behavioral part is also important, but don't forget the tech.
- How do we separate effects? Very difficult to control for the effect of a particular variable. Cause and effect.

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