Building a Solar PV Roadmap

The National Academies

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Purpose

- Accelerate PV progress in order to meet national needs in
  - Climate change
  - Energy prices
  - Oil imports (with electric vehicles)
  - Do so in the most cost-effective and low-risk manner

Solar Partnership for Cost-Optimized Terawatt Deployment

Technology Push

- R&D
- Technology Development
- Demonstration

Market Pull

- State Incentives
- Federal Incentives
- GHG Offsets
- Regulations
- World markets

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Government R&D 2009

Organization	Style	Purpose	Timing
NSF	University "blue sky" and "transformational"	Education and a new generation of solar technologies	Futuristic
DOE Basic Energy Sciences, Office of Energy Research	National Lab and university "blue sky" and "transformational"	Education and a new generation of solar technologies	
DOE ARPA E	Cross-cutting "transformational"	Bright ideas and a new generation of solar technologies	
DOE, Energy Efficiency and Renewable Energy, Solar Energy Technology Program	Applied and goal oriented (Corporate, university, National Lab)	Progress with existing solar technologies	Now

State of US Solar PV Research

- PV Companies
  - But they mostly do near-term, (their) product-specific research
- EERE-sponsored
  - Universities
  - NREL
  - Sandia
  - Companies
- Non-EERE PV research is in the “start-up” phase, and is mostly on high-risk technologies with uncharacterized payoffs
- EERE PV research is focused on existing PV options that have proven worth and clear potential

Solar Roadmap #1

- The first solar roadmap might be one that would help Congress, DOE, and the Administration understand the immediacy of the solar opportunity
  - The robustness and promise of existing PV in terms of meeting low-cost goals; and
  - The immediacy of the opportunity to cost-effectively deploy PV on an energy-significant scale

The PV Generations

Existing (EERE)

- Silicon and thin films (Gen 1,2)
  - About $4/W installed best practices
    - Hearing $3/W possible now
  - **Goal of $2/W installed seems *certain* within decade**
  - **Progress to $1.5/W and even $1.25/W possible**

Pre-Commercial and Blue Sky

- Gen 2 Concentrators (EERE)
- Gen 3+ (non-EERE)
  - Should aim at below $1.5/W installed systems
    - **Possibly sub-$0.5/W**
  - *Yet no one can validate they can make these goals*
  - 25-40 years away, based on experience
  - **More Importantly: Achieving Gen3 goals is NOT necessary for deploying cost-effective TWs of PV**

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Depending on location and financial assumptions, $1/W is about 5 ¢/kWh intermittent electricity during amortization period; much less, afterward

Proposed Top-Level of EERE PV Roadmap

- "Commercial, with Proven Potential To Make Low-Cost Goals" (main funding)
  - Crystalline Silicon PV
  - CdTe
  - CIS-alloys
  - Thin film silicon
- "Post-Proof of Concept" (much less funding)
  - Pre-commercial, but with proof-of-concept cell and module results sufficient to attract initial private funding.
  - Content of this category changes, which is important for program evolution
  - Possible potential for meeting low-cost goals
  - Entrants
    - Dye cells
    - PV concentrators

Technical Roadmap Philosophy

- Goals in ¢/kWh are:
  - Primarily for module development (*nickel*/kWh goals), since the module
    - Is the majority of system cost
    - Drives balance-of-system (BOS) cost/output via efficiency ("module" includes cells)
  - Secondarily (*penny* a kWh goals) for:
    - Inverter and creative BOS designs
    - Grid integration
    - Sustainability
  - Non-technical: Reduce non-hardware siting and permitting costs

More Philosophy

- Goals should be high-level and light-handed
  - Efficiency, cost per unit area, reliability
  - Allow creativity just below top-level goals
  - Be aware of the breadth of work and patience needed to make progress
- Goals and approaches should always be open to criticism, new insights, revision
  - The roadmap and its resulting program emphasis should be the subject of continuous improvement (especially free-wheeling, external criticism)
  - “Proof of concept” category accepts promotion and demotion

Technical Roadmap: *Identify Key Pinch Points*

- For *Each Technology Option* Identify Pinch Points and Critical Paths
  - Efficiency
    - Cell
      - Key pinch points (e.g., voltage, doping, contacting)
    - Module
      - Key pinch points (e.g., interconnection resistance, maximum active area)
  - Area cost
    - Process (e.g., faster or simpler process)
    - Cell design (e.g., simpler, thinner, different)
    - Module (e.g., faster, simpler)
  - Reliability
    - Intrinsic (identification, stress tests to bin approaches)
    - Encapsulation and module design (identification, stress tests to bin approaches)
  - Other (e.g., thin cells due to materials availability, ESH due to product acceptance)

After High-Level Roadmap…

- Select issues for RFPs (pinch points and critical paths)
- Understand capabilities needed
- Develop issue-specific RFP asking for right mix of capabilities
  - "Virtual Lab" team addresses each problem over multi-year period
- NREL and SNL participate in every winning proposal *because they must also be working on the key issues*

Denouement

- The first needed "solar roadmap" **is the one that clearly identifies existing PV technologies as sufficient to meet low-cost goals within about a decade and builds this consensus**
- The second roadmap is the one needed to help assist existing technologies to meet those goals
- The technical roadmap should be "high-level," technology-specific, define key problems, define needed operational capabilities, and then solicit teamed solutions
- **Such a roadmap would re-energize critical near- and mid-term gov't-funded R&D**