Educational Modules on Solar Energy

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Background

- Sustainable energy has become a key piece of power companies IRP's (Integrated Resource Plans)
- Large-scale development and testing of advanced batteries, fuel cells, geothermal, wind turbines, and solar panels
- Growing role of distributed power / smart grids
- Module approach allows problems to be "dropped in" to curricula in CHE, ME, ECE, etc.

Background

- CACHE Corporation initially sponsored the "fuel cell curriculum development project"
  - J. Keith (Michigan Tech), H. S. Fogler (Univ. of Michigan), D. Chmielewski (Illinois Inst. of Tech.), and M. Gross (Bucknell Univ.)
- Led to grant from U. S. Department of Energy
- Currently supported by Mississippi State University
- Hydrogen and fuel cell Modules available at website:
  - http://tinyurl.com/h2bulldog

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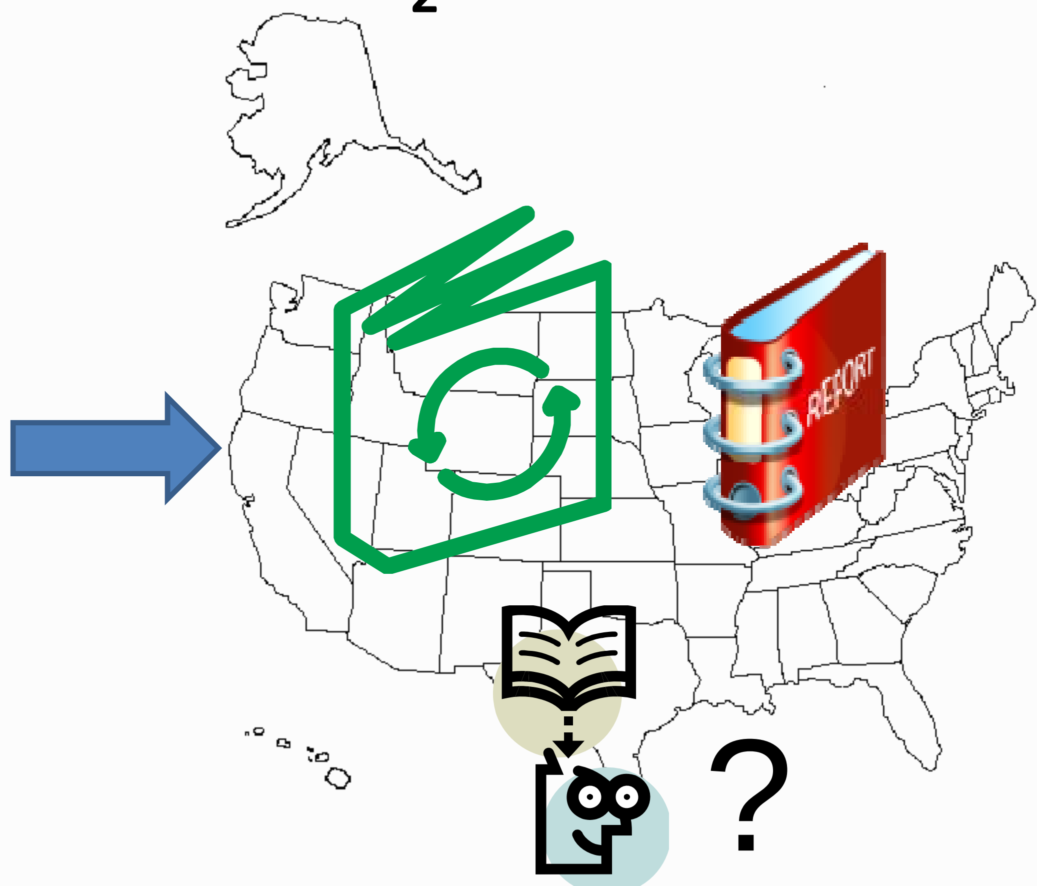
Approach: Broad Impacts

National Dissemination of H_2 Modules

Chem Eng   Mech Eng   Elec Eng



Hydrogen Courses & Curriculum

Modules

Text Supplements

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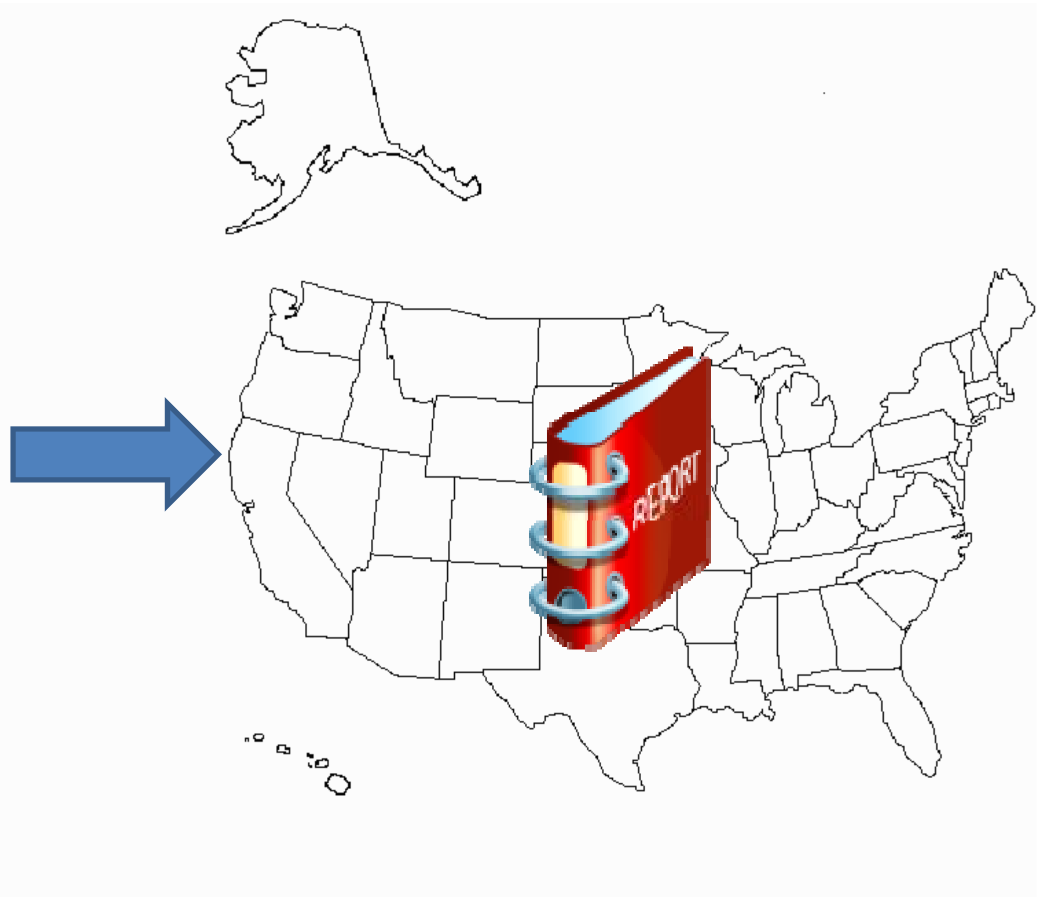
Approach: Broad Impacts

National Dissemination of Solar Modules

Chem Eng Mech Eng Elec Eng



Hydrogen Courses & Curriculum
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Solar Energy

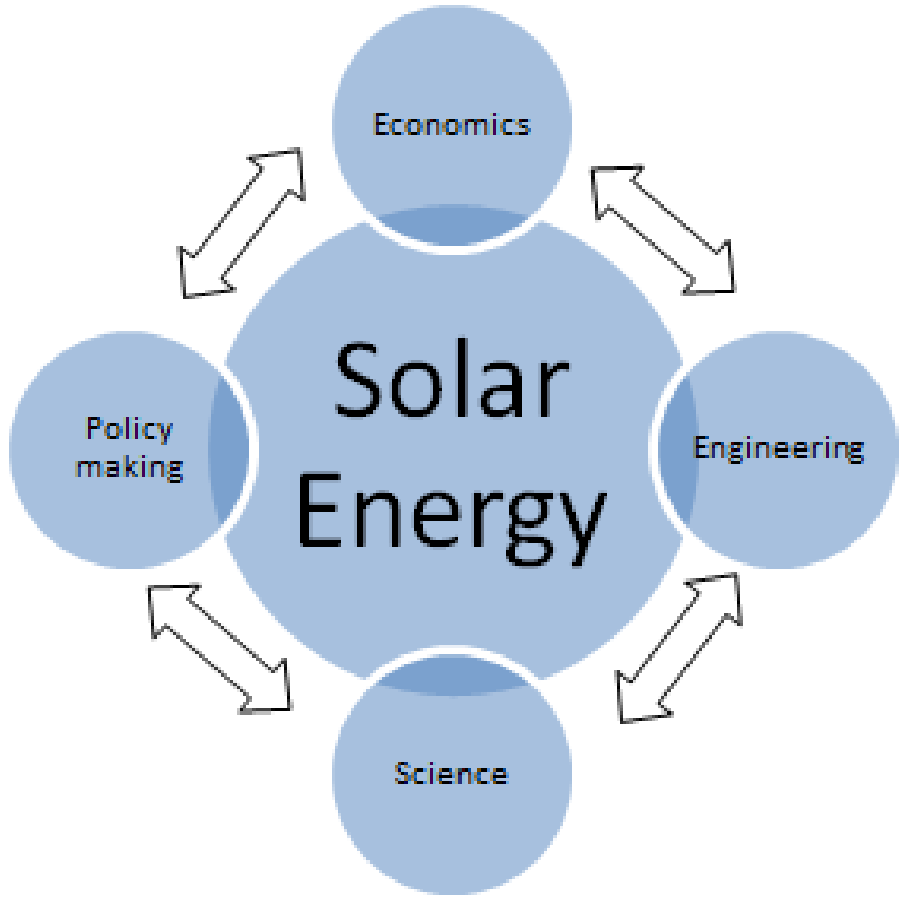
- Total installed capacity doubled between 2012 and 2013
- U.S. DOE allocated $310 MM in FY13
- 120,000 jobs created in solar energy in 2011
- Bipartisan Support (2011 National Solar Survey)
  - 80% Republicans
  - 90% Independents
  - 94% Democrats

Examples of Web-Based Modules

- Bio-related (http://www.bioemb.net)
- Materials-related (http://matdl.org)
- MIT Open Courseware (http://ocw.mit.edu)
- Multimedia Educational Resource for Learning and Online Teaching (http://www.merlot.org)
- Hydrogen Energy (http://www.che.msstate.edu/pdfs/h2ed)
- Alternative Energy (http://www.che.msstate.edu/pdfs/energy/index.html)

Solar Energy: A Multidisciplinary Technology

- Materials
- Energy management
- Finances
- Public policy



Module Structure

- Problem motivation
- 2-3 Example problem statements
- Example problem solutions
- 2-3 Home problem statements
- Home problem solutions

Listing of Solar Modules

- The Power of Solar Energy
- Solar Water Heating
- Solar Steam Turbine
- Solar Fill Factor
- Solar Panel Economics
- Policies Related to Residential Solar Energy Usage
- Absorber Material Usage
- Energy Payback Time
- Greenhouse Gas Emissions
- Power and Inverters
- Using the PV Watts Tool
- Using the SAM Software Tool

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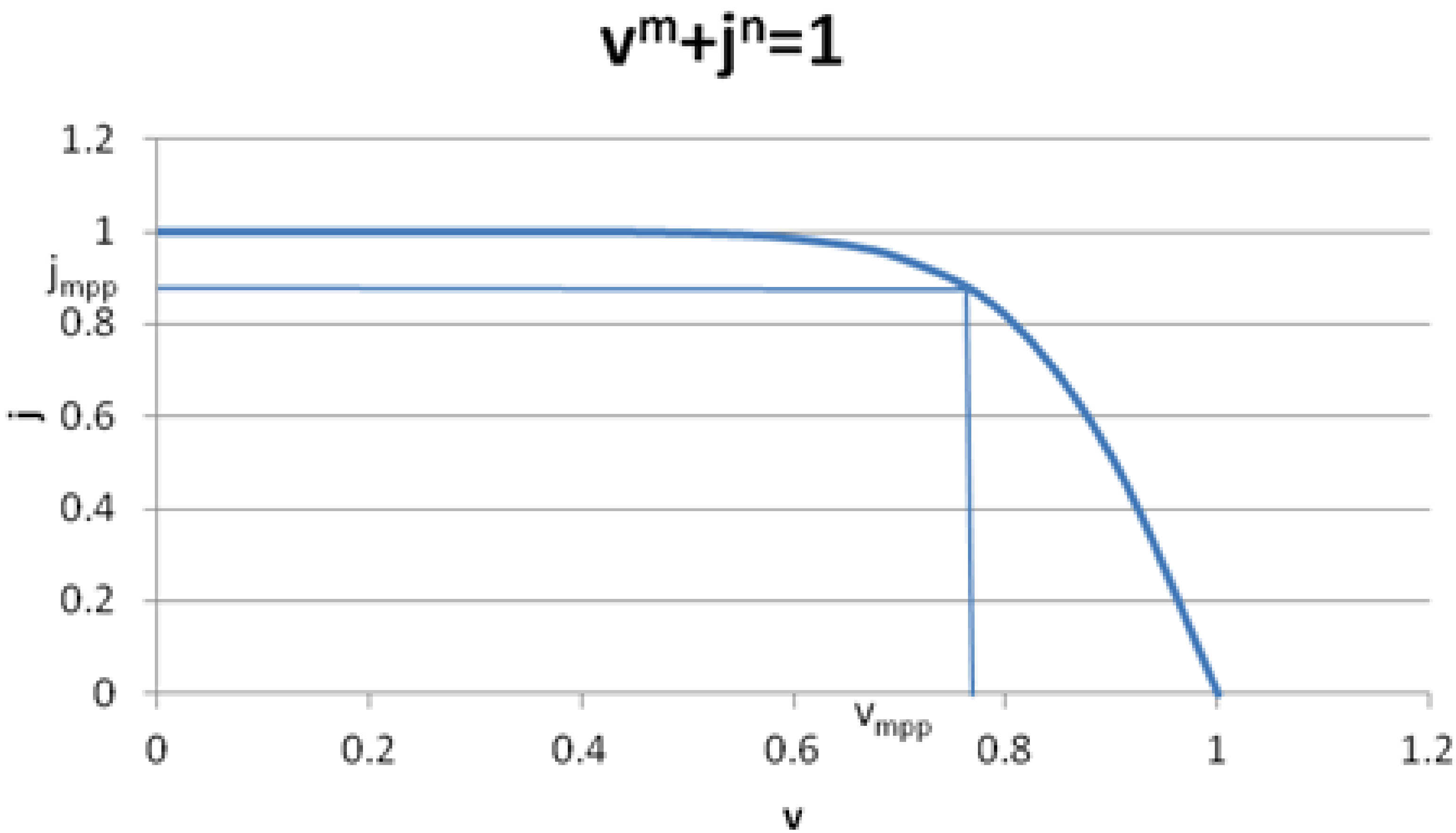
Databases and Software Used

- PV Watts
  - Web application developed by the National Renewable Energy Laboratory
  - Estimate electricity production of a grid connected roof or ground mounted photovoltaic system
- SAM (System Advisor Model)
  - Performance and financial model for renewable energy decision making
- eGRID (Emissions and Generation Resource Integrated Database)
  - Environmental database of U.S. generated electric power

Solar Energy Panel Output Module

- Define V_{oc} = open circuit voltage
- Define J_{sc} = short circuit current density
- Normalized voltage $v = V/V_{oc}$
- Normalized current density $j = J/J_{sc}$
- Current / voltage relationship given by:
  - $v^m + j^n = 1$
- Derive fill factor $FF = (m/n)^{1/n}(1+m/n)^{-(1/m+1/n)}$

Solar Energy Panel Output Module



mpp = maximum power point

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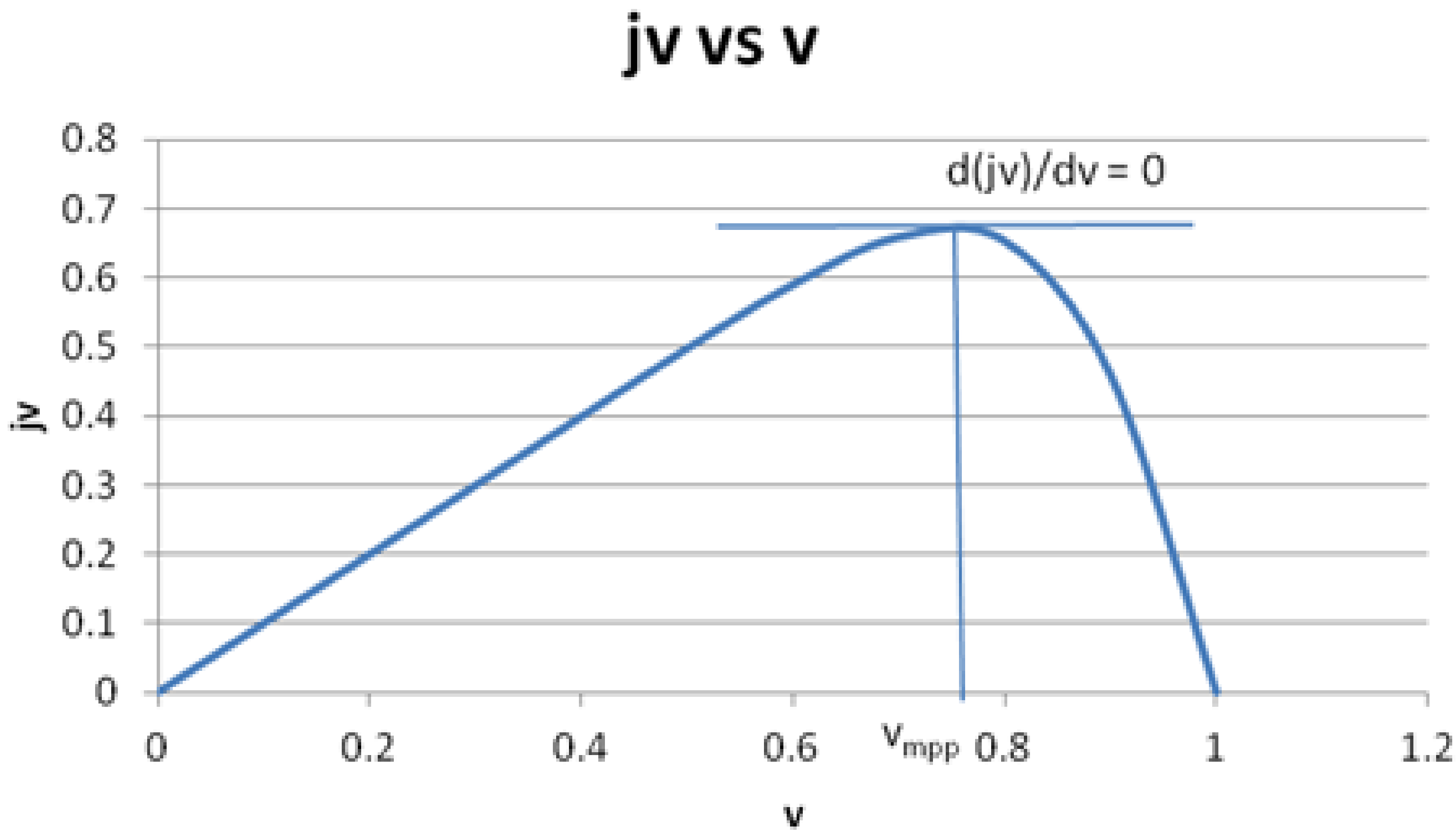
Solar Energy Panel Output Module



mpp = maximum power point

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Solar Energy Panel Output Module

- Estimate v_{mpp} = 0.76 from power curve
- From jv curve find j_{mpp} = 0.88
- Cacculate FF = $v_{mpp}j_{mpp}$ = 0.67
- Ideally, fill factor is closet to unity (very sharp jv curve)

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Solar Energy Panel Output Module

- For a silicon solar cell, m = 12.7 and n = 1.14.
- $FF = (m/n)^{1/n}(1+m/n)^{-(1/m+1/n)}$
- Substitute to give
- $FF = (11.14)^{0.88} (12.14)^{-0.96}$
- Therefore
- FF = (8.29) (0.092) = 0.76

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Summary / Future Directions

- Modules show a connection between traditional ChE fundamentals and applications to real world energy problems
  - Domestic energy independence
  - Worldwide energy availability
  - Stewardship of energy resources
- Future assessment activities to focus on impact of course content on student retention

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  - Dave C. Swalm School of Chemical Engineering
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