JISEA Joint Institute for Strategic Energy Analysis

Responding to the Opportunity: Clean Energy Manufacturing

2016 Annual Meeting

30 March 2016

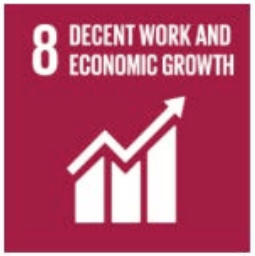
Moderator: Jill Engel-Cox, Director, CEMAC

NREL NATIONAL RENEWABLE ENERGY LABORATORY · COLORADO SCHOOL OF MINES · Colorado State University · MIT Massachusetts Institute of Technology · STANFORD UNIVERSITY · University of Colorado Boulder

Importance of Manufacturing to Meet Sustainable Development Goals

JISEA

Importance of Manufacturing to Meet Sustainable Development Goals



Importance of Manufacturing to Meet Sustainable Development Goals

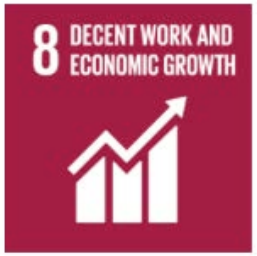
To ensure universal access to affordable reliable energy and increase share of renewable energy in global energy mix…

Manufacturing firms contribute by:

- Decreasing technology costs
- Designing for ease of installation
- Designing for reliability and low maintenance in variety of conditions
- Collaborating with project developers and operators

JISEA

Importance of Manufacturing to Meet Sustainable Development Goals



To sustain economic growth, promote innovation, and achieve productive employment for men and women…

Manufacturing firms contribute by:

- Creating skilled jobs open to all
- Providing training to those entering workforce
- Upgrading manufacturing to include high value work
- Considering manufacturing site location to optimize production as well as economic development

JISEA

Importance of Manufacturing to Meet Sustainable Development Goals

To promote inclusive and sustainable industrialization and to upgrade infrastructure and make industry more sustainable…

Manufacturing firms contribute by:

- Researching new innovations
- Developing new technologies that are easy to deploy
- Designing for environmental protection
- Coordinating with other industries to create industrial ecosystems

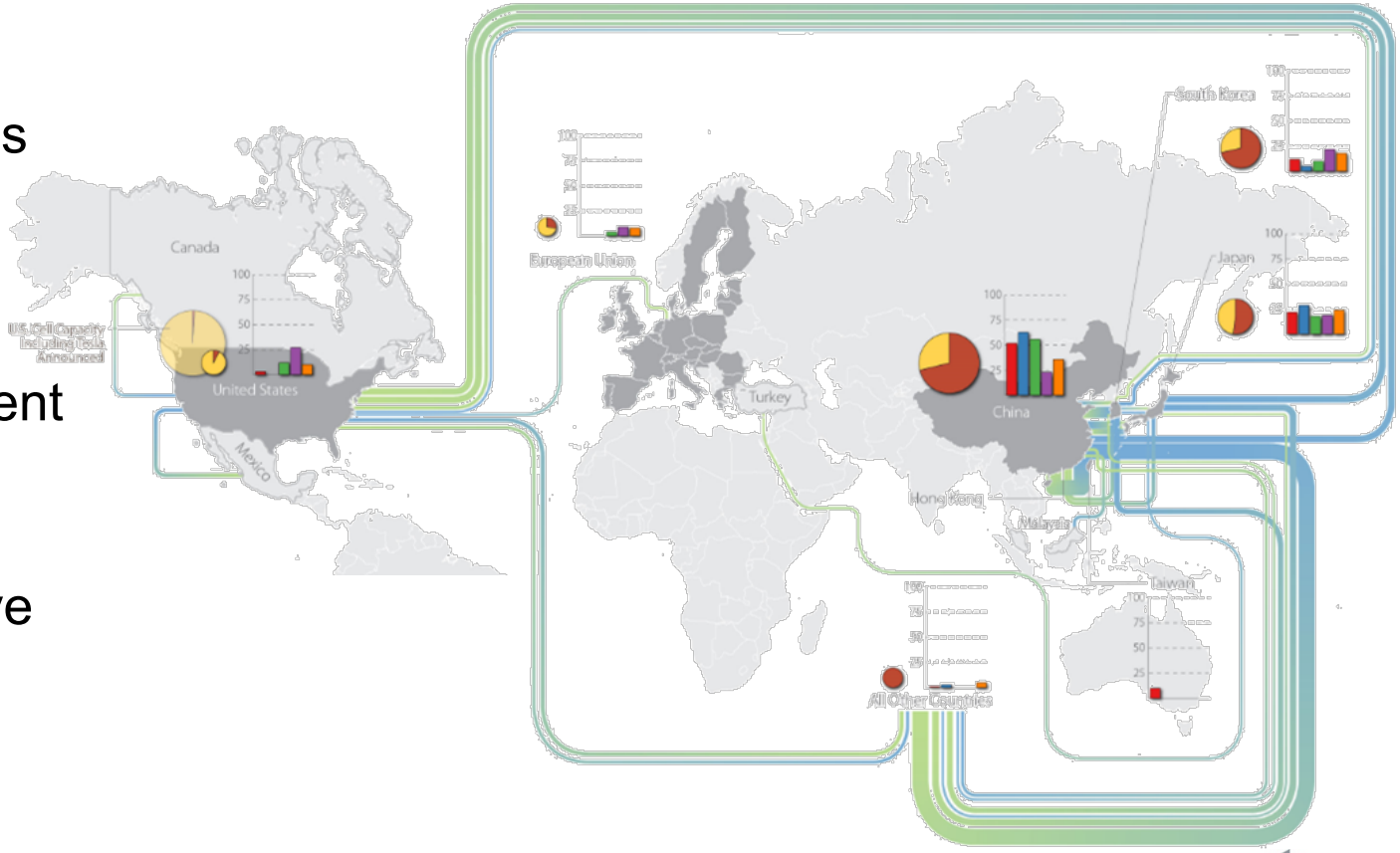
JISEA

Clean Energy Manufacturing Analysis Center increases understanding of global manufacturing

CEMAC provides credible, objective, and recurring global clean energy manufacturing analysis to promote the transition to a clean energy economy

CEMAC will:

- Deliver world class analysis of clean energy manufacturing
- Engage government and industry decisionmakers
- Develop innovative models and tools
- Increase capacity for clean energy manufacturing analysis



Website: www.manufacturingcleanenergy.org

CEMAC
Clean Energy Manufacturing Analysis Center

JISEA Joint Institute for Strategic Energy Analysis

Steven Freilich

DuPont Central R&D (Emeritus)

David Eaglesham

CEO, Pellion Technologies

Wayne Mays

Director of Engineering, Iberdrola Renewables

JISEA Joint Institute for Strategic Energy Analysis

Steven Freilich

DuPont Central R&D (Emeritus)

Market Implications for Innovation in Renewables

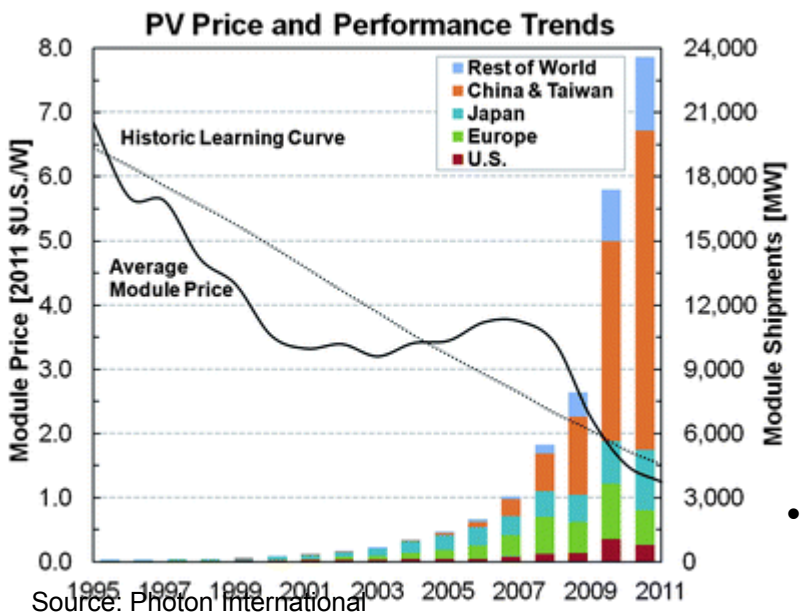
RTS Corp Japan

Steven C. Freilich

Director of Materials Science (emeritus)
DuPont Central Research and Development

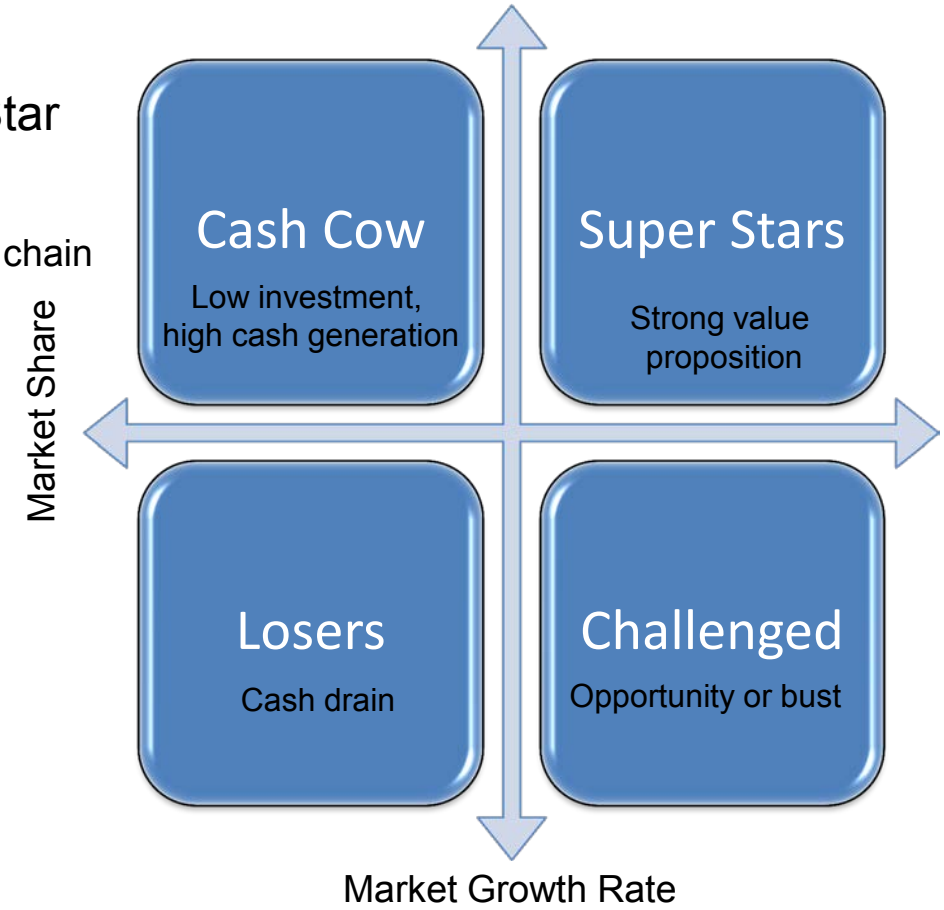
Market Dynamics in PV- Affordability/Profitability Challenge

- PV moved from Challenged to Super Star
  - Rapidly moved down the experience curve
  - Focus on lowering cost of manufacturing
  - Dramatic improvements in scale and supply chain
  - Usually results in high profit margins
  - But…….



Source: Photon International

AC Goodrich, *et.al., Energy and Environmental Science,*

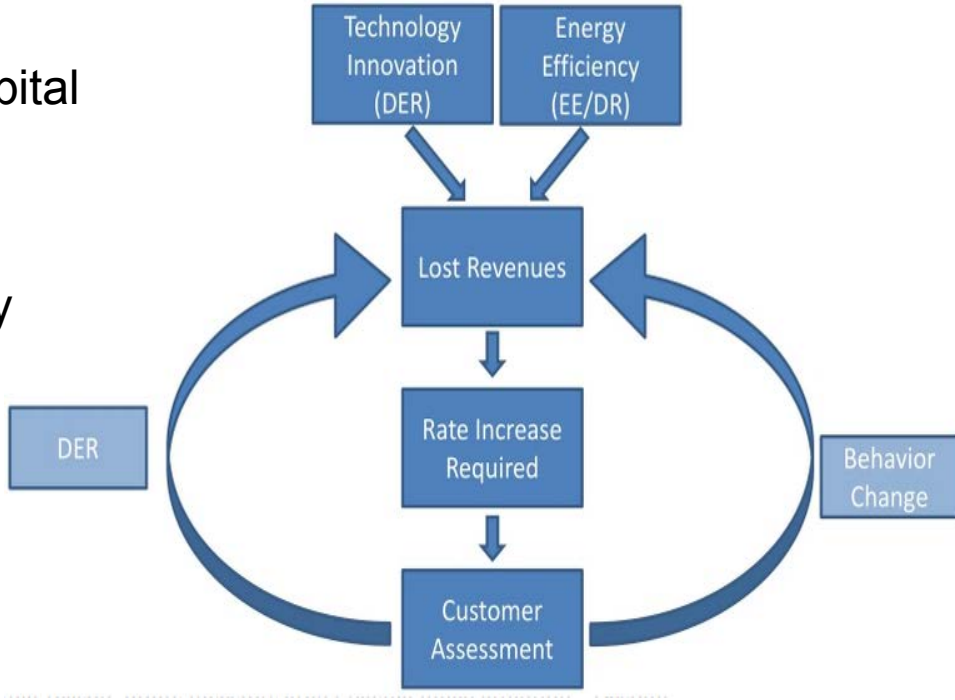


- Low profitability → reduced investment

Downstream Dynamics for Utilities and PV Innovation

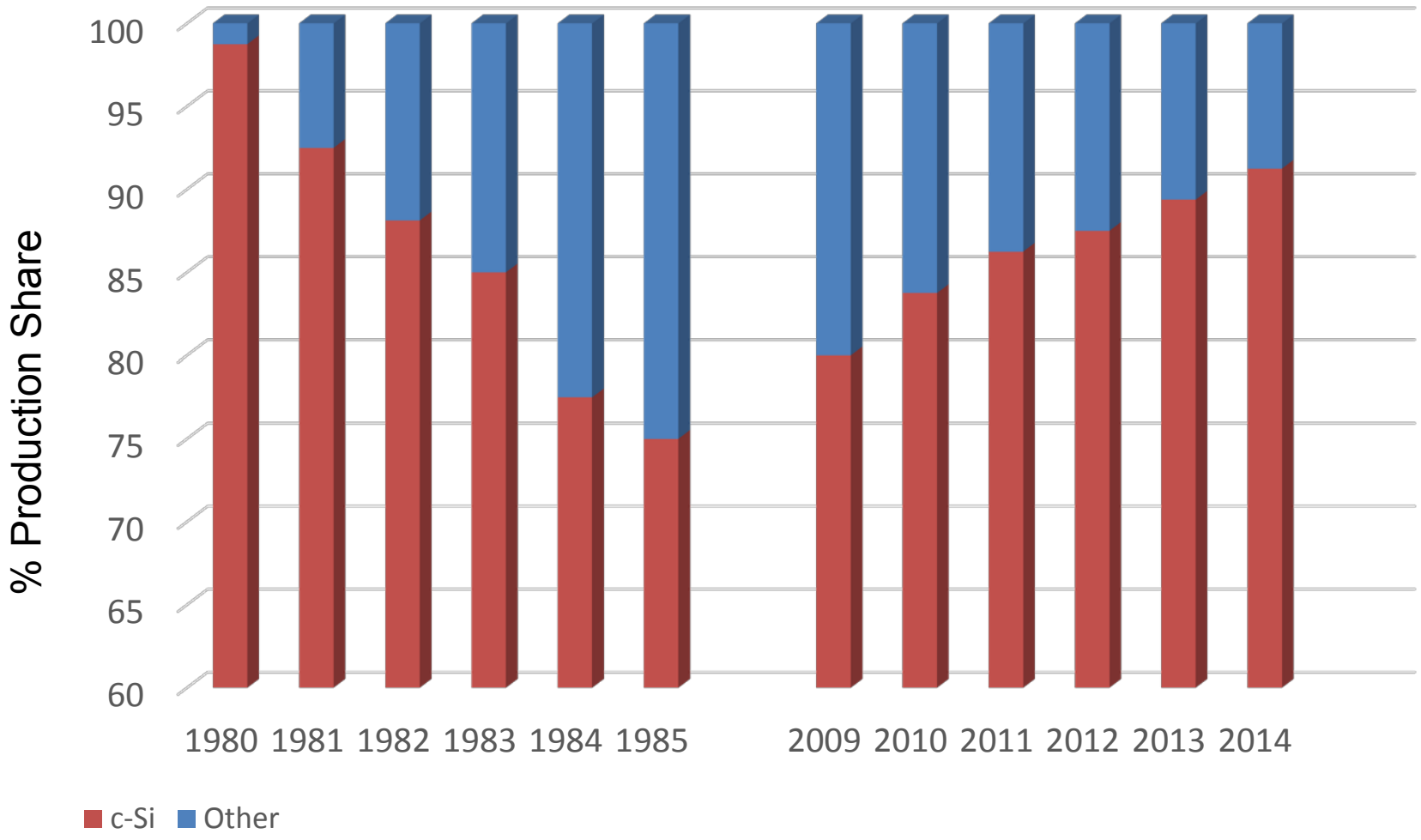
- Investor uncertainty increases cost of capital
- Generation falls
  - Rates increase on remaining customers
  - PUC's respond with blunt instruments
- "Market saturation" happens more rapidly
  - Inventories rise, price falls

- Investment reduced for innovation
  - Market pressures reducing prices
  - Squeeze on upstream suppliers
  - High risk of new technology
  - Advances only through incremental changes



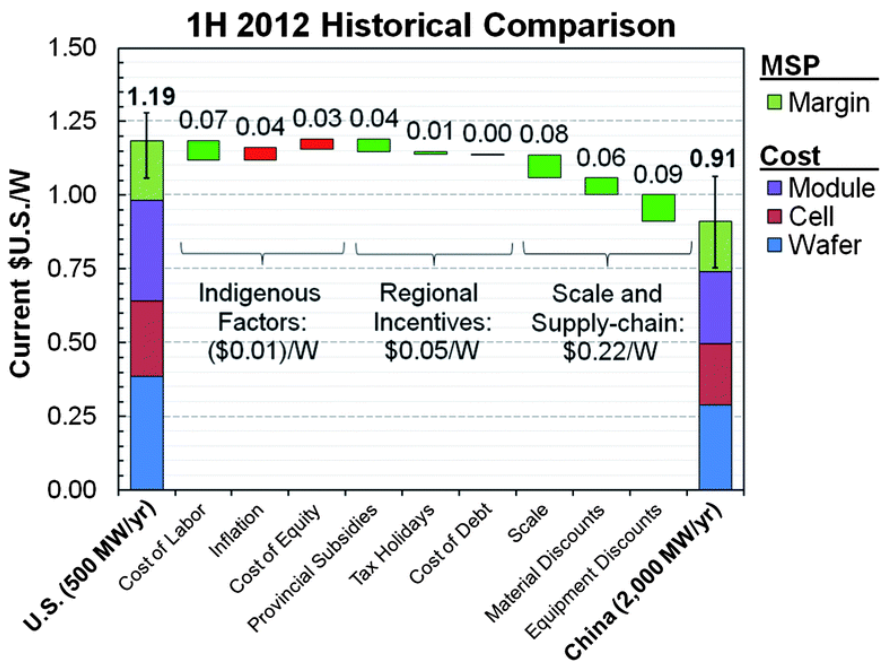
Source: P. Kind, Edison Electric Institute Report, January 2013

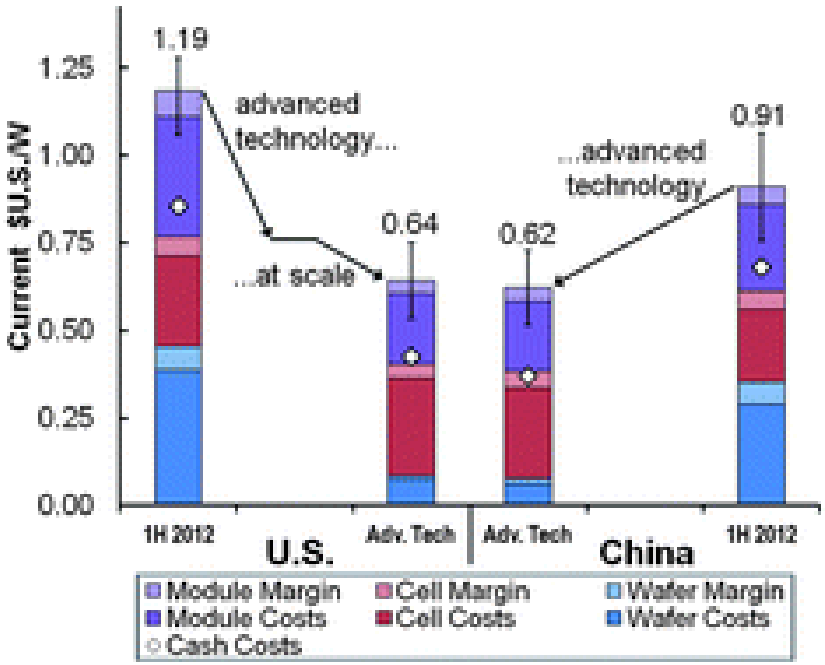
Value of Scale and Incumbency



Source: Fraunhofer ISE Photovoltaics Report November 17, 2015

Advanced Technology Can Change PV Dynamics



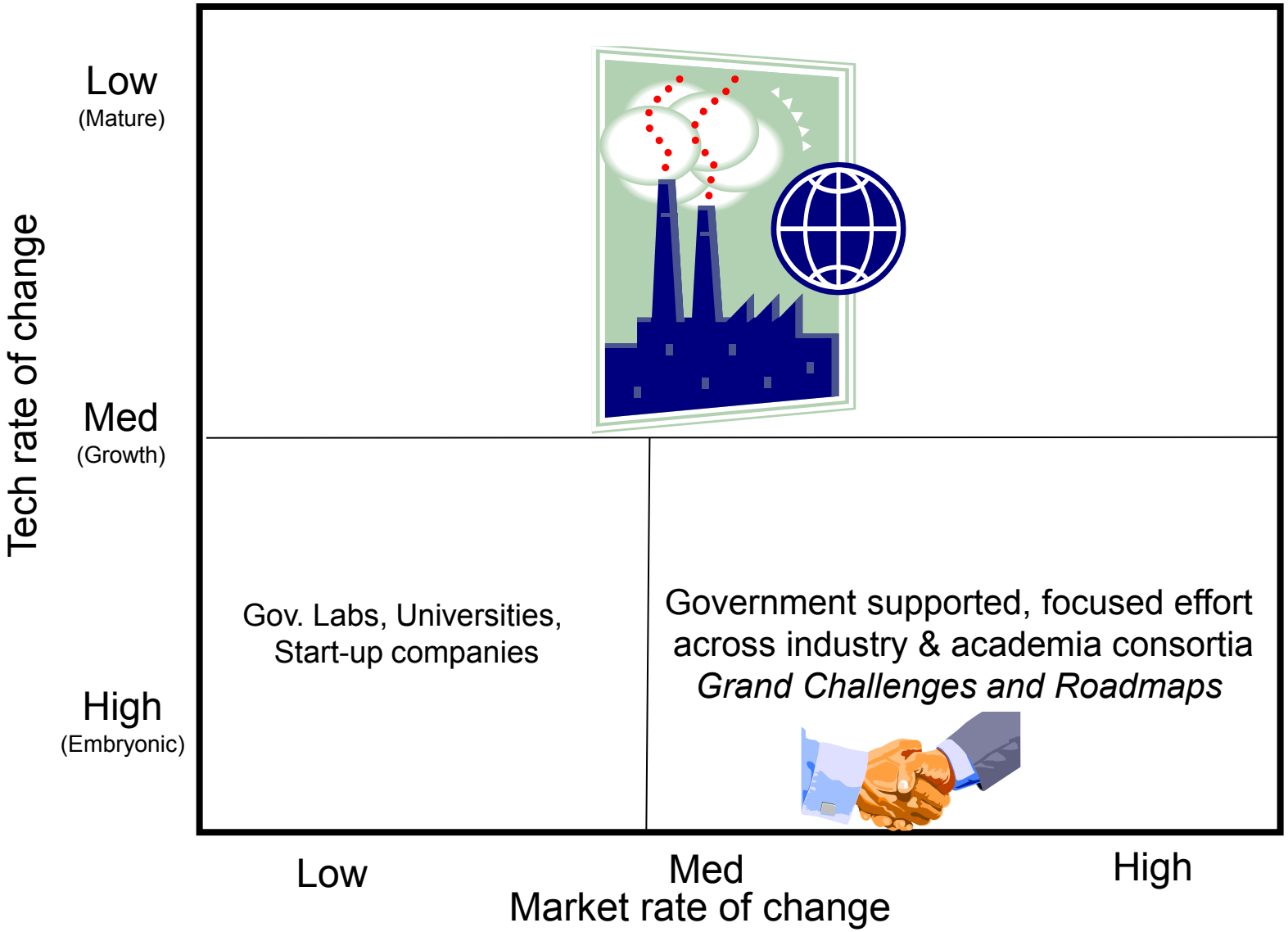


- US vs. China cost: scale & supply chain, not labor
- Can be reproduced but installed base challenges

- Advanced technology can drive step-change
- Performance transformation leads to:
  - Better figure of merit
  - Larger scale for better value proposition
  - Discontinuity in the experience curve

AC Goodrich, *et.al.*, *Energy and Environmental Science,* 2013, **6,** 2811-2821

Strategies for different scenarios lead to improved results



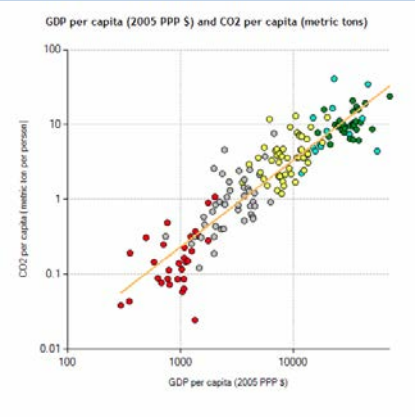
JISEA Joint Institute for Strategic Energy Analysis

David Eaglesham

CEO, Pellion Technologies

A C-footprint Calculation

$ = C

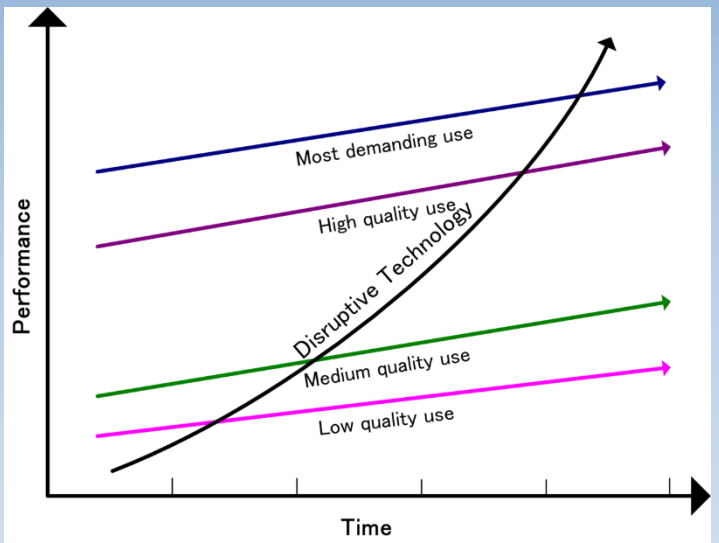


0.5MT/$k

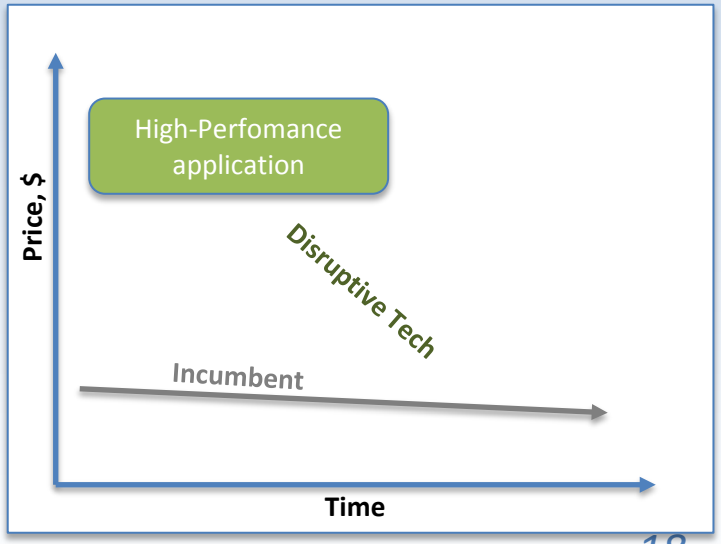
Innovation in Energy Technologies

- Innovator's Dilemma: "low-end disruption"
  - low-cost low-performance technology
  - moves up performance curve
  - Displaces high-margin incumbent

- Energy technologies go the opposite direction
  - Disruptive technology enters a high-performance "niche" THEN drives cost/reliability until competitive with Incumbent
  - E.g. LEDs won the laptop on lumens/W, then auto, then factory, …
  - Wide-Eg FETs = same route
  - Li-ion = camcorder => phone => tablet => car
  - PV = satellite => calculator => off-grid => grid



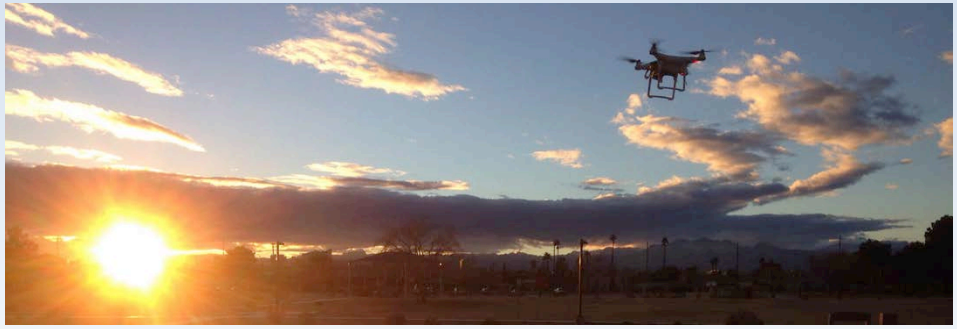
Christensen

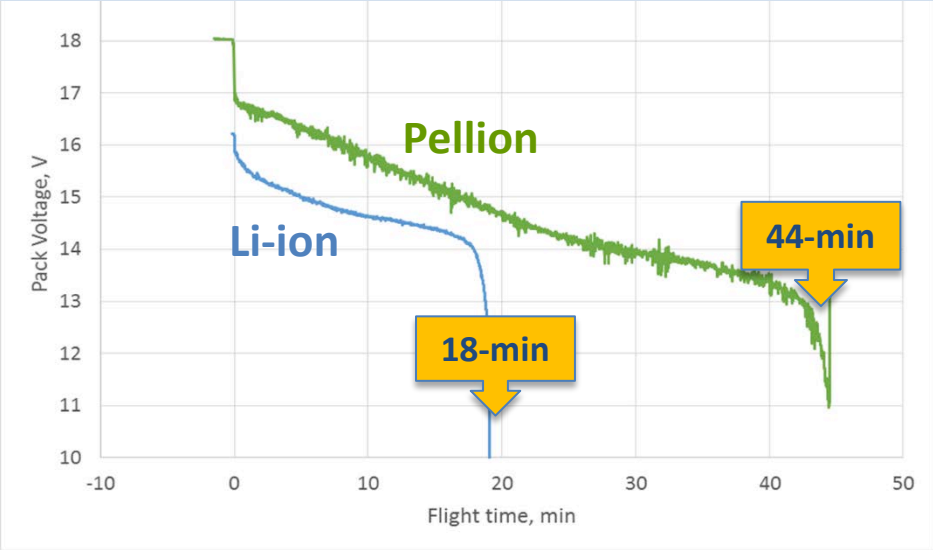


Eaglesham

Pellion high-performance niche

- **Wh/kg** ~2x Li-ion
- Demo Pellion pack in OEM drone
  - Pellion pack typically 2x Li-ion, similar volume, mass
- Flight ~2x the duration of the Li-ion
- Market ~$500M this year





JISEA Joint Institute for Strategic Energy Analysis

Wayne Mays

Director of Engineering
Iberdrola Renewables

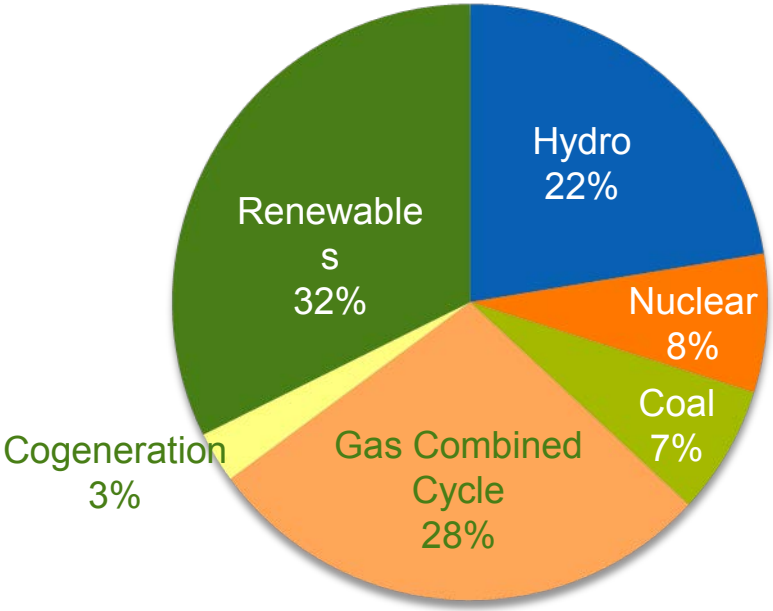
Iberdrola Group

More than 45,000 MWs of installed capacity…

- 150-year history with roots in hydroelectric power
- Leading renewables producer worldwide with >14 GW installed
- 28,000+ employees in nearly 40 countries
- One of the lowest CO_2 emissions levels in the electricity sector
- Strategic focus on US, UK, Latin America and Spain

Generation Capacity

(62% emissions-free)



…that is flexible and competitive.

Updated Sept. 2015

Iberdrola Renewables, LLC

A collection of exceptional assets…

- #2 owner of wind projects in the U.S. with more than 6 GWs owned and contracted
- More than $10 billion of U.S. assets at nearly 60 installed plants
- 750+ employees at the end of 2015, compared with 12 in 1999
- 636 MW of CCGT & peaking capacity on the strategic CA-OR border
- Represents 39% of Iberdrola S.A.'s global wind capacity

US Renewables

Wind

6,000+ MW

Power

536 MW CCGT
100 MW peaking

Solar & Biomass

50 MW Solar
55 MW Biomass

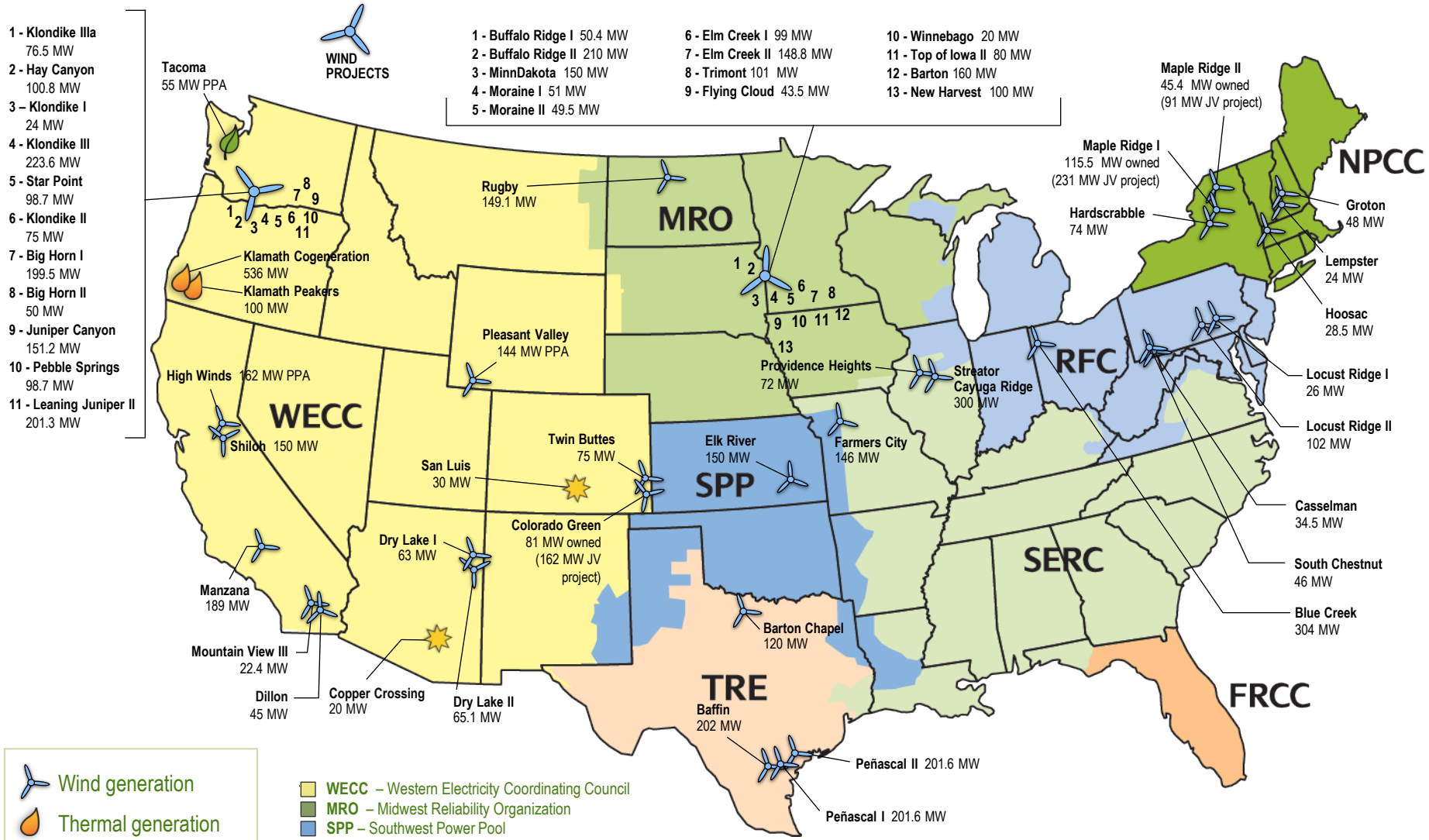
And clean gas generation

…focused on operational excellence and selective growth

Updated Sept. 2015

U.S. Power Assets (by NERC region)

IBERDROLA RENEWABLES



Assets owned by Iberdrola Renewables, LLC

Rev. 9/30/2015

JISEA Joint Institute for Strategic Energy Analysis

Questions and Answers