

## The Future of the Electricity Market in a Diversified Grid

ICEPAG 2015  
23 March 2015  
University of California - Irvine

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Empowered Energy

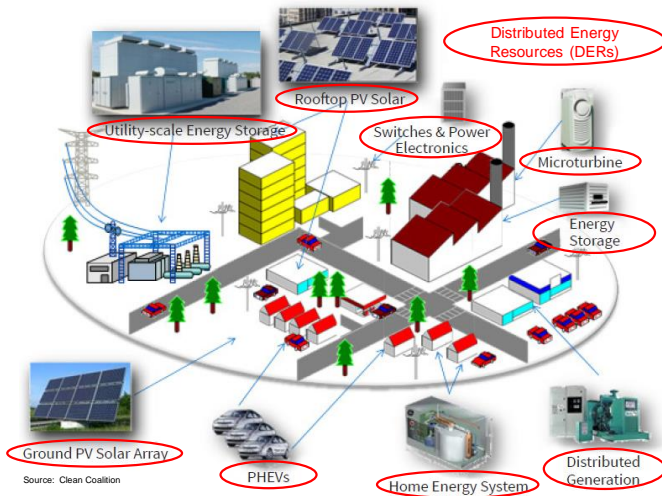
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## The Changing Face of the Electric Grid: From Here...



## To Individual Microgrids...



Source: Clean Coalition

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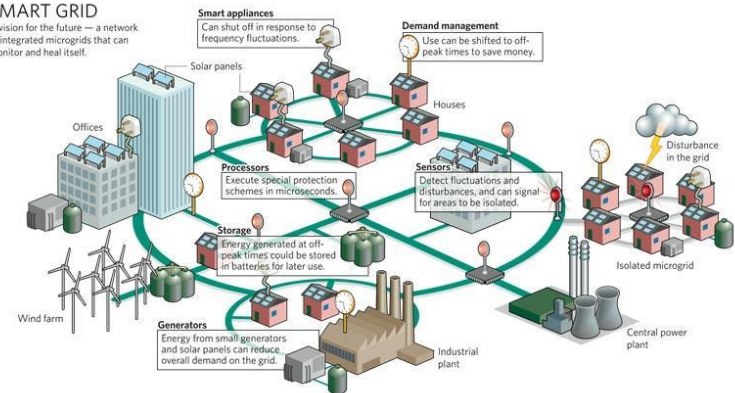
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## To Fully Integrated Smart Grid: Can Be Done, Won't Be Easy

### SMART GRID

A vision for the future — a network of integrated microgrids that can monitor and heal itself.



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## The Changing Face of the Electric Grid: Primary Drivers



- Climate change concerns, carbon pricing, EPA's Clean Power Plan, plant retirements
- Required infrastructure & capacity investment
- Declining costs: DERs, renewables, storage
- Improved control technologies/connectivity, ability to elicit behavioral demand response
- Rising peak-to-average demand ratios, push for transportation electrification/alternate fuels
- Low fossil fuel prices (natural gas, oil)

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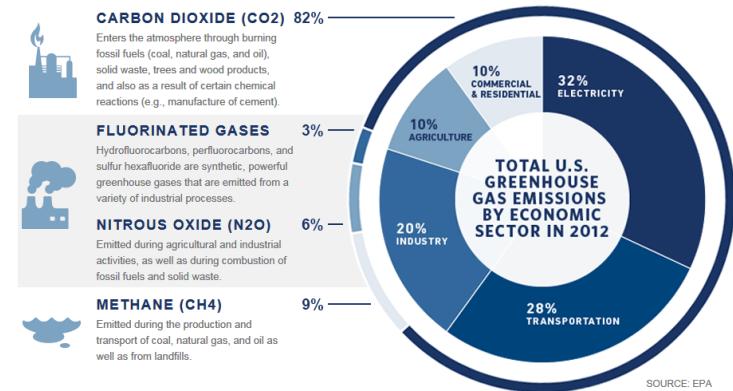
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## Climate Change: Electricity & Transportation “Prime Targets”



### U.S. GREENHOUSE GAS POLLUTION INCLUDES:

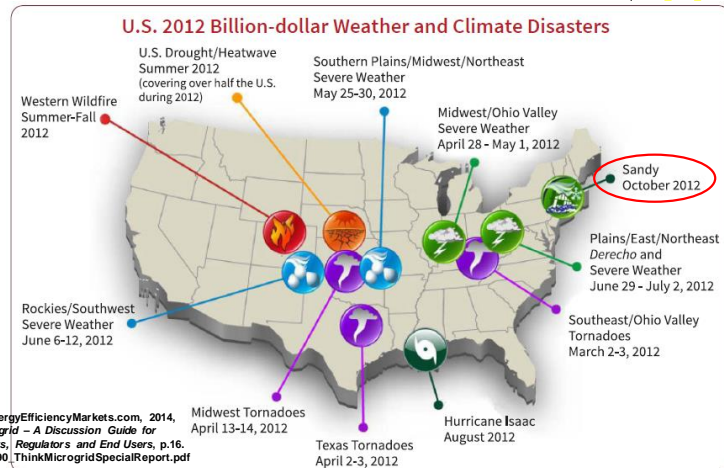


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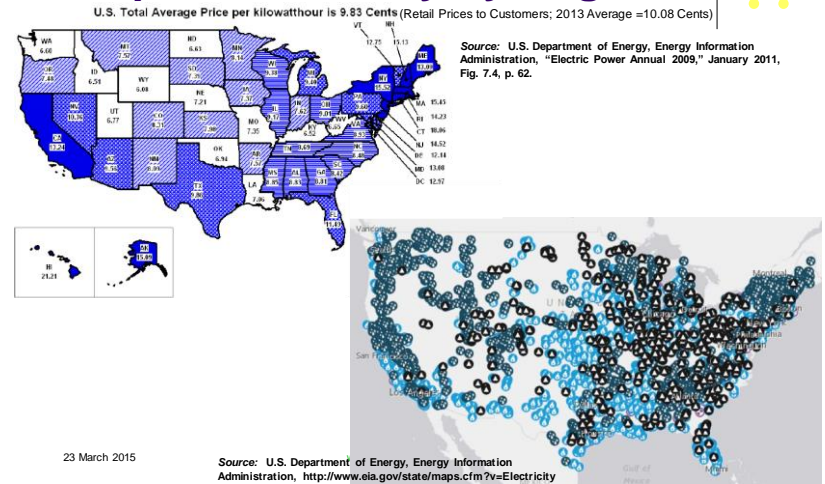
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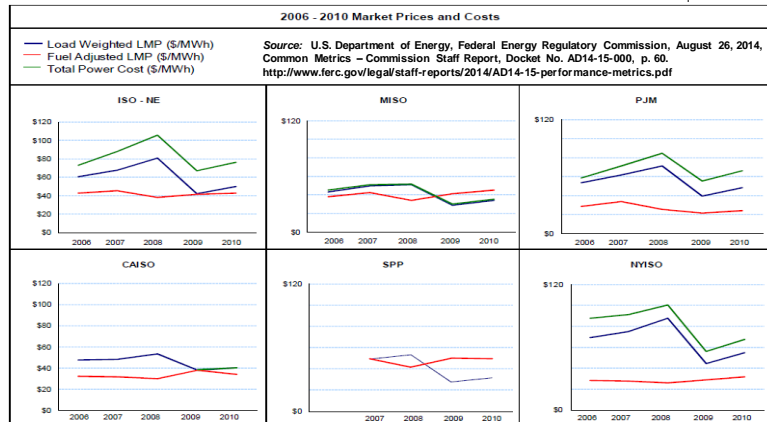
## Increasing Number of Extreme, Destructive Weather Events



## EPA's Clean Power Plan: Impacts Will Vary by Region



## Wholesale Market Prices Differ, Depending on Supply/Demand



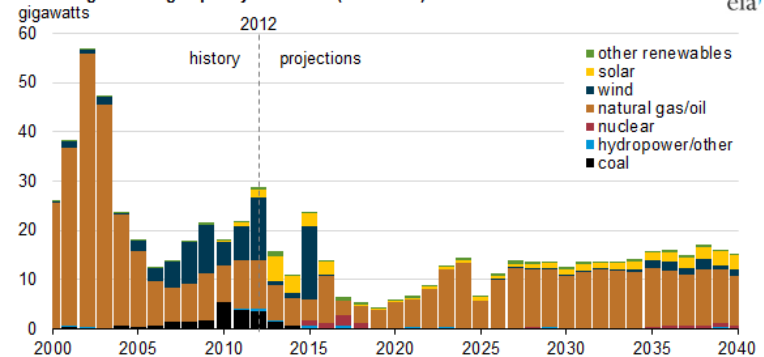
### Notes

CAISO did not provide Total Power Cost data for 2006-2008. CAISO Total Power Cost and load-weighted LMP are identical in 2010. SPP did not provide Total Power Cost data. LMP data for SPP is only available since 2007.

## Natural Gas Continues to Dominate Capacity Additions



Electric generating capacity additions (2000-2040)



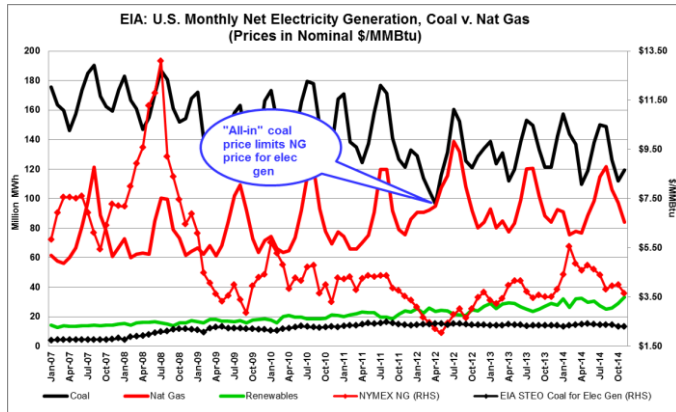
Source: Form EIA-860 and Annual Energy Outlook 2014, <http://www.eia.gov/todayinenergy/detail.cfm?id=17131>

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## Renewables on the Rise, but... Coal & Nat Gas Still Dominate

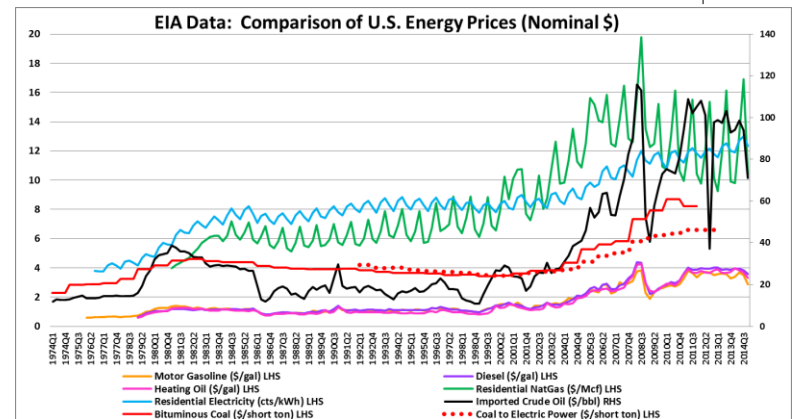


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## Energy Prices *Never* Conform to “Hockey Stick” Forecasts...

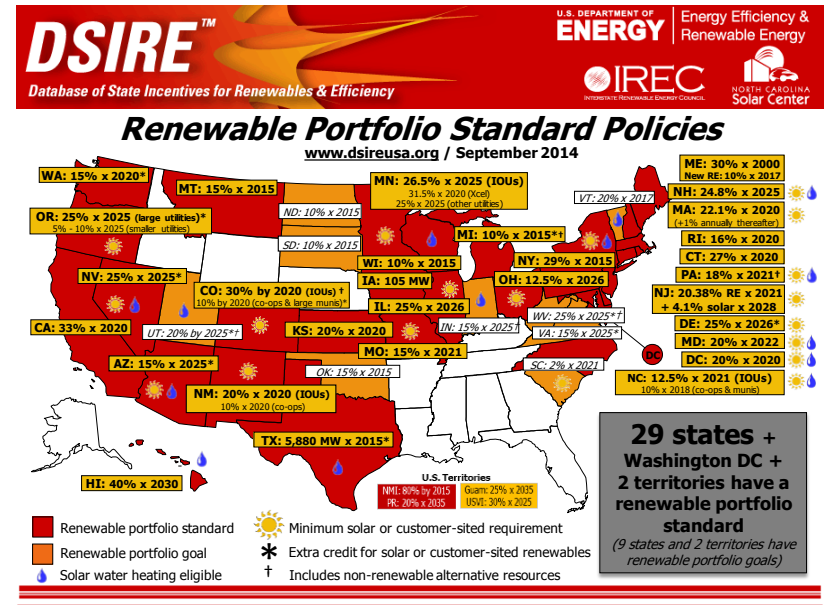
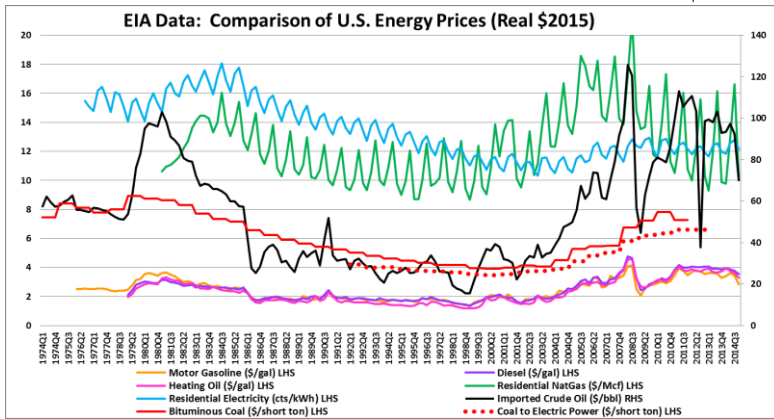


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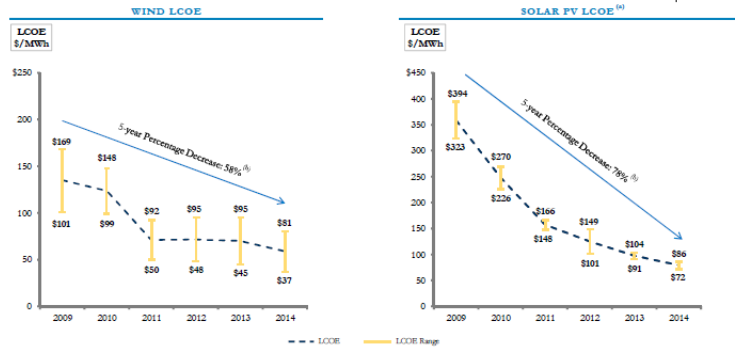
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## ...In Either Nominal or Real (Inflation-Adjusted) Dollars





## Increasing Renewable Capacity ➔ Market Transformation



Source: Lazard estimate.  
(a) Represents LCOE range of utility-scale crystalline silicon PV. High end represents fixed installation, while low end represents single-axis tracking in high insolation jurisdictions (e.g., Southeast U.S.).  
(b) Represents average percentage decrease of high and low of LCOE range.

Source: Lazard, Levelized Cost of Energy Analysis Version 8.0, page 9, September 2014, <http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf>

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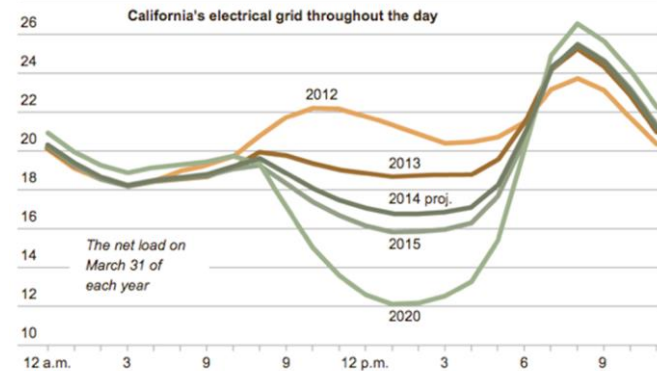
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## Solar Takes a Mid-Day Demand Bite - “Duck Bill” Shifts Peak



28 thousand megawatts



Source: CalISO

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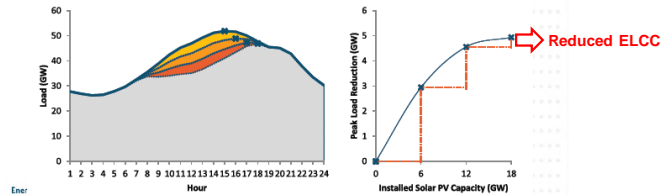


# Solar Capacity Value Changes as Solar Generation Increases



## Capacity Planning with High Renewable Penetrations

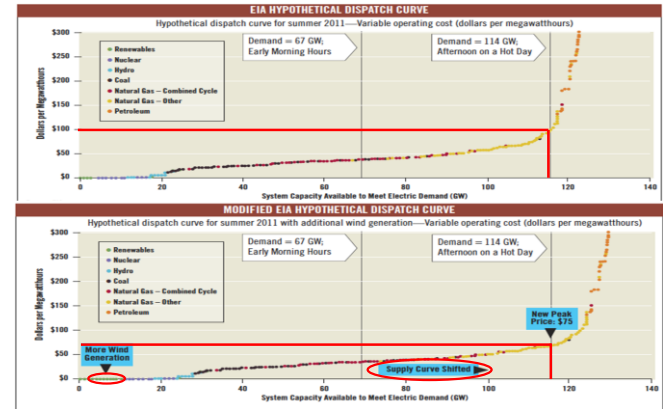
- + A resource's contribution towards reliability depends on the other resources on the system
- + The diminishing marginal peak load impact of solar PV is illustrative of this concept
  - While the first increment of solar PV has a relatively large impact on peak, it also shifts the "net peak" to a later hour in the day
  - This shift reduces the coincidence of the solar profile and the net peak such that additional solar resources have a smaller impact on the net peak



Source: Energy • Environmental Economics, "2017 Draft TDV Updates," Slide 15, CEC Staff Workshop, April 29, 2014, [http://www.energy.ca.gov/files24/2016standards/preulemakingdocuments/2014-04-29\\_workshoppresentations/Brian\\_Horli-Eric\\_Cutter\\_2017\\_TDV\\_Updates.pdf](http://www.energy.ca.gov/files24/2016standards/preulemakingdocuments/2014-04-29_workshoppresentations/Brian_Horli-Eric_Cutter_2017_TDV_Updates.pdf)

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# Impact of Increased Renewable Generation on Dispatch Curve



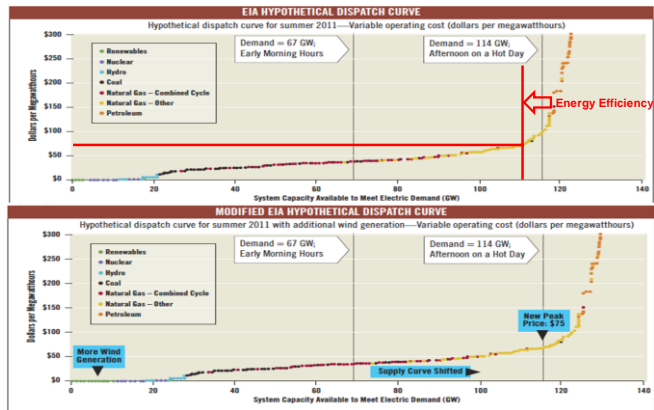
Source: <http://www.eia.gov/todayinenergy/detail.cfm?id=7590>

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## Energy Efficiency Has Similar Permanent Directional Impact



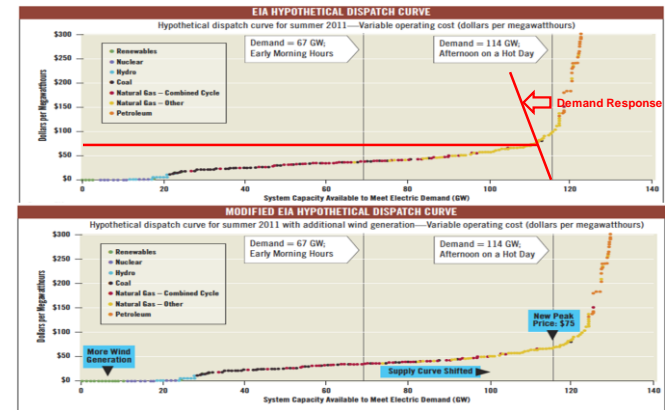
Source: <http://www.eia.gov/todayinenergy/detail.cfm?id=7590>

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## As Does Demand Response, Though Only Temporarily



Source: <http://www.eia.gov/todayinenergy/detail.cfm?id=7590>

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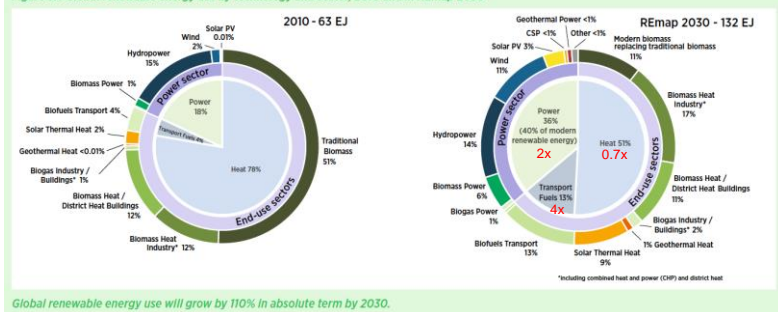


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# Doubling Renewables by 2030 Shifts Energy Usage Patterns



Figure 3.6 Global renewable energy use by technology and sector, 2010 and in REmap 2030



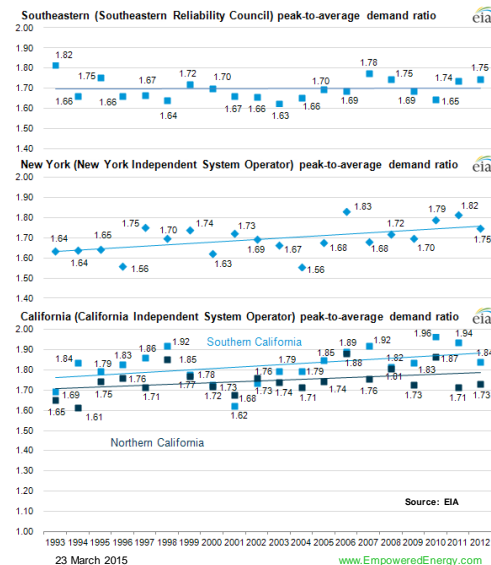
Global renewable energy use will grow by 110% in absolute term by 2030.

Source: International Renewable Energy Agency, *REmap 2030 - A Renewable Energy Roadmap*, p. 23, June 2014, [http://irena.org/remap/REmap\\_Report\\_June\\_2014.pdf](http://irena.org/remap/REmap_Report_June_2014.pdf)

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- Increasing peak-to-average demand ratios require additional peak capacity to satisfy peak demand



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## New York “REV” Shakes It Up - “Reforming the Energy Vision”



### THE DISTRIBUTED SYSTEM PLATFORM (DSP)

The DSP is an intelligent network platform that will provide safe, reliable and efficient electric services by integrating diverse resources to meet customers' and society's evolving needs.

#### Key Functions of the DSP

- Design and plan distribution system that integrates DERs as primary means of meeting system needs
- Plan for and accommodate new distributed generation and demand response
- Balance production and load in real time
- Monetize system & social values
- Coordinate interactions between customers, with the distribution system and with energy services markets (DSP markets and NYISO)

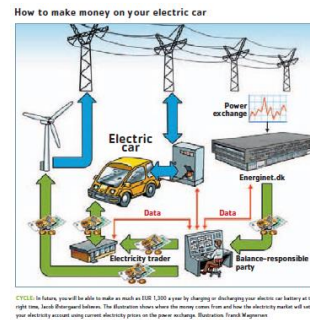


Source: Rocky Mountain Institute, *New York's Reforming the Energy Vision (REV) Initiative - Overview and Status Update*, Lena Hansen, Principal, November 13, 2014, <http://demandresponse.martgrid.org/Resources/Documents/EF%20REV%20Webinar%2014.11.13%20FINAL%20SLIDES.pdf>

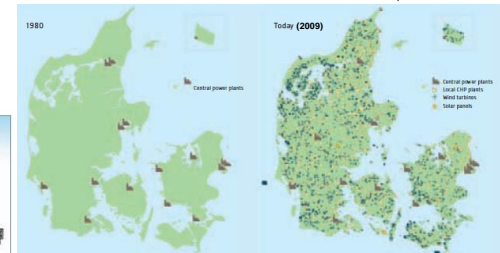
## Denmark's Transformation to Distributed Energy Resources



- 30 years on...



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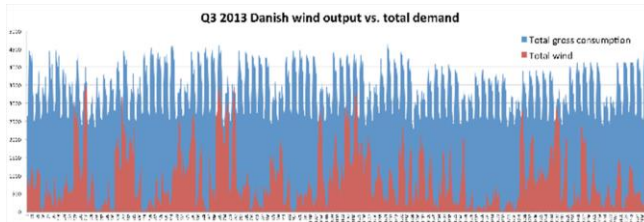
- In 2014, 39.1% of Denmark's electricity came from wind

Source: Energinet.dk, *Wind Power to Combat Climate Change - How to Integrate Wind Energy Into the Power System*, p.10 (upper), p.36 (lower), 4 April 2009, <http://www.e-pages.dk/energinet/126/>

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## What About Intermittency?



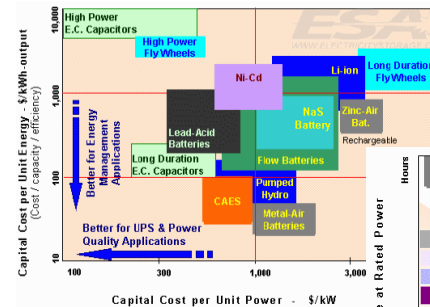
- Increases importance of imports/exports
  - Regional diversity potential (seasonal, daily)
- Increases value of flexible generation/demand
- Increases value of data and dynamic controls
- Leverages onsite vs. utility-scale economics and capacity investment

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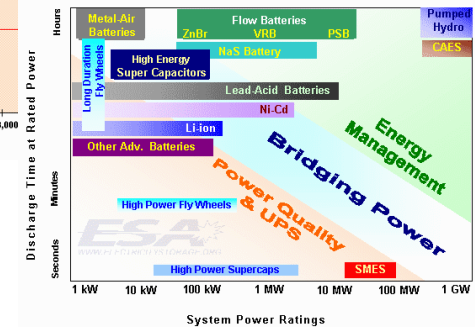
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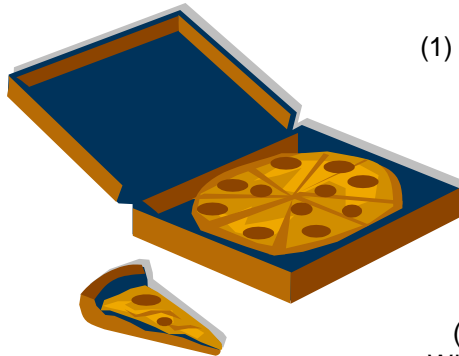
## Is Energy Storage the Holy Grail of a Diversified Grid??



- Power vs. Energy
- Capacity vs. Flow



## New Rate Paradigm: Align Incentives or Ensure Failure



(1) Revenue Requirement:  
How much revenue  
does the utility need  
to cover its cost of  
service? (What  
services does it  
provide?)

How big is the pizza?  
(Take out or eat in?)

(2) Cost Allocation:  
Which costs go where?

How are the ingredients arranged?

(3) Rate Design:  
Who pays how much?

How big a piece of pizza does each customer get?

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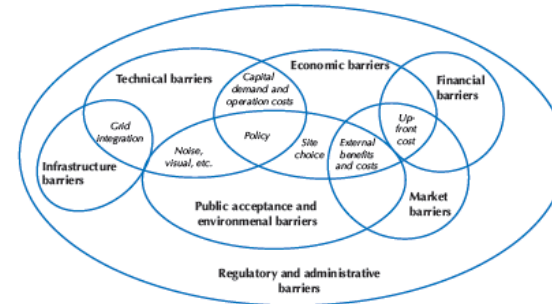
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## Market Transformation Is Not Easily Accomplished...



Figure 3.5 Barriers to RE technology deployment



### Key point

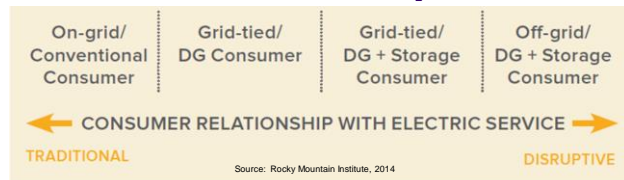
Different types of barriers to RE technology deployment are closely linked and may work together to hinder deployment.

Source: International Energy Agency, Deploying Renewables 2011 – Best and Future Policy Practice, p. 74.  
[http://www.iea.org/publications/freepublications/publication/Deploying\\_Renewables2011.pdf](http://www.iea.org/publications/freepublications/publication/Deploying_Renewables2011.pdf)

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## RMI Postulates Four Stages of Consumer/Grid Separation



- Do consumers really want real-time pricing?
- How to turn potential into behavioral reality?
  - **OPower** “Transforming the Way Utilities Relate to Their Customers”
    - Segmentation and Targeting Tool
    - “Moments That Matter”



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## Prognostications: Thinking Expansively About Success

- Grid will become more complex
  - Two-way information flows will be commonplace
- Flexibility and intermittency must be properly priced
- Price transparency must prevail at all levels
  - If peak-to-average demand ratios/prices fall
  - Then capacity investment issues are exacerbated
- Vehicle-to-Grid will become more important
- Intermittency increases regional trade flows
  - Partial offsets: Energy storage & dynamic DERs

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## Key Success Factors, Continued...



- Ironically, importance of regulators increases
  - Strength of policy commitment ~ rate of change
- Getting the incentives right is crucial
  - Market provision of DERs minimizes total cost
  - Dynamic demand response offsets supply (in part)
- Smarter smart phones will be the key to customer engagement
  - Existence of supply-side controls is a given
  - Recipe for success is already in our hands.

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