



# Integration of Renewables: Challenges and Policy Options

Christopher R. Knittel  
William Barton Rogers Professor of Energy Economics  
Sloan School of Management  
Director, Center for Energy and Environmental Policy Research  
Massachusetts Institute of Technology,

Research Associate  
National Bureau of Economic Research

# Renewables: What we like

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- Lower emissions
  - Not just an issue with climate change
  - Renewables also have lower criteria pollutant emissions
    - Value of this varies from location to location
- *Can* be generated at the sources
  - May lead to lower transmission and distribution costs
  - This is uncertain, however
    - Transmission: depends on where the renewables are best suited
    - Distribution: depends on level of penetration

# Renewables: What we don't like

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- Some (notably wind and solar) renewables are intermittent
- Some (notably solar) are still expensive
- Some (notably wind) often generate during off-peak periods

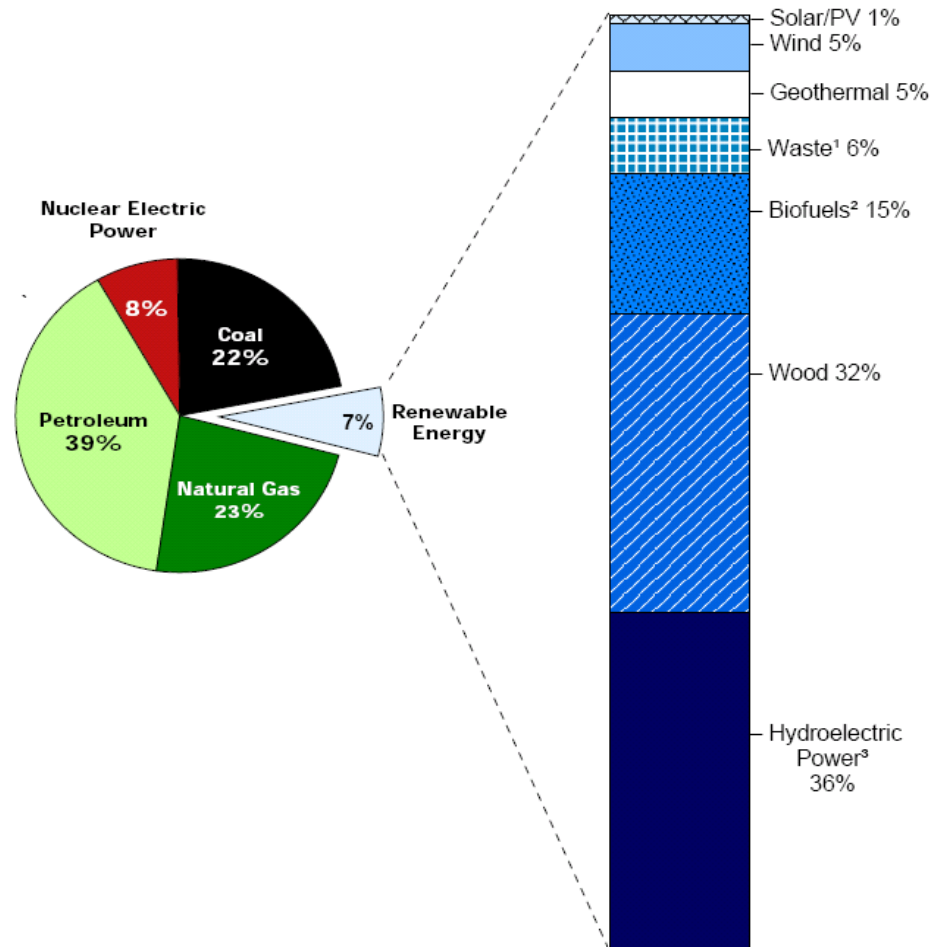
# Outline

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- What is the state of renewables in the US?
- What do cost estimates tell us? Would do they ignore?
- Intermittency: How large is the problem?
- Distributed generation: How large are the benefits?
- Policies to promote renewables: What should we be doing?

# State of renewables in the US: Across all energy

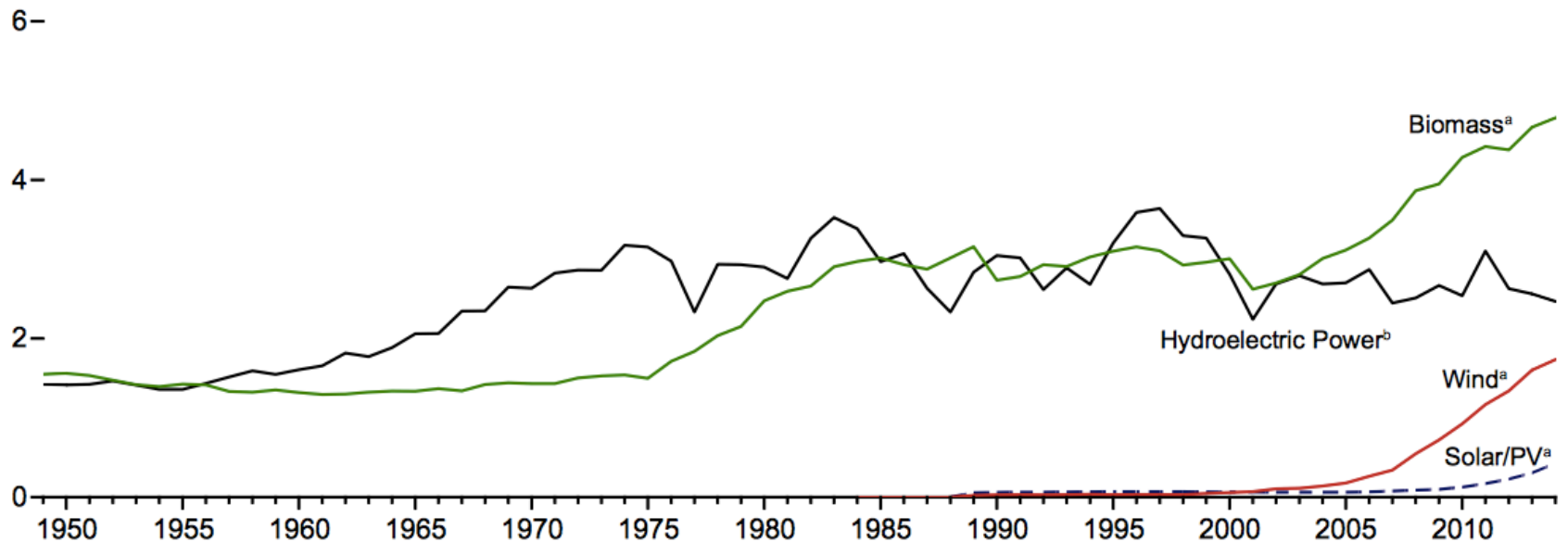
- Many types of renewable, of course



# Trending upward

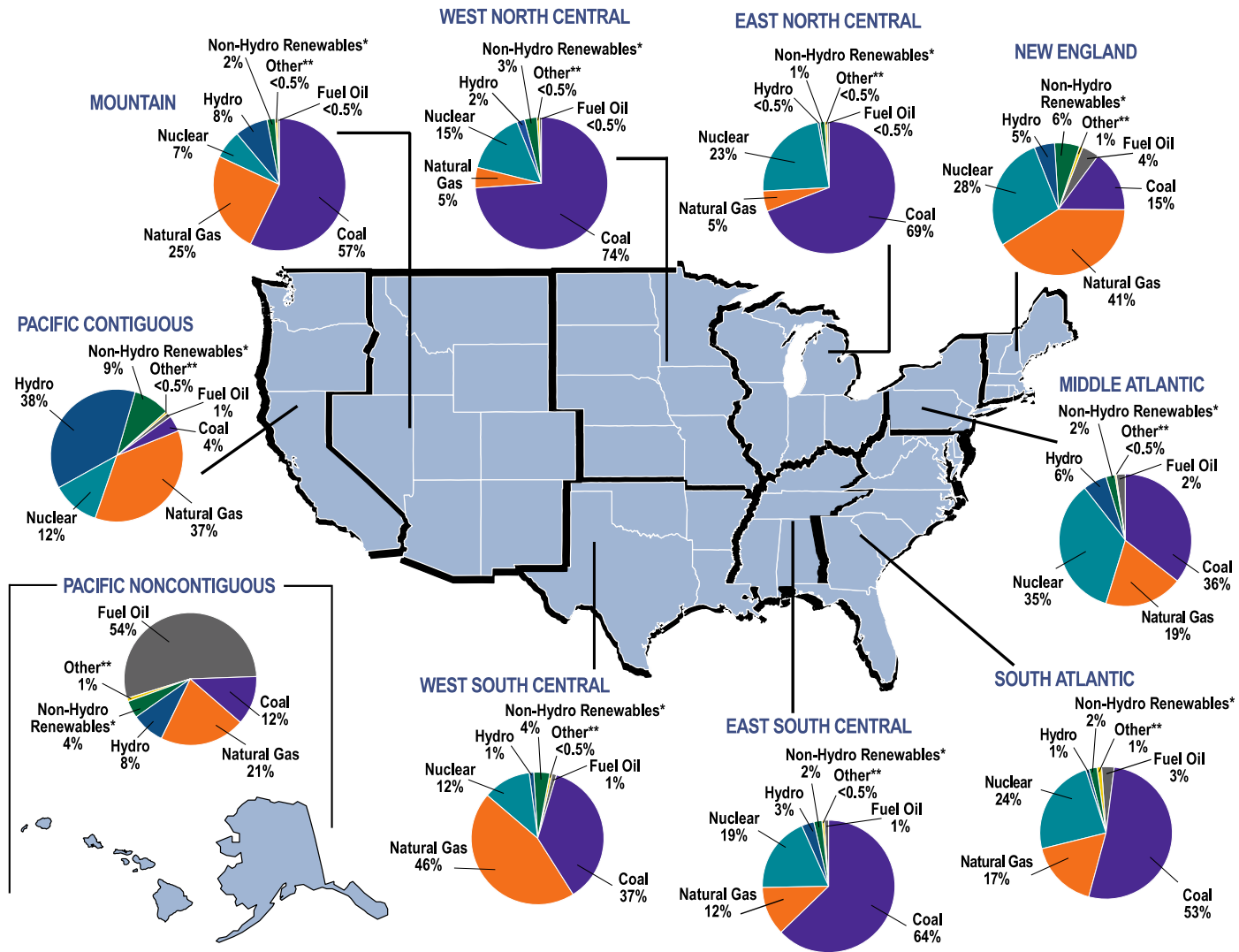
**Figure 10.1 Renewable Energy Consumption**  
(Quadrillion Btu)

Major Sources, 1949–2014

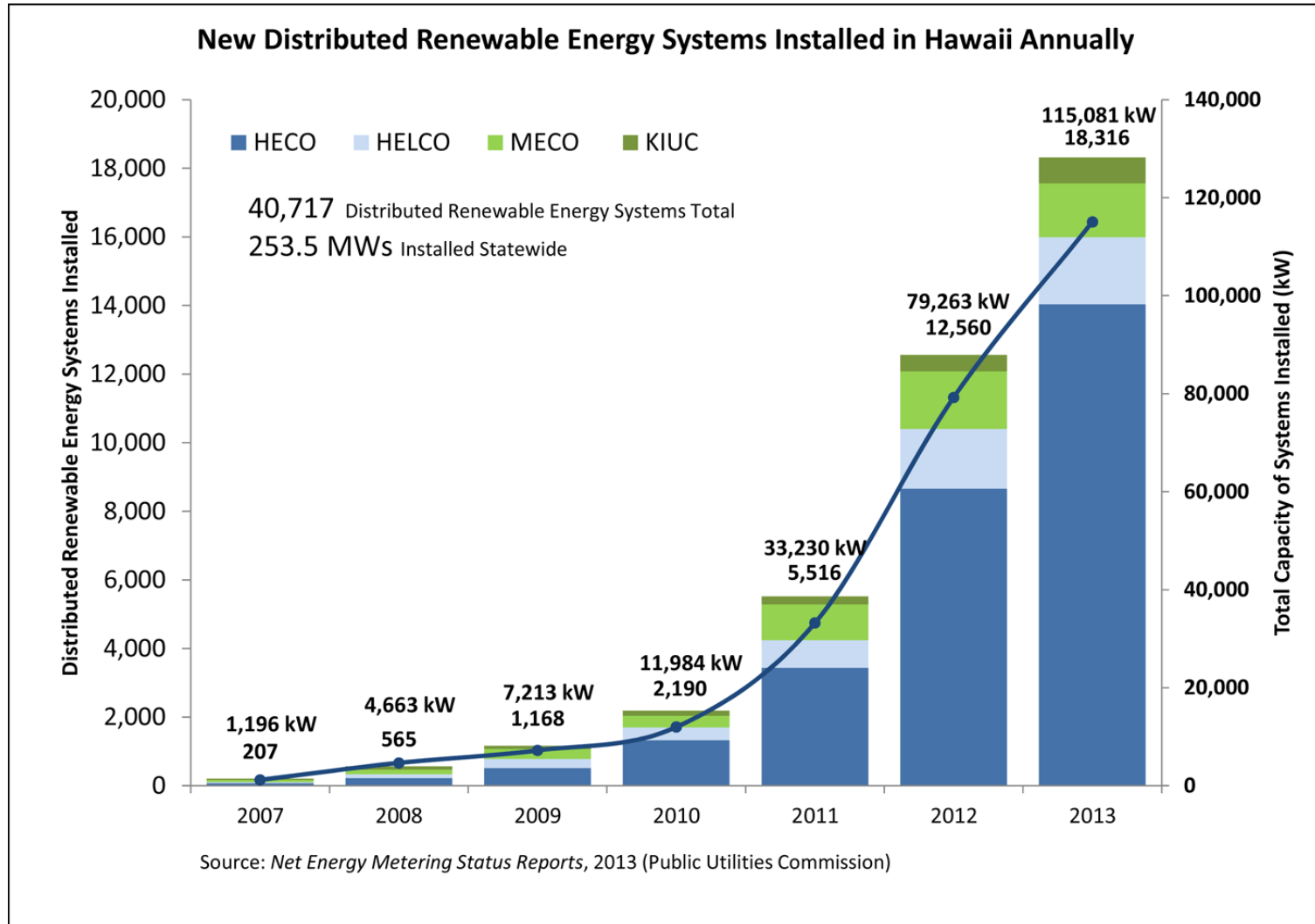


Fossil fuels + nuclear  $\approx$  90 quads

# Recall variation, as high as 9% (non-hydro)



# 1 in 9 Hawaiian homes have solar



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# Measuring the costs of renewables

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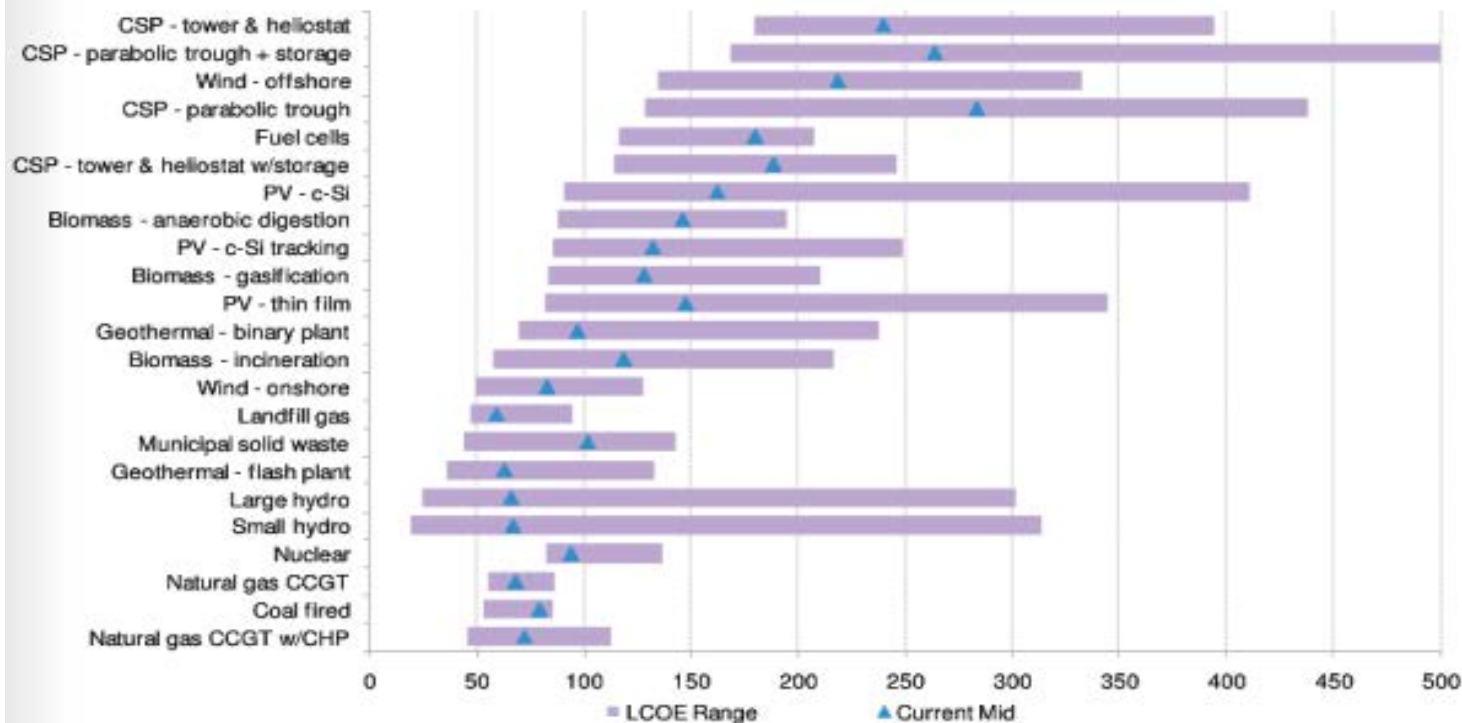
- How should we *start* thinking about costs?
- Often, we start with estimates of the Levelized Cost of Energy

$$LCOE = \frac{\sum_{t=0}^T \frac{C_t(q_t)}{(1+r)^t}}{\sum_{t=0}^T \frac{q_t}{(1+r)^t}}$$

- Simply the present discounted value of average costs
  - Add up all of the discounted costs
  - Divide this by the PDV of production

# Tons of LCOE estimates exist

## Q4 2012 LEVELIZED COST OF ENERGY FOR SELECT TECHNOLOGIES

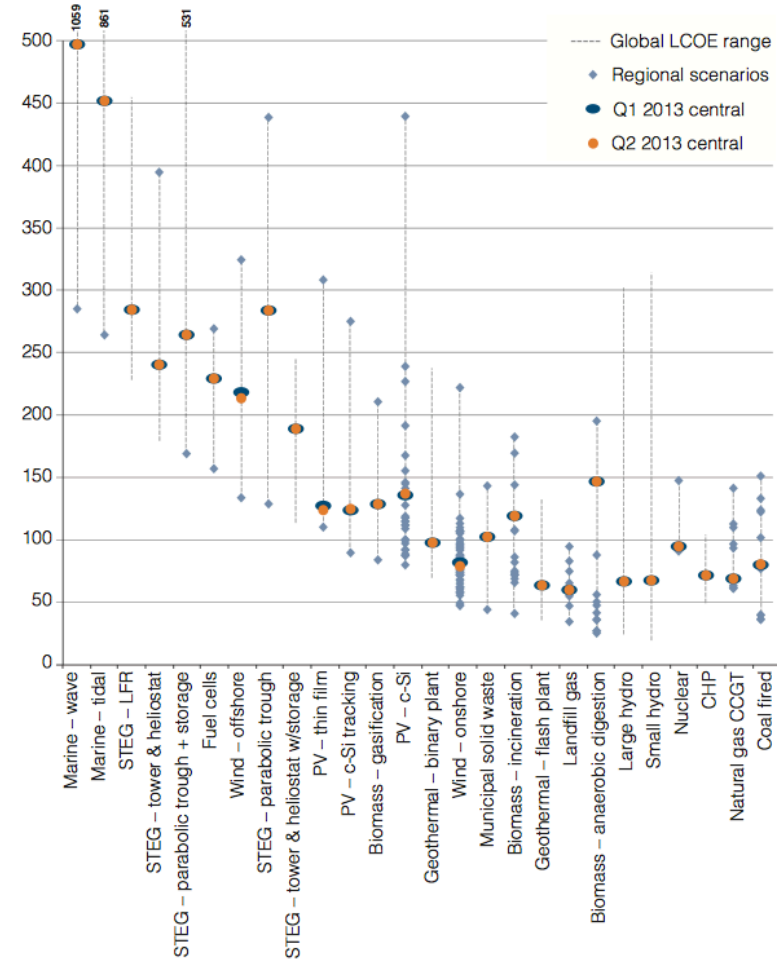


\$/MWh

Source: Bloomberg New Energy Finance, EIA

Global levelised cost of energy in Q2 2013 (USD/MWh)

Source: Bloomberg New Energy Finance



# Why so much variation?

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- Two things go into calculating the LCOE
  - Engineering assumptions
  - Economic assumptions
- Engineering assumptions
  - Costs
  - Output
- Economic assumptions
  - Discount rate
  - Time horizon
  - Future input costs
  - Private v. social costs (subsidies, taxes, regulation)
  - Opportunity/less-salient costs

# What does the LCOE miss?

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- At least four things:
  - 1. Externalities
  - 2. Value of generation depends on when it is generated
  - 3. Intermittency
  - 4. Distributed generation

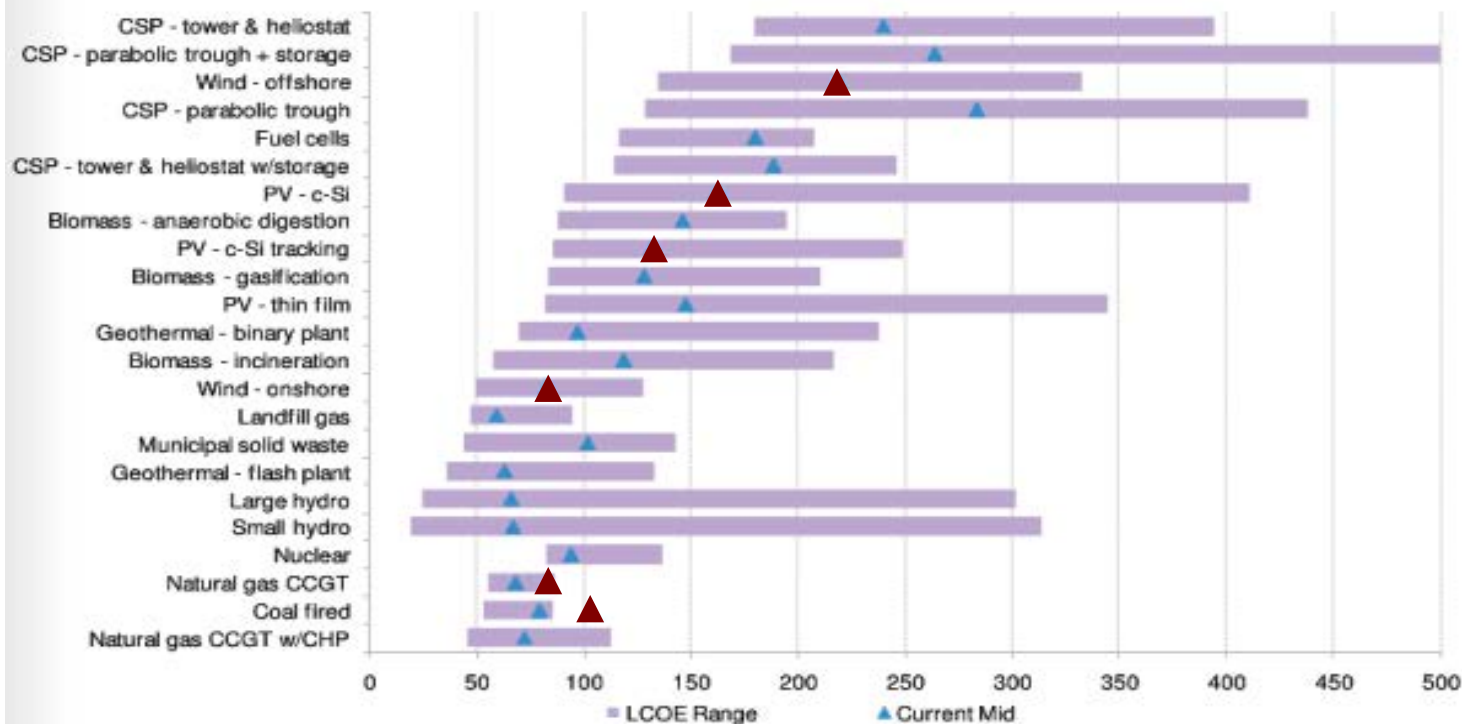
# Externalities

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- It is relatively straightforward to include externalities into LCOEs
- Externalities represent a social cost associated with generation
  - Simply add to the numerator
- The social costs of greenhouse gas emissions add roughly \$45/MWh to coal and \$20/MWh to a CCGT

# Better, but not quite there

## Q4 2012 LEVELIZED COST OF ENERGY FOR SELECT TECHNOLOGIES



Source: Bloomberg New Energy Finance, EIA

# LCOE calculates costs; we really want **value**

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- For intermittent (and flexible) sources, we need to account for when the electricity is generated
  - If generation is correlated with wholesale prices for electricity, then the LCOE cannot be directly compared to the LCOE of other sources
    - Also, can't be compared to average wholesale prices to gauge profitability
- This will tend to understate the value of solar
  - The implications for wind vary depending on location, but this tends to overstate the value of wind
- This issue also has implications for optimal pricing

# Aligning incentives for solar

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Real-Time Price ..... PV - South - - - - PV - West

Source: Borenstein. "The Market Value and Cost of Solar Photovoltaic Electricity Production."

# Power to the people

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- LCOE also ignores transmission and distribution costs
  - How this affects renewables is ambiguous
- Transmission:
  - Transmission costs might fall if renewables are placed closer to load source
    - However, often the best locations for solar and wind are often not near load source
- Distribution:
  - This, too, is ambiguous

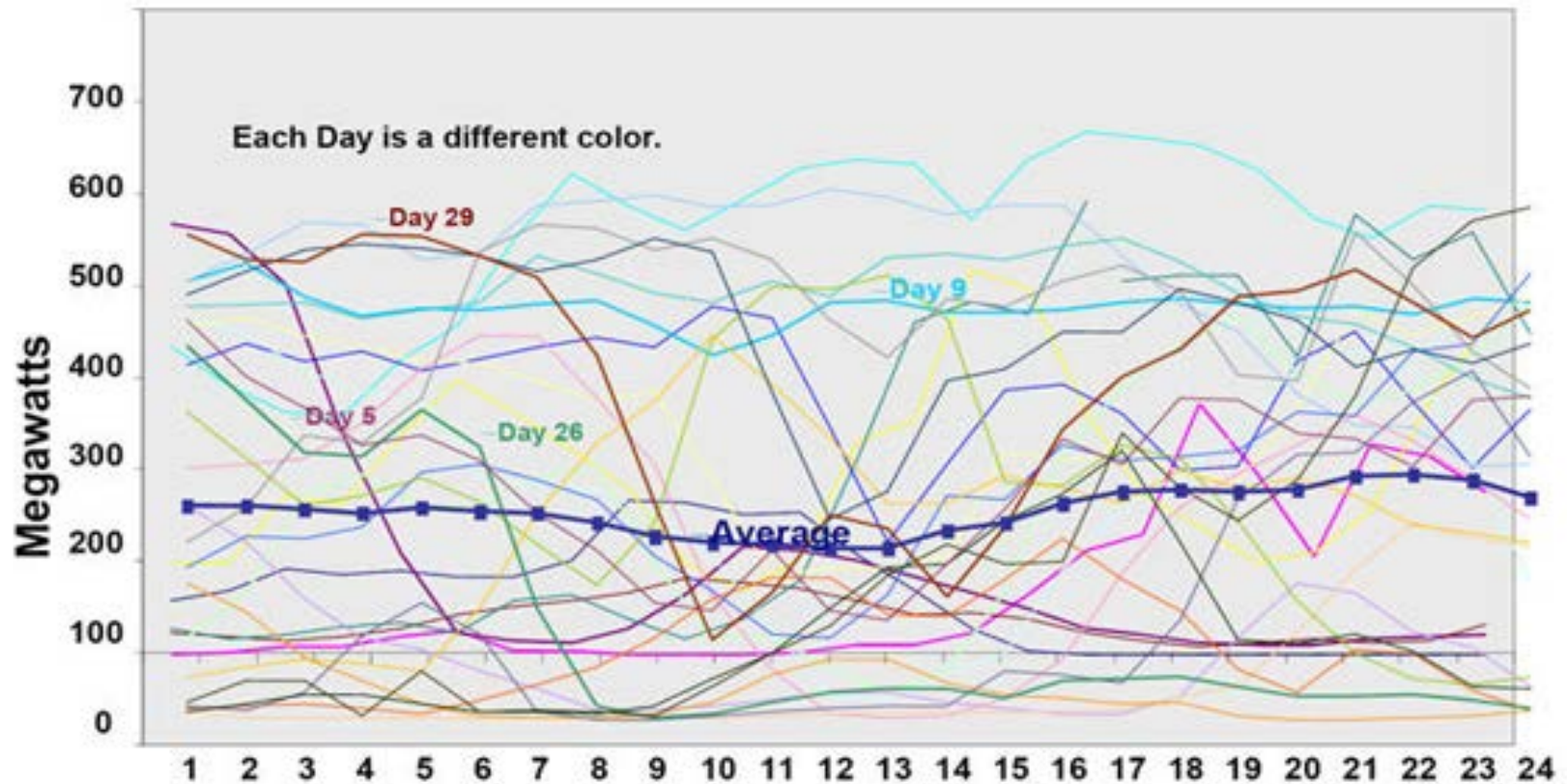
# The elephant in the room

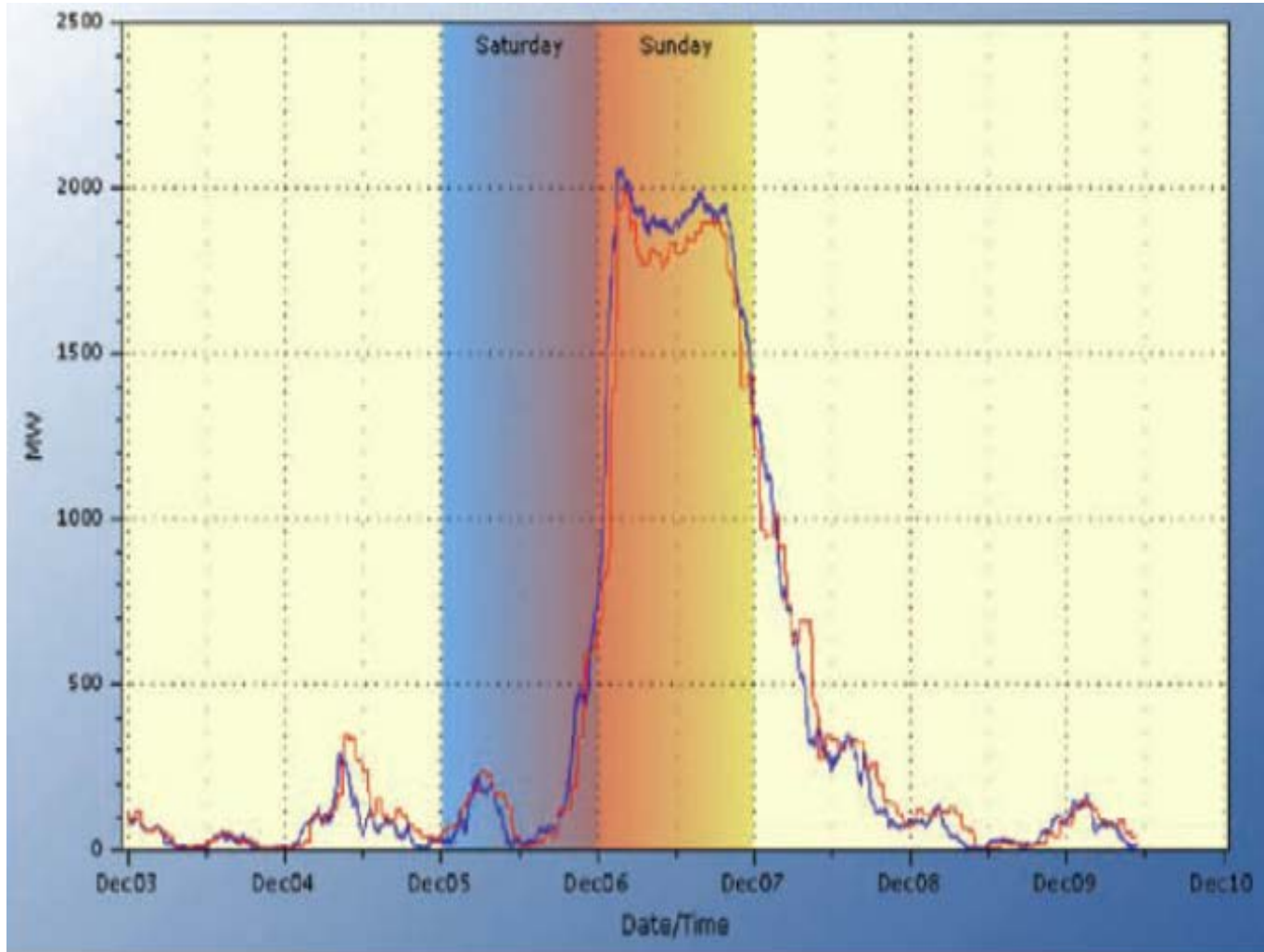
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- Intermittency is also ignore in LCOE calculations
- This has an economic cost
  - Intermittency requires *flexible* back up generation (or storage)
  - The back up generation has real costs which increase the true LCOE of solar and wind
- Notice, too, that intermittency may have implications for GHG emissions
  - Two reasons
    - 1. You may be required to run fossil fuel plants less efficiently
    - 2. Back up generators will be less efficient than CCGTs

# Intermittency: Wind in California

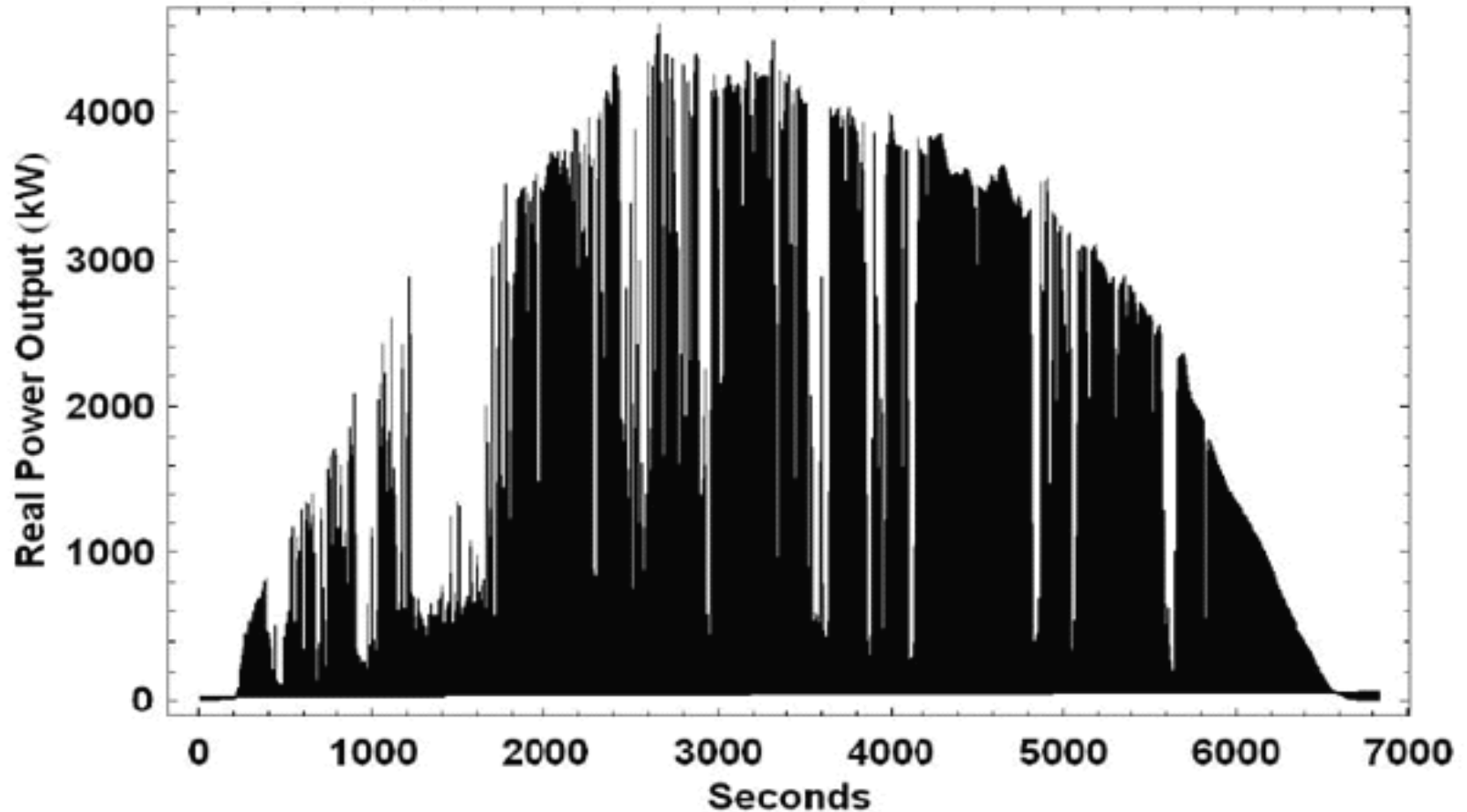
- The classic spaghetti graph from California:





# Intermittency, 10 second increments

(largest solar PV array)  
Springerville AZ, One Day at 10 Second Resolution



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# The MIT Utility of the Future Study



# Utility of the Future – The storyline

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## **Our approach** in a nutshell:

- A comprehensive system of **economic signals** (*market prices, regulated charges & incentives*) must relate all the agents with one another
  - A **detailed analysis of the agents** of change (the **DESSs**) will reveal
    - their **performance** characteristics
    - their techno-economic **viability** as a business
  - **Centralized & decentralized** agents will compete to provide services in plausible future scenarios
- ➔ This thorough analysis requires the use of a **suite of computer models**

# The Utility of the Future Study

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## Faculty Committee

Prof. Michael Caramanis (BU)  
Prof. John Deutch (MIT)  
Prof. Tomas Gomez (Comillas)  
Prof. William Hogan (Harvard)  
Prof. Steven Leeb (MIT)  
Prof. Richard Lester (MIT)  
Prof. Les Norford (MIT)  
Dr. John Parsons (MIT)  
Prof. Richard Schmalensee (MIT)

## Project Directors

Dr. Raanan A. Miller  
Dr. Richard D. Tabors

## Research and Project Advisors

Prof. Robert Armstrong (MIT)  
Prof. Carlos Batlle (Comillas-MIT)  
Louis Carranza (MIT)  
Stephen Connors (MIT)  
Prof. Pablo Frías (Comillas)  
Prof. Javier Reneses (Comillas)  
Prof. Michel Rivier (Comillas)  
Prof. Álvaro Sánchez (Comillas)  
Dr. Robert Stoner (MIT)

## Principal Investigators

Prof. Ignacio Perez-Arriaga  
Prof. Christopher Knittel

## Research Team

Ashwini Bharatkumar (MIT)  
Michael Birk (MIT)  
Scott Burger (MIT)  
Dr. José Pablo Chaves (Comillas)  
Sam Huntington (MIT)  
Jesse Jenkins (MIT)  
Max Luke (MIT)  
Dr. Raanan Miller (MIT)  
Dr. Richard Tabors (MIT)  
Dr. Karen Tapia-Ahumada (MIT)  
Dr. Claudio Vergara (MIT/Comillas)  
Nora Xu (MIT)

## Consortium Members

### Sponsors

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Shell  
WBCSD

### Participants

NEC  
Northeast Utilities  
PSEG  
Siemens

### Observers

Duke Energy  
Paul & Matthew Mashikian

# A suite of models is needed

Established Model

Under Development

- Impact of DES on transmission operations, expansion, costs
- Pricing of ISO services
- Design/ extension of ISO markets (ancillary services)

ROM+

TEPES

PSO

- Interface between ISO & DSO operations & markets

ROM+

- Interplay with other sectors: buildings, transportation, gas, etc.

MASTER

- Impacts of DES on generation mix, wholesale prices & plant revenues, CO2 emissions

Operation

ROM

PSO

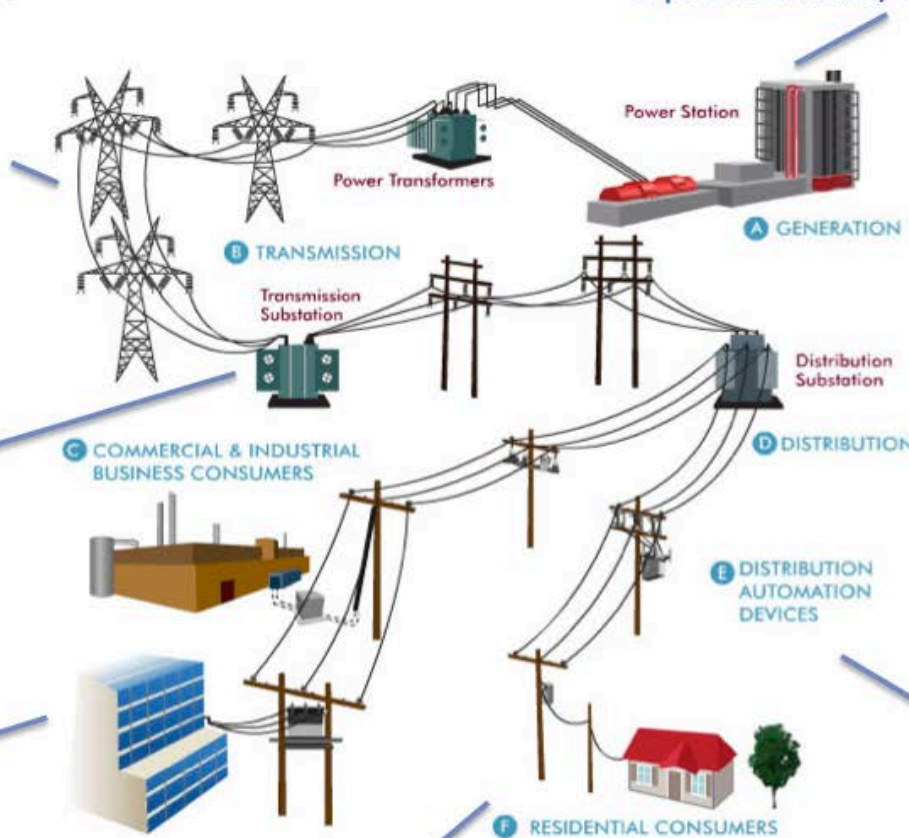
ROM+

Investment

LEEMA

IMRES

GenX



- Impacts of DES on distribution operations & expansion (costs)
- Pricing of DSO services

RNM

D-Sim

- Characterization of network user behavior & end-user service needs

DER-CAM

- Characterization & evaluation of DES technologies & business models

DER-CAM

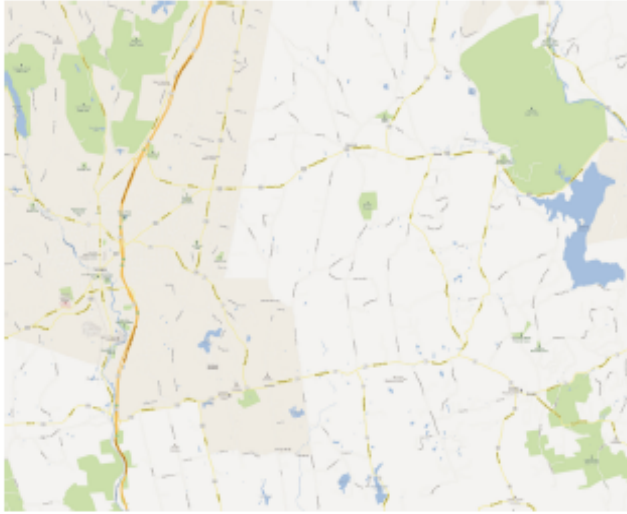
# Impacts & integration of service providers

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- What we want to find out
  - Efficacy or impact of **alternative designs of prices and charges** on the features & behavior of system actors
  - Impact of **penetration of different DES** on retail & wholesale markets & in power systems at all levels
  - Understand the significant factors in the coexistence & competition of **centralized & decentralized resources** in the future provision of electricity services

# Example Modeling Tool:

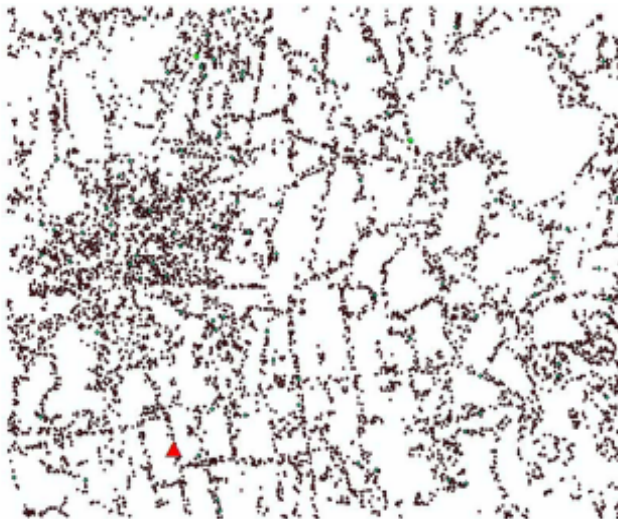
## Reference Network Model



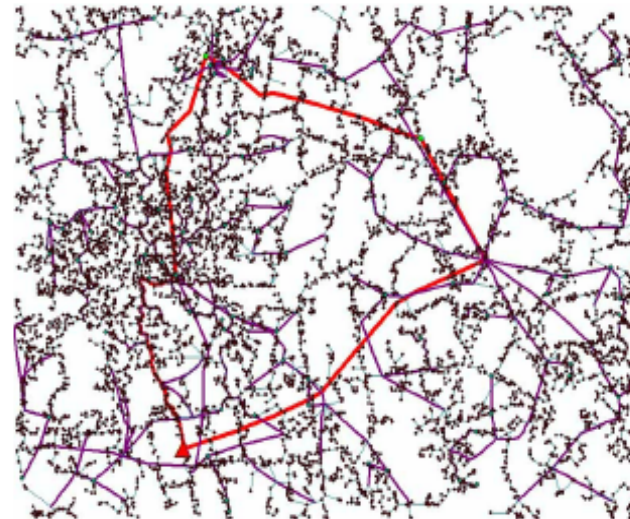
(a) Map of the selected region



(b) Streets are recognized



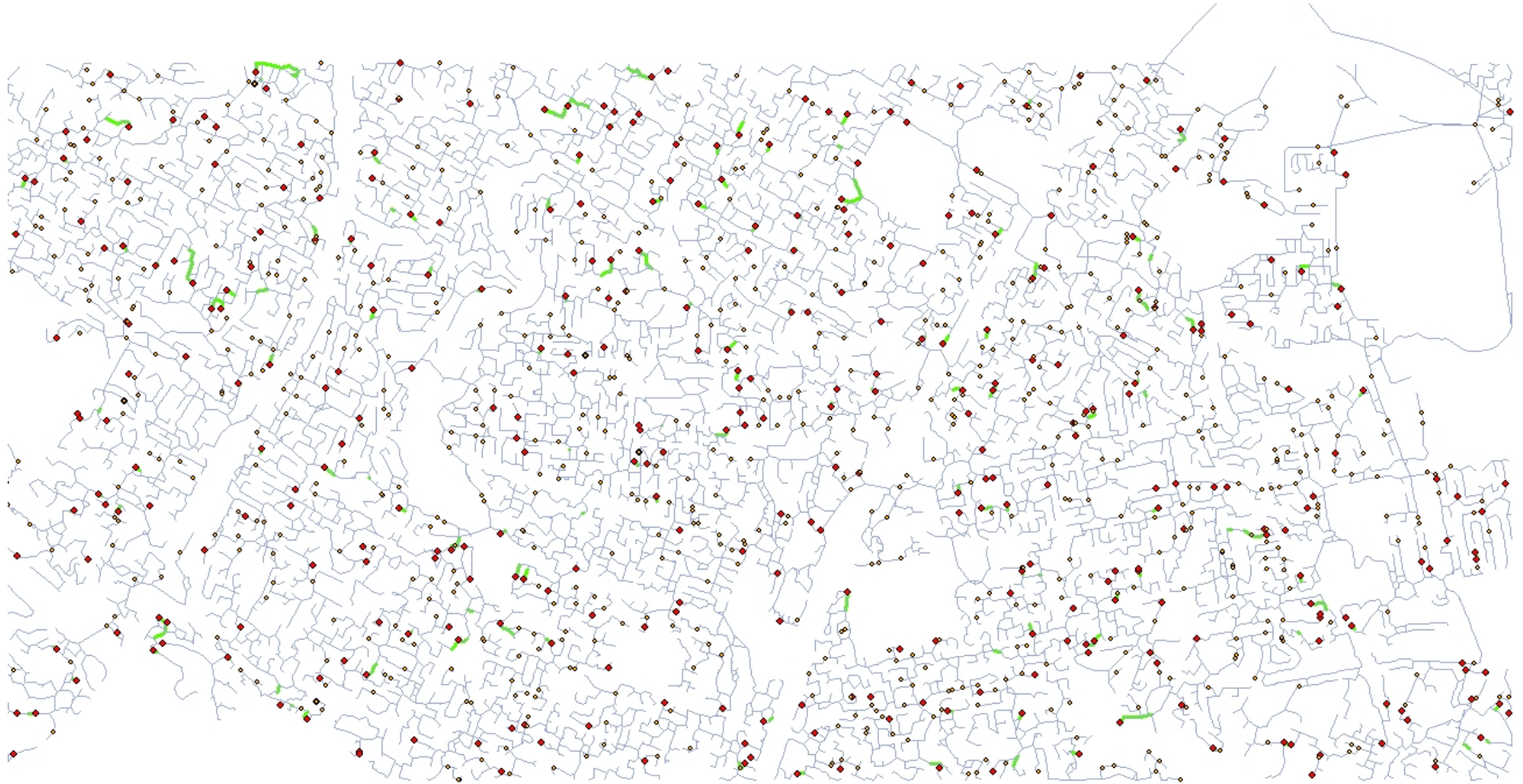
(c) Customers and substations

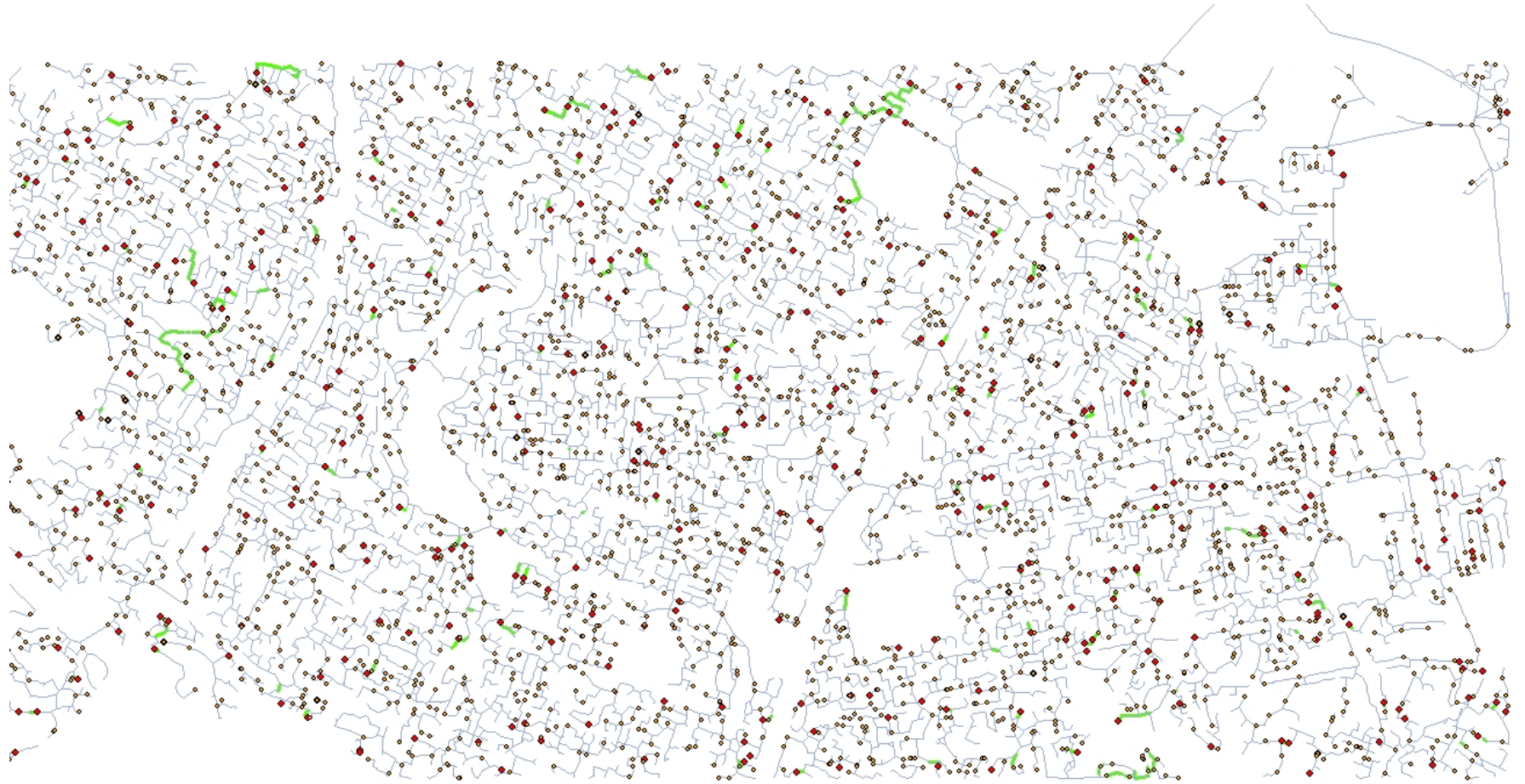


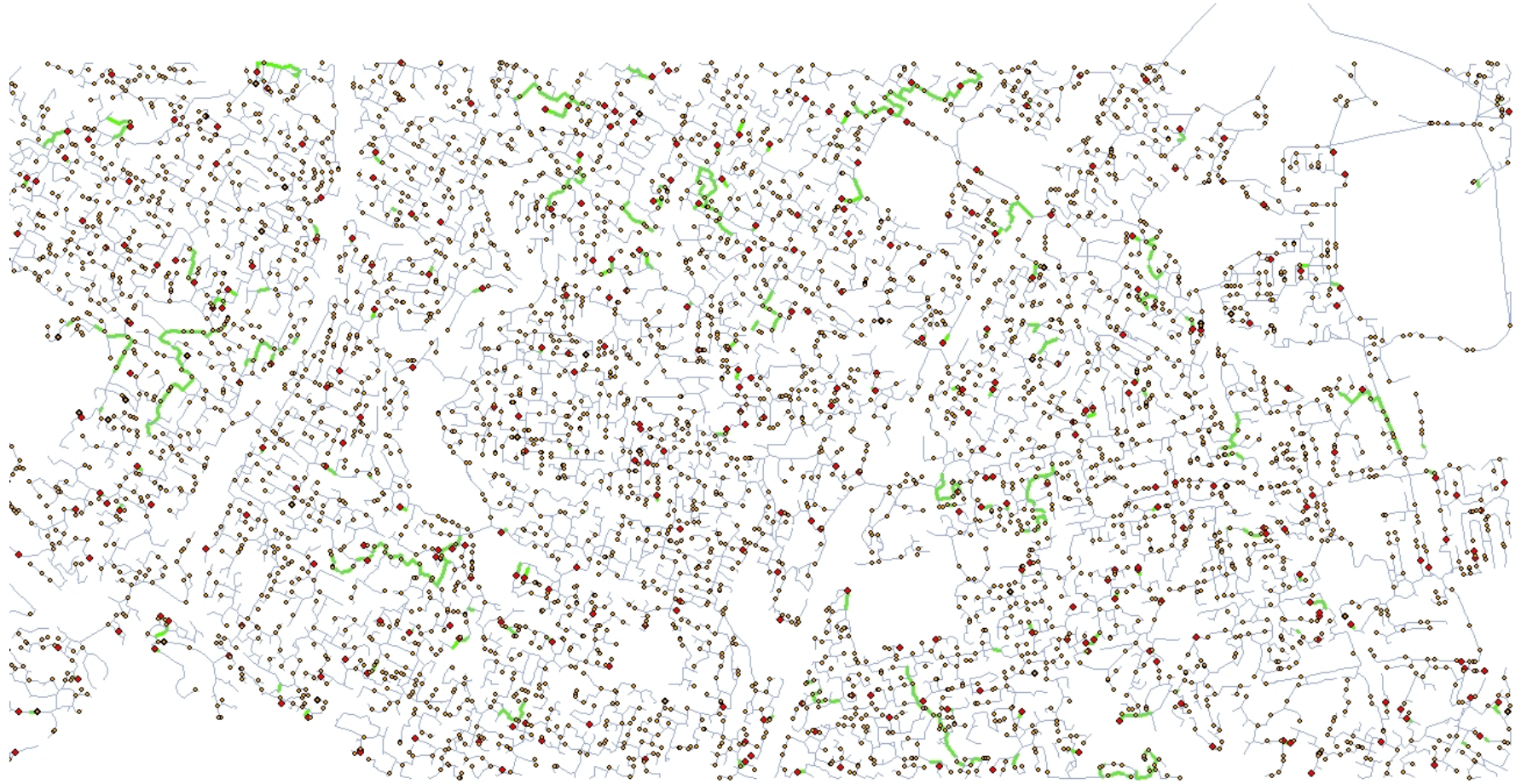
(d) Base network

# Example Modeling Tool:

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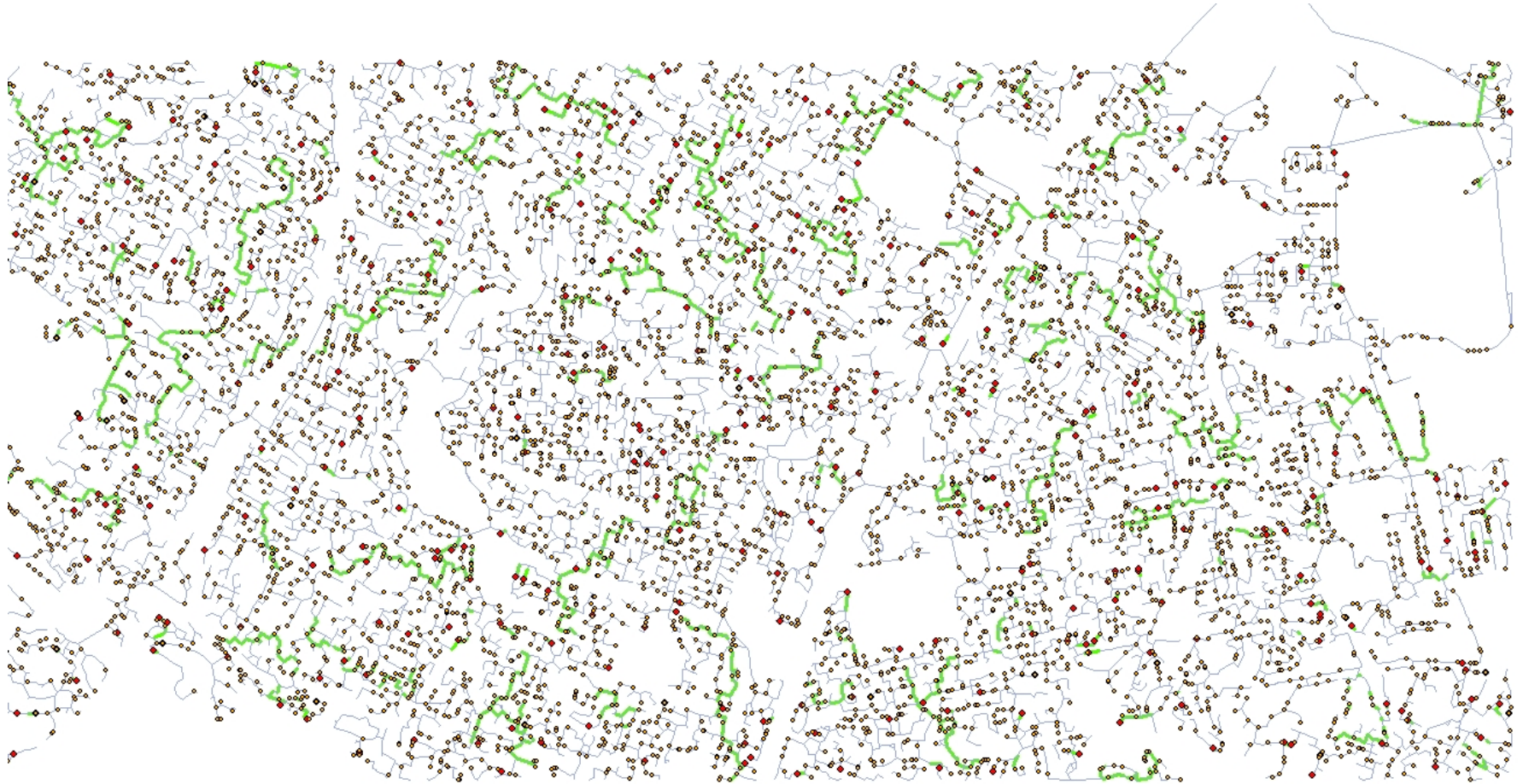






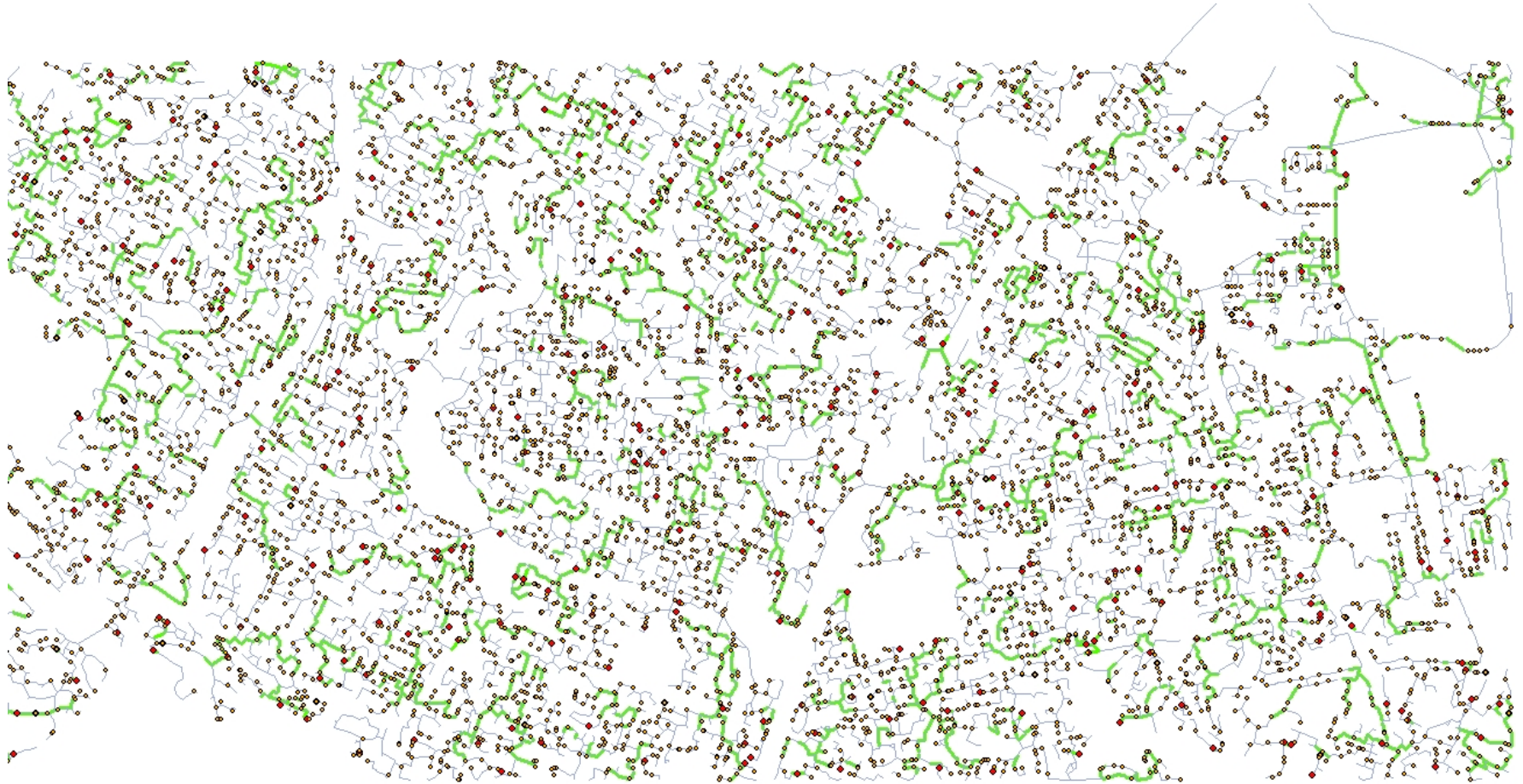
# Example Modeling Tool:

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# Example Modeling Tool:

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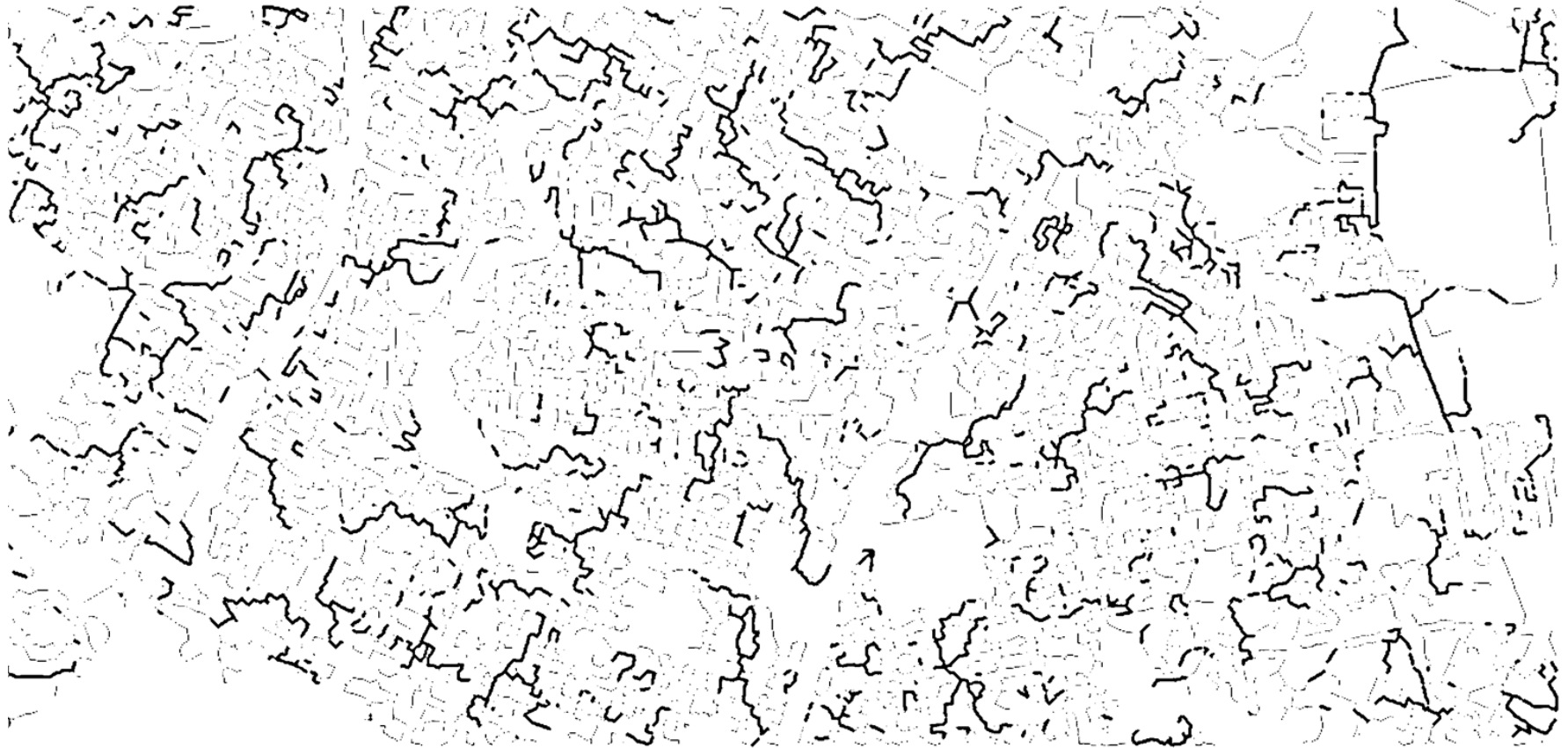


# Example Modeling Tool:

## Distribution network reinforcements

(and their associated costs) can be significant

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# Where Are We Now

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- Developed novel regulatory mechanisms for distribution network company remuneration under high DES penetration
- Developed novel tariff structures for efficient network cost allocation
- Developed framework for business model characterization and analysis
- Performed preliminary assessment of distributed energy technologies
- Performed comprehensive literature review
- On-going work on modeling tool assessment/development

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# Policy options

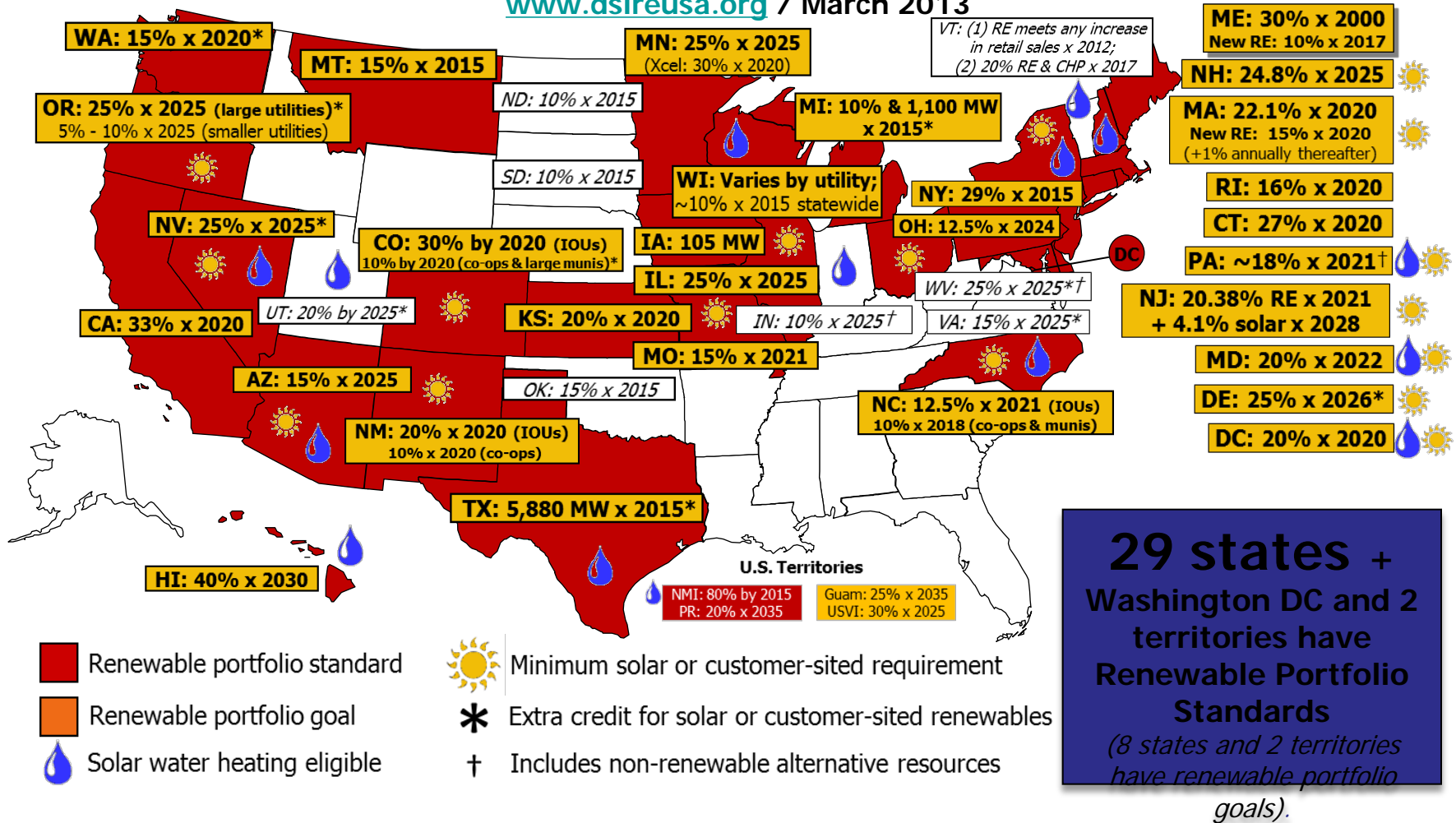
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- There are lots of policy options to incentivize renewable integration
- Important: We want to incentivize the **right** amount of renewables in the **right** locations
- Policy options:
  - Pollution taxes
  - Direct subsidies through either construction or feed-in tariffs
    - E.g., investment tax credits, Federal production tax credit
  - Indirect subsidies through “Renewable Portfolio Standards”
  - Dynamic pricing

# Policy of choice: Renewable Portfolio Standards

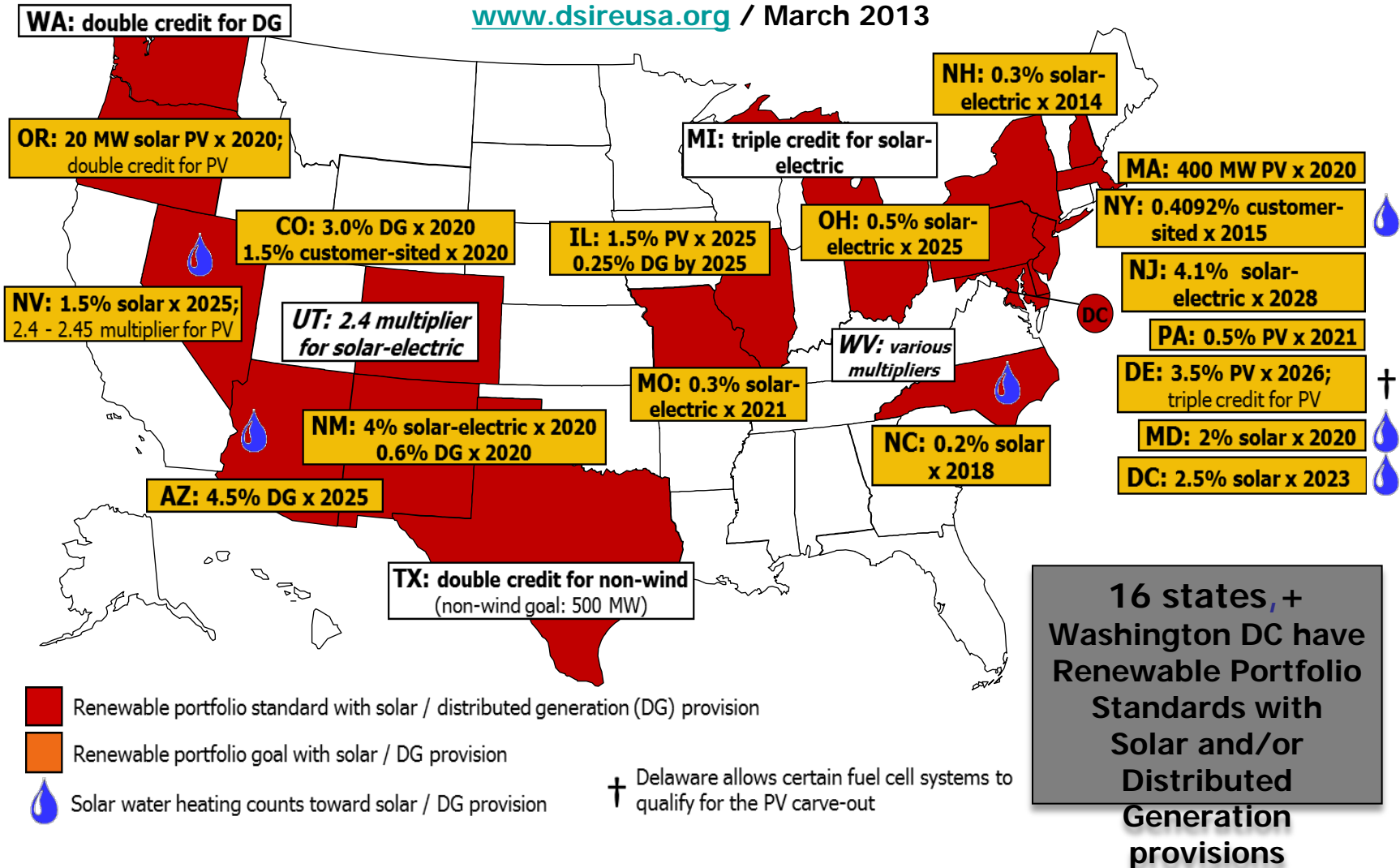
## Renewable Portfolio Standard Policies

[www.dsireusa.org](http://www.dsireusa.org) / March 2013

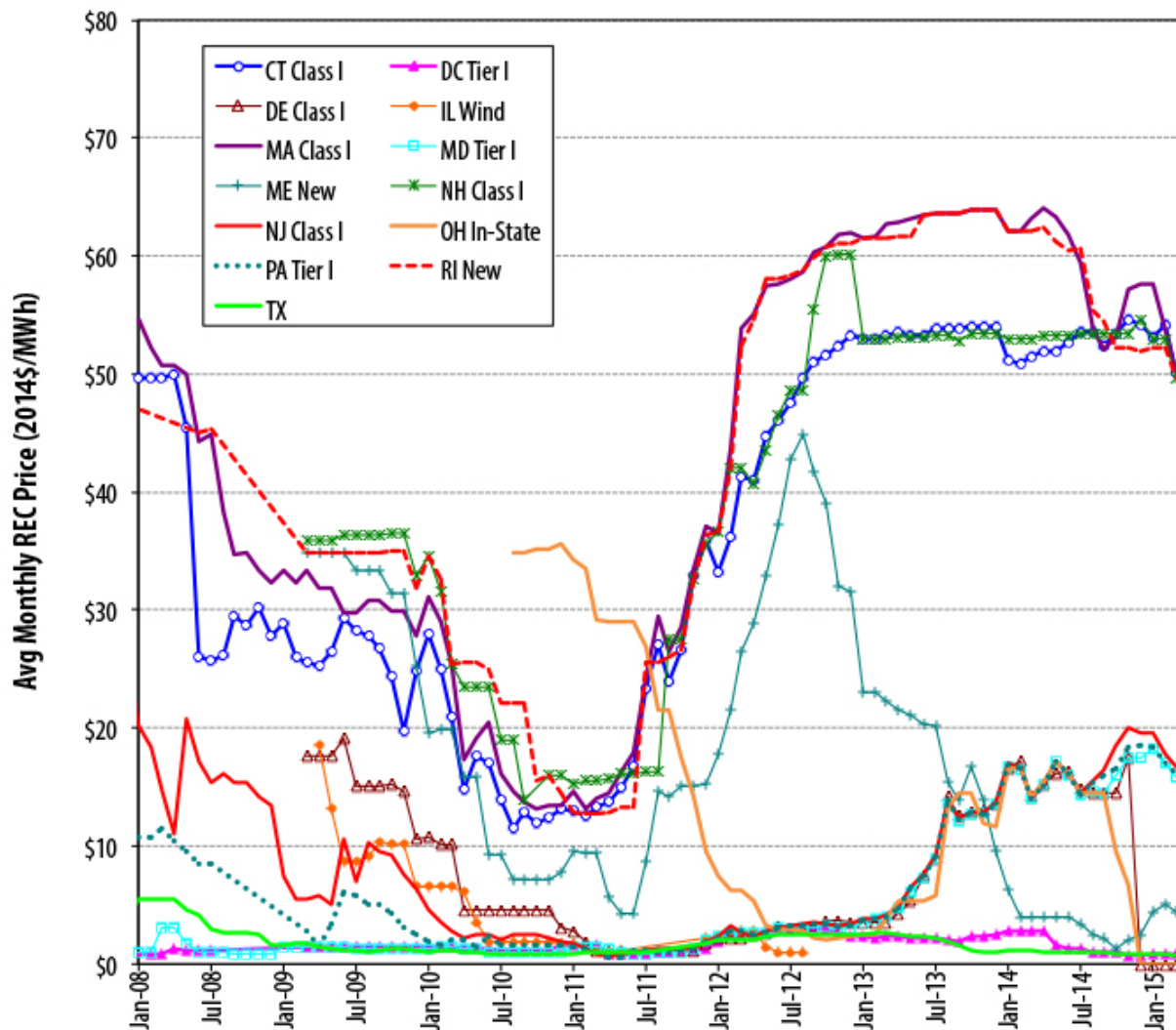


# Solar carve outs

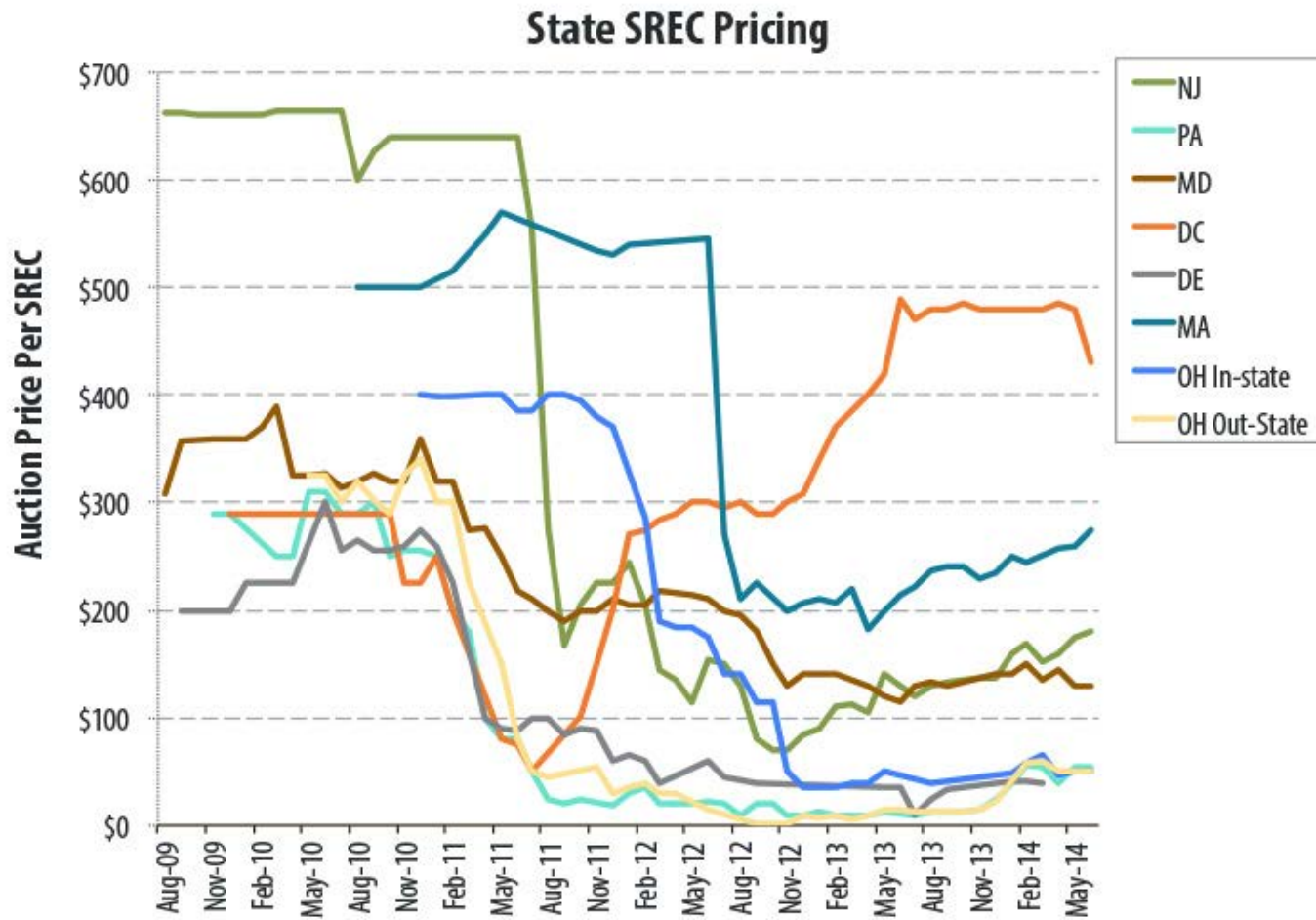
[www.dsireusa.org](http://www.dsireusa.org) / March 2013



# REC prices across a variety of states

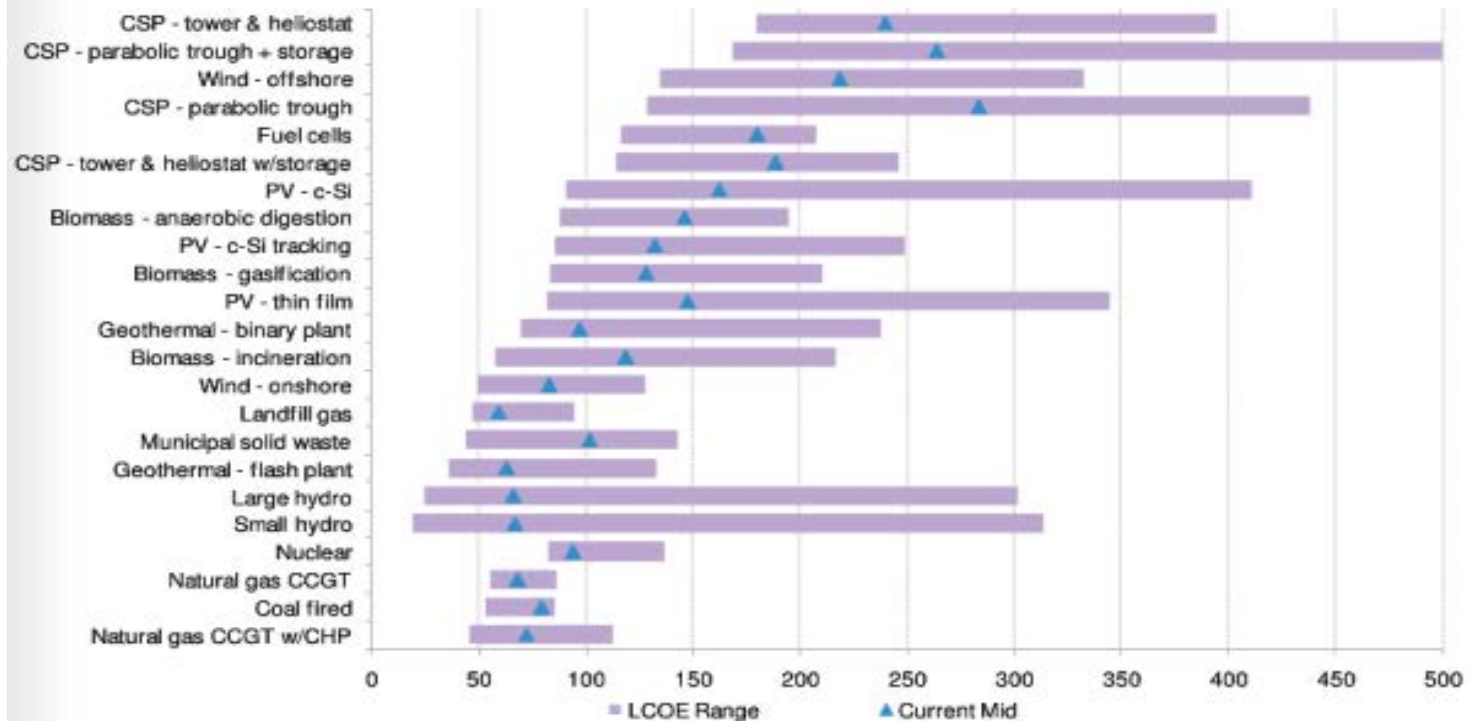


# Solar-specific RECs



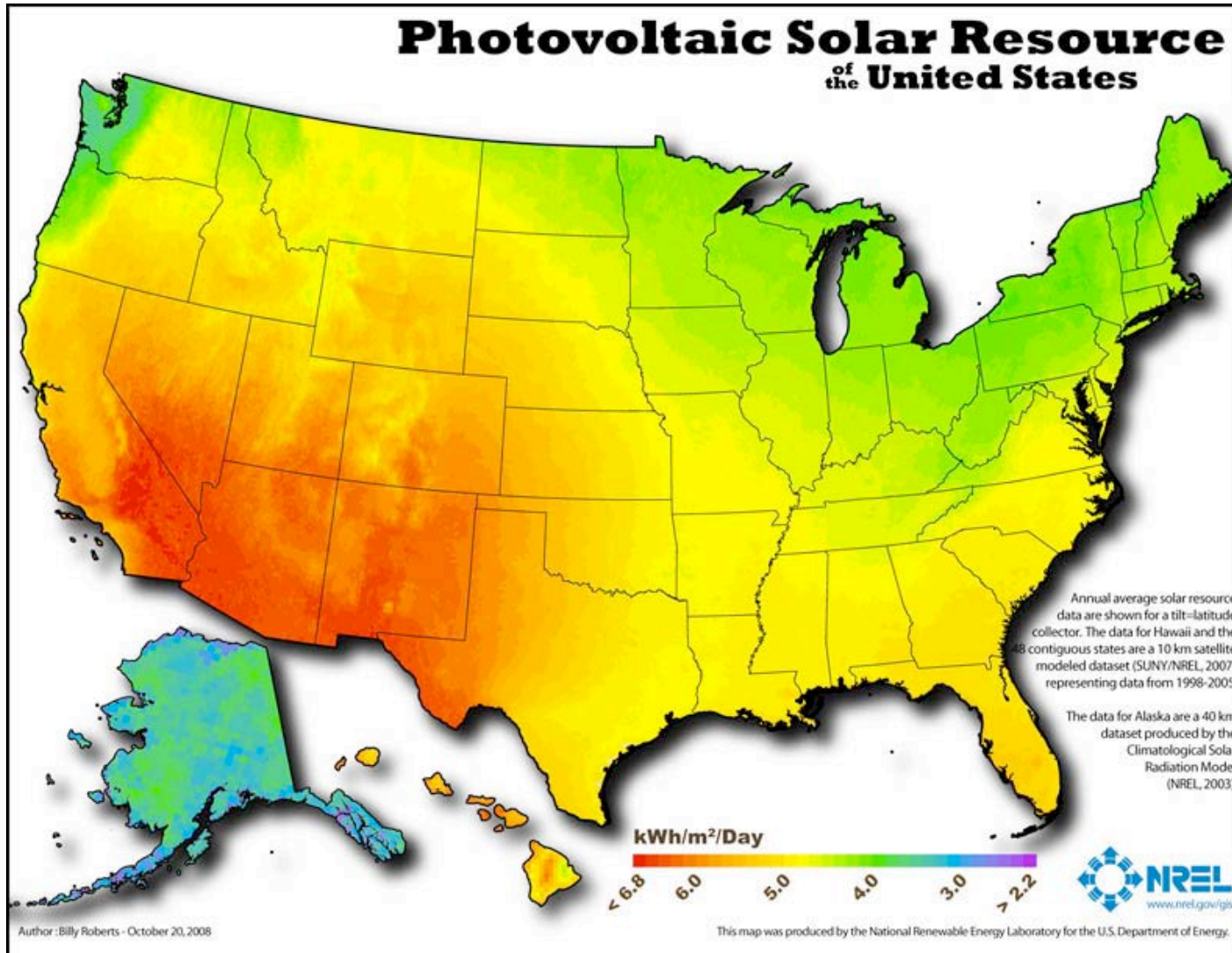
# REC prices really change LCOEs, but create uncertainty

## Q4 2012 LEVELIZED COST OF ENERGY FOR SELECT TECHNOLOGIES



Source: Bloomberg New Energy Finance, EIA

# Location, location, location



# Favorite policies among economists

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- Basic economics tells us to adopt policies that directly correct market failures
- What are the market failures?
  - Big one: un-priced externalities
  - Possible: Learning-by-doing **spillovers**
    - Note: learning-by-doing by itself is not a market failure
  - Also possible: Market failures associated with innovation
- What is important is to get the right amount of renewables and not distort other decisions
  - Many of the alternative policies create perverse incentives
    - E.g., production tax credits for wind
- RPSs (and feed in tariffs) are likely very inefficient ways to attract renewables

# Key take-a-ways

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- Solar and wind have a lot to offer
- Some major issues remain, however
  - They are not quite at grid parity, despite claims (even ignoring intermittency)
    - Wind, might be, but generation not at ideal times
    - If they were, we wouldn't see SREC prices being so high
- The benefits of distributed generation are the topic of current research
  - Existing work suggests initial benefits, but then distribution costs increase