The Future of Power

Innovation, disruption& transformation in energy

UPME Study

11-13 October 2016

Bogota, Colombia

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Menlo Energy Economics

San Francisco CA

www.menloenergy.com

Thank you

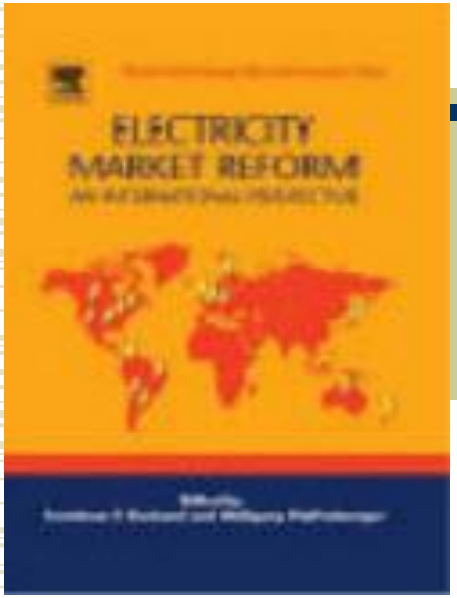
- Thank you for the opportunity to contribute
- Caveat: My views are California-centric
  - US vs. Colombia; Silicon Valley vs. Bogota
- I aim to:
  - Be bold & provocative
  - Serve as a “contrarian”
  - Focus on technological innovation & disruption
  - Encourage UPME to step “out of the box”

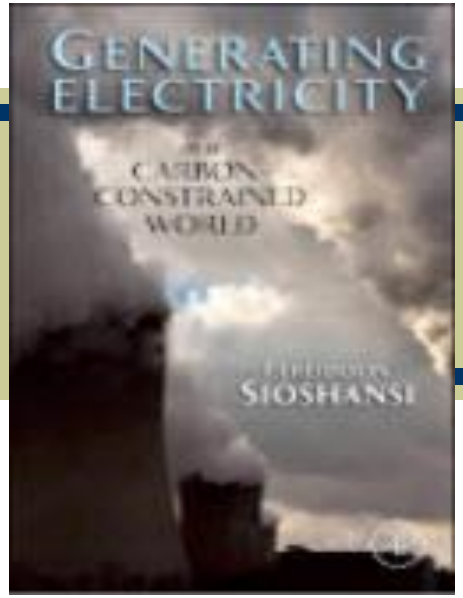
Outline

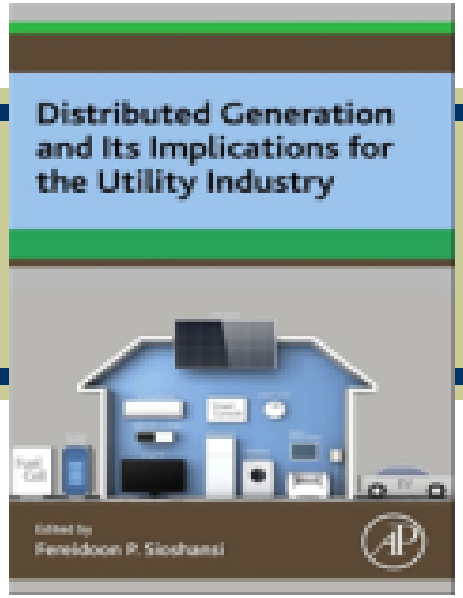
- Introduction
- California in a nutshell
- Energy transformation
- Relevance to Colombia

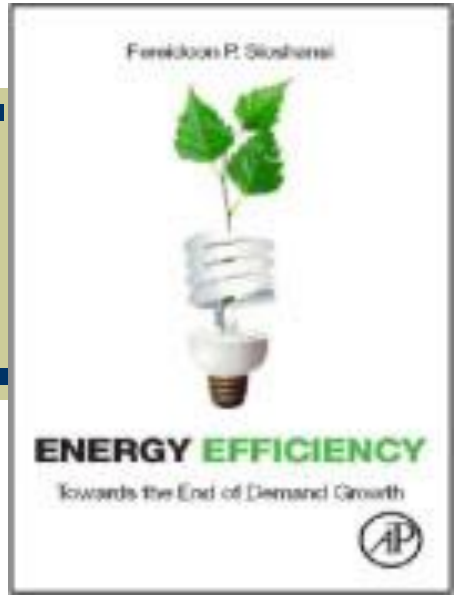
My background/experience

- Engineer turned energy economist
  - BS & MS in engineering, MS & PhD in economics, Purdue
  - SCE, EPRI, NERA, Henwood Energy & others
- Independent consultant since 2002
- Editor & publisher of ***EEnergy Informer***
  - 26 years
- Frequent speaker at events such as this
- Book editor
  - 9 and counting


ELECTRICITY
MARKET REFORM


GENERATING
ELECTRICITY
CARBON-
CONSTRAINED
WORLD
SIOSHANSI


Distributed Generation
and Its Implications for
the Utility Industry
Fereidoon P. Sioshansi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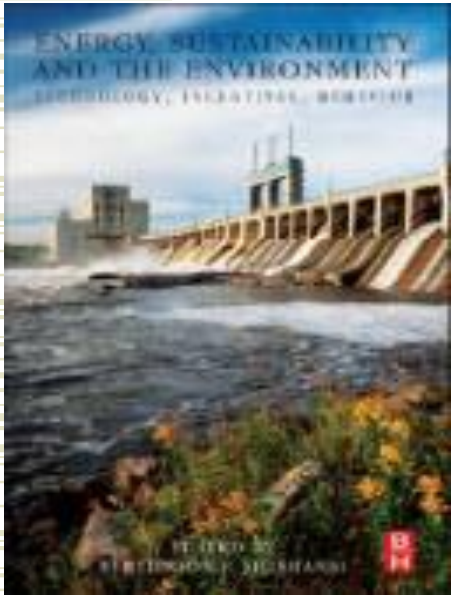
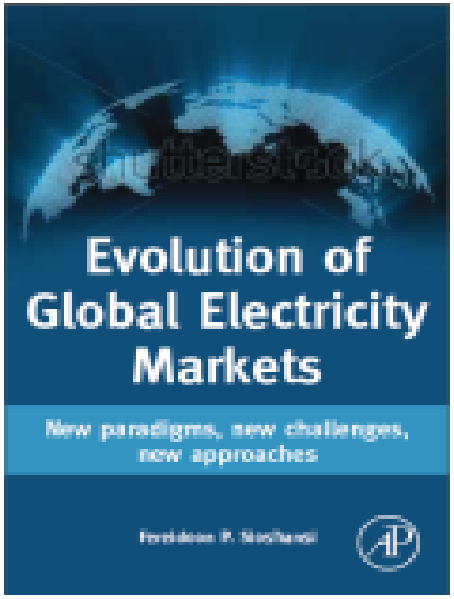
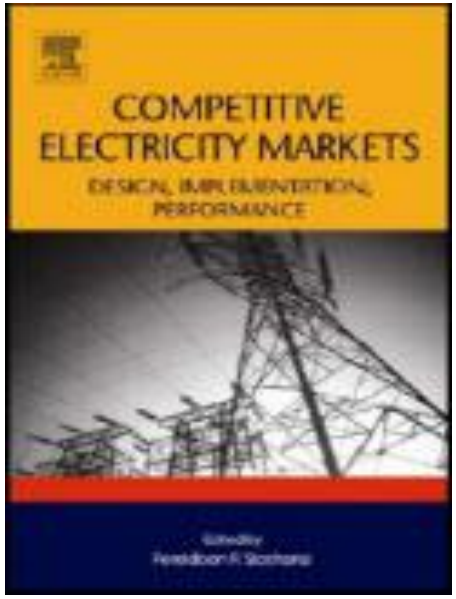
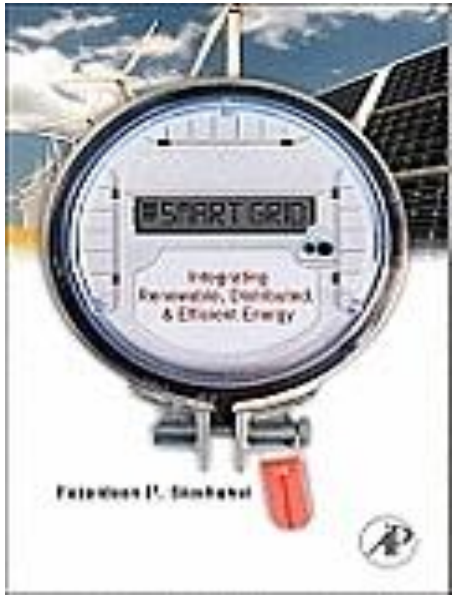
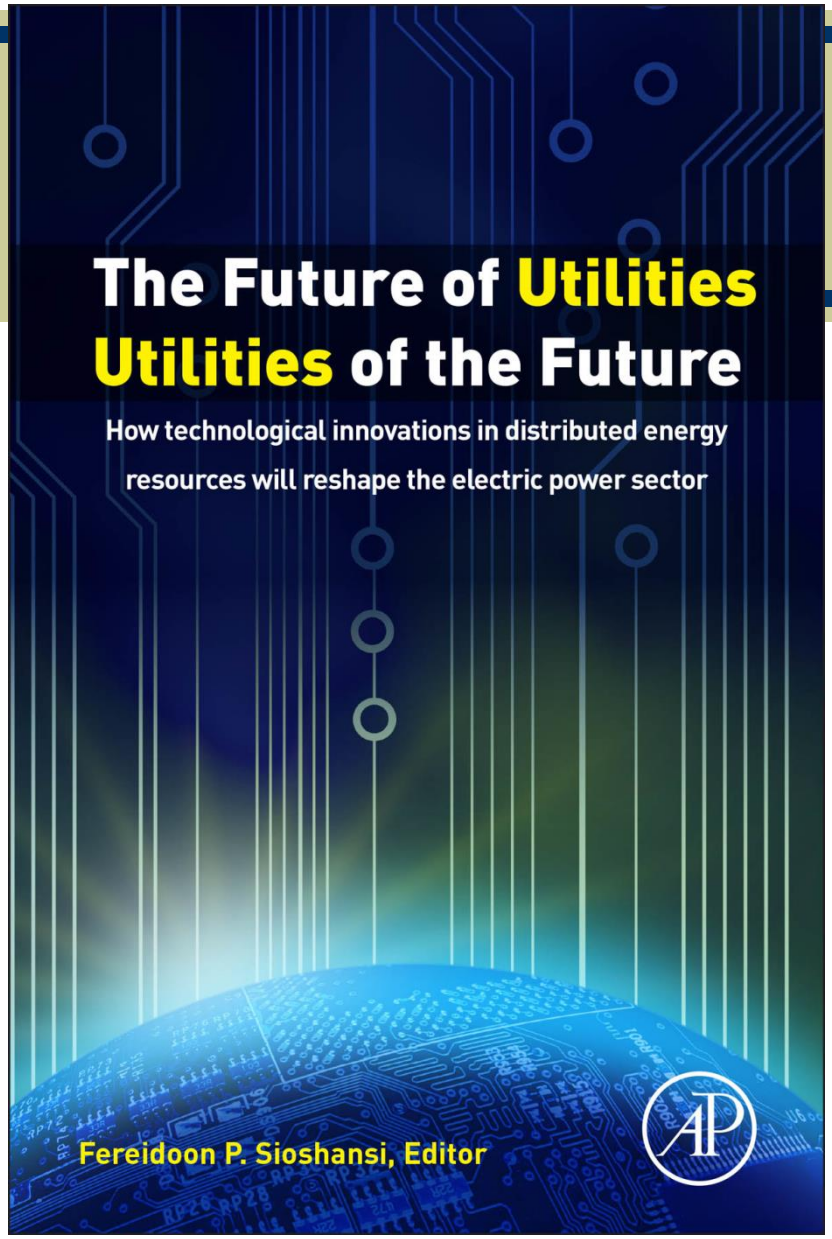
ENERGY EFFICIENCY
Towards the End of Demand Growth


ENERGY, SUSTAINABILITY
AND THE ENVIRONMENT


Evolution of
Global Electricity
Markets
New paradigms, new challenges,
new approaches
Fereidoon P. Sioshansi


COMPETITIVE
ELECTRICITY MARKETS
DESIGN, IMPLEMENTATION,
PERFORMANCE


SMARTGRID
Fereidoon P. Sioshansi

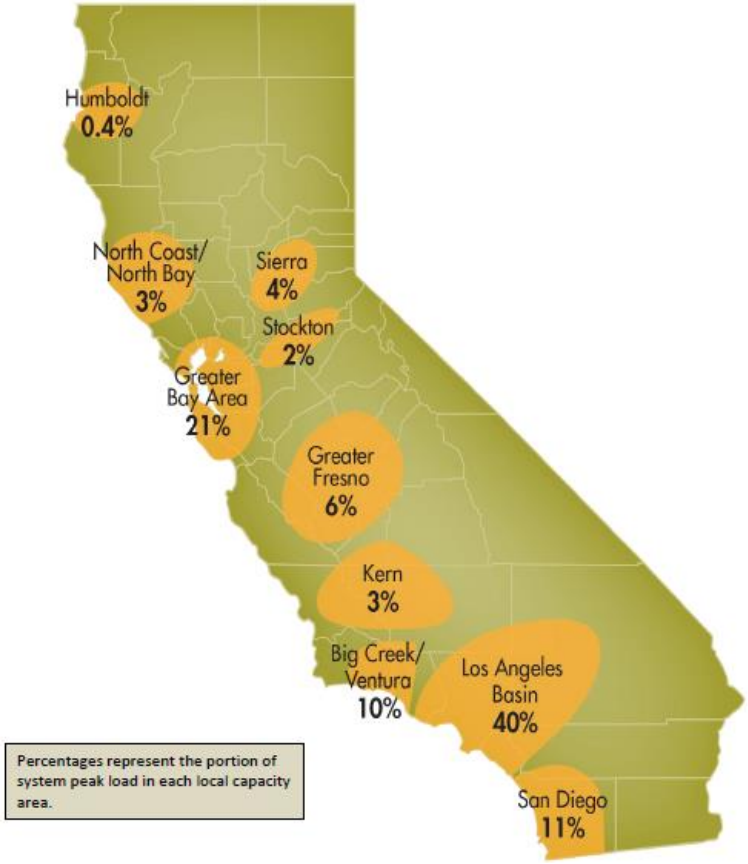

The Future of Utilities
Utilities of the Future
How technological innovations in distributed energy resources will reshape the electric power sector
Fereidoon P. Sioshansi, Editor

Innovation & Disruption At the “grid’s edge”

- Topic of next book
- Why “innovation & disruption?”
- Why “the grid’s edge?”

Golden State

Major load centers along the coast

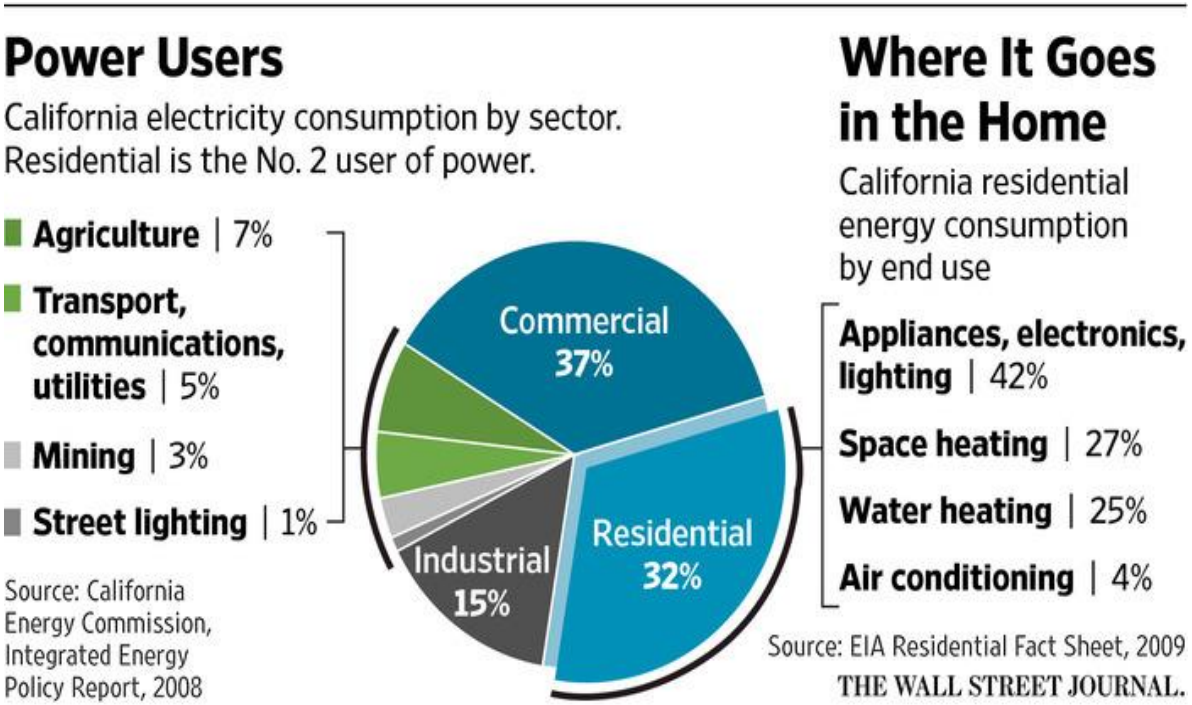


Source: CAISO 2013 Annual Report On Market Issues & Performance

The Golden State

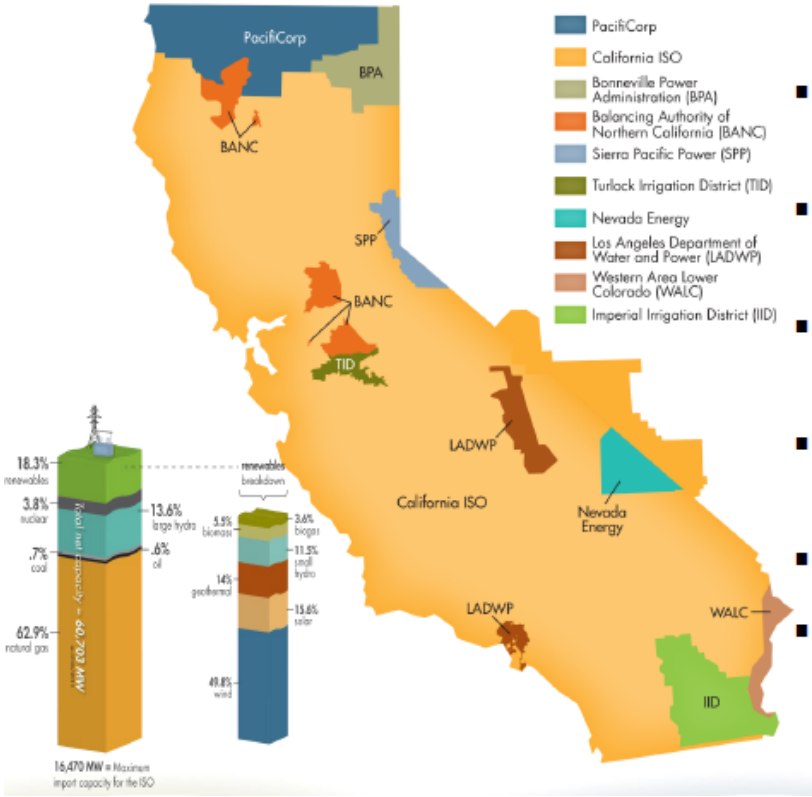
- Population: 39 m US:320 m
- Median family income $70K US: 54K
- Little heavy industry; no coal generation
- Biggest employer: Univ. of Calif. System
- Biggest companies: Apple, Google, Facebook, Uber, Tesla, SolarCity
- VC capital of world: Menlo Park
- Hub of innovation & disruption: Silicon Valley
- ½ of US EVs
- ½ of rooftop solar PVs

CA's electricity consumption



Source: The Quest for Home Utility Bills of…Zero, by Gabriel Khan, The Wall Street Journal 14 Set 2016

CAISO by the numbers



- **60,703** MW of power plant capacity (net dependable capacity)
- **50,270** MW record peak demand (July 24, 2006)
- **27,589** market transactions per day
- **26,024** circuit-miles of transmission lines
- **30 million** people served
- **246 million** megawatt-hours of electricity delivered annually

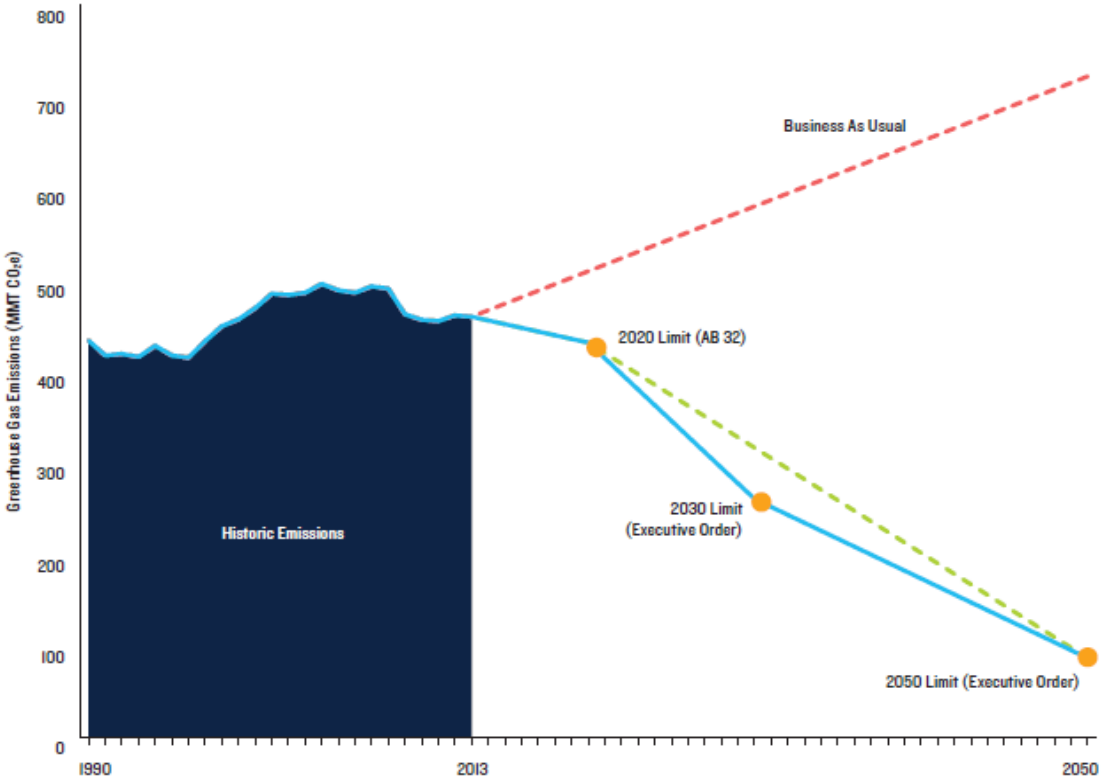
Source: CAISO Discussion of Markets, Mark Rothleder, 3 June 2014

Firing on too many cylinders

- Climate bill first passed in 2006
  - Reduce emissions o 1990 level by 2020
  - Reduce 40% below 1990 level by 2030
  - 80% below 1990 level by 2050
- Renewable mandate
  - 33% by 2020; 50% by 2030
- Zero net energy buildings
  - New residential by 2020; commercial by 2030
- Energy efficiency
  - Flat per capita electricity consumption since 1978
- And many more …

California dreaming

Future is low carbon



Source: California's golden energy efficiency opportunity: Ramping up success to save billions and meet climate goals, Natural Resources Defense Council, Aug 2015

Debate

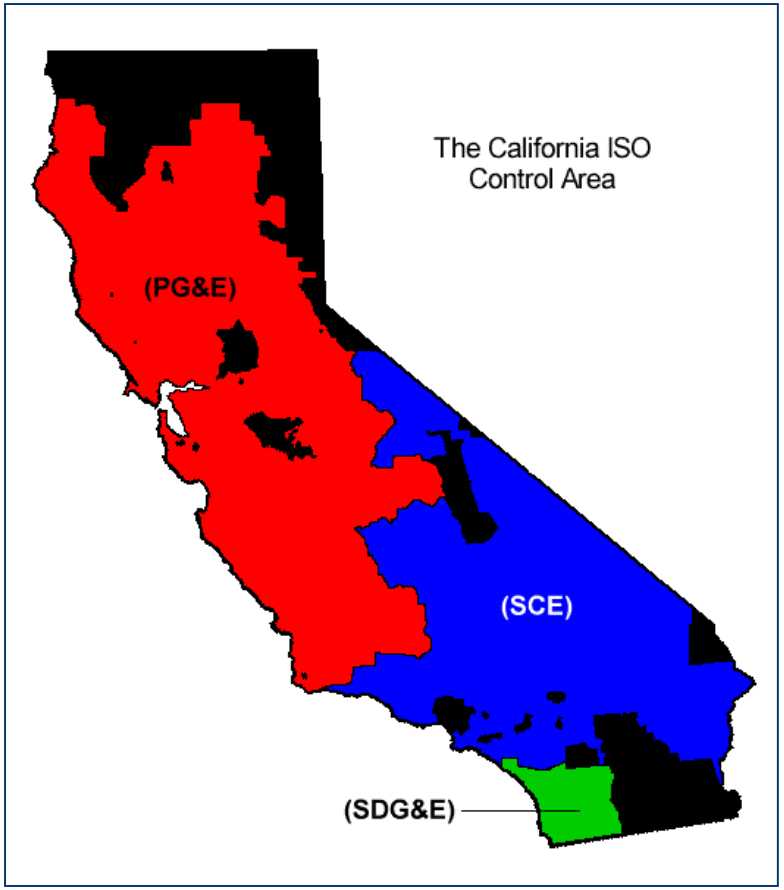
- Can it be done?
- How much would it cost?
- Does it make sense?
- Why?

How does it work?

- From the people, by the people, for the people!
- Public desire => Political vision => Policy/regulations
- Legislature => Governor => Regulators/agencies
- California's electricity sector:

CPUC	Retail rates
CEC	Energy policy
CAISO	Grid reliability/transmission mgmt.
CARB	Climate bill
3 IOUs, 2 Municipals + others	Distribution network, billing/retail
Business community, investors	Comply/remain competitive
Consumers/ratepayers/taxpayers	Pay for they asked for

3 IOUs, CAISO, CPUC & CEC



Source: Stern & Harris, SCE, 2008

Contents

- 1. What energy transformation?
- 2. Why it is difficult to predict the future
- 3. Different time horizons
- 4. Different “forecasting” approaches
- 5. Main drivers of change
- 6. Mega trends in the electric sector
- 7. Technological innovation & disruption
- 8. Role of regulation/policy
- 9. What do future consumers want/need?
- 10. Conclusions: Relevance to Colombia

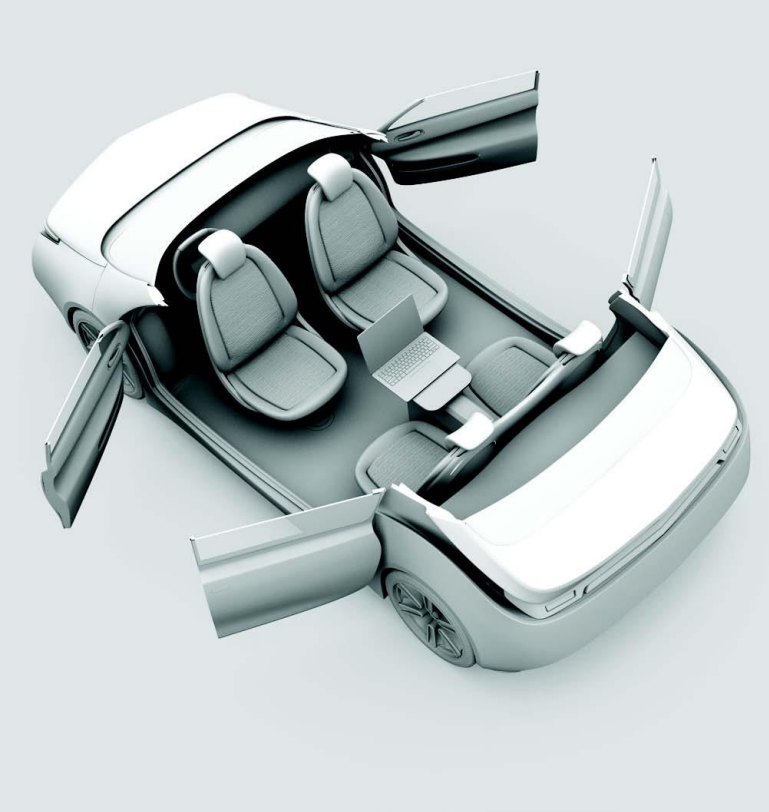
1. What energy transformation?

- Uber, worth $70 billion, offers driverless rides in Pittsburg, PA
- Ford to introduce driverless car in 2021
- Car ownership to peak by 2020
- 5 of top 10 global listed companies are virtual
- Renewables beat natural gas 70 to 1 in 1st Qtr. 2016 in US
- Record renewable investment despite low oil prices in 2015
- Renewables grow from 7 to 32% in 15 years in Germany
- Over 1 million solar roofs in Australia, population 23 million
- Solar generation in 2016 to exceed coal in UK
- Coal consumption has peaked in China
- CA & NY 50% renewable by 2030, 100% in HI by 2045

UberWorld

Source: The Economist, 17 Sept 2016

No wheels, no brake, no gas pedal & no gas



Hard to believe but true

- Buildings that need no energy!
- Windows & roofs that produce energy!
- Batteries that can recharge in 90 seconds
- Energy-independent communities
- Consumers trading electrons w neighbors
- Solar power at 2.4 cents/kWh
- A world mostly run on “free”” renewables
- Plane flying around the world w/o fuel

Energy independent?

Self sufficient on kWhs yet reliant on the grid

Source: The economics of grid defection: When & where distributed solar generation plus storage competes with traditional utility service, Rocky Mountain Institute et al, 2014

Solar roofs

Makes no sense to build a roof <u>and</u> add solar panels

Guess what?

Sun shines not just on the roofs

Source: Lawrence Berkeley National Laboratory's FLEXLAB

Queen Victoria era train station

Kings Cross, London

PV panels integrated in roof

Future of buildings is BIPV

Big customer, no revenues

Apple’s new office building under construction in Cupertino, CA

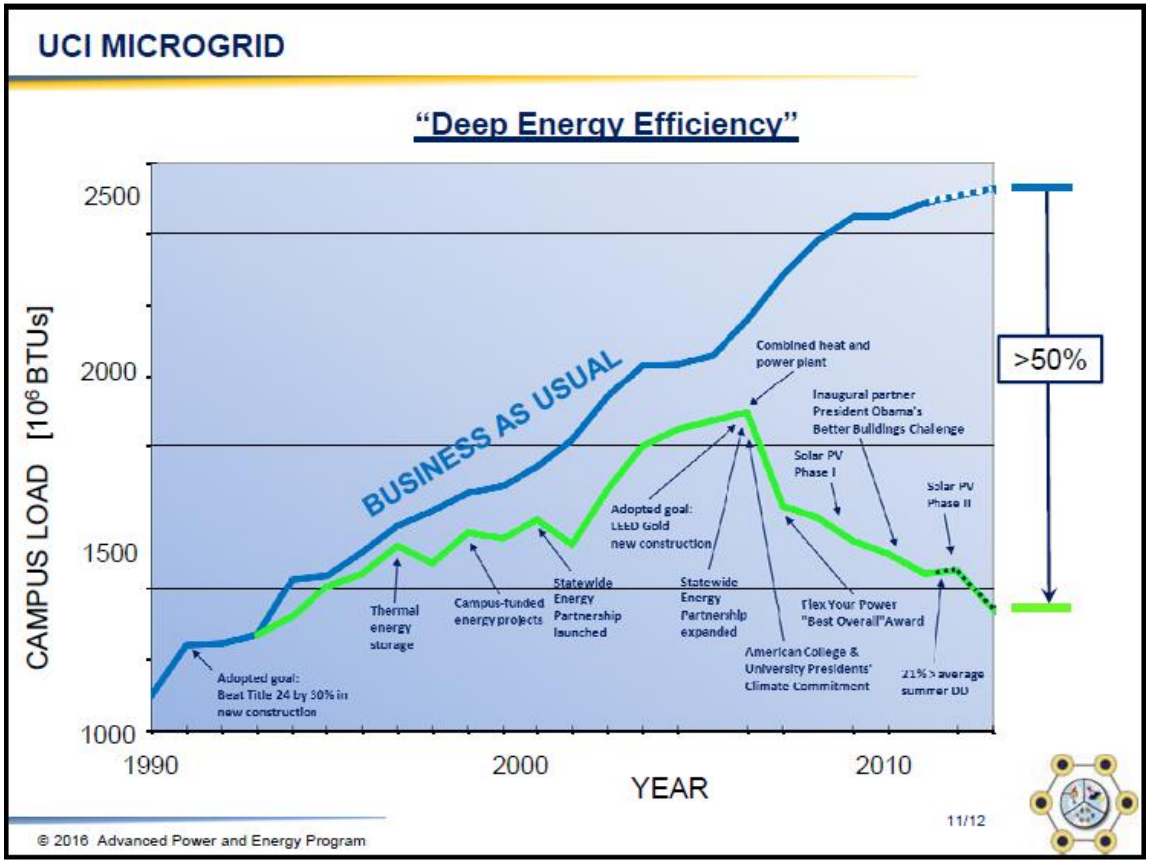
Future is Zero Net Energy

Office parks, shopping malls, hospitals, universities, whole cities

Source: NREL

Micro-grids allow deep cuts

University of California, Irvine



SOLARIMPULSE ACROSS AMERICA

Recap

- Energy transformation is happening
- Faster than at any time in history
- Hard to predict the future

2. Why difficult to predict?

- Hopefully you know why
  - Disruption, discontinuity, surprise

Tesla Car

Google

Face of disruption

Will Tesla's Powerwall usher in prosumage?

Source: The Wall Street Journal 2 May 2015

3. Time horizons

- Pipeline analogy
  - Already in pipeline: 1-5 years
  - Which pipeline? 5-10 years
  - Pipeline not built Beyond 10 years

1-5 years: Already in pipeline

- 2016 Uber testing driverless car
- 2016 Tesla's Gigafactory
  50% drop in storage cost
- 2017 Tesla's Model S: $35,000 EV
- 2017 Tesla/SolarCity/Powerwall
  Integration of EV/PV/Storage
- 2020 CA's climate target, ZNE, RPS
- 2021 Ford's "driverless" car

5-10 years: Which pipeline

- 20xx? End of new car ownership
- 20xx? Decline of gasoline age
- 20xx? “Free” electrons
- 20xx? Rise of “Millenials”
- 20xx? LEDs, BIPVs, Microgrids
- 20xx? Transactive energy, P2P trading
- 20xx? VPPs, variable demand

10+ years: Pipeline not built

- 2030 CA, NY hit 50% RPS
- 2030+ COP21 begins to bite
- 2030+ Fossil fuel divestment: Ditto
- 2030+ New business models
- 2030+ Transactive grid
- 2030+ Network access charge
- 2030+ Dawn of “prosumagers”
- 2030+ Digitization of power

4. Different approaches

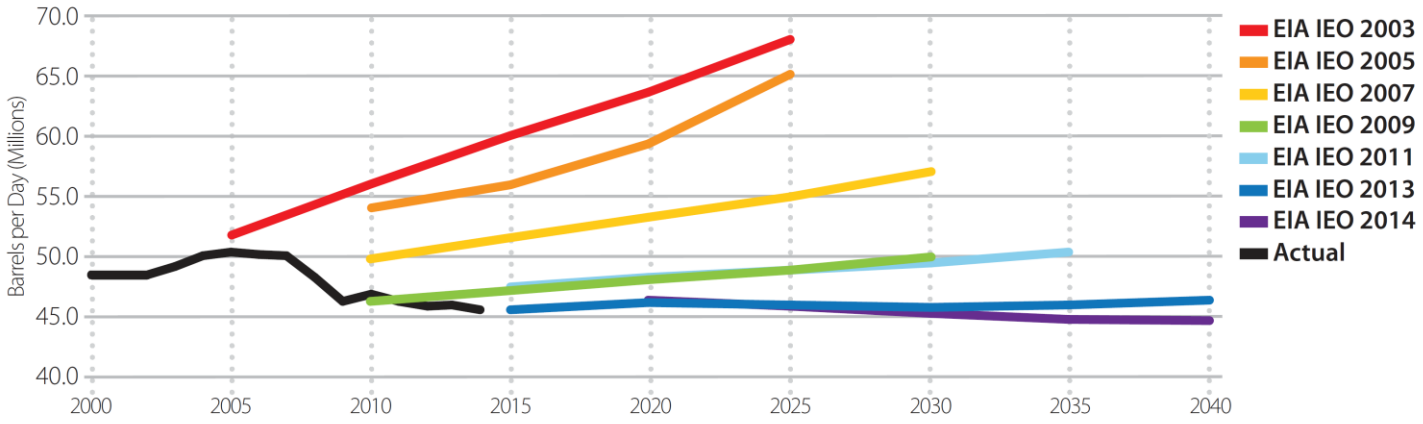
- Extrapolating the past
  - Not good when future is different than the past or discontinuity
- Following trends/indicators
  - But which trends or indicators to follow?
- Following “gurus”
  - But which guru?
- Scenarios
  - But how many & which?
- Delphi method
  - But who do you ask, how do you add?

Extrapolating the past

- Not particularly useful
- Historic trends don’t apply
- Technology/costs radically change
- Carbon constraints

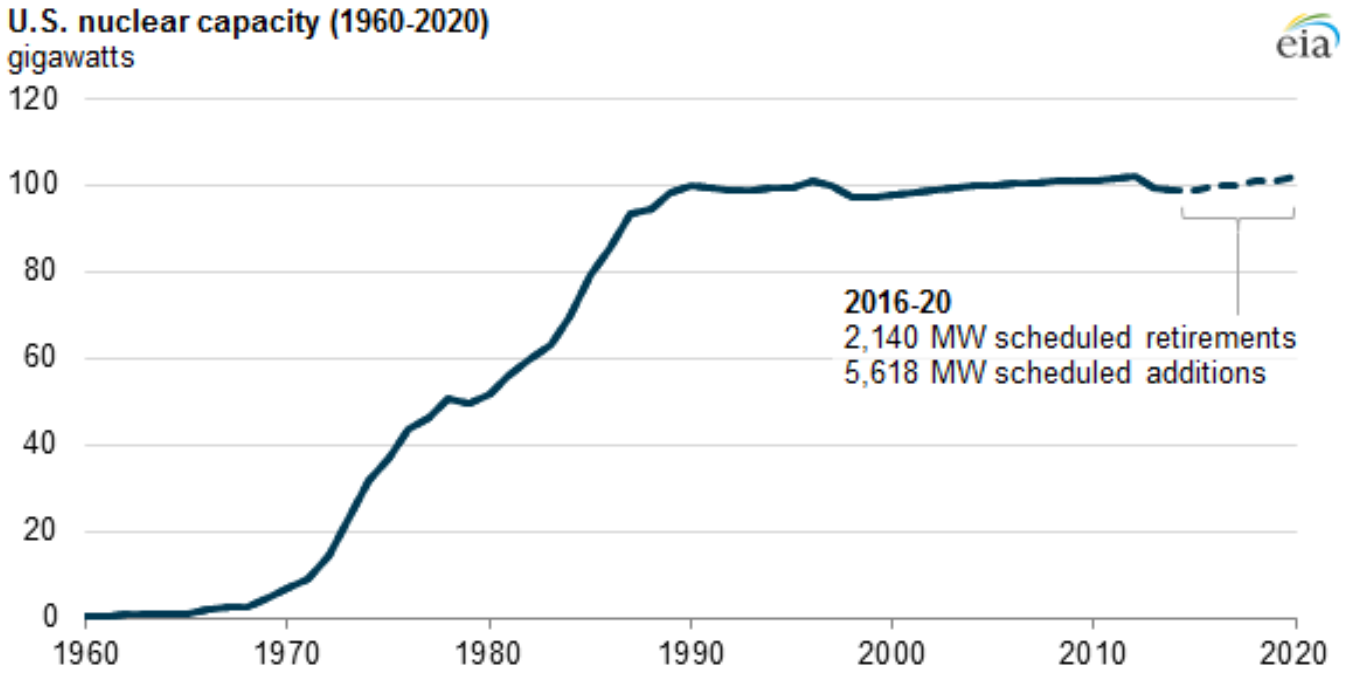
Historic trends don’t apply

Peak oil is real & already here



Source: Unconventional Risks, As you sow, 13 Jul 2016

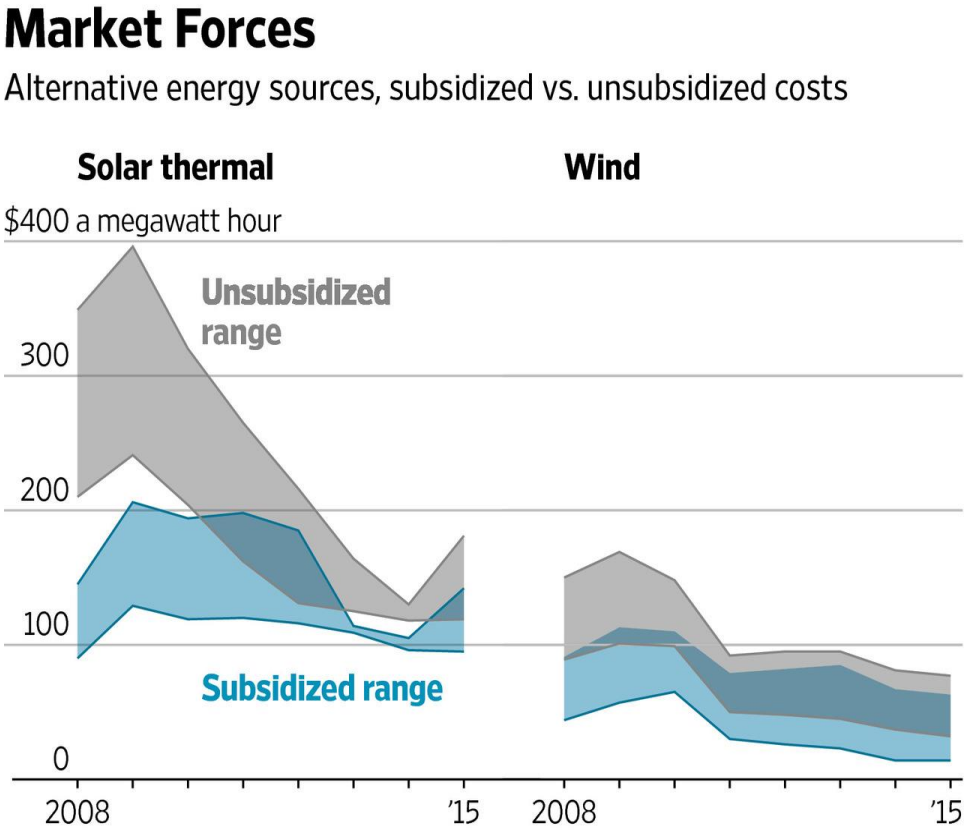
Historic trends don't apply US nuclear plateau



Source: Energy Information Administration, Monthly Energy Review

Historic trends don't apply

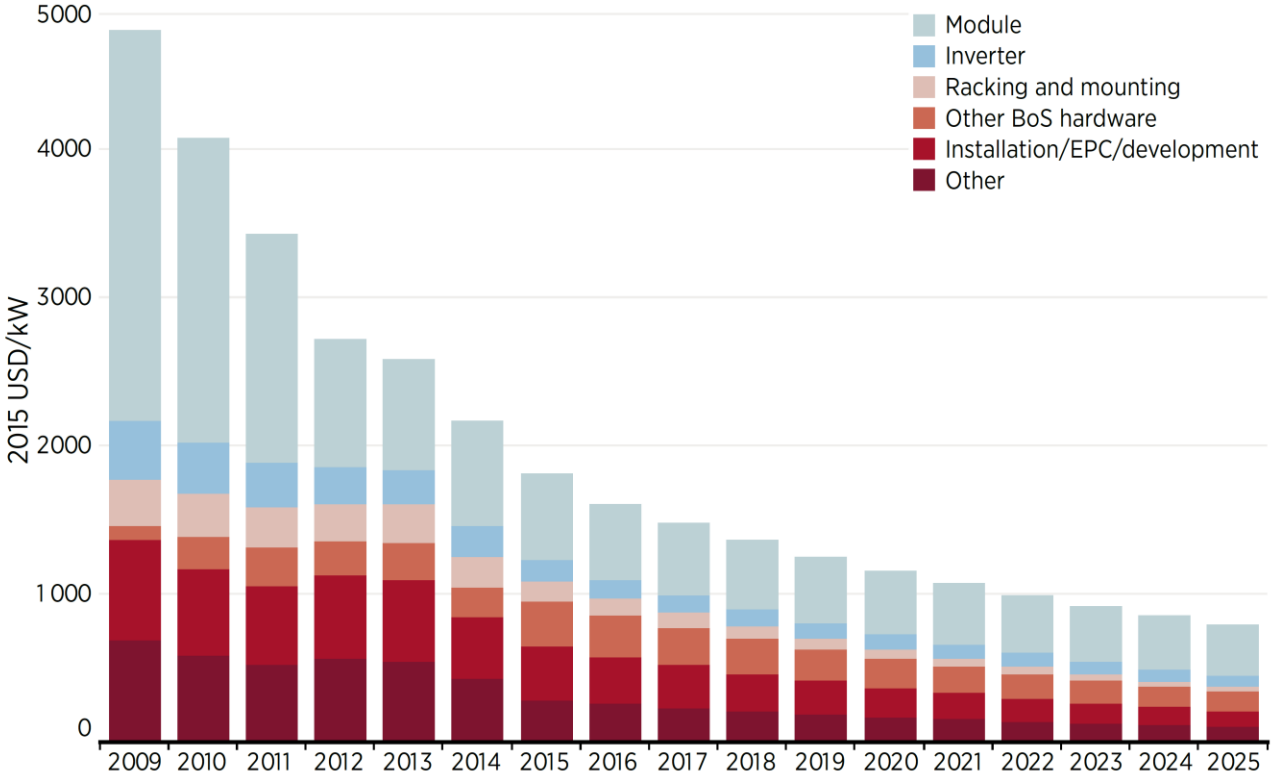
Solar & wind competitive



Source: Which State Is a Big Renewable Energy Pioneer? The Wall Street Journal 29 Aug 2016

Historic trends don’t apply

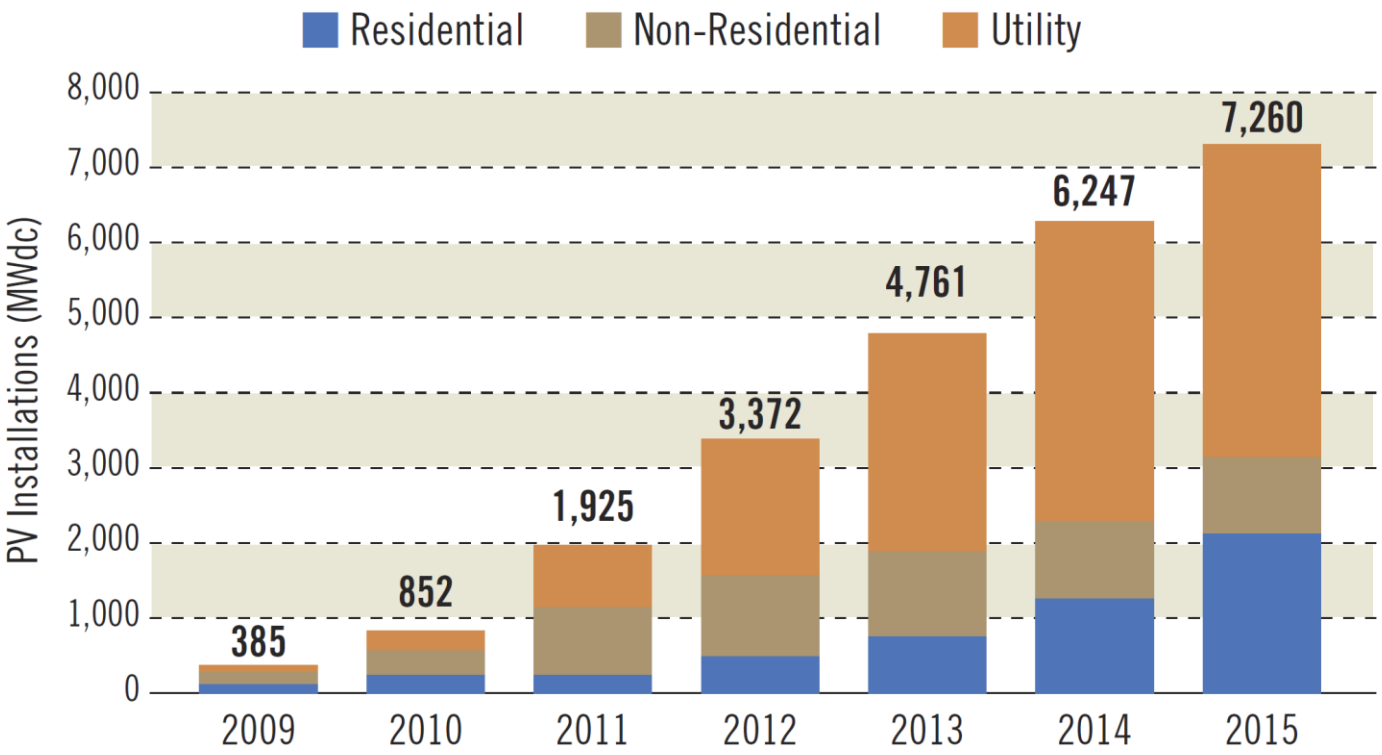
Solar costs falling



Source: The Power to Change: Solar and Wind Cost Reduction Potential to 2025, IRENA

Historic trends don't apply

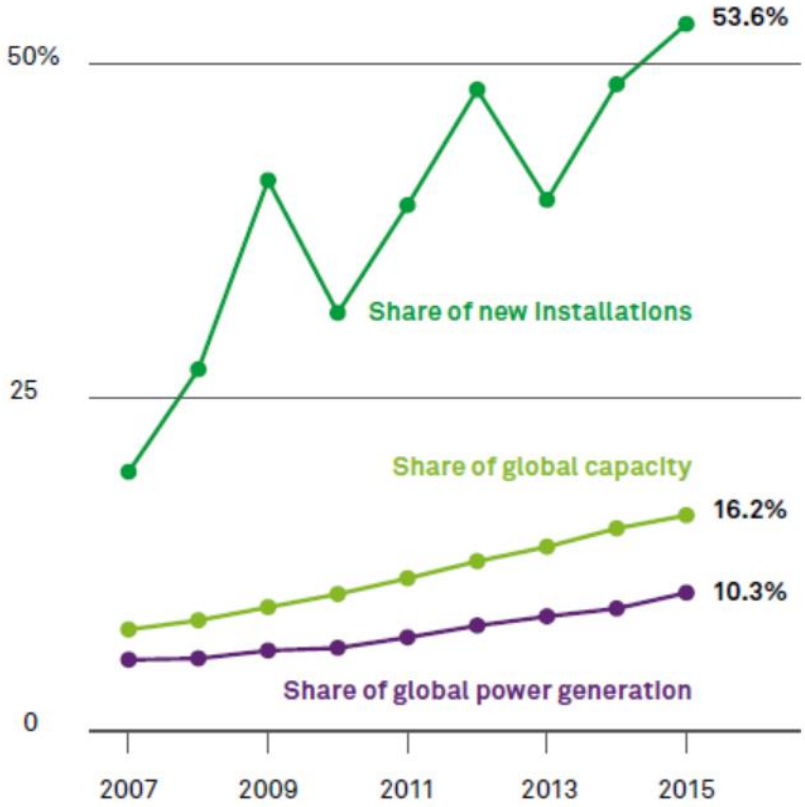
PVs installations grow



Source: Benchmarking Utility Clean Energy Deployment: 2016, Ceres, June 2016

Historic trends don't apply

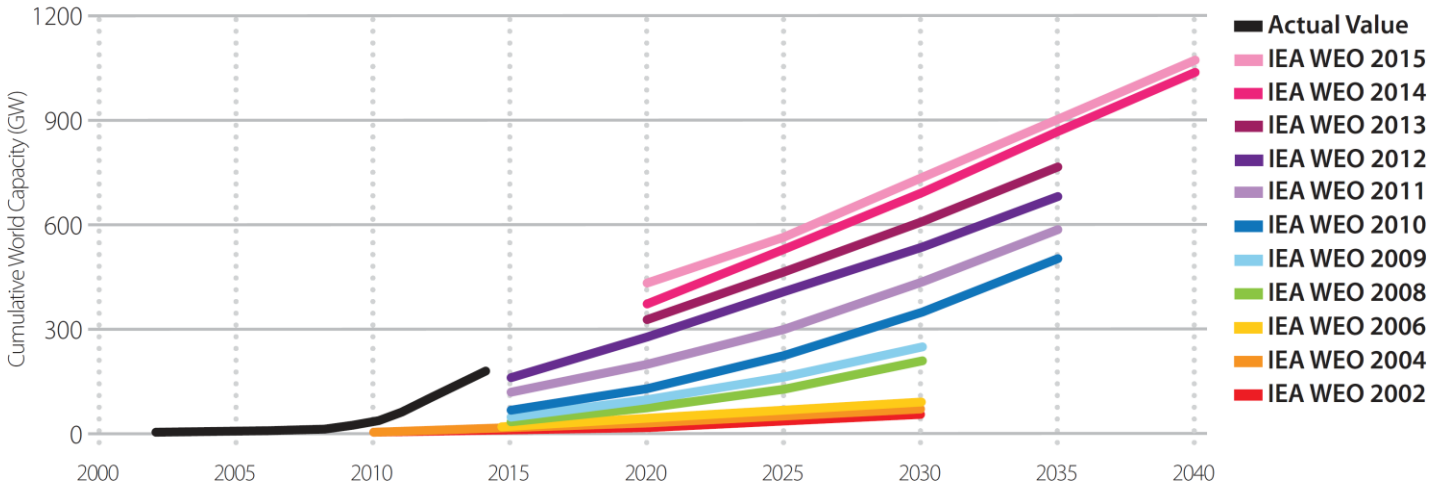
Renewable investments rising



Source: Adapting portfolios to climate change BlackRock., Sept 2016

Historic trends don't apply

Solar's growth chronically underestimated



Source: Unconventional Risks, As you sow, 13 Jul 2016

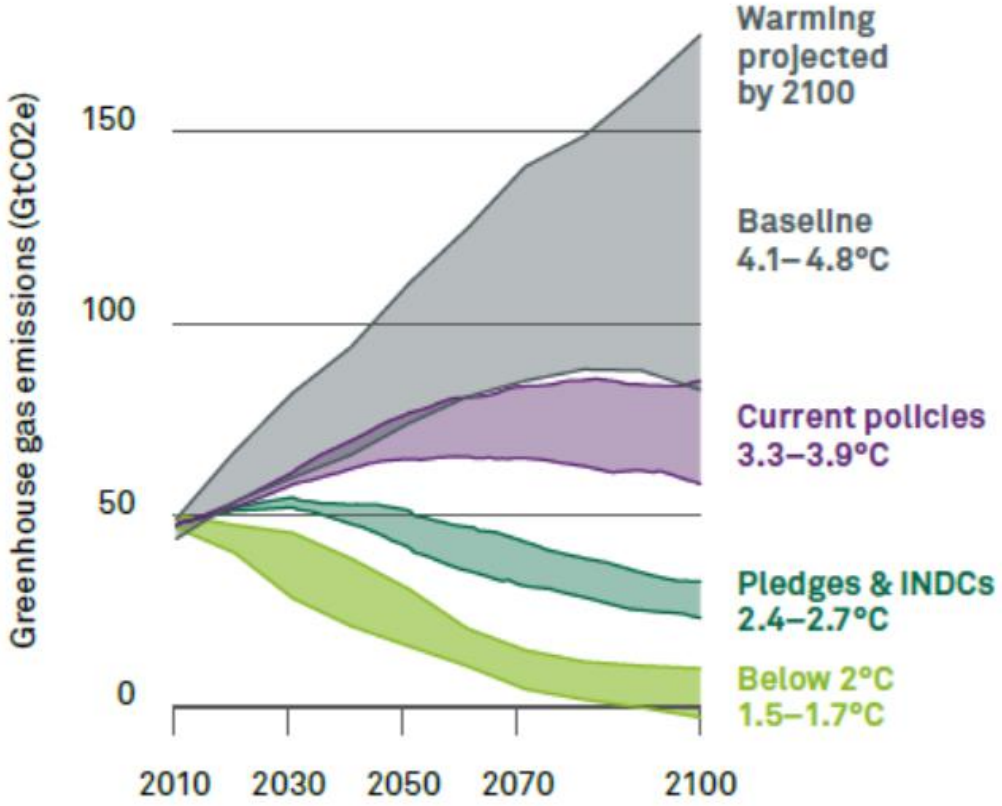
COP21

It is really happening!

Source: UN

Carbon diet

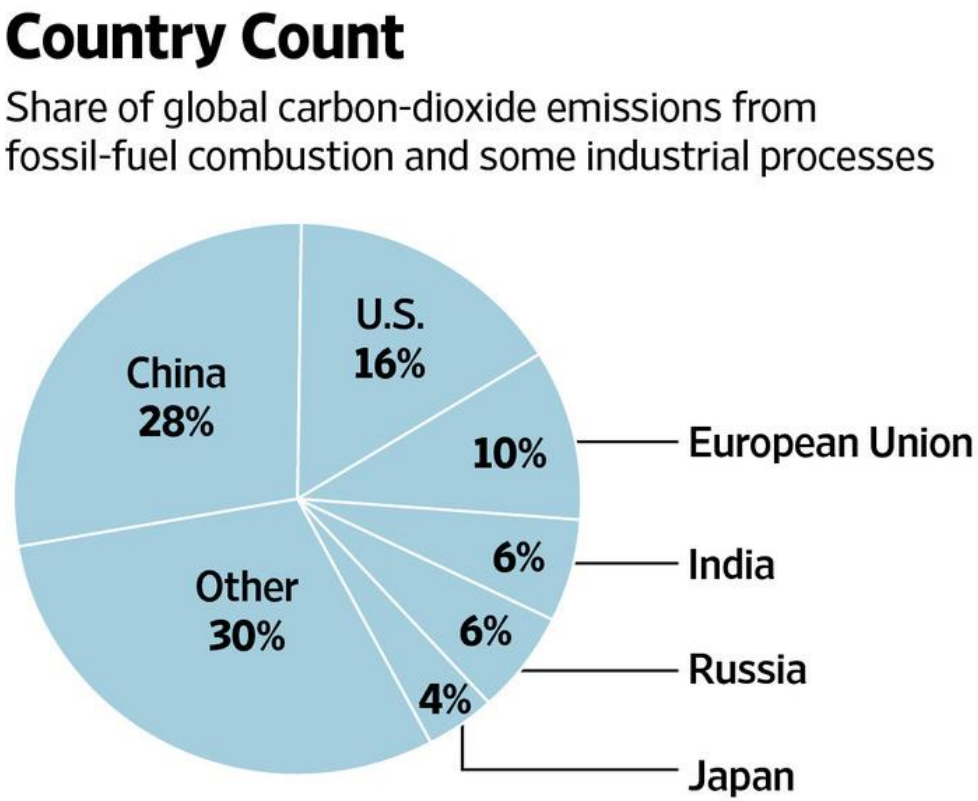
Stop the damage before it is too late



Source: Adapting portfolios to climate change, BlackRock, Sept 2016

Climate challenge

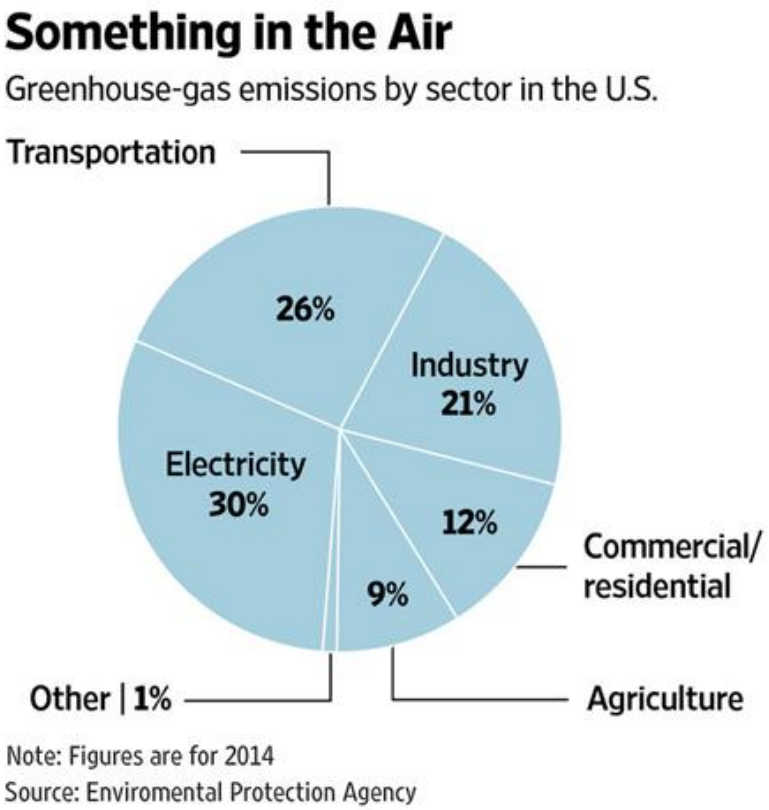
The more you emit, the more you have to cut



Source: The Wall Street Journal, 14 Sept 2016

US emission sources

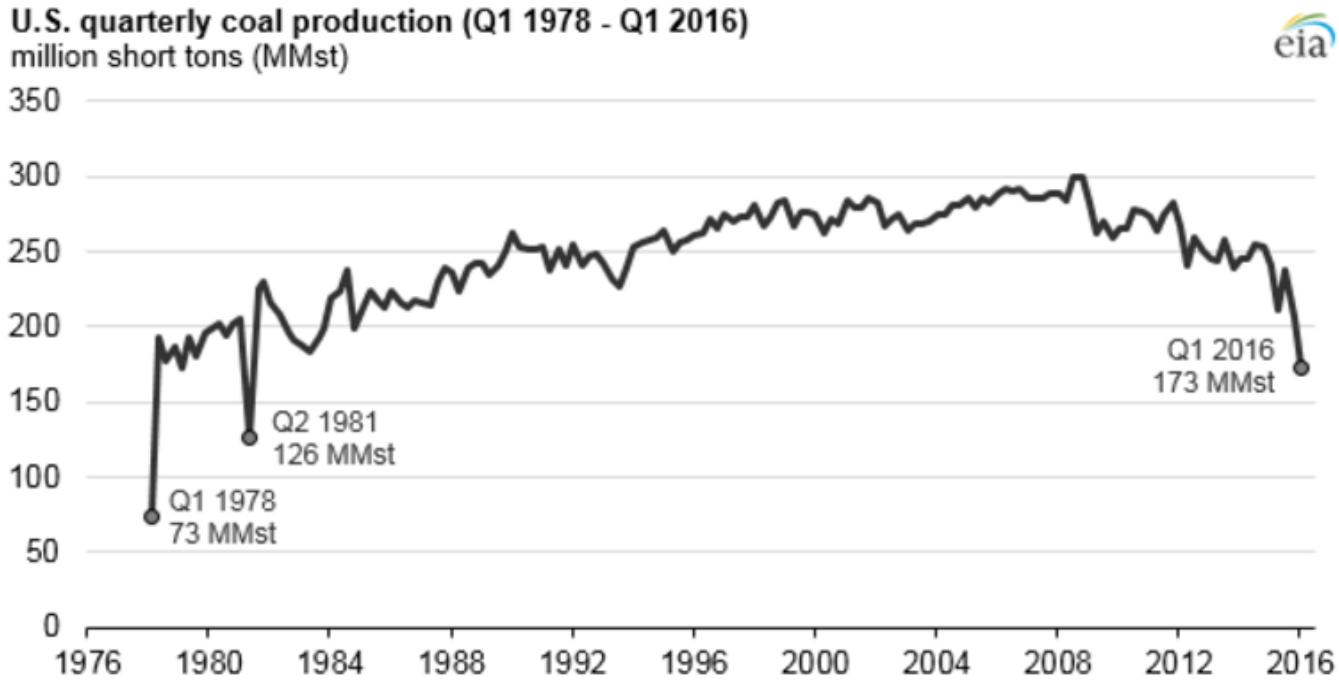
Transportation soon to surpass power sector emissions



Source: A Price on Carbon May Be Coming Soon to the U.S., Amy Jaffe in 14 Sept 2016 issue of The Wall Street Journal

Historic trends don’t apply

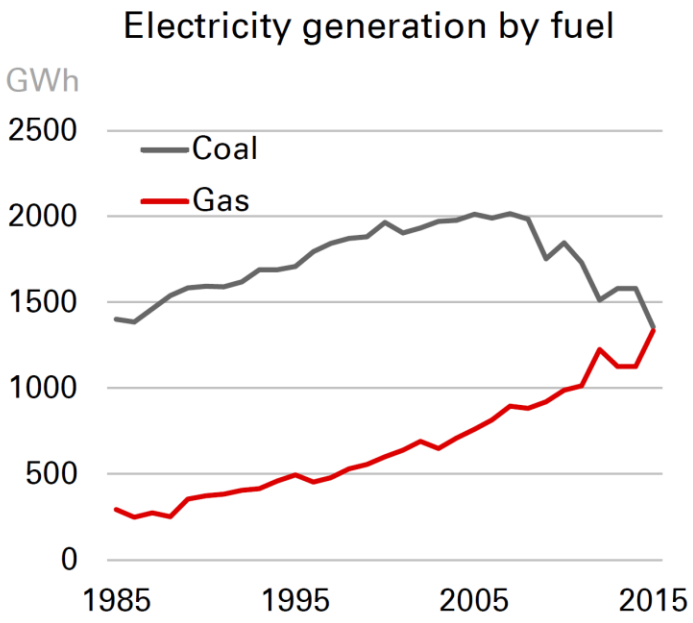
Coal is history

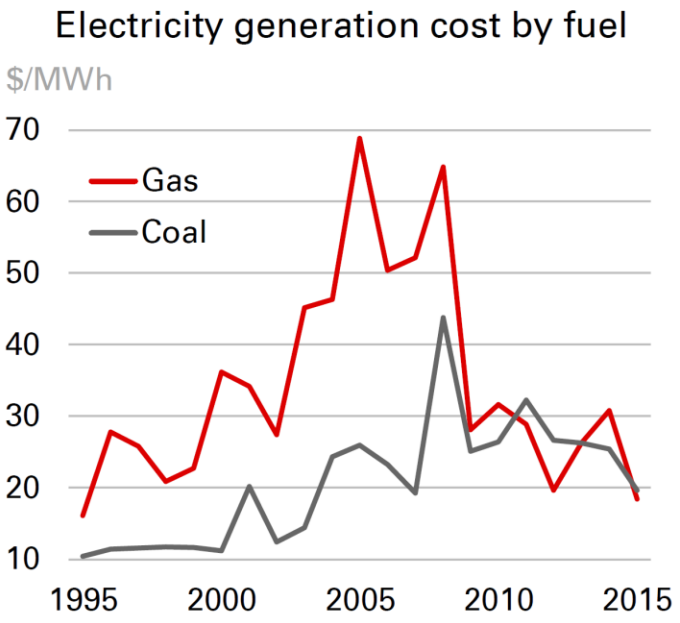


Source: King Coal is dethroned in the US and that is good news for the environment, David Lukas, Blog posted on 22 Aug 2016

Historic trends don't apply

Natural gas displacing US coal

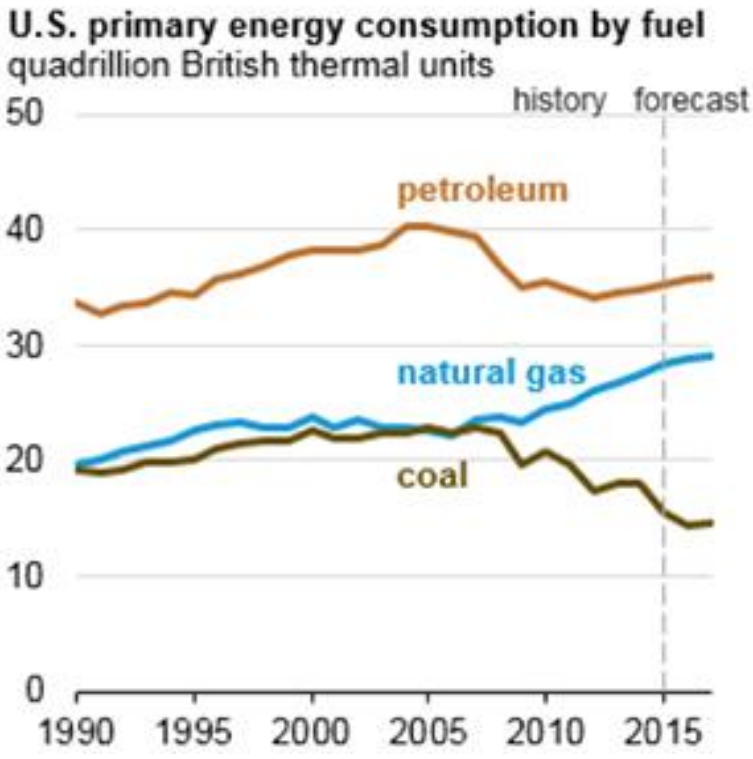


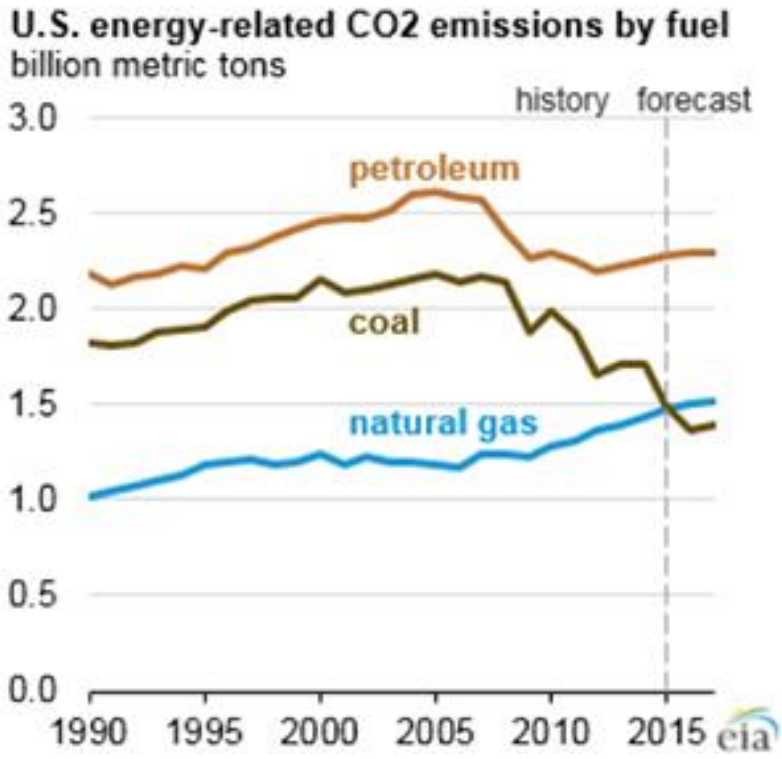


Source: Spencer Dale, Energy in 2015: A year of plenty, BP, 8 June 2016 and BP's Statistical Review of World Energy 2016 edition, BP June 2016

Historic trends don't apply

US natural gas emissions exceed coal





Source: EIA

Tesla’s mega factory

Recently completed in Reno. NV

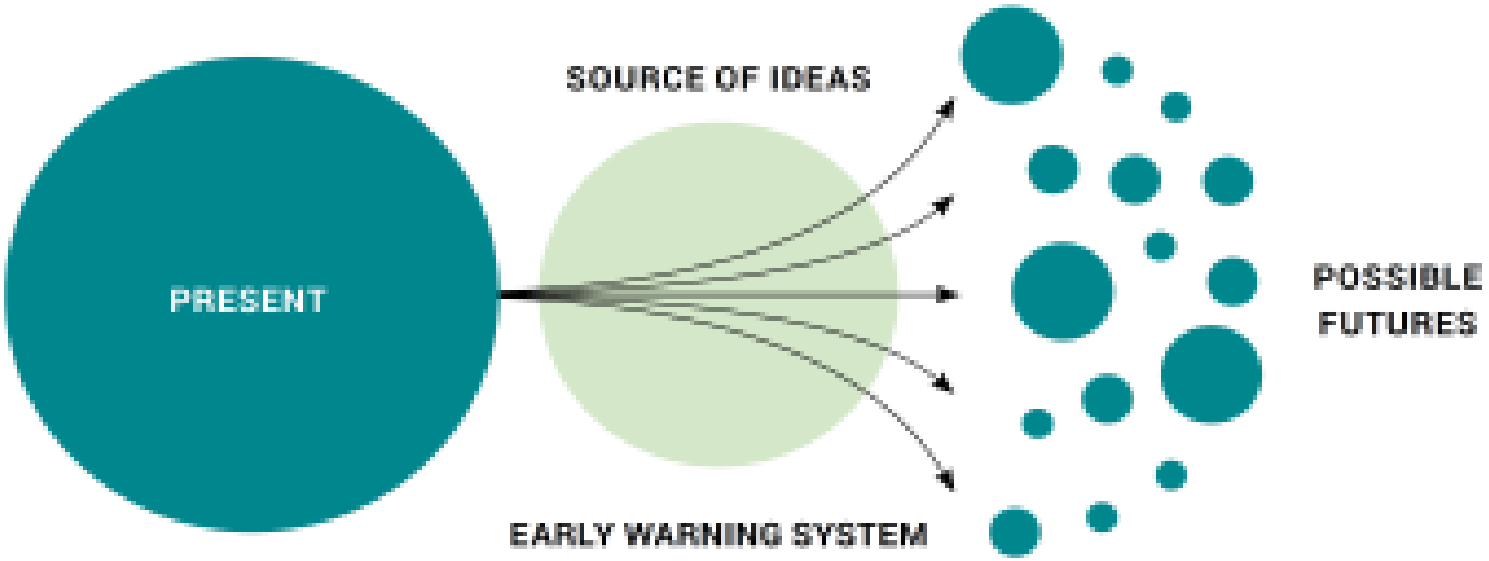
Tesla Gigafactory under construction, by Bob Tregilus (CC BY-NC-SA 4.0)

GIZ Delphi study

- Delphi energy future study 2040
- BDEW, GIZ & PwC
- Published July 2016
- 350 global experts participated
- Results were aggregated

Ask the gurus

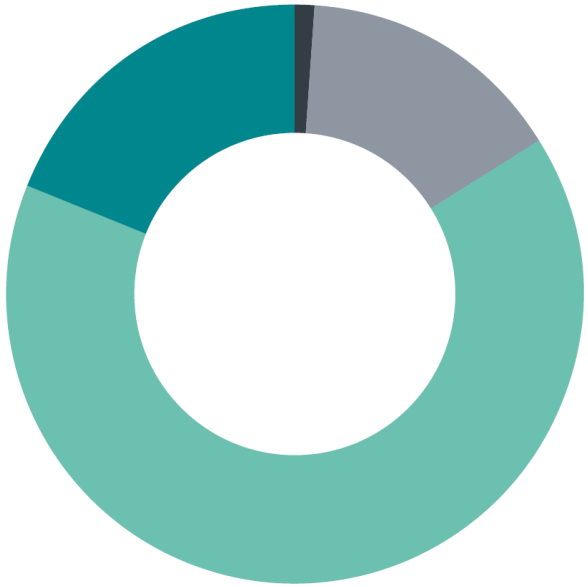
Delphi technique



Source: Delphi energy future study 2040, BDEW, GIZ and PwC, July 2016

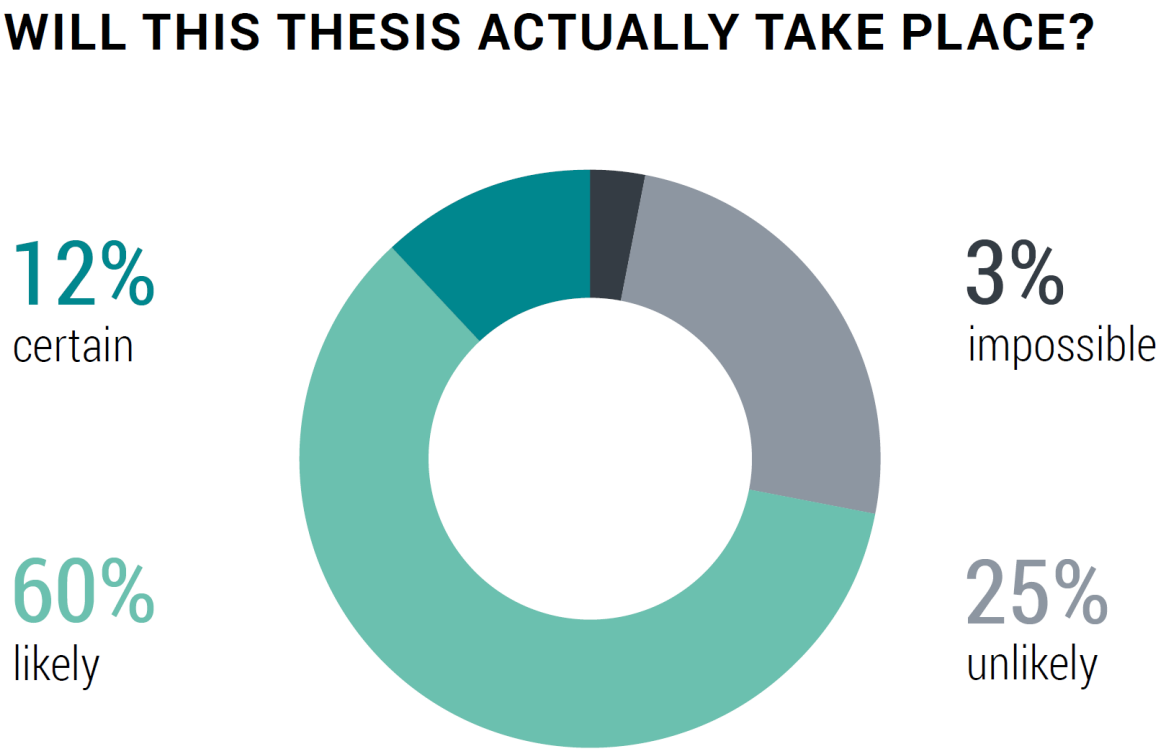
Binding global CO2 regime

WILL THIS THESIS ACTUALLY TAKE PLACE?



Source: Delphi energy future study 2040, BDEW, GIZ and PwC, July 2016

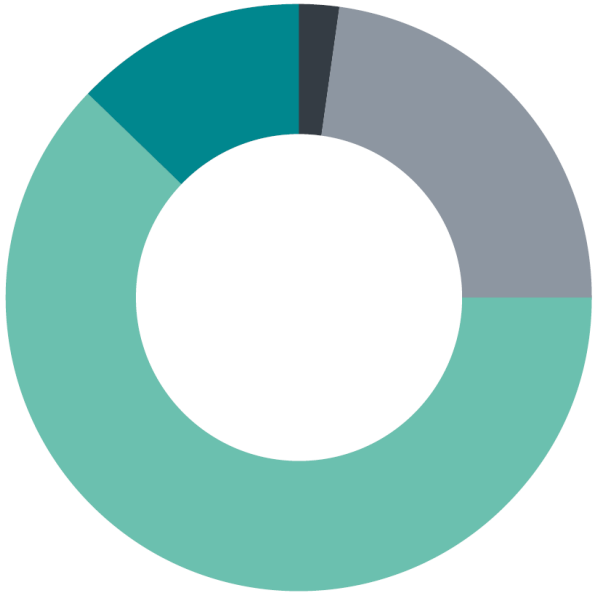
Distributed, renewable, storage



Source: Delphi energy future study 2040, BDEW, GIZ and PwC, July 2016

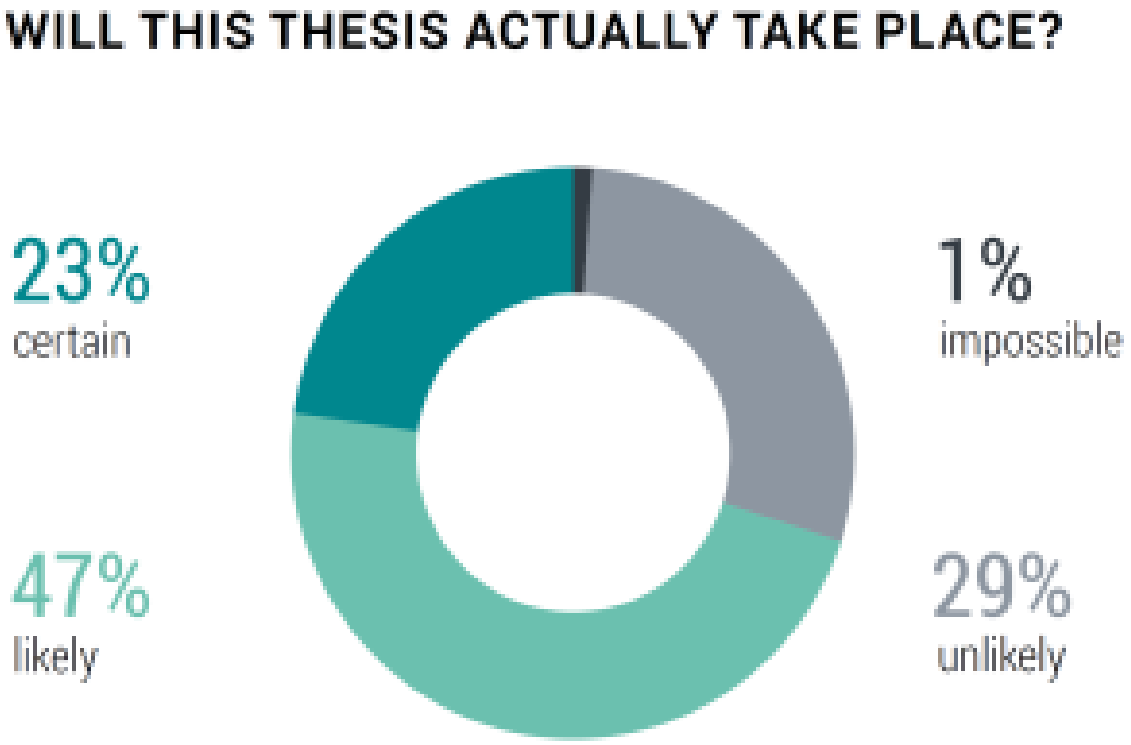
Electric transportation from renewable sources

WILL THIS THESIS ACTUALLY TAKE PLACE?



Source: Delphi energy future study 2040, BDEW, GIZ and PwC, July 2016

“Free” electricity



Flat network fees

WILL THIS THESIS ACTUALLY TAKE PLACE?

Source: Delphi energy future study 2040, BDEW, GIZ and PwC, July 2016

Delphi approach

Pros & cons

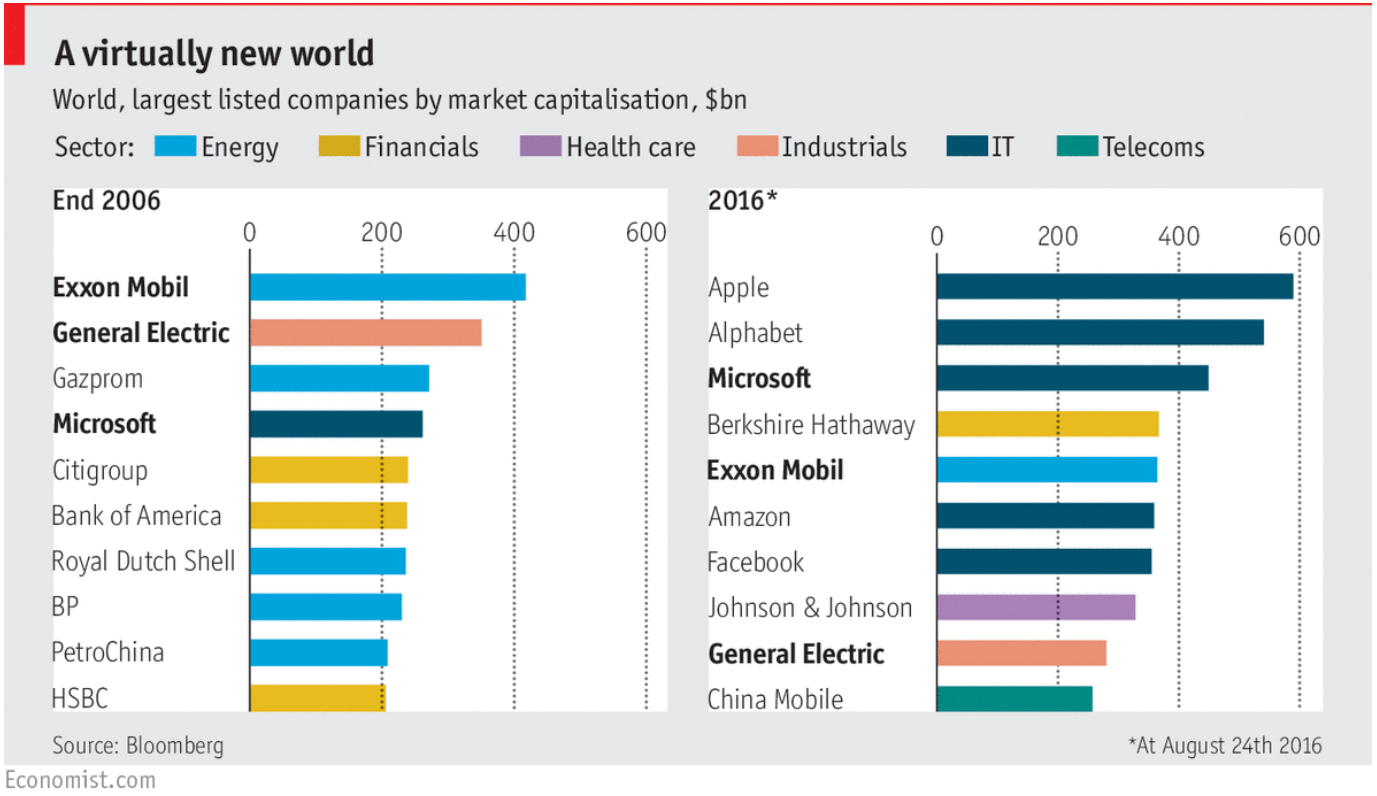
- Pros
  - Better than asking a single “guru”
  - Diversity of perspectives
  - Geographical/technical diversity
  - Outliers marginalized
- Cons
  - Not all “gurus” equally good/competent
  - An expert’s view may be can cancelled by a non-expert
  - Outliers may be the ones to focus on rather than eliminate

5. Drivers of change?

- Millenials: An entirely different species
- Shared economy, virtual enterprise
- Digitization & “third wave”
- Rise of renewables
  - Free electrons
- Re-inventing mobility
  - No driver, no wheel, no brake or gas pedal and no gas!
- COP21: Paris agreement is ratified
  - Phase out of fossil fuels & “ethical” investing

A Virtual New World

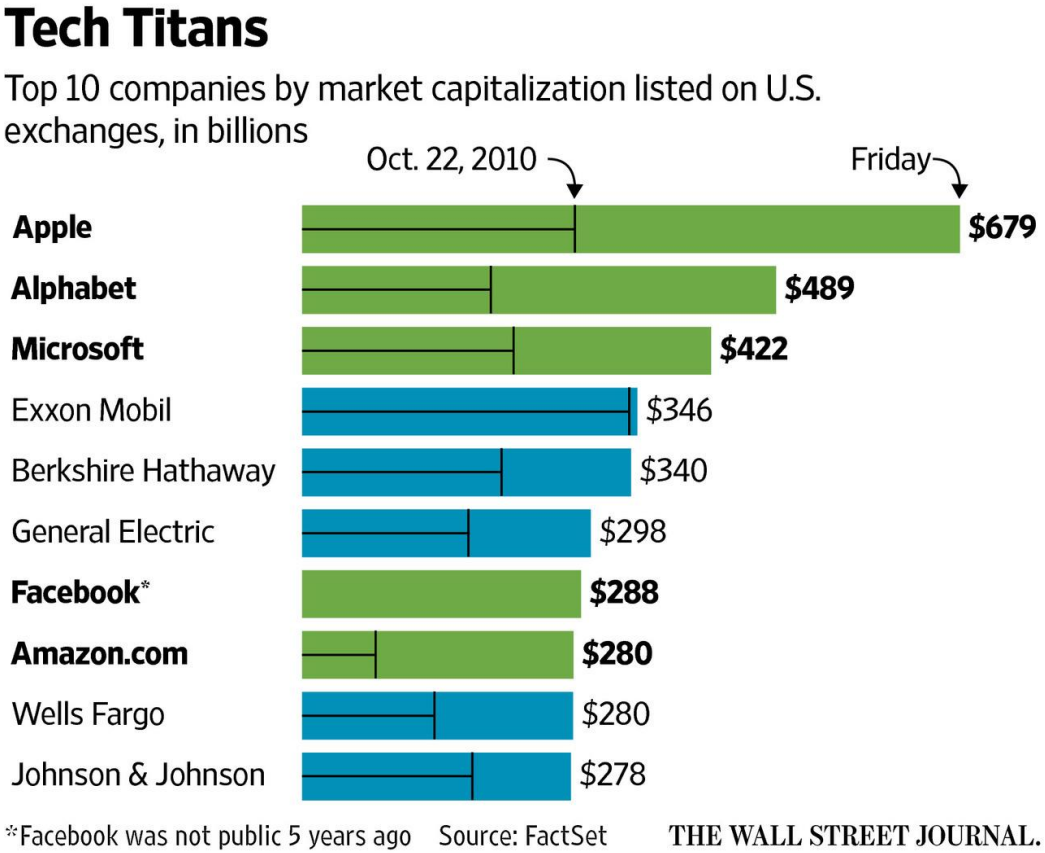
Virtual enterprise on the rise



Source: The Economist, 17 Sept 2016

America's top 10

Half are "virtual" & growing



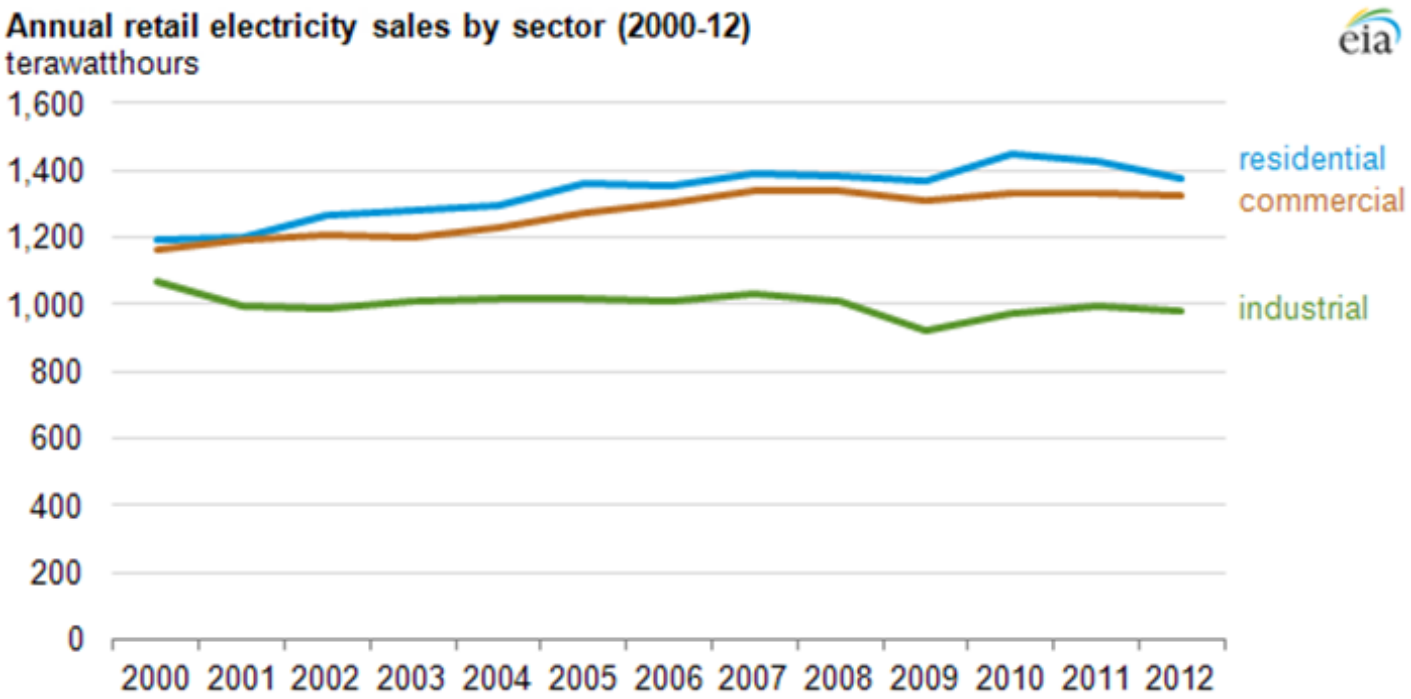
6. Power sector mega trends

Happening within OECD; Colombia next?

- End of demand growth
- Consumer => prosumer
- Prosumer + storage => “prosumage”

First

Forget demand growth



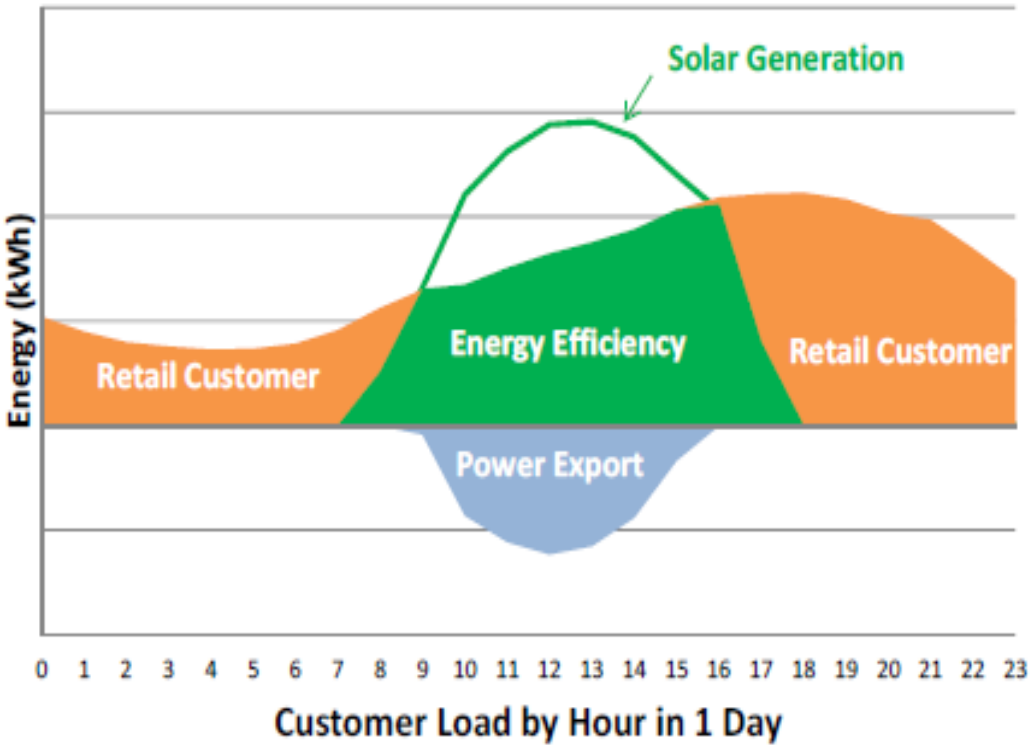
Source: Americans are buying less electricity. That's a big problem for utilities Brad Plumer, The Washington Post, 23 Dec 2013 based on data from EIA

NY's experience typical

Period	Avg. sales growth for period
1966-76	3.8%
1976-86	1.5%
1986-96	1.4%
1996-2006	0.9%
2003-2013	0.3%
2014-2024	0.16%

Source: NY Pub Service Commission, 26 Feb 2015

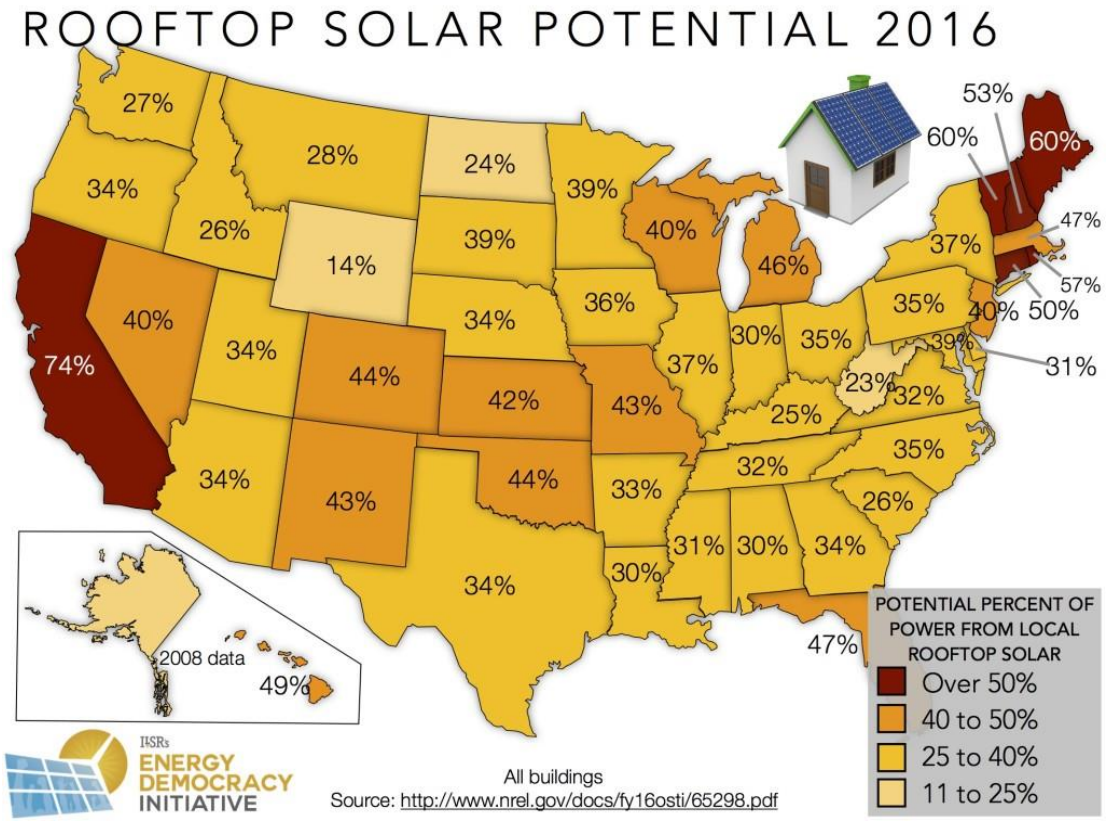
Second
Consumers => Prosumers



Source: Evaluating the benefits and costs of NEM laws in California, prepared for Vote Solar, Jan 2013

Solar rooftop energy

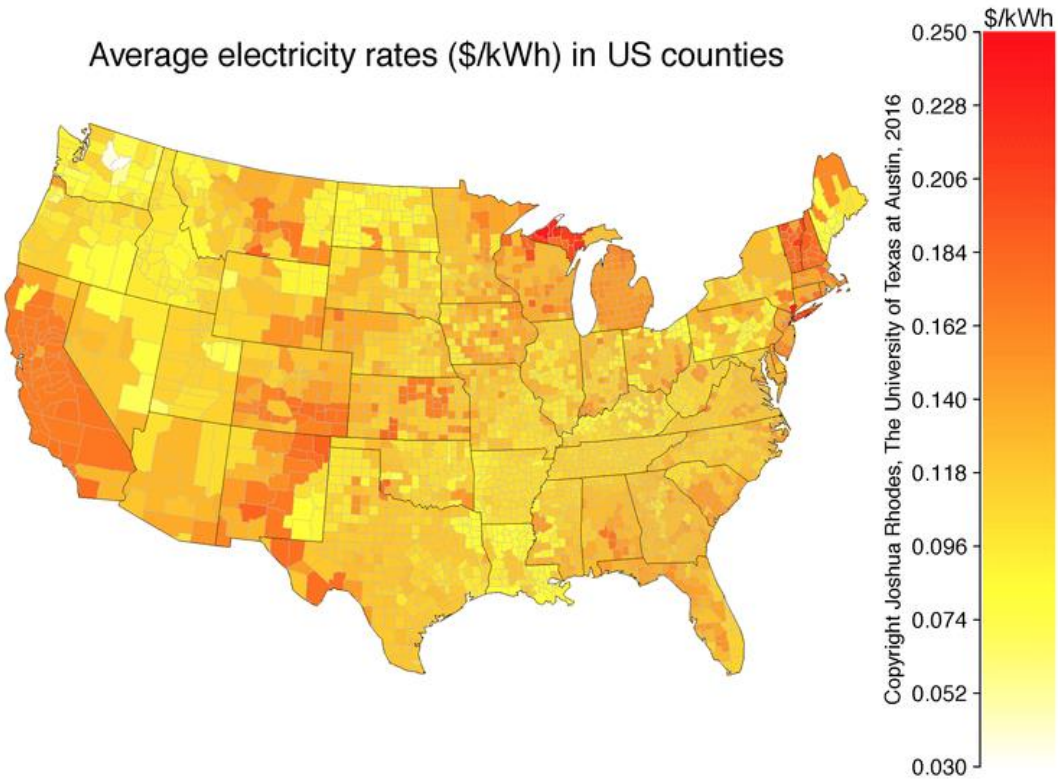
In many states rooftop solar can provide 40% of electricity



Source: John Farrell, Institute for Local Self-Reliance

High tariffs => self generation

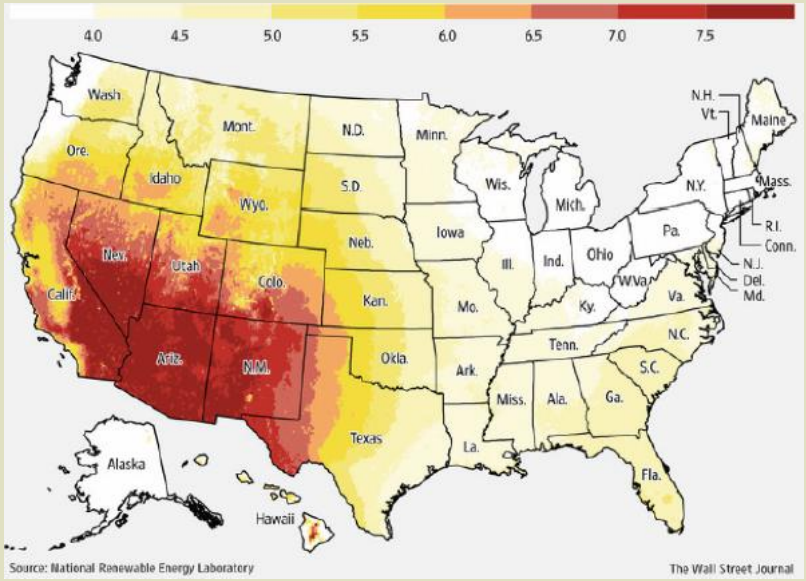
Rise of prosumers

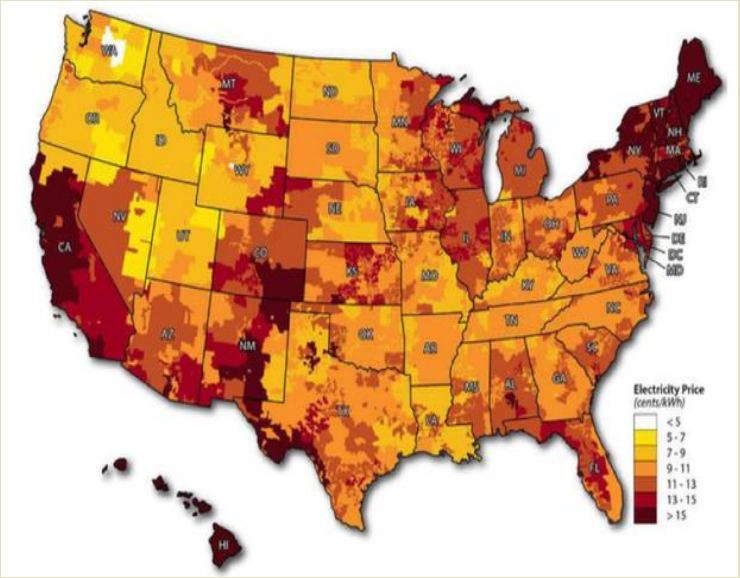


Map of average electricity rates across the U.S. EIA.

Solar insolation + retail price

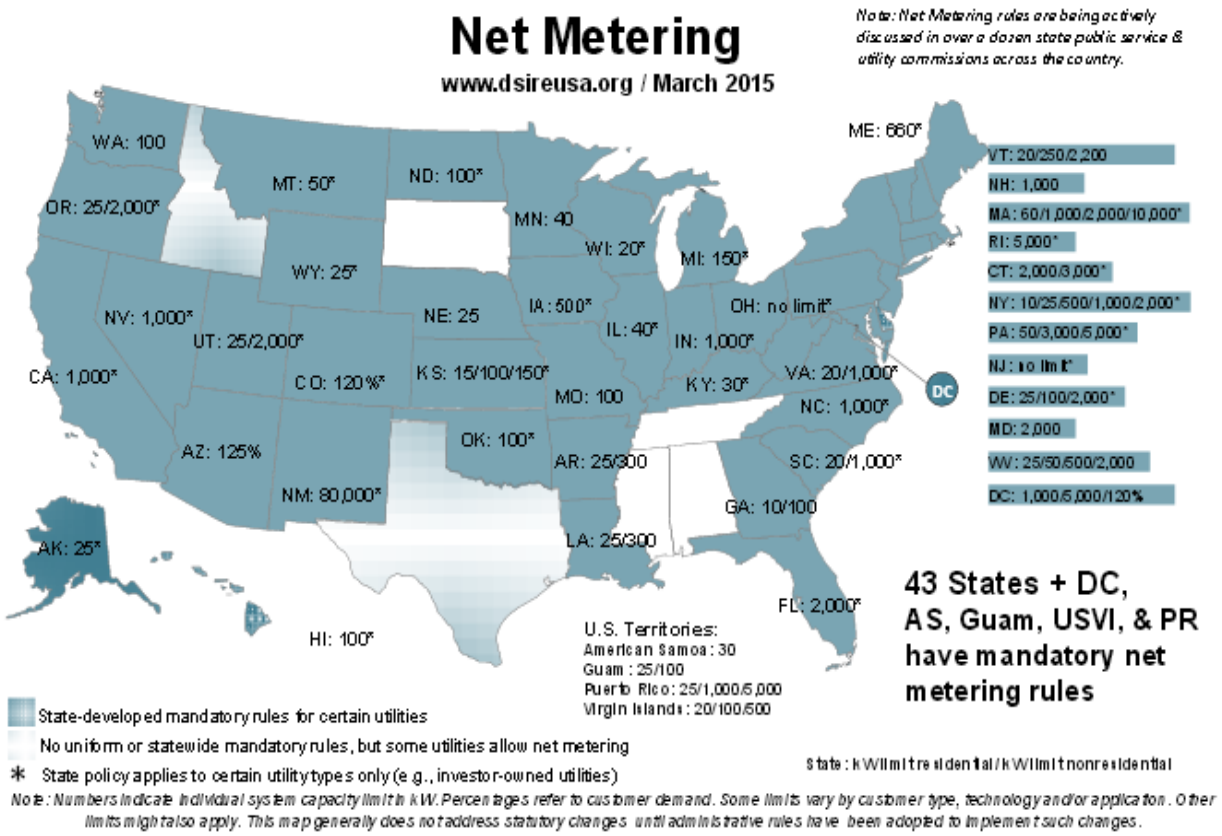
Solar insolation, kWh/sq. m. (left); retail prices, c/kWh (right)





Net Energy Metering (NEM)

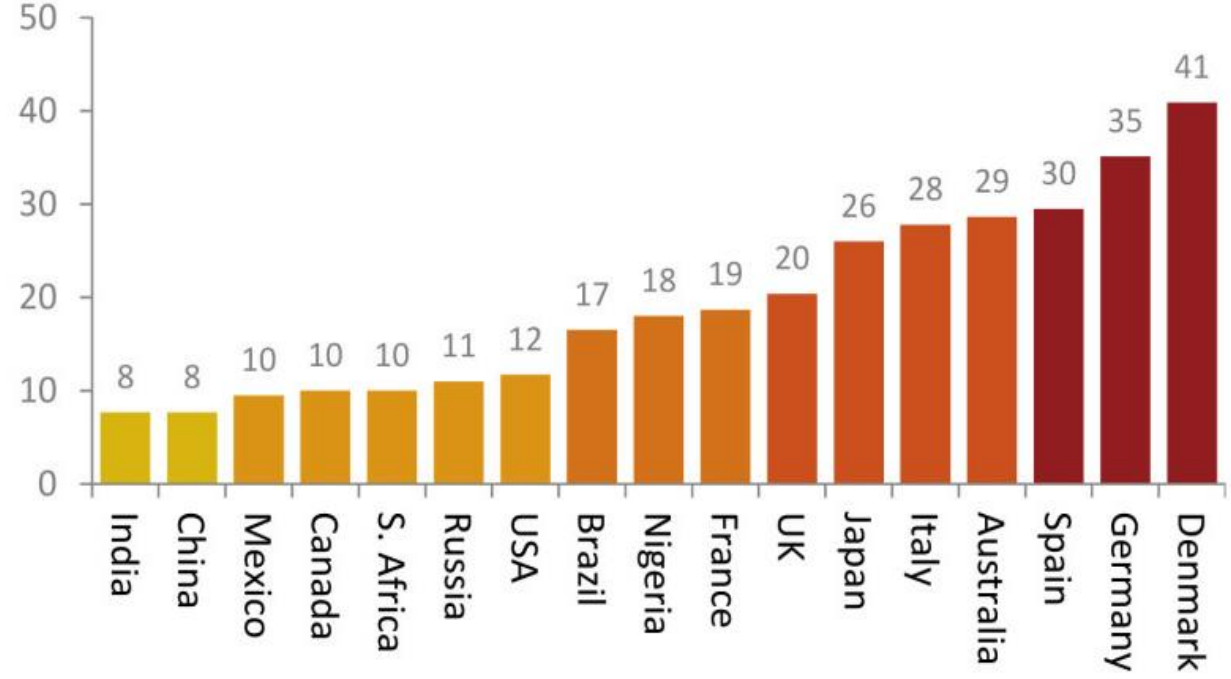
Current net energy metering schemes, subject to change w/o notice



Source: Database of State Incentives for Renewables & Efficiency (DSIRE)

Who will buy from the grid?

High retail tariffs are driving distributed generation revolution

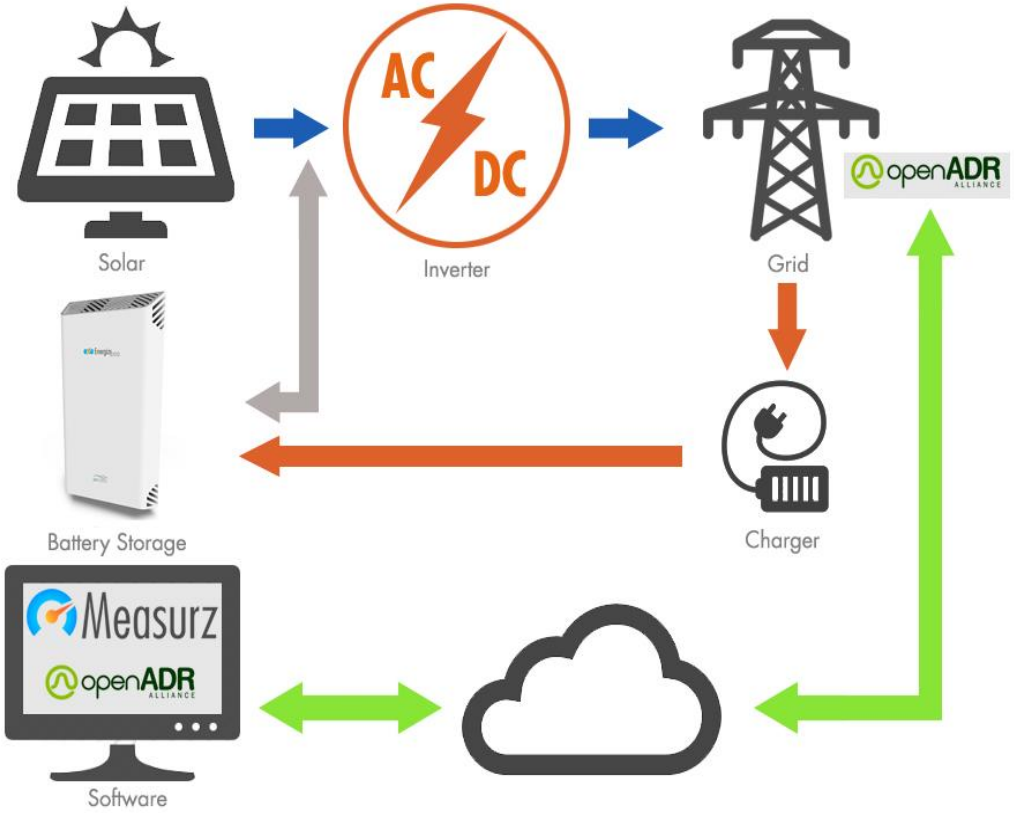


Data: average prices from 2011 converted at mean exchange rate for that year

Source: ESAA based on data from IEA, EIA, etc.

Third

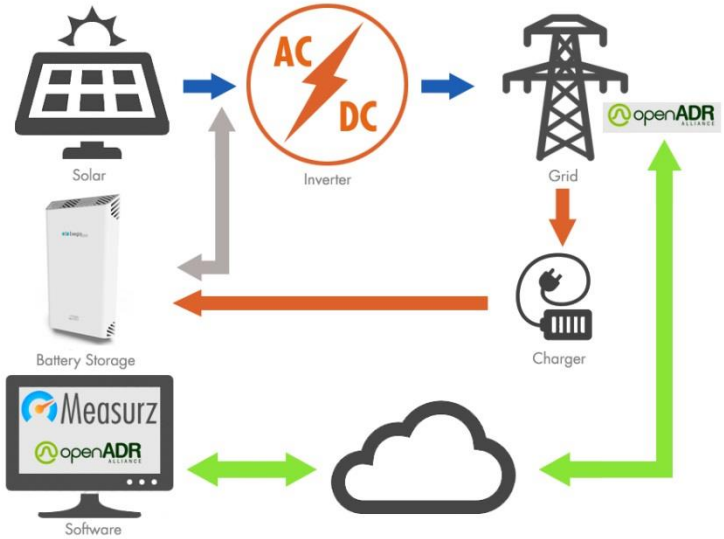
Add storage, energy management & control in the cloud!

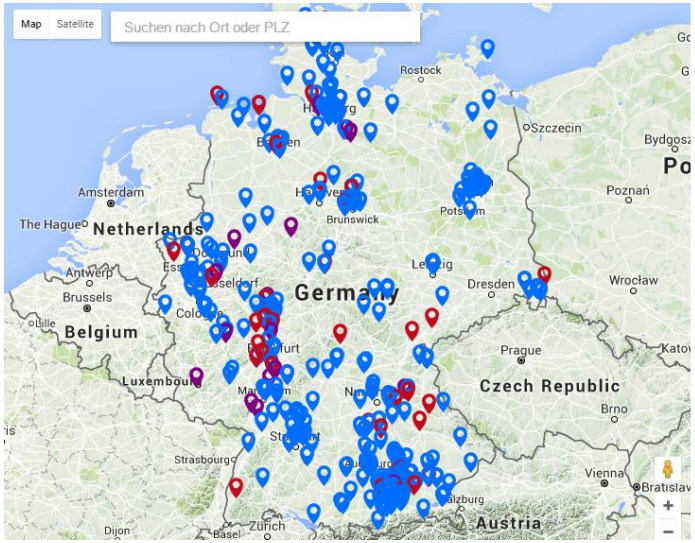


Source: JLM Energy

Transactive energy/P2P trading

The next eBay?



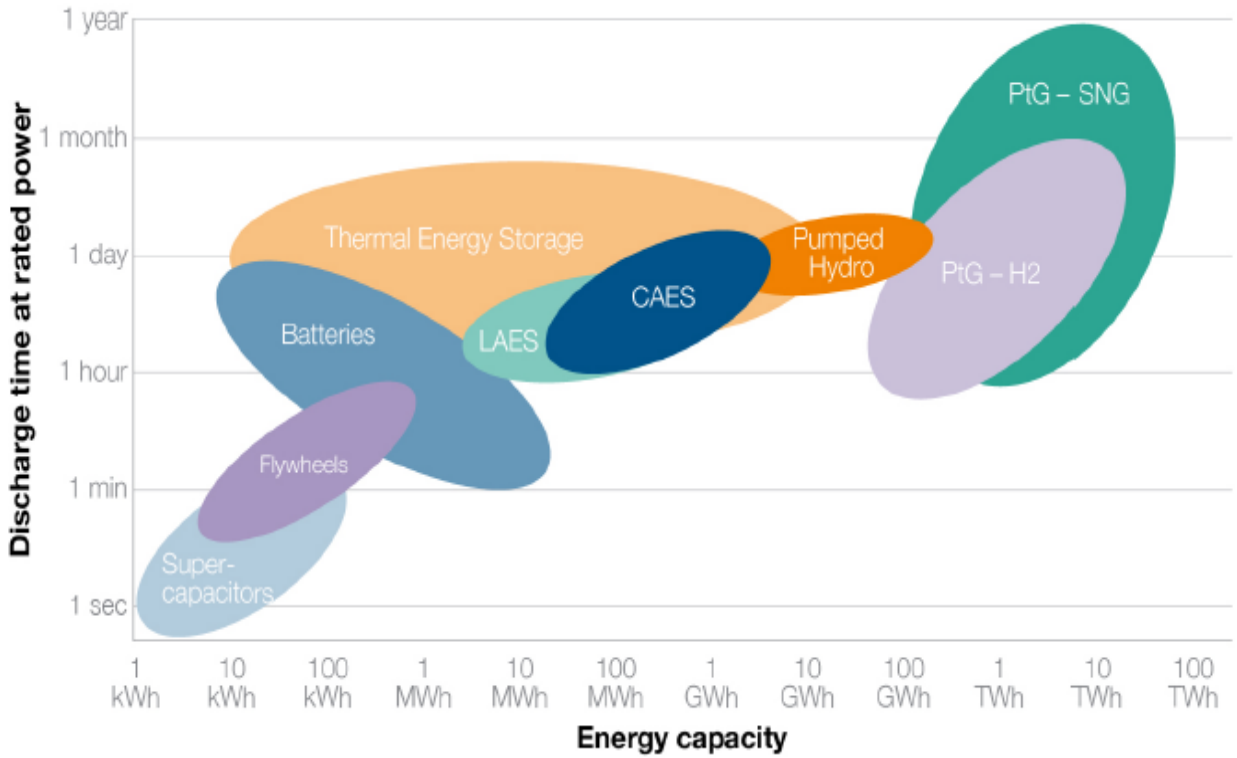


7. Technological innovation & disruption

- Topic of next book
- No longer <u>if</u>, but when/how/whom?
- Examples abound
- ***EEnergy Informer,*** Aug 2016
  - Who will disrupt utility monopolies?
  - What next? Apple Energy
  - Tesla's complete picture
  - Watch out for virtual utilities, VPPs

Storage is more than batteries

From MWs & multiple MWhrs to kW & milliseconds



Source: World Energy Council, E-Storage: Shifting from cost to value, 2016

What to make of this?

- Think “prosumage”
- Assume disruption
- Rethink strategy

New electric company: Your home

Wall Street Journal 21 Jan 2015

Innovators/disrupters?

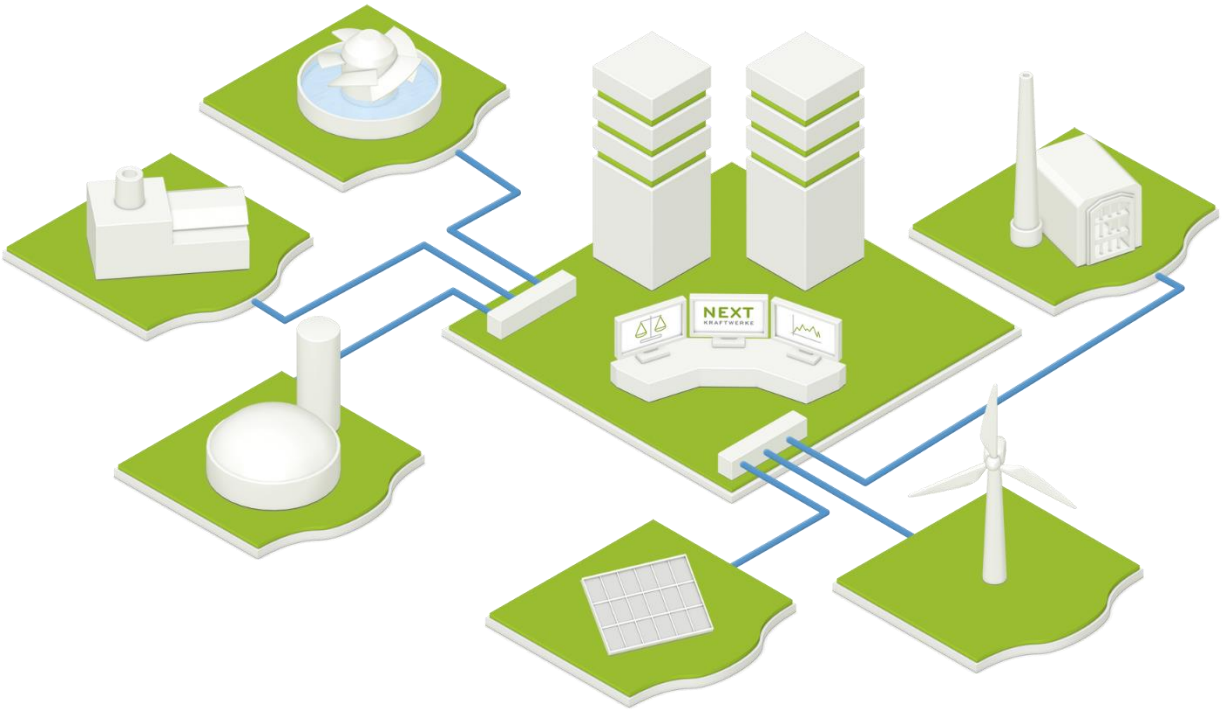
- Apple Energy
  - Renewable reseller
- Tesla/SolarCity/Powerwall
  - Integrator of electric mobility, distributed solar + storage
- ZNE Microgrids
  - Semi-autonomous power islands
- Flexible load/DG/storage aggregators
  - Offering flexible load/generation
- Shared, autonomous, electric mobility

What next?

- Utility as “service integrator”
  - Edison Energy focused on “energy as a service”
- Solar leasing: AGL Australia
- Battery leasing: Green Mountain Power
- EV charging infrastructure: California IOUs
- Demand Response: Next Kraftwerke
- Home Energy Management: Nest
- P2P trading among prosumers: Open Utility

Virtual utilities

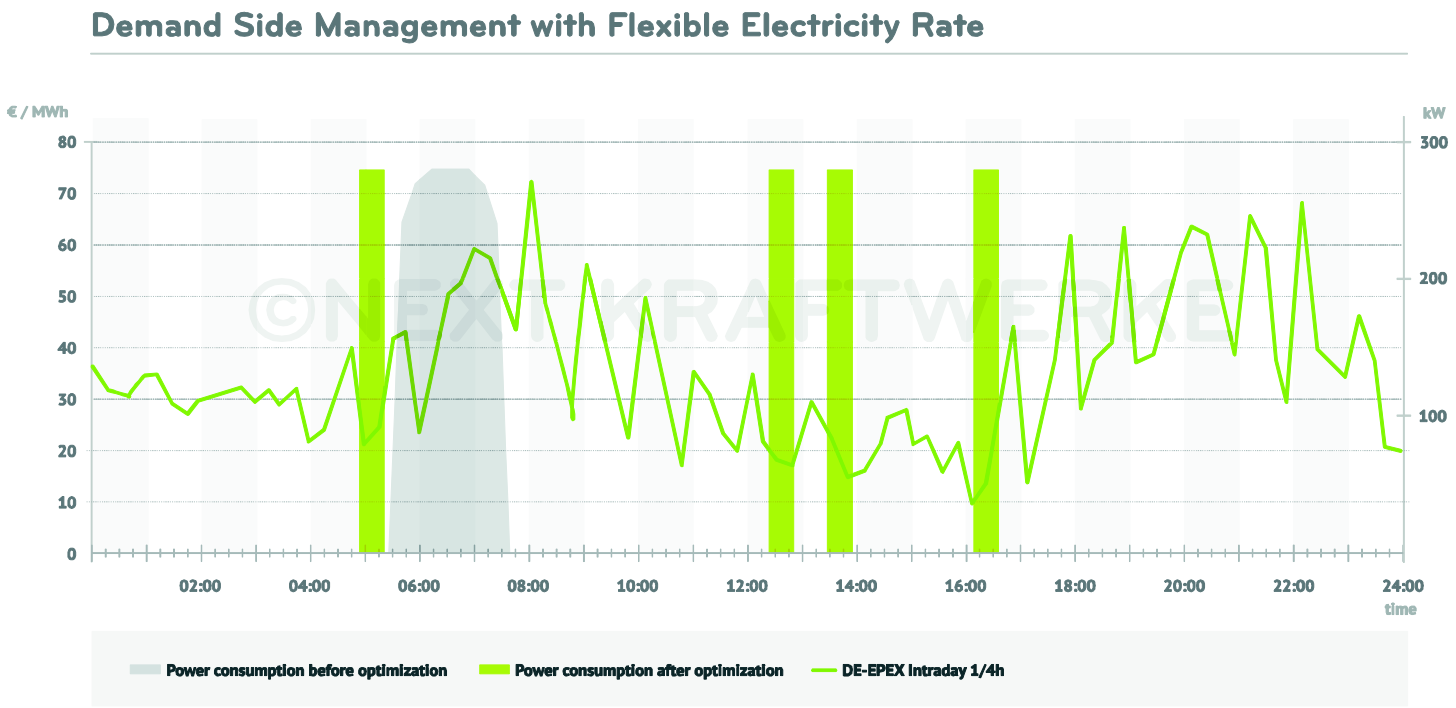
Aggregating flexible load and geneeration



Source: Next Kraftwerke

Demand Response at its best

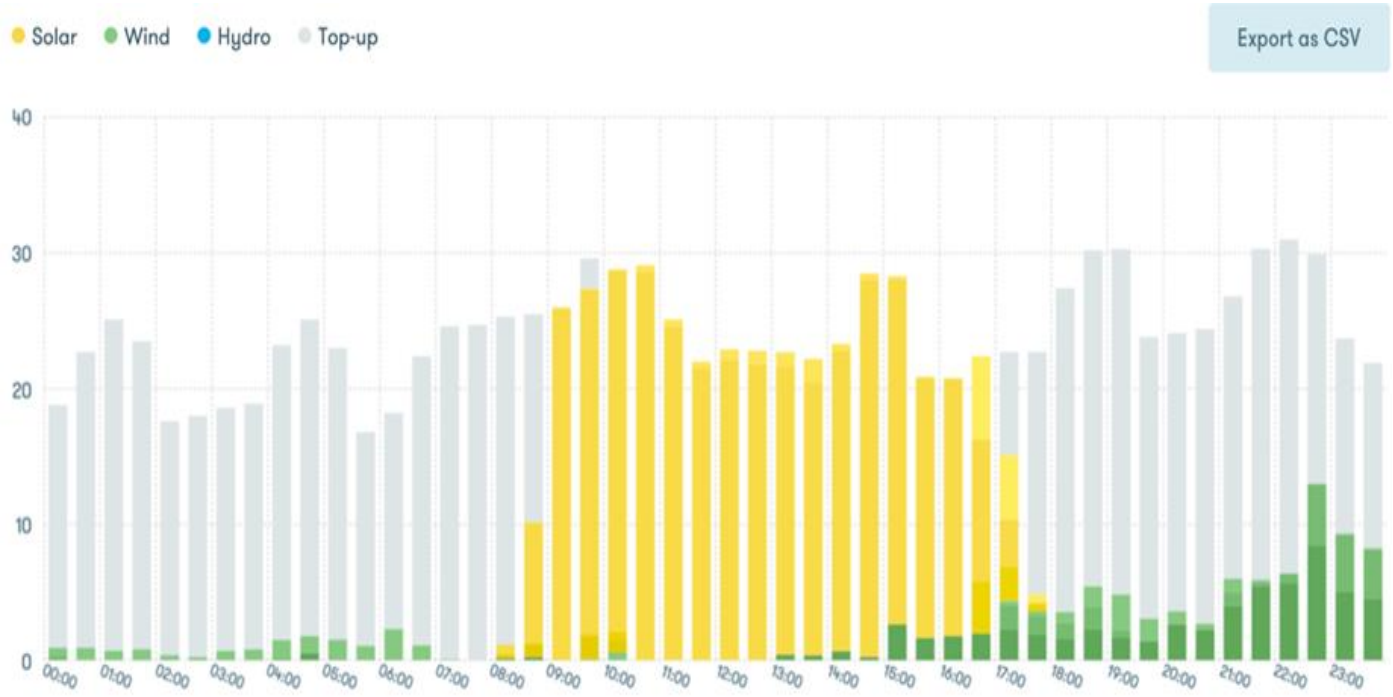
M2M communications makes it possible



Source: Next Kraftwerke

Transactive transparency!

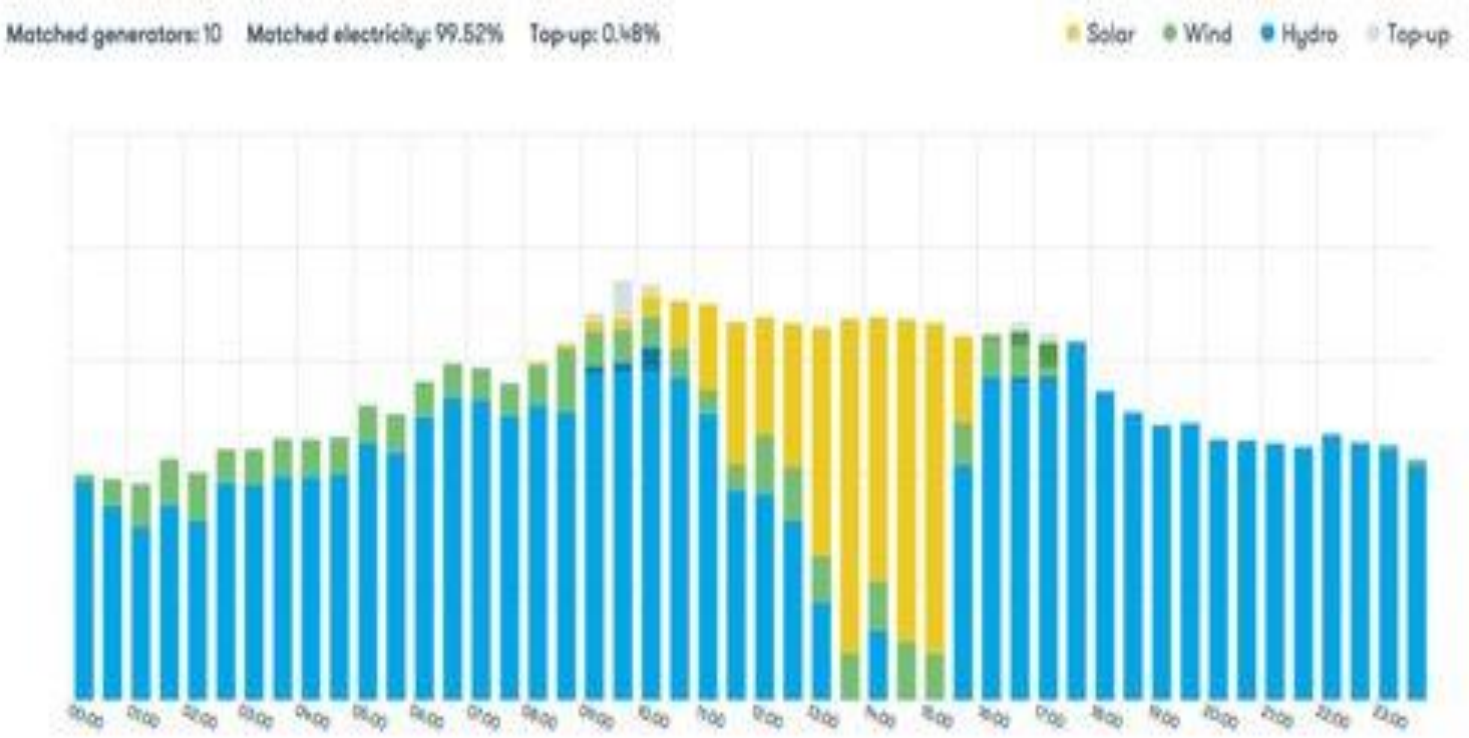
Prosumagers interface with suppliers, peers & own load



Source: Open Utility

Win-win-win!

Prosumers, retailer & network better off



Source: Open Utility

Aloha to Yeloha

Peer-to-peer trading at the grid's edge

Source: http://www.yeloha.com/about

8. Role of regulation/policy

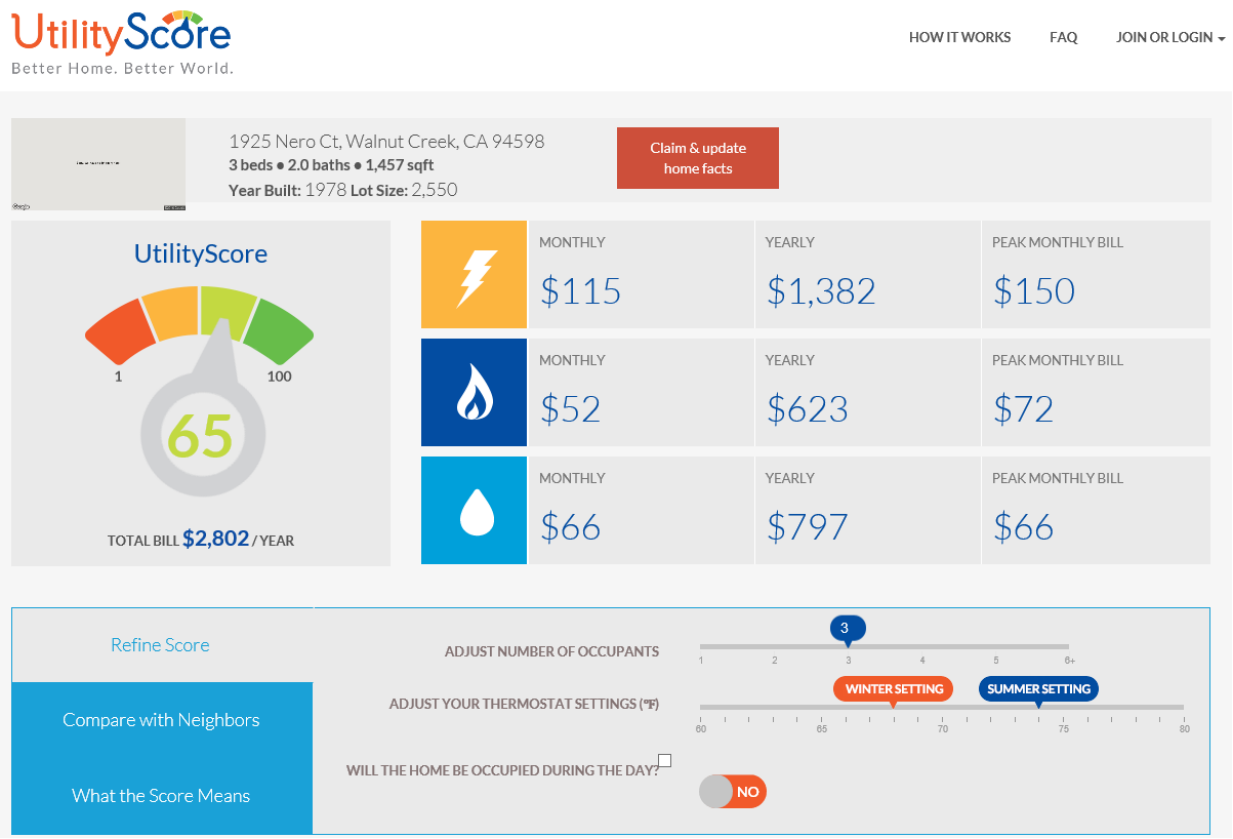
- Critical in most countries
- Network is/will remain natural monopoly
- Regulators face tough decisions
  - They cannot mandate innovation
  - Nor should they stifle it
- Regulatory focus: Distribution network
- Fundamentals of “service” changing
  - Prosumagers needs different than passive consumers

Digital Age?

Backbone of US distribution network: 130 million wooden poles

My Utility Score

Regulators can make a difference



Source: https://www.myutilityscore.com/

Biggest uncertainty?

Reading the regulator's mind

New York

At the cutting edge

- **Reforming the Energy Vision** (REV)
- Building a clean, resilient & affordable energy system for all New Yorkers
- 2030 targets
  - 40% reduction in GHG emissions from 1990 levels
  - 50% RPS
  - 23% reduction in energy consumption in buildings from 2012
- https://www.ny.gov/programs/reforming-energy-vision-rev

NY’s regulatory reform

Widely watched in the US

- At its core, REV is about new ways of using & paying for distribution network
- “We are changing New York's energy policy to put customers first and make sure energy efficiency, increased use of renewables, and reliance on more resilient distributed energy resources like microgrids are at the core of our energy system.”

Fate of distribution network

- Key questions:
  - How will it function?
  - Who will maintain it?
  - Who will use it?
  - Who will pay for it?

Role of regulators?

NY or CA? Market-driven or micro-managed?

CPUC Commissioners:

President
Michael Picker
More

Commissioner
Mike Florio
More

Commissioner
Catherine J.K. Sandoval
More

Commissioner
Carla J. Peterman
More

Commissioner
Liane M. Randolph
More

NEW YORK STATE

Department of Public Service

Audrey Zibelman, Chair

Patricia L. Acampora

Gregg C. Sayre

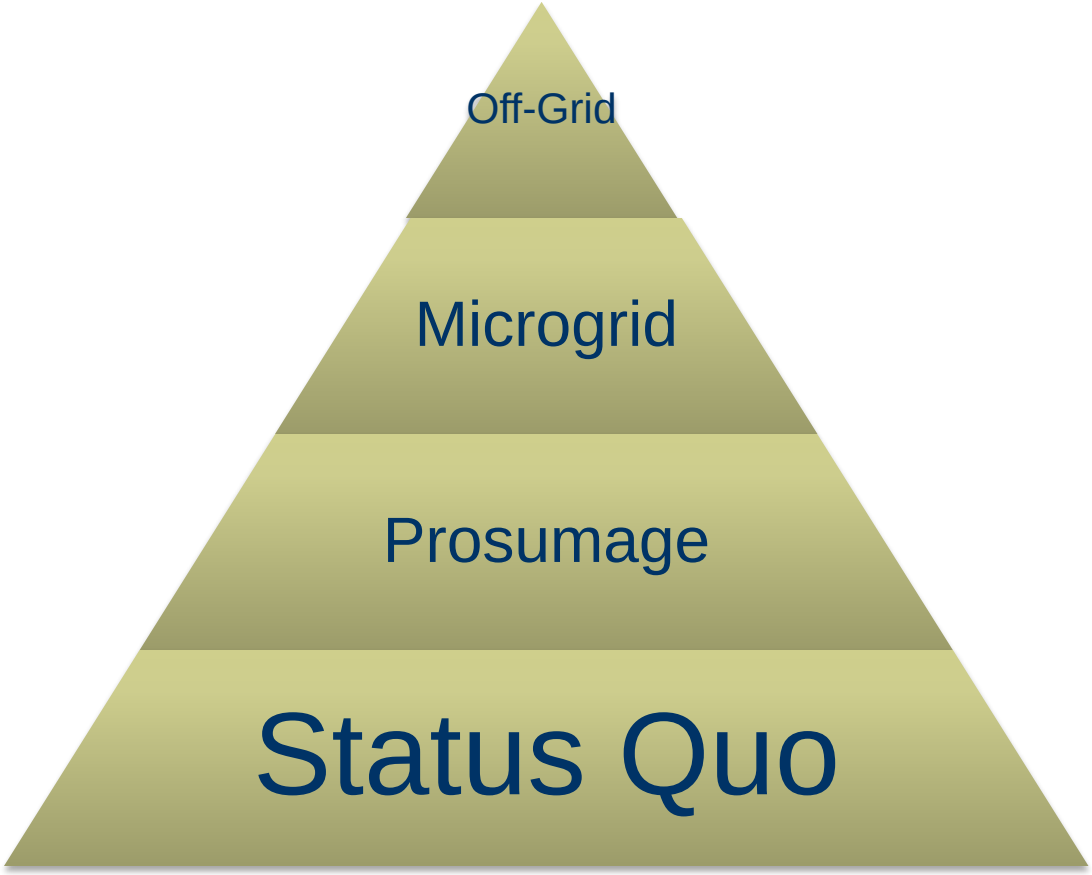
Diane X. Burman

9. What do customers want?

- Key question: Ultimately they must pay
- Which customers?
- Residential?
  - Affluent or poor; consumer, prosumer or prosumager?
- C&I
  - Energy-intensive or not?
  - Export sensitive?
- What about other users of network?
  - DERs, PVs, Storage, EVs, EV operators, others?

Customer pyramid

Majority content with status quo



Who will stay, who will pay?

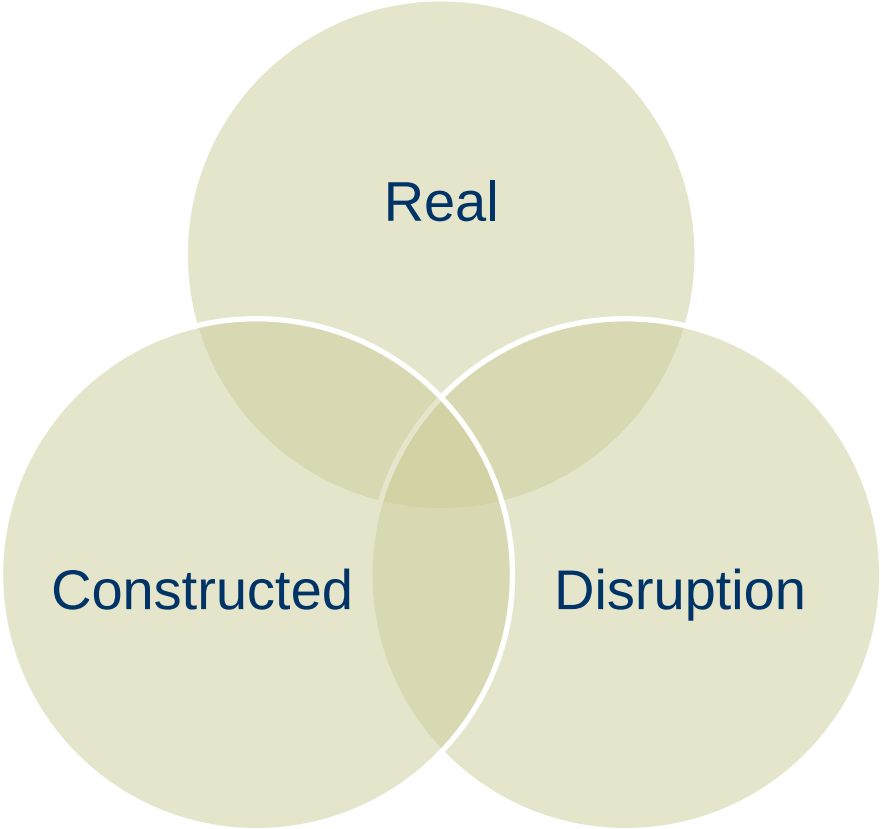
- Nearly all will stay …
  - Going totally off-grid totally uneconomic
- Fundamentals of “service” will radically change
- “Connectivity” & “reliability “ priceless
  - Prosumers will pay for reliabiliy & balancing services
- Network as a “social good”
  - In the end, it may be easiest to “socialize” costs
  - MIT study agrees
    - “It’s like public library: everybody pays regardless of how often used”

10. Where do we go from here?

- Good question

Outcome?

Confluence of 3 factors

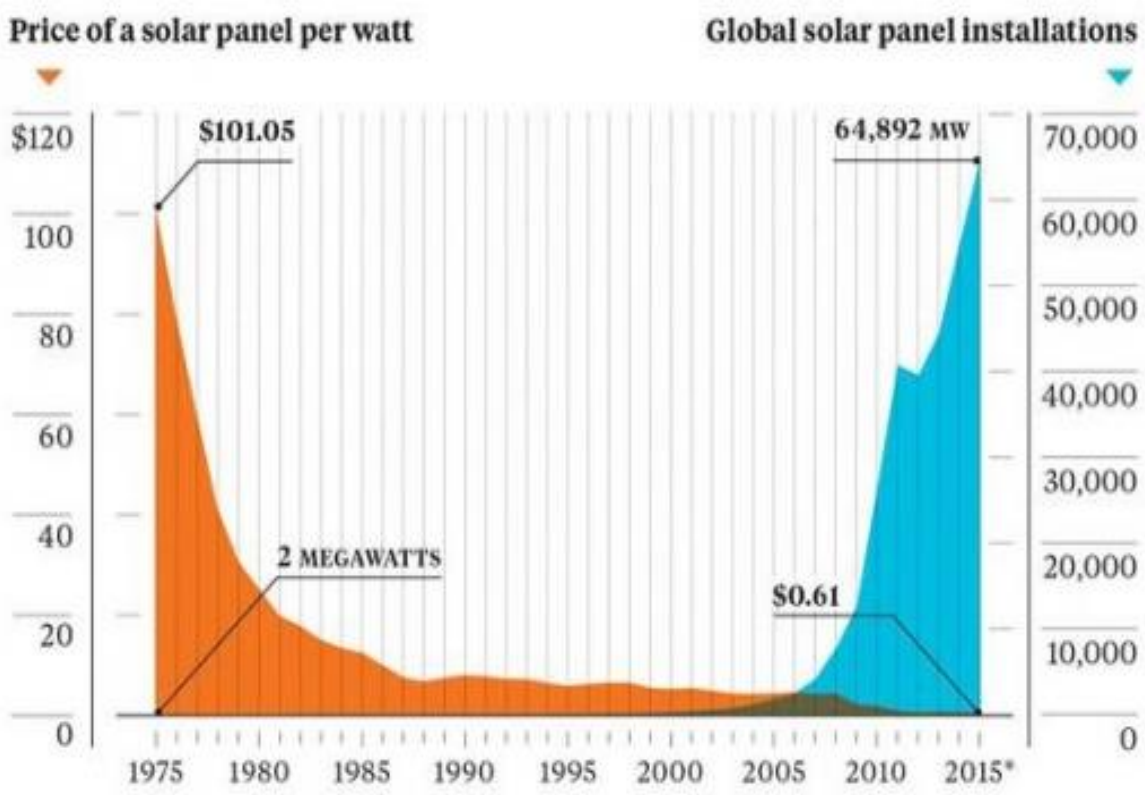


Real, constructed, disruption

- What is “real?”
  - Economics
- What is “constructed” or “artificial?”
  - Regulations
- “Disruption?”
  - Surprise, discontinuity, game changers

Real

1 every 3 minutes



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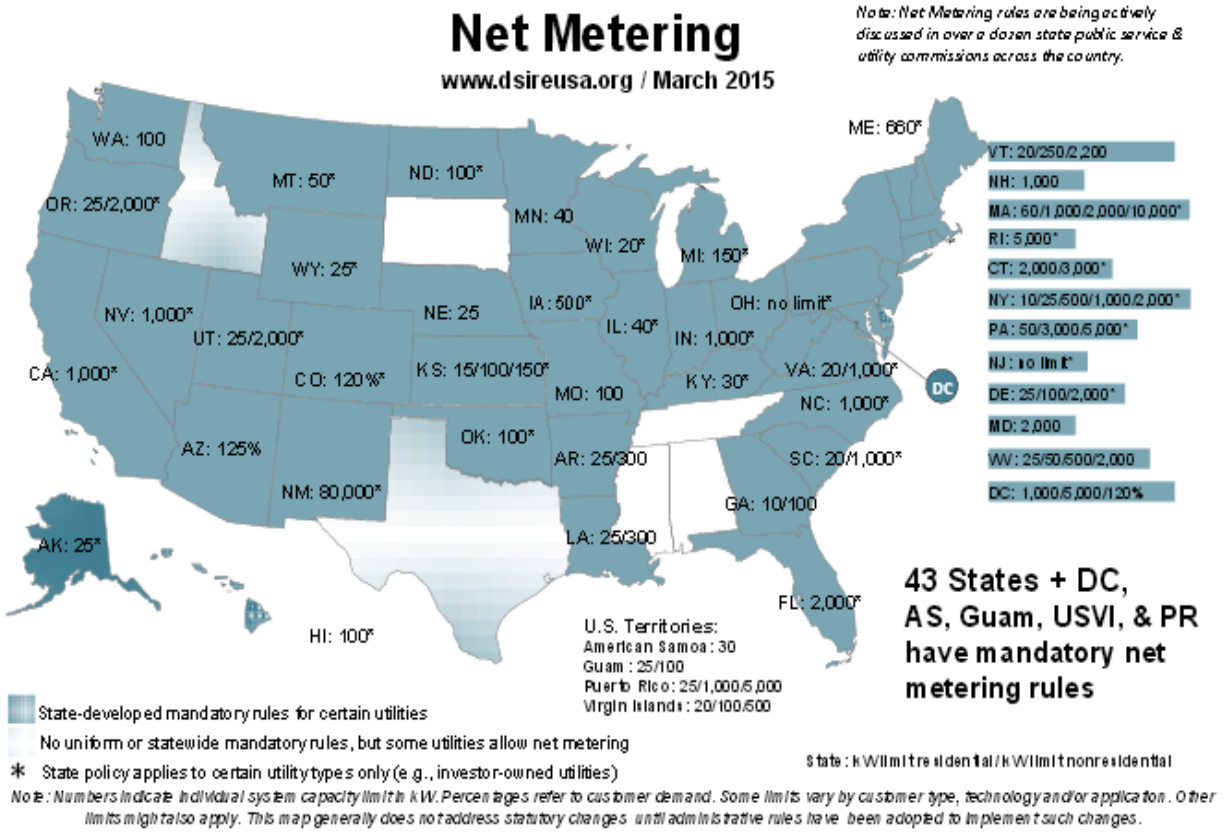
Reproduced from Giles Parkinson's Renew Economy, 7 Feb 2016

Constructed

Current net energy metering schemes, subject to change w/o notice



Source: Database of State Incentives for Renewables & Efficiency (DSIRE)

Disruption: Solar leasing

An offer few customers can refuse

Another game changer?

UCLA Prof. Richard Kaner

Source: www.chem.ucla.edu/dept/Faculty/kaner/images

Electric bus

Supercapacitors will revolutionize mass transit

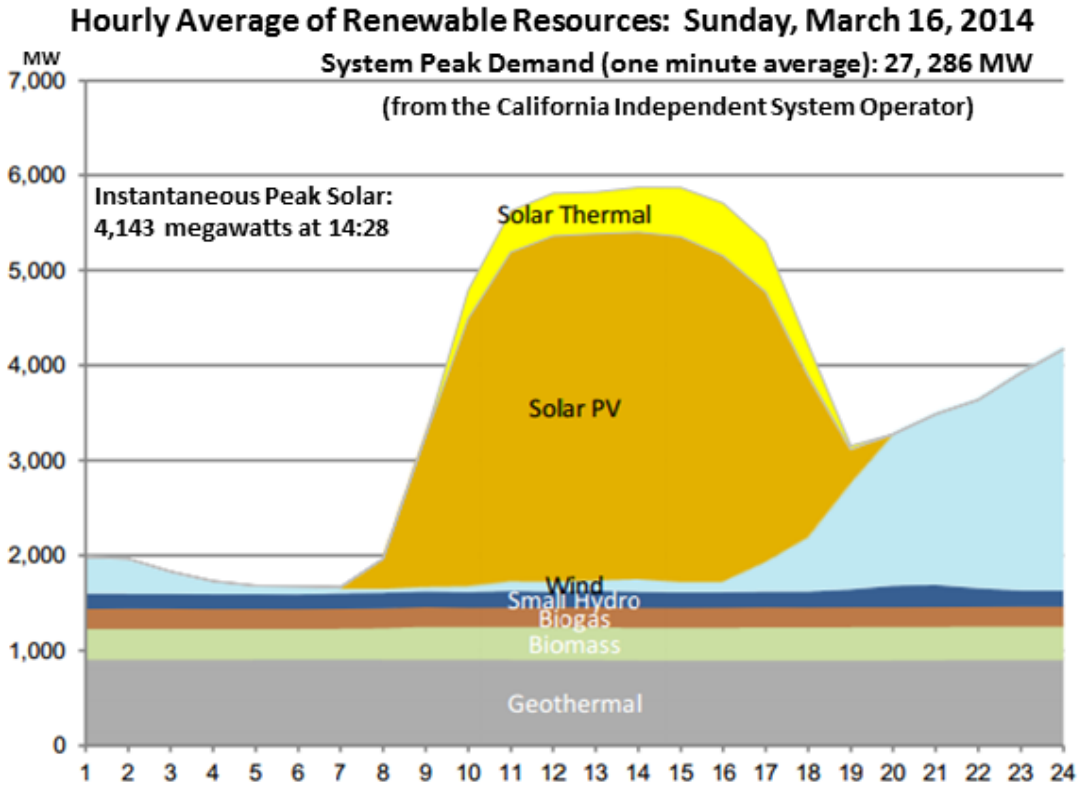
Source: Solaris Urbino 12 electric from Braunschweiger Verkehrs-GmbH (Germany)

Challenges?

- Low carbon energy mix? No problem
  - Expanded geographic footprint
  - Transmission
  - Flexible generation
  - Flexible load
  - Storage
- Prosumage?
  - Who pays for the grid?
- Utility business model?
  - Start from scratch

Mid-day sun = “over-generation”

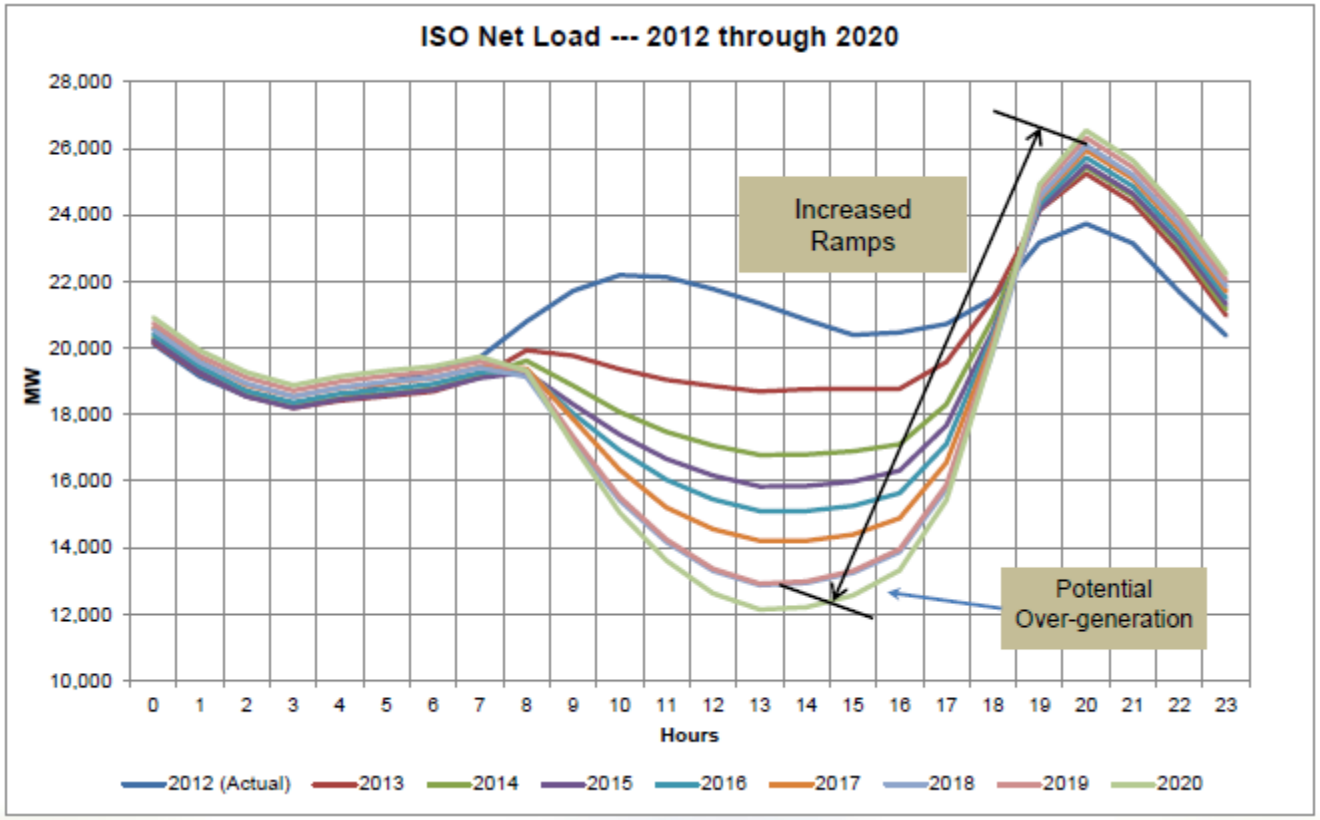
In many networks mid-day peaks have disappeared



Source: ISO

CA Duck curve

ISO's net load projection for 2012 through 2020



Source: CAISO Discussion of Markets, Mark Rothleder, 3 June 2014

CAISO

Is this a dispatch center or weather forecasting station?

Source: CAISO

Thank you

- Questions?