
ROCKY MOUNTAIN
INSTITUTE

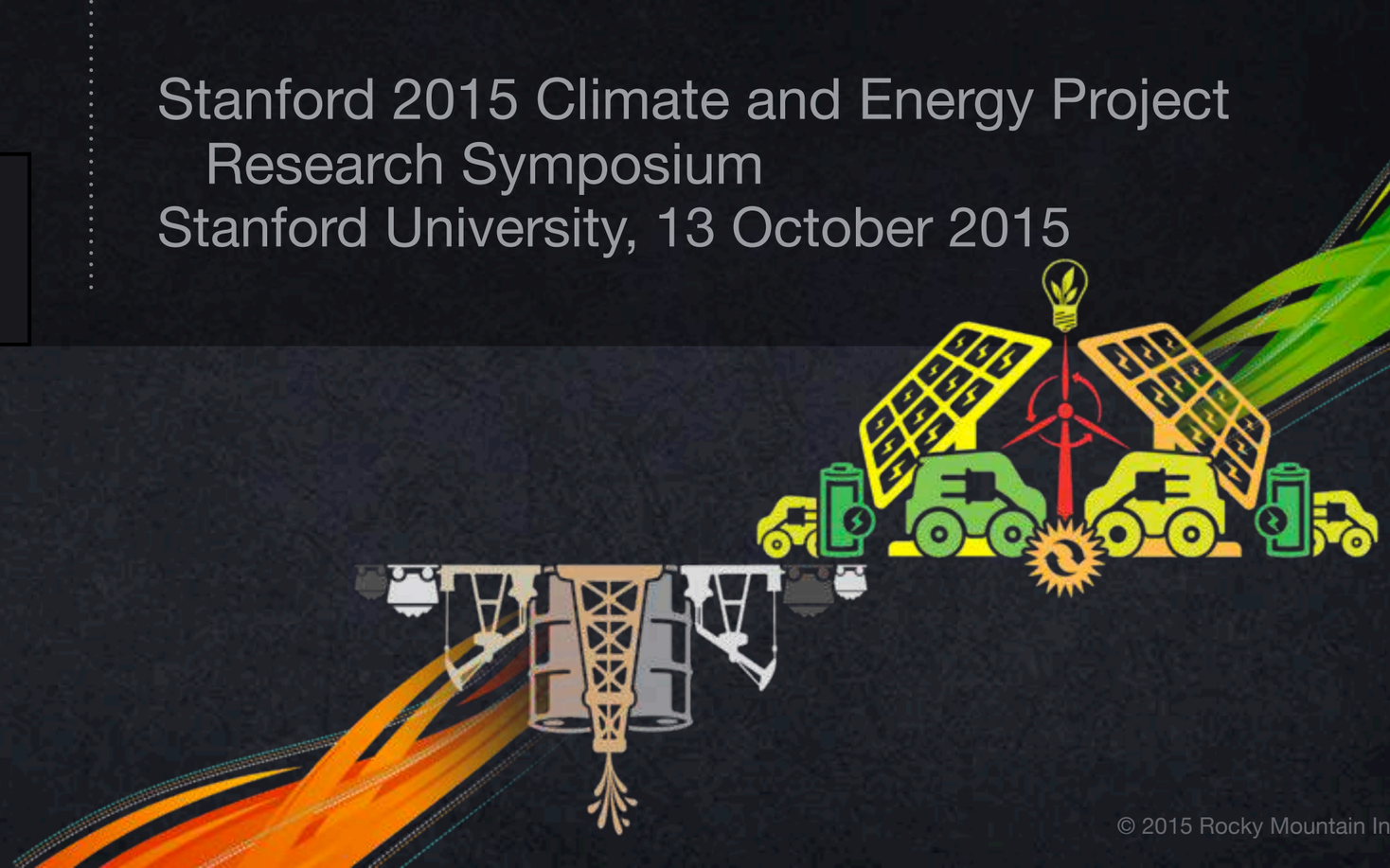

CARBON
WAR ROOM

Oil and Electricity's Disruptive Futures

Amory B. Lovins

Cofounder and Chief Scientist

Stanford 2015 Climate and Energy Project
Research Symposium
Stanford University, 13 October 2015



The rise and fall of the U.S. whaling industry

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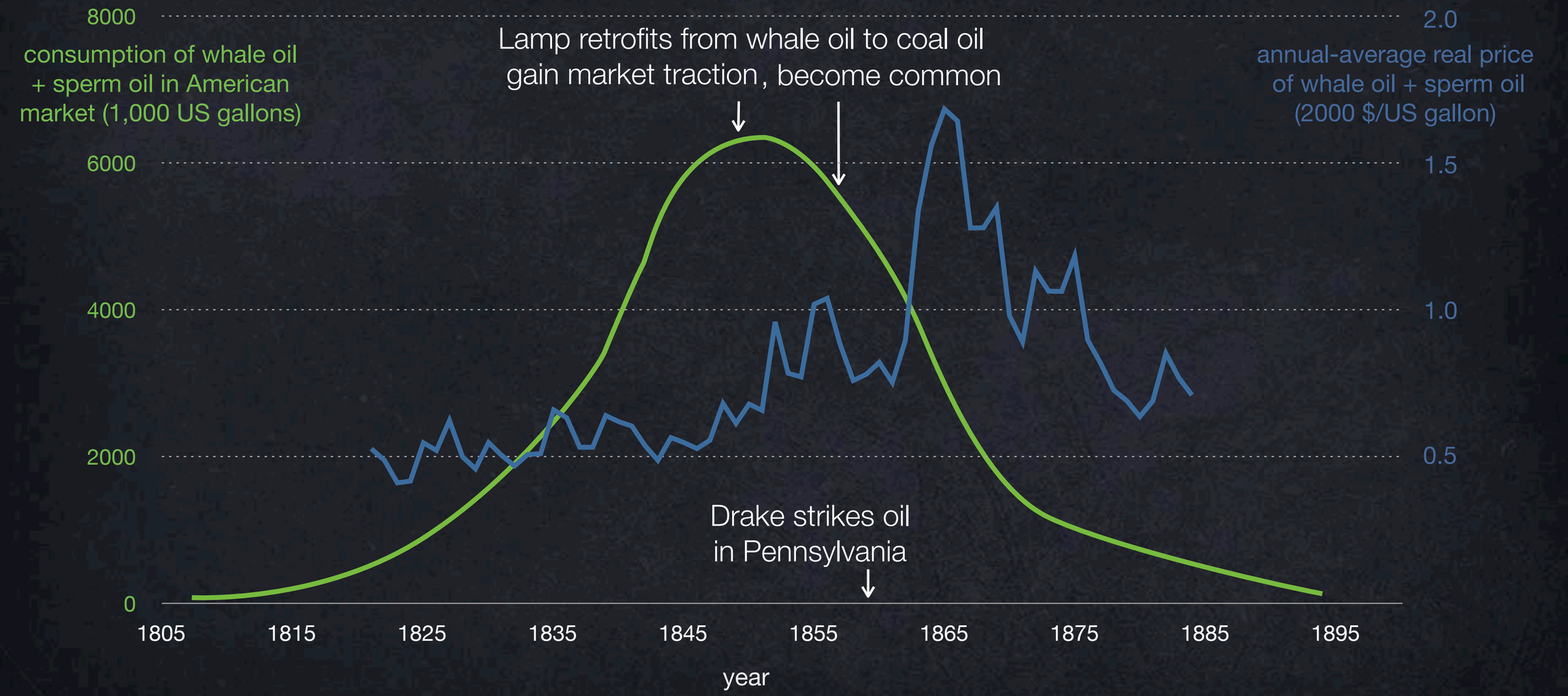
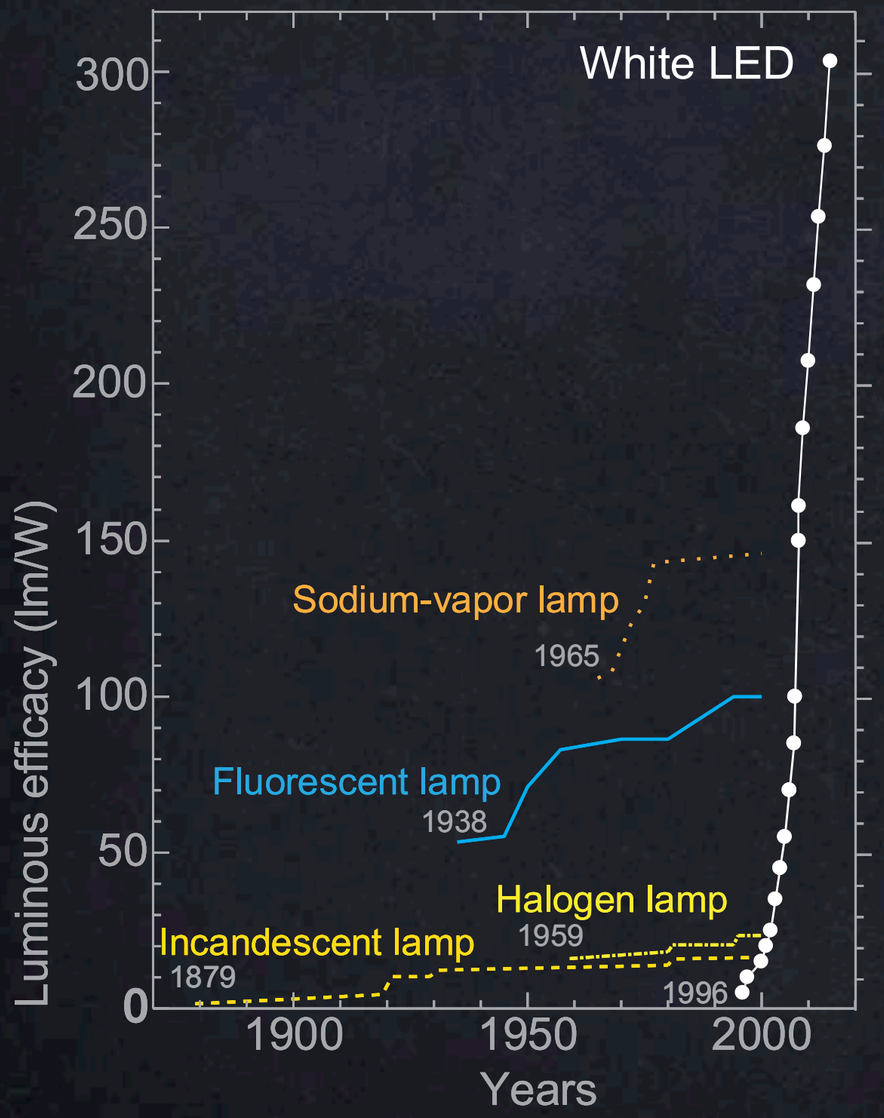
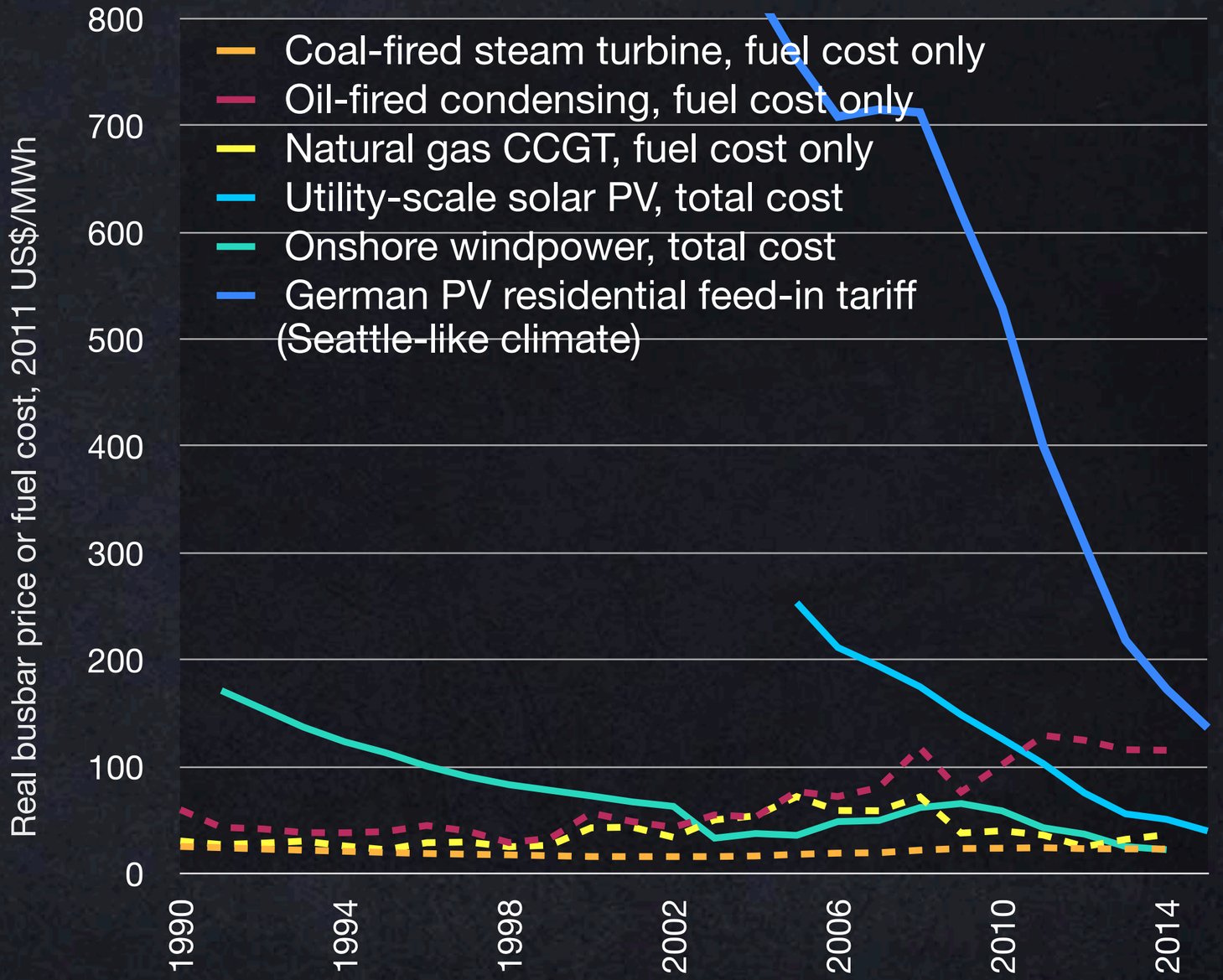


LED and PV

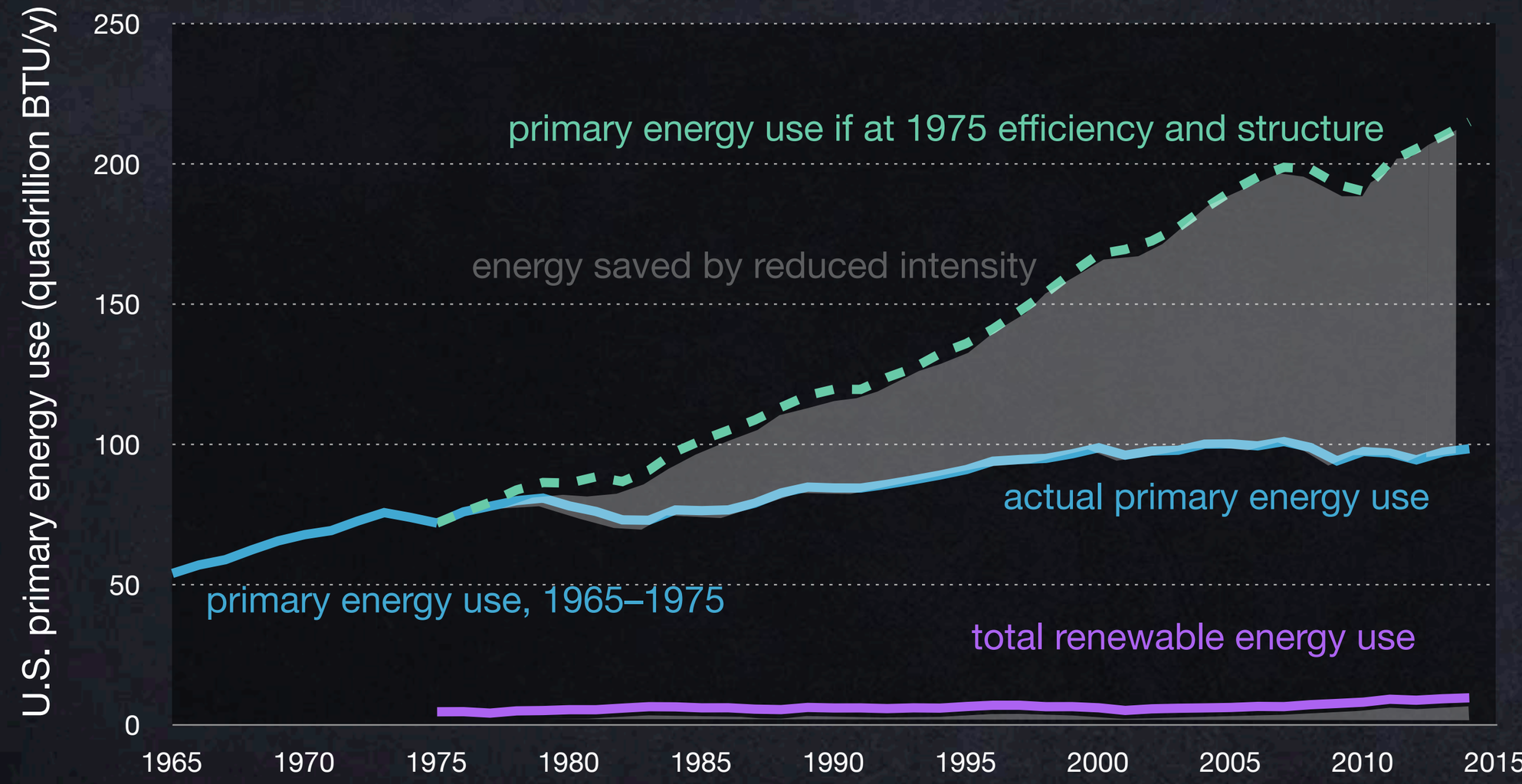




Sources: L: courtesy of Dr. Yukio Narukawa (Nichia Corp., Tokushima, Japan) from *J. Physics. D: Appl. Phys.* ***43***(2010) 354002, doi:10.1088/0022-3727/43/35/354002, updated by RMI with CREE lm/W data, 2015, www.cree.com/News-and-Events/Cree-News/Press-Releases/2014/March/300LPW-LED-barrier;. R: RMI analysis, at average 2013 USEIA fossil-fueled generation efficiencies and each year's real fuel costs (no O&M); utility-scale PV: LBNL, *Utility-Scale Solar 2013* (Sep 2014), Fig. 18; onshore wind: USDOE, *2013 Wind Technologies Market Report* (Aug 2014), "Windbelt" (Interior zone) windfarms' average PPA; German feed-in tariff (falls with cost to yield ~6%/y real return): Fraunhofer ISE, *Cost Perspective, Grid and Market Integration of Renewable Energies*, p 6 (Jan 2014); all sources net of subsidies; graph inspired by 2014 "Terrordome" slide, Michael Parker, Bernstein Alliance

What if the biggest threats weren’t on the radar?

Intensity decrease has had 31× the impact of renewable growth



1975–2014 savings from intensity reduction: 2,089 qBTU

1975–2014 growth in total renewable output: 67 qBTU

Who’s the competition?

Rex Tillerson
Chairman and CEO, ExxonMobil

Ali bin Ibrahim al-Naimi
Saudi oil minister

Pål Kibsgård
CEO, Schlumberger Ltd.

Who’s the competition?

Elon Musk, Tesla,
SolarCity, SpaceX

Sebastian Thrun,
Google’s self-driving car

Anna Jaffe,
Mobi

Lee Eng Lock,
efficiency engineer

Robin Chase,
Zipcar, GoLoco, Buzzcar

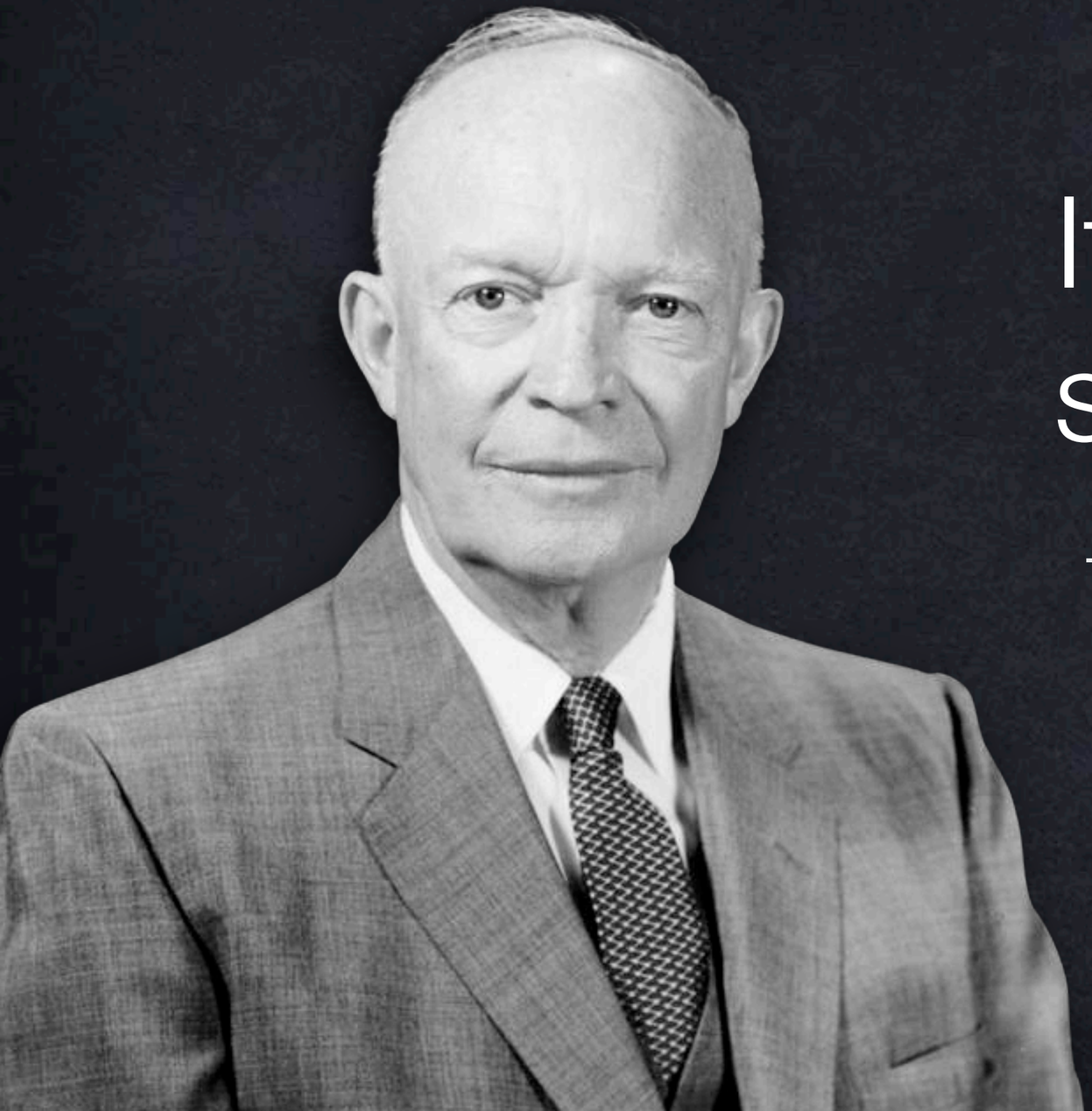
Michael Brylawski,
VisionFleet

Peter Calthorpe,
architect

Ferdinand Piëch,
Volkswagen (ret.)

“I can’t wait to see what happens when our industries merge.”

188.5610 from https://www.thehenryford.org/exhibits/pic/2004/July.asp



If a problem can’t be solved, enlarge it.

—attributed to Dwight Eisenhower

Volume Production of Electrified Carbon-Fiber Cars

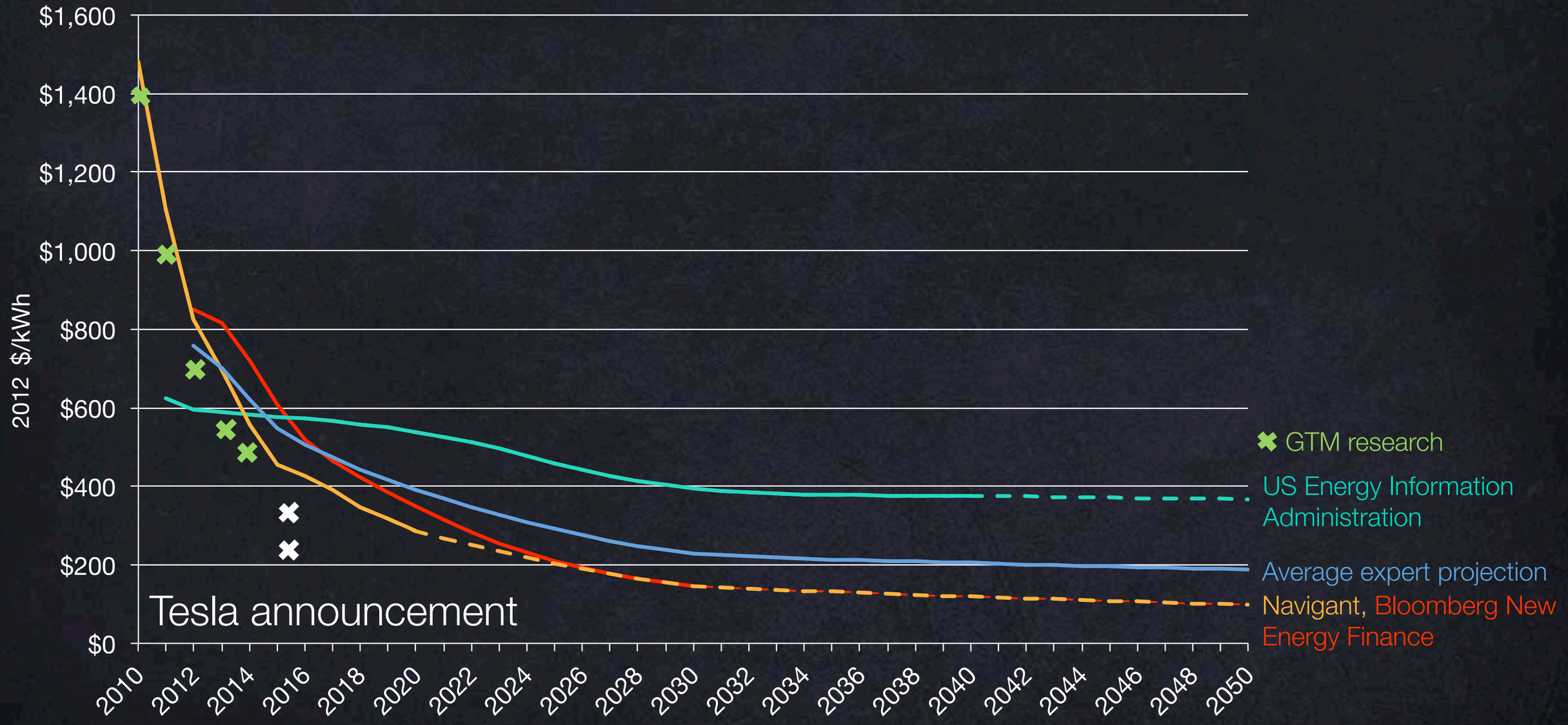
Hypercar *Revolution* 5-seat hybrid SUV
2000 virtual design (RMI with two Tier Ones)
67 mpg (gasoline) or 114 mpge (H_2), 1,887 lb (–53%)
3.6 L/100 km (gasoline) or 2.1 (H_2), 857 kg (–53%)

Toyota *1/X* 4-seat plug-in hybrid
2007 concept car
131 mpge, 926 lb (–70%)
1.8 L/100 km, 420 kg (–70%)

VW *XL1* 2-seat plug-in hybrid
2014 low-volume production
235 mpge, 1,759 lb
0.9 L/100 km, 798 kg

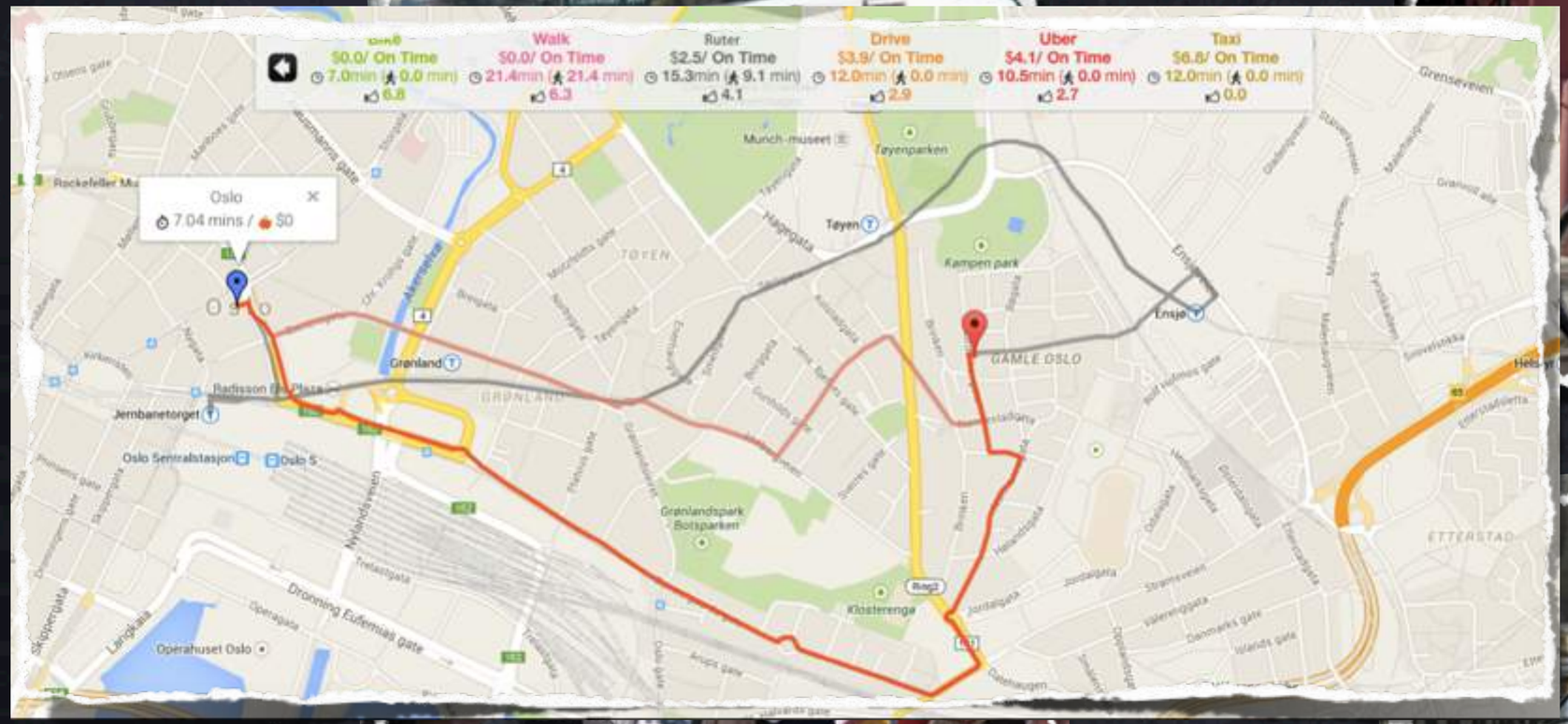
BMW *i3* 4-seat battery-electric hatchback
2013– midvolume production, $41–45k
124 mpg, 185+-mile range-extender option
1.9 L/100 km, 300+-km range-extender option

Batteries' Costs Continue to Plummet

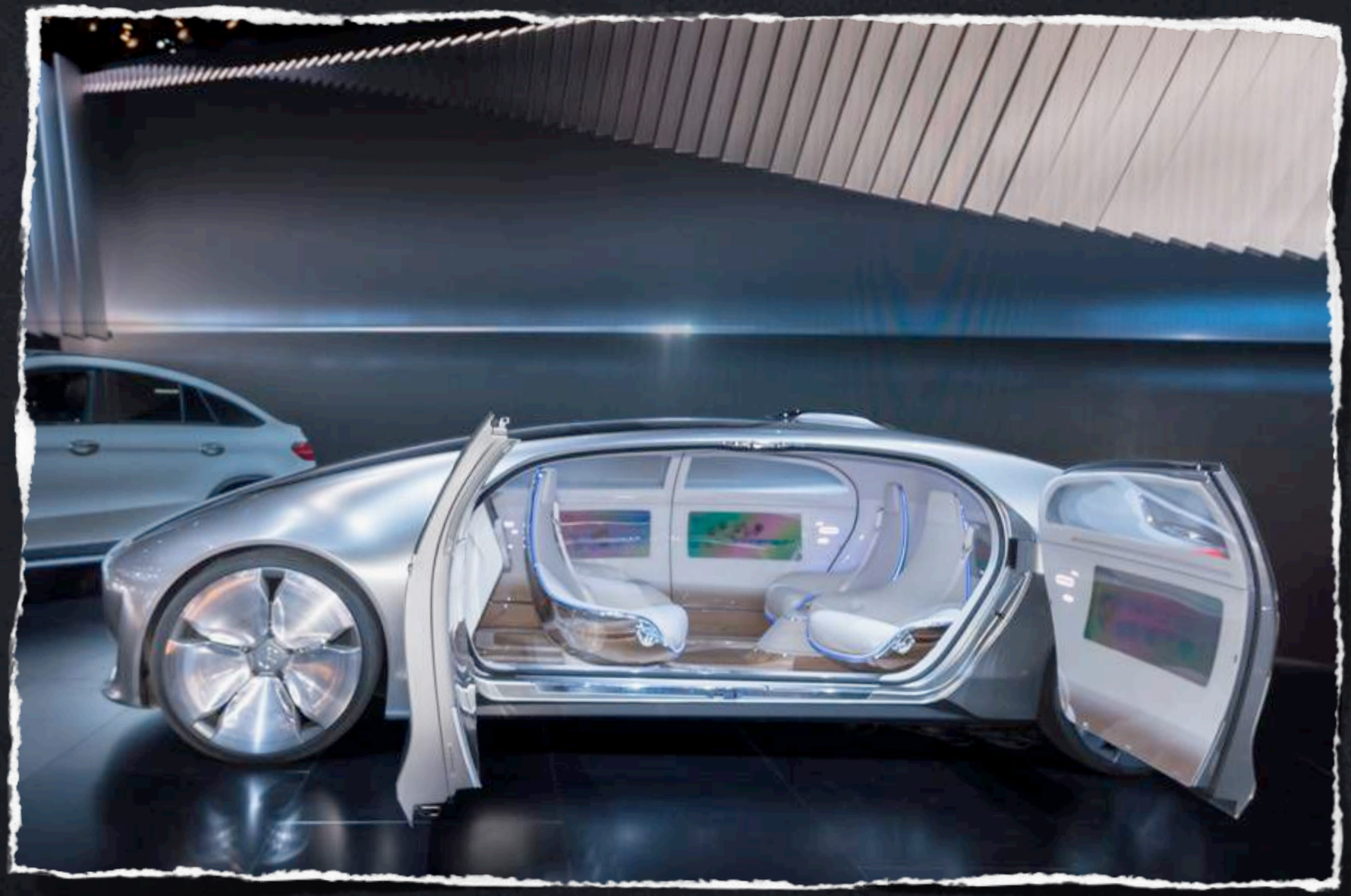


Tripled-Efficiency Trucks and Planes

Enabled by IT, multiple transportation methods provide a seamless, cheaper, more pleasant user experience



Autonomous vehicles: from PIGS to SEALs

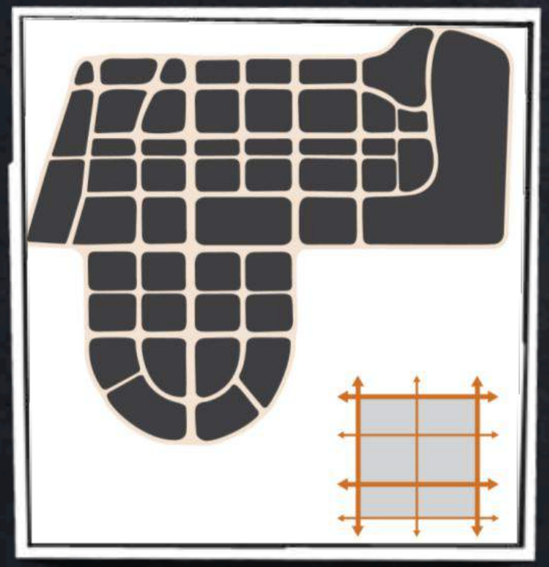


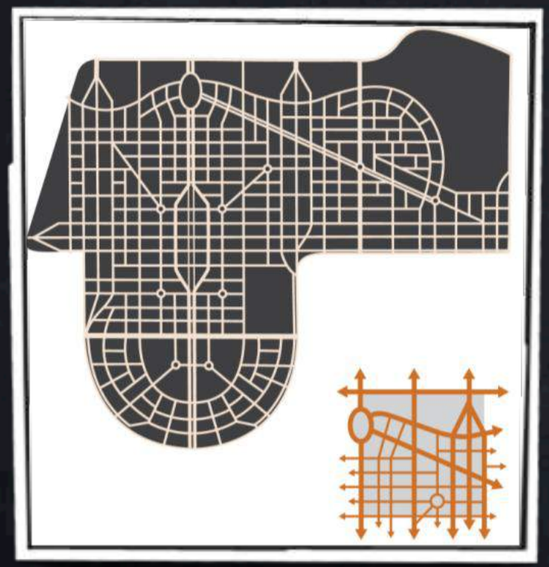
From PIGS to SEALS

Transportation problems in China

From disorganized chaos to smooth travel experience

From superblock to walking distance

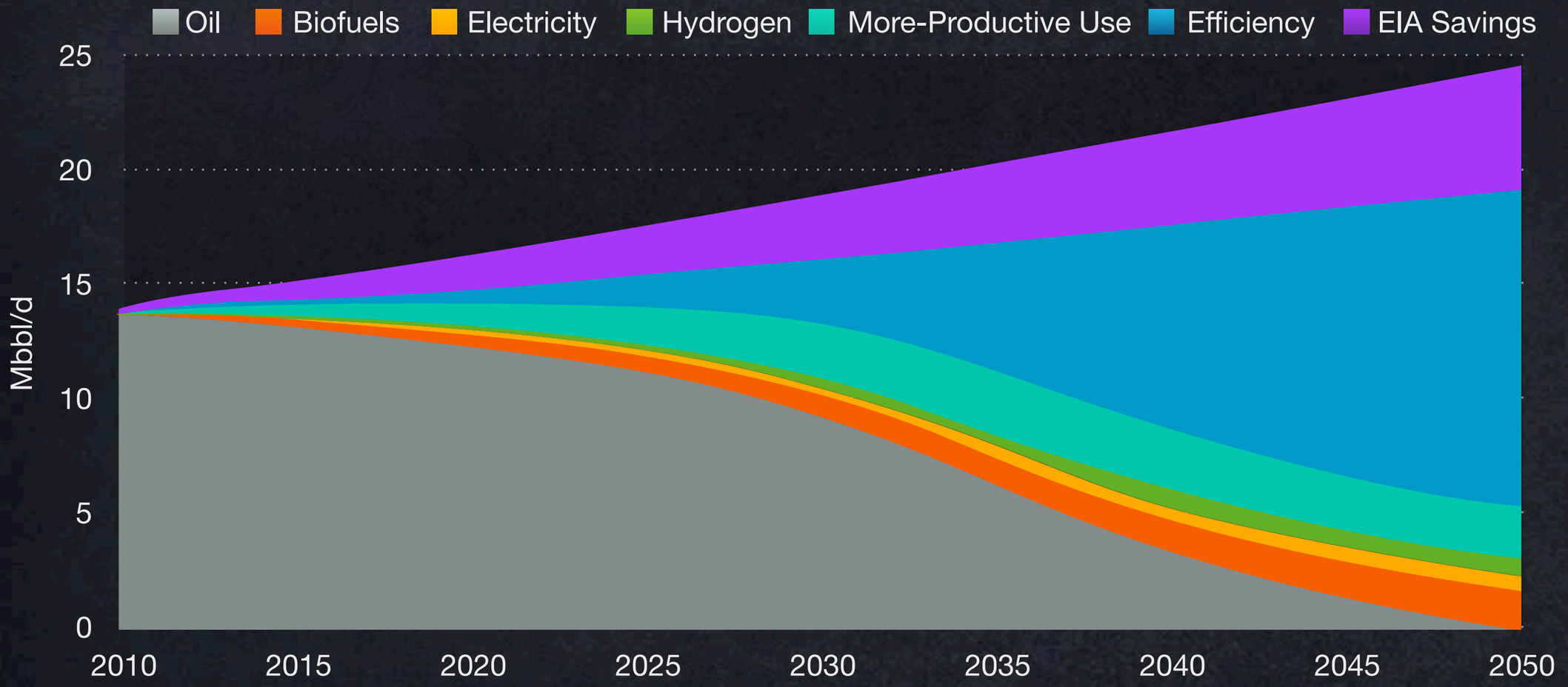




Graphics courtesy of Peter Calthorpe

Transportation Without Oil

despite 90% more automobility, 118% more trucking, 61% more flying

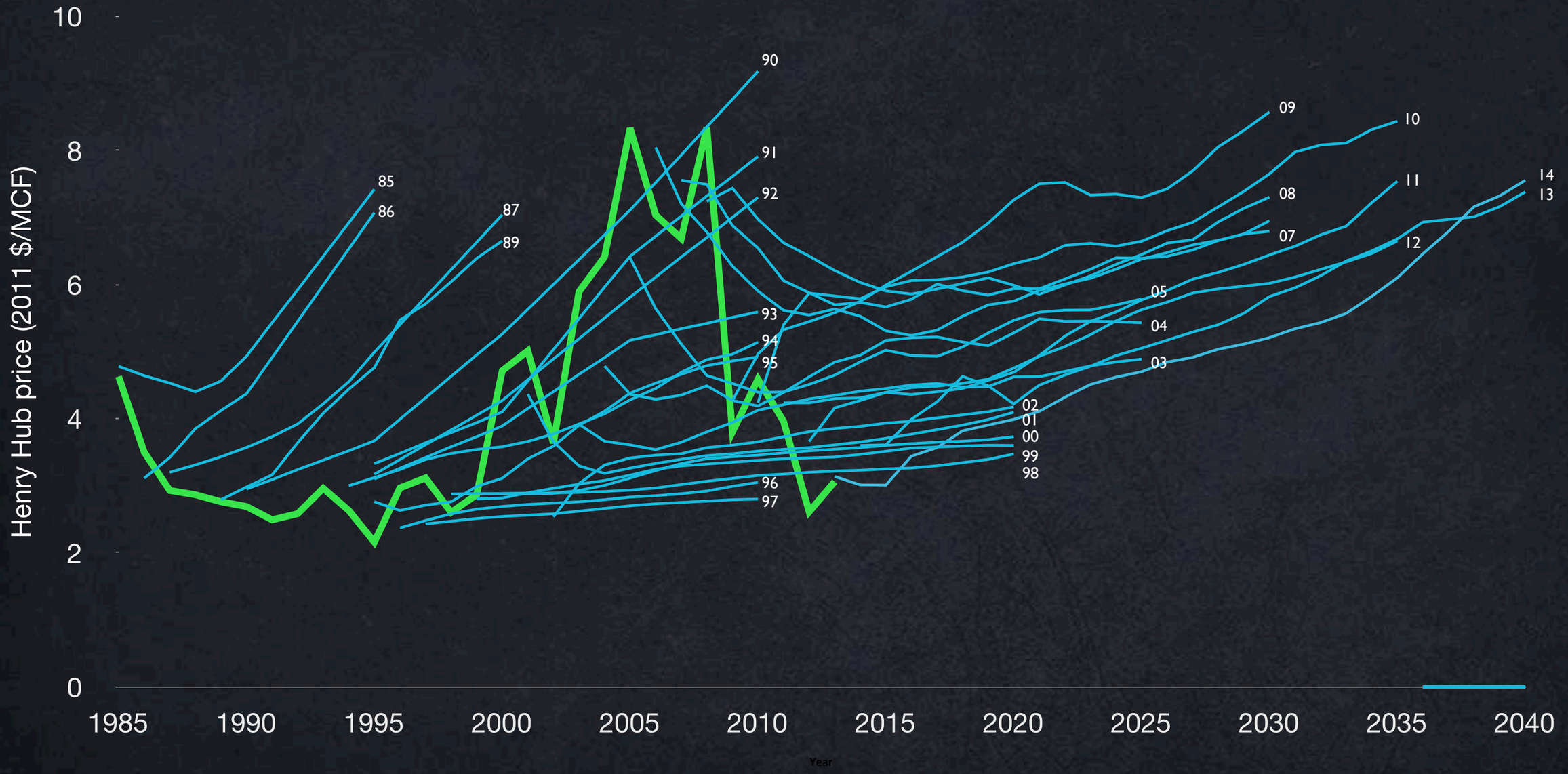


Source: A.B. Lovins & RMI, *Reinventing Fire* (2011), Chelsea Green (White River Junction VT), www.rmi.org/reinventingfire.

“We must leave oil before it leaves us.”

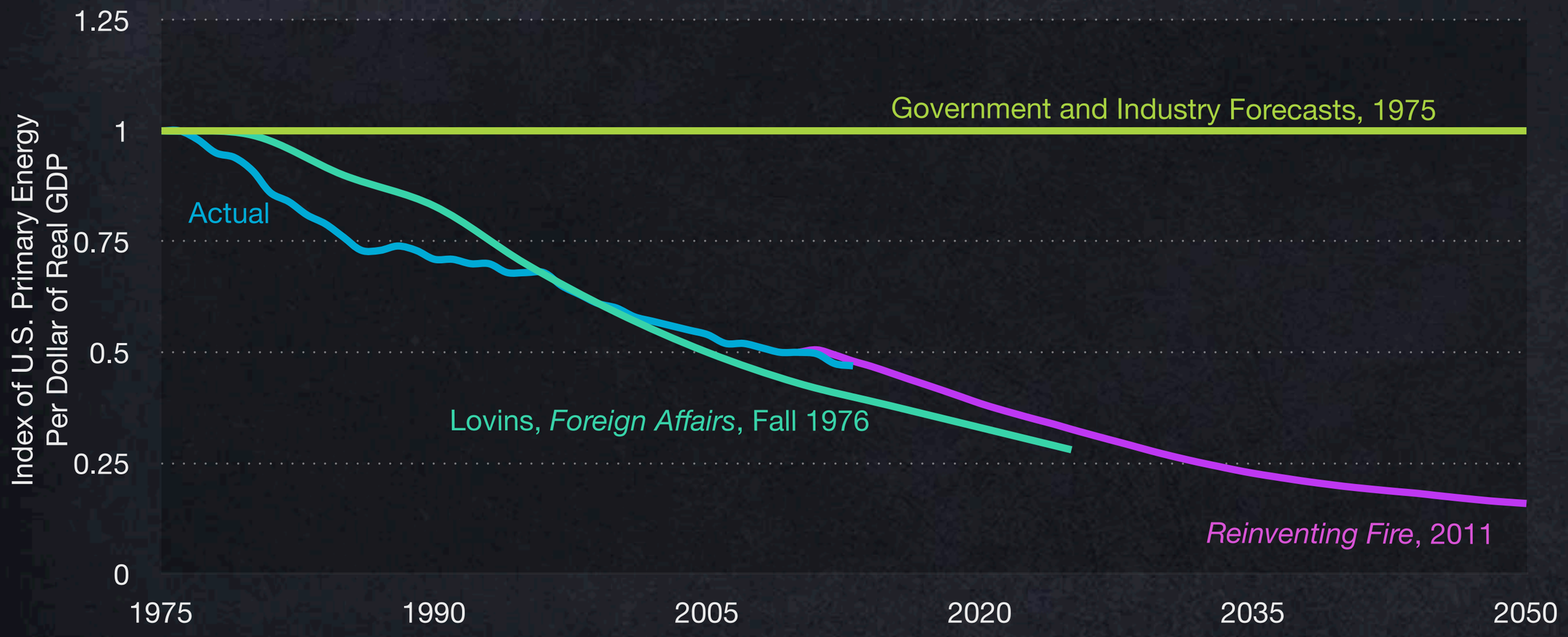
Fatih Birol
~~Chief Economist~~ Executive Director
International Energy Agency 2008

U.S. natural gas prices, 1985–2015: official forecasts vs. reality



Heresy Happens

U.S. energy intensity



Lovins House, Old Snowmass, Colorado (1983)

U.S. buildings: 3–4× energy productivity worth 4× its cost

(site energy intensities in kWh/m^2-y; U.S. office median ~293)

~277➡173 (–38%)

2010 retrofit

284→85 (–70%)

2013 retrofit

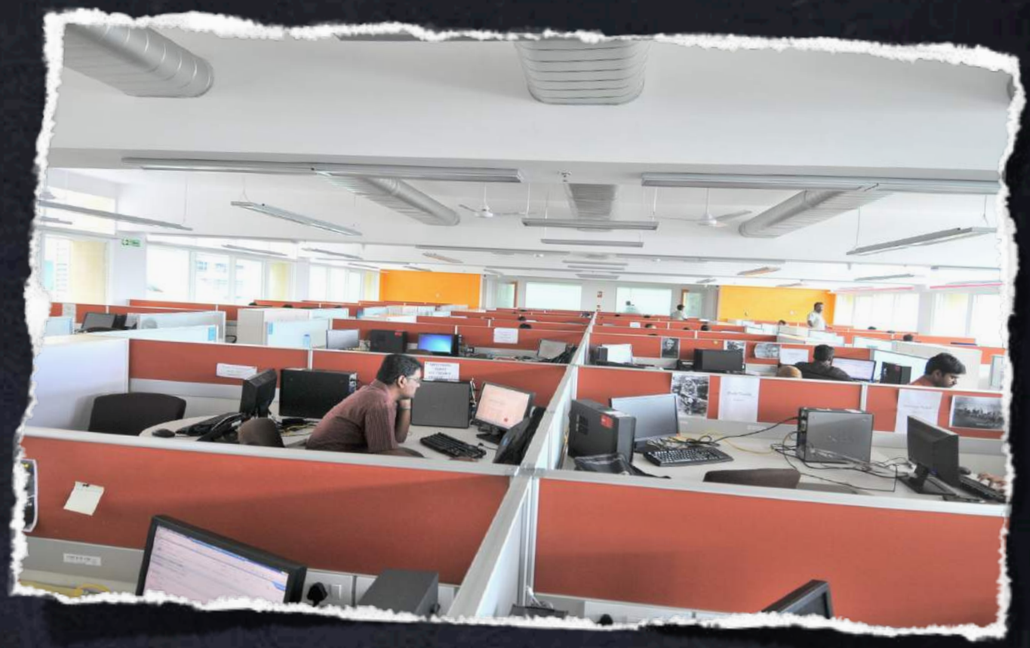
...→108 (–63%)

2010–11 new

...→≤50 (–83% to –85%)

2015 new

80% energy savings in Hyderabad office, lower capex



Infosys DSB1 (2009): world's largest side-by-side HVAC experiment
Radiant side (11,152 m^2): 66 kWh/m^2-y (–80%), capex –9%

Courtesy of Peter Rumsey PE FASHRAE (Senior Advisor, RMI) and Rohan Parikh (Infosys, Bangalore)

Radical Efficiency

motors, pumps, *and* pipes

Less Capital Investment

smaller equipment

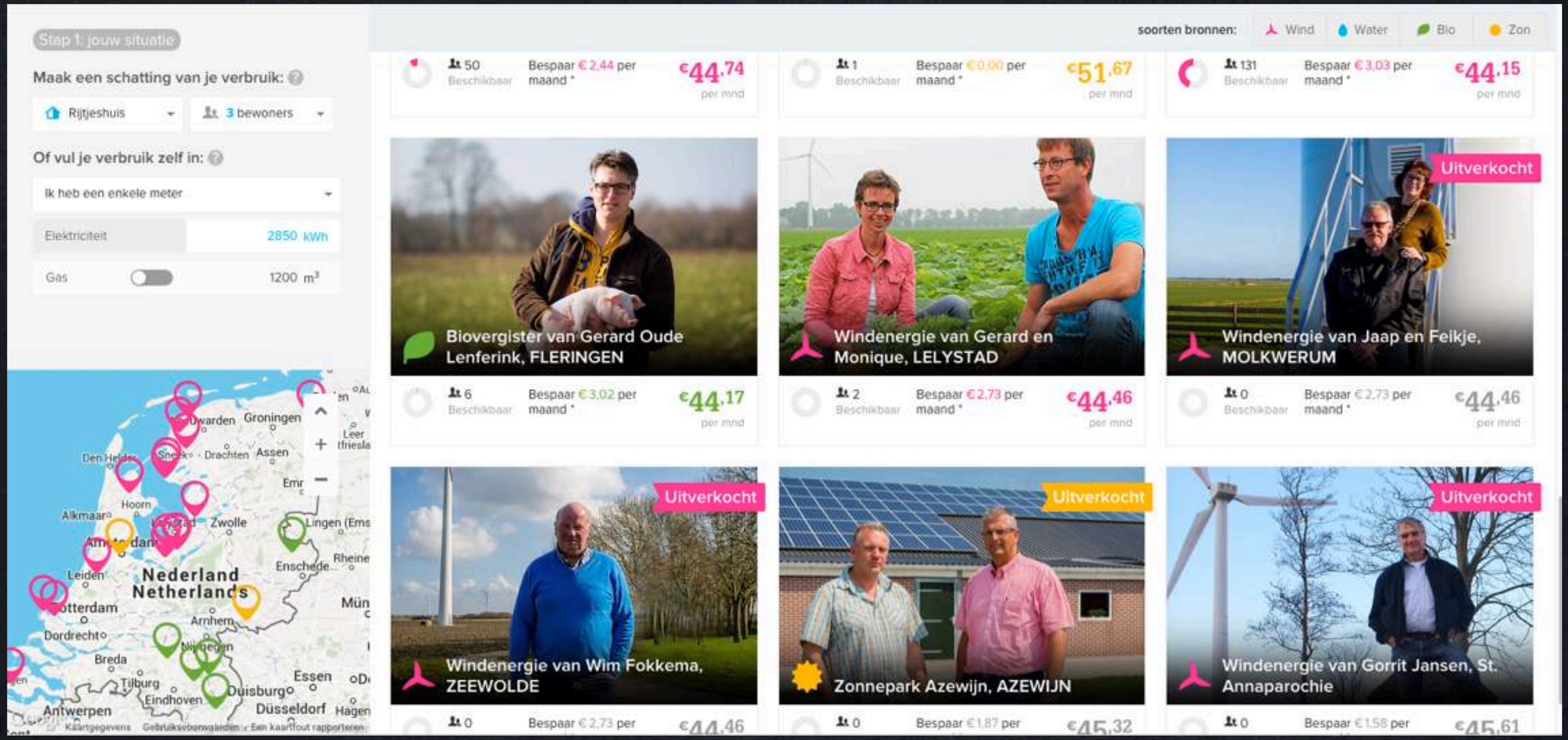

100
Energy units
-70%
Power Plant
-9%
Power Grid
-12%
Motor/Drivetrain
-55%
Pump/Throttle
-20%
Pipe
5%
Delivered flow

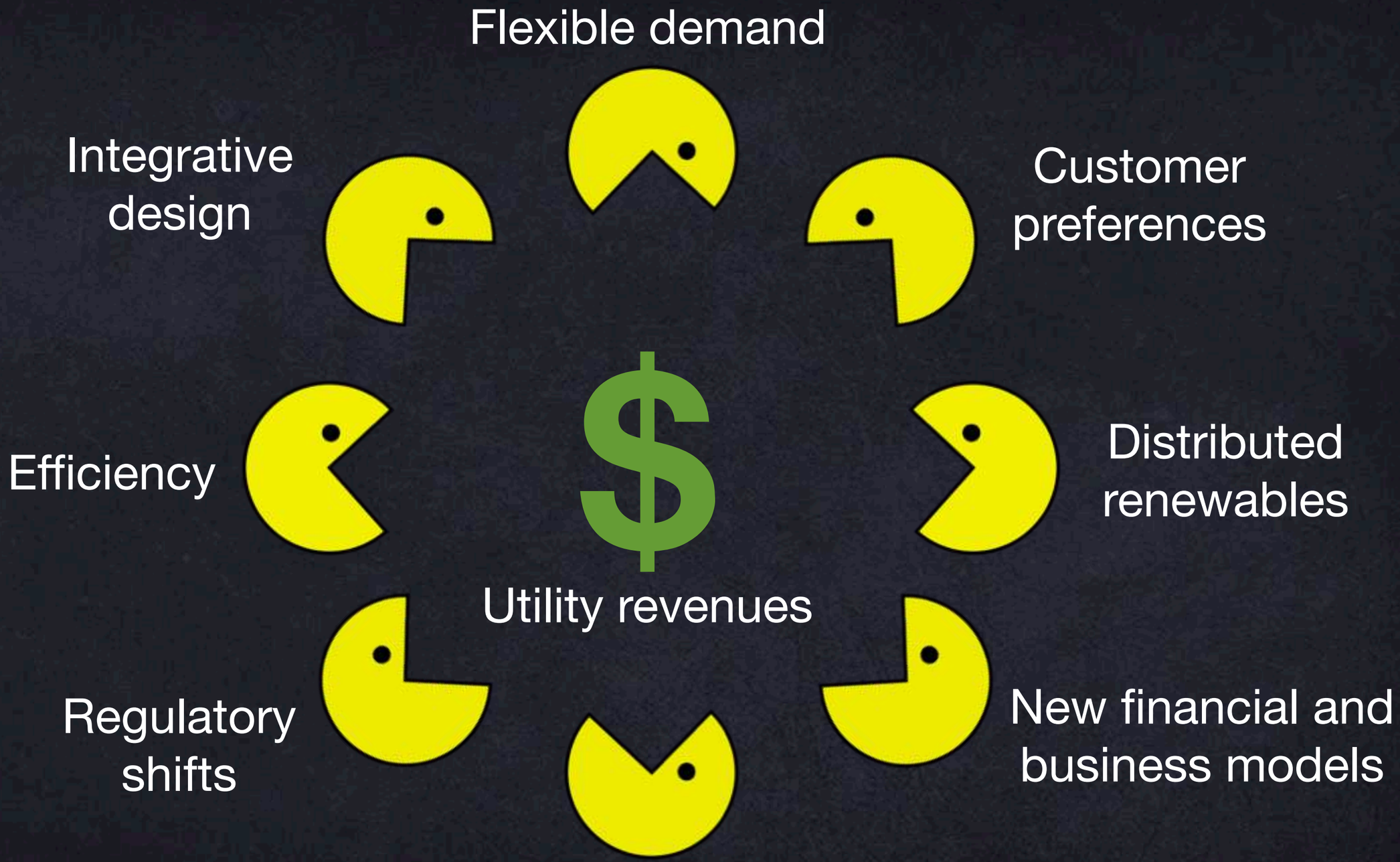

50
Energy units
-70%
Power Plant
-9%
Power Grid
-12%
Motor/Drivetrain
-55%
Pump/Throttle
-20%
Pipe
5%
Delivered flow

radically efficient industrial redesign


76

Netherlands: community connection




Flexible demand
Integrative design
Customer preferences
Efficiency
$
Distributed renewables
Utility revenues
Regulatory shifts
New financial and business models
Storage (including EVs)

Integrative design

Efficiency

Utility revenues

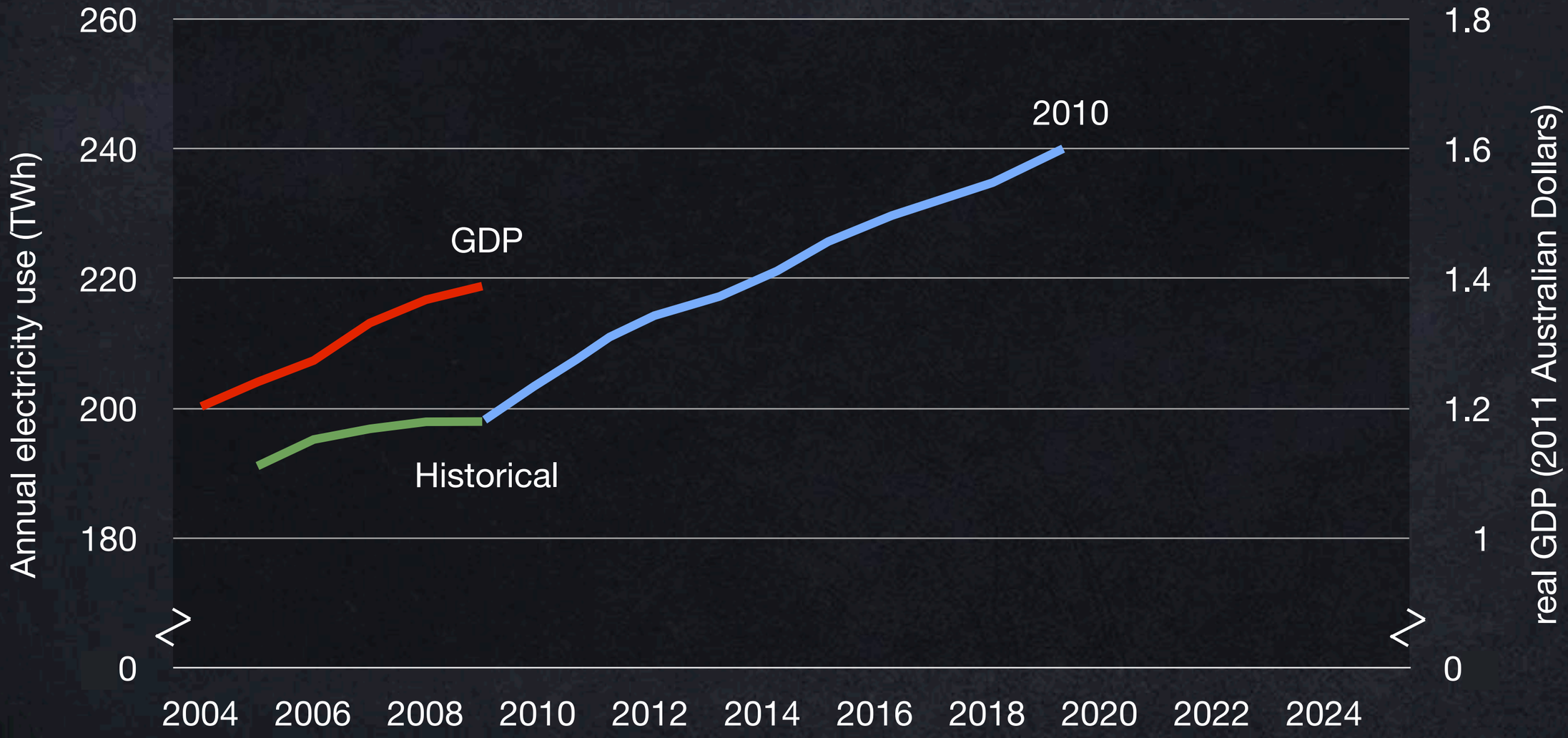
Australia national electricity market

Actual vs. forecast operational electricity demand

Source: M. Liebreich, keynote, Bloomberg New Energy Finance summit, April 2015; 2014–15

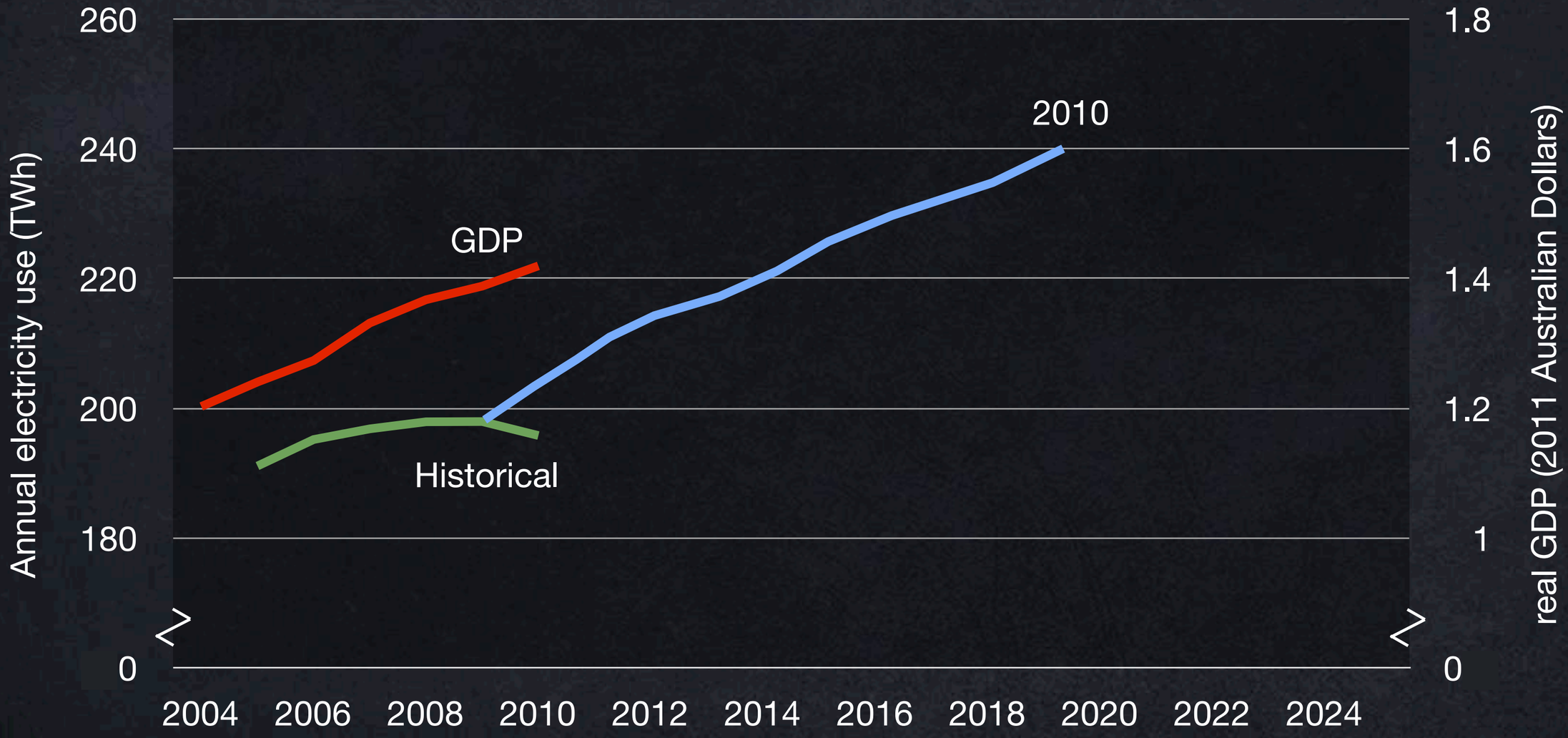
Australia national electricity market

Actual vs. forecast electricity demand



Australia national electricity market

Actual vs. forecast electricity demand



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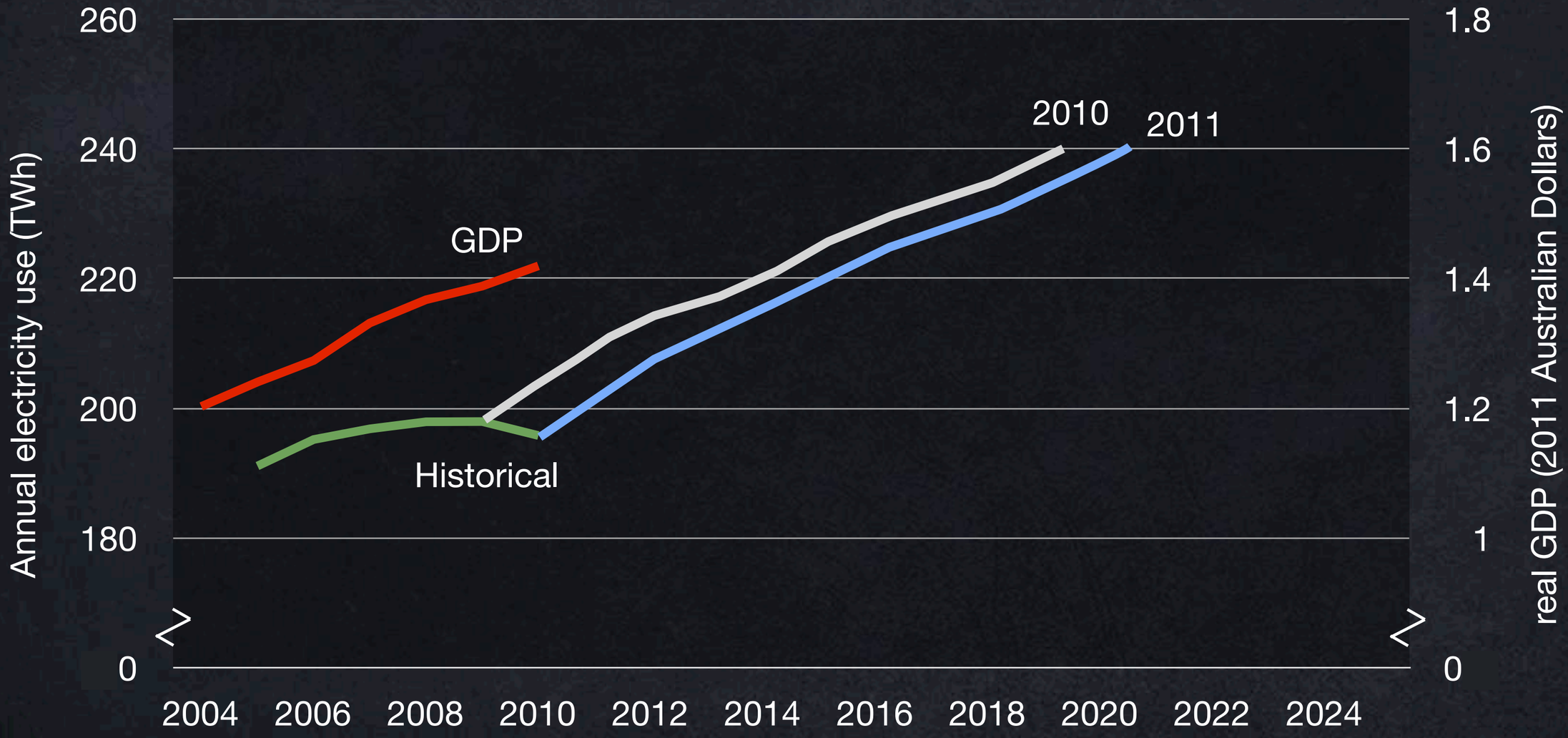

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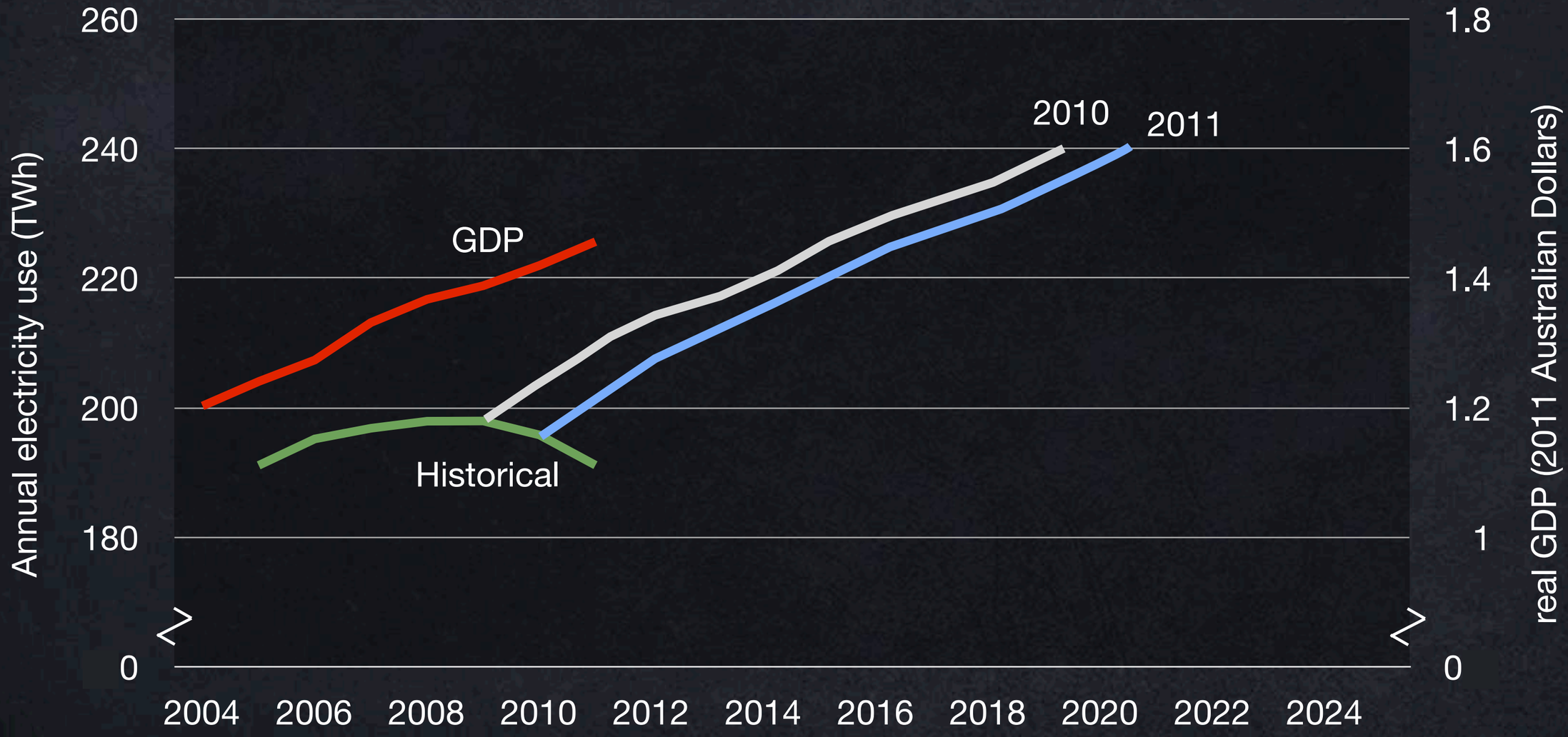

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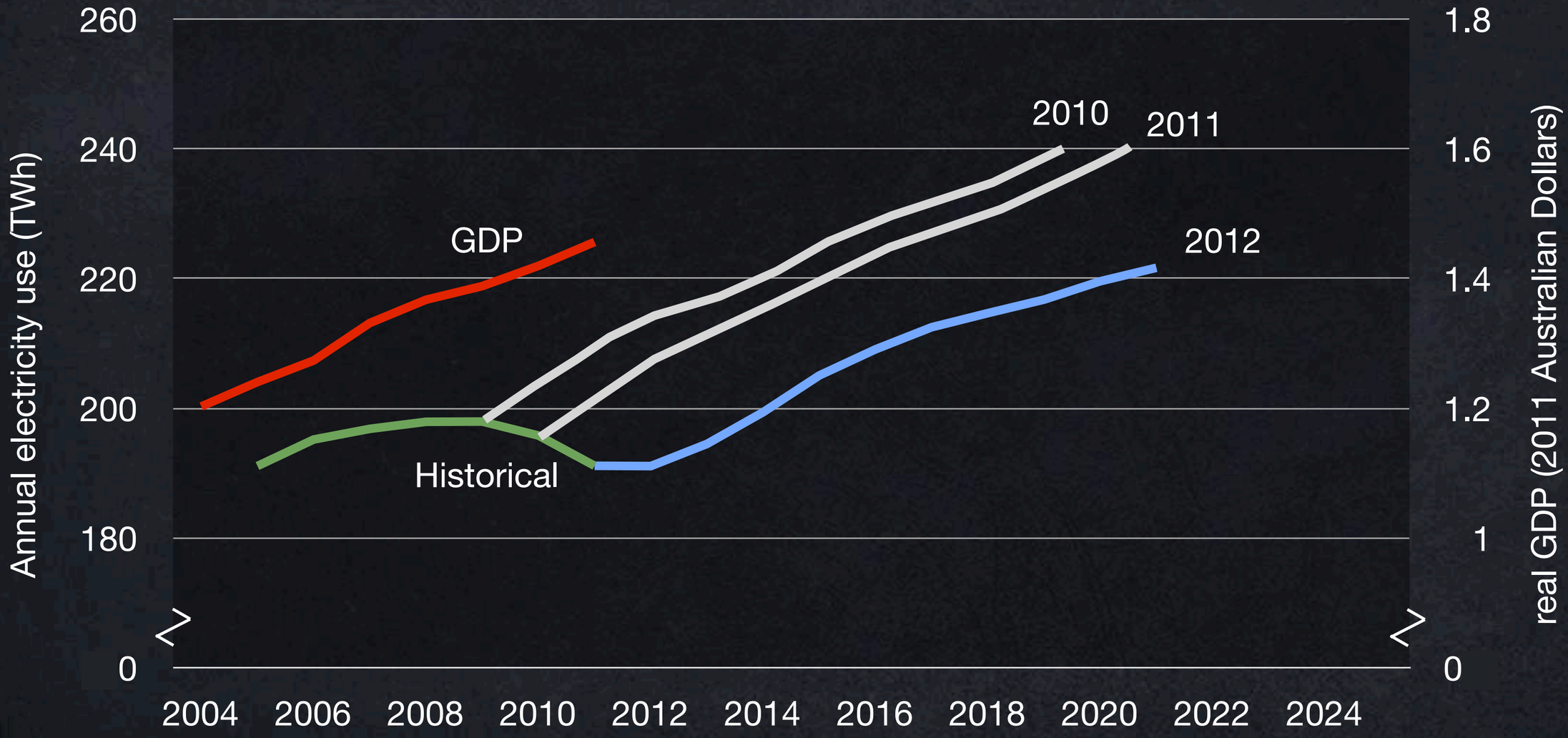

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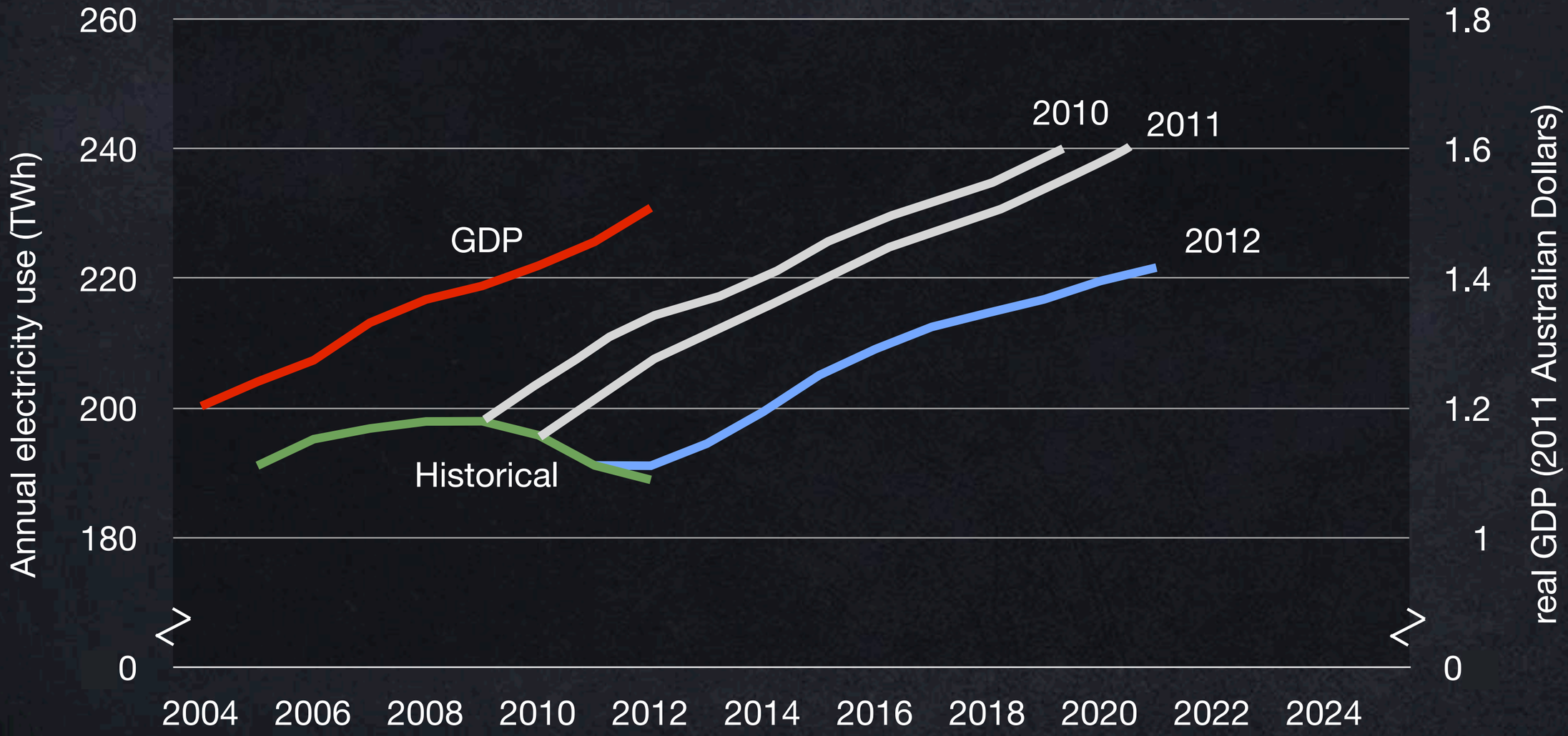
Actual vs. forecast electricity demand



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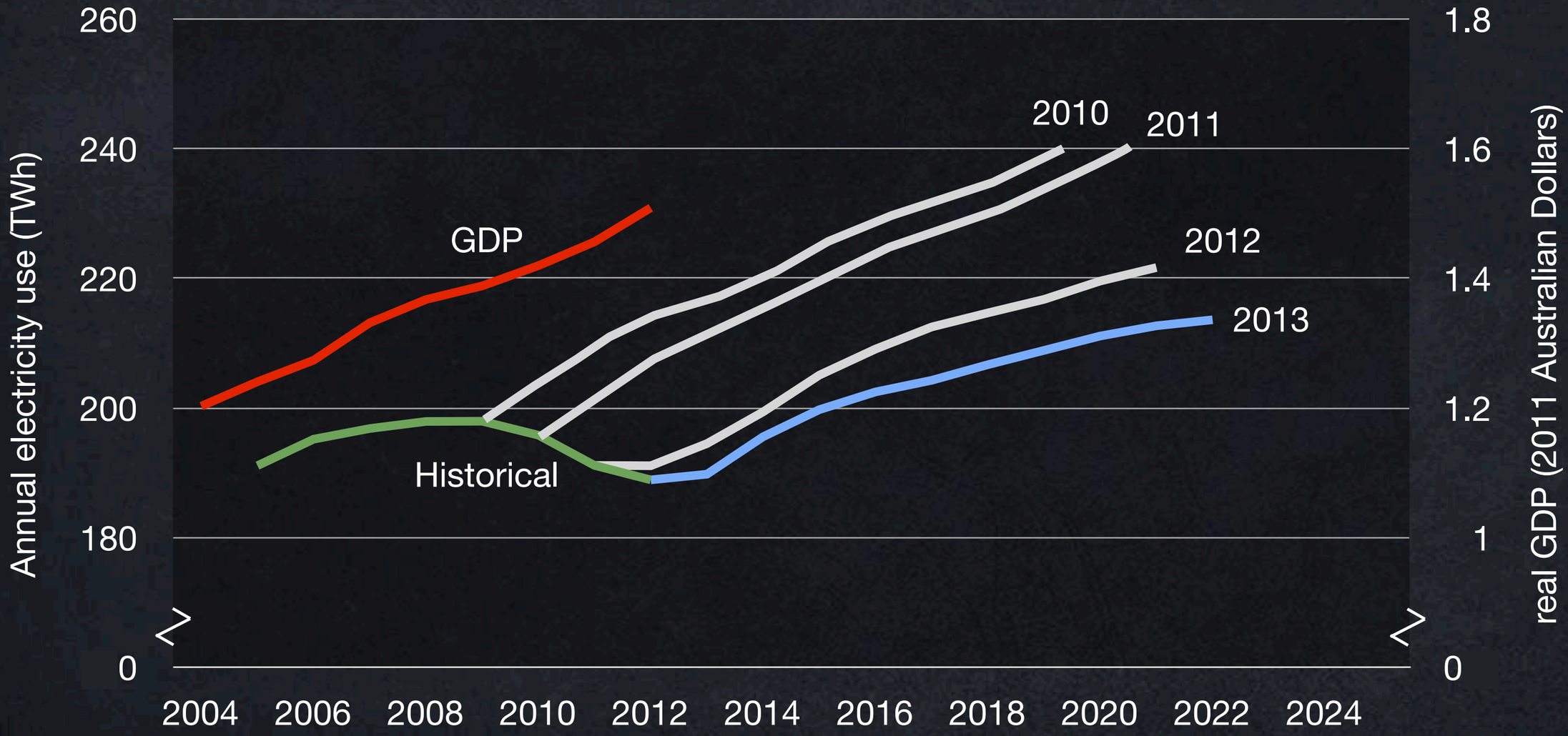

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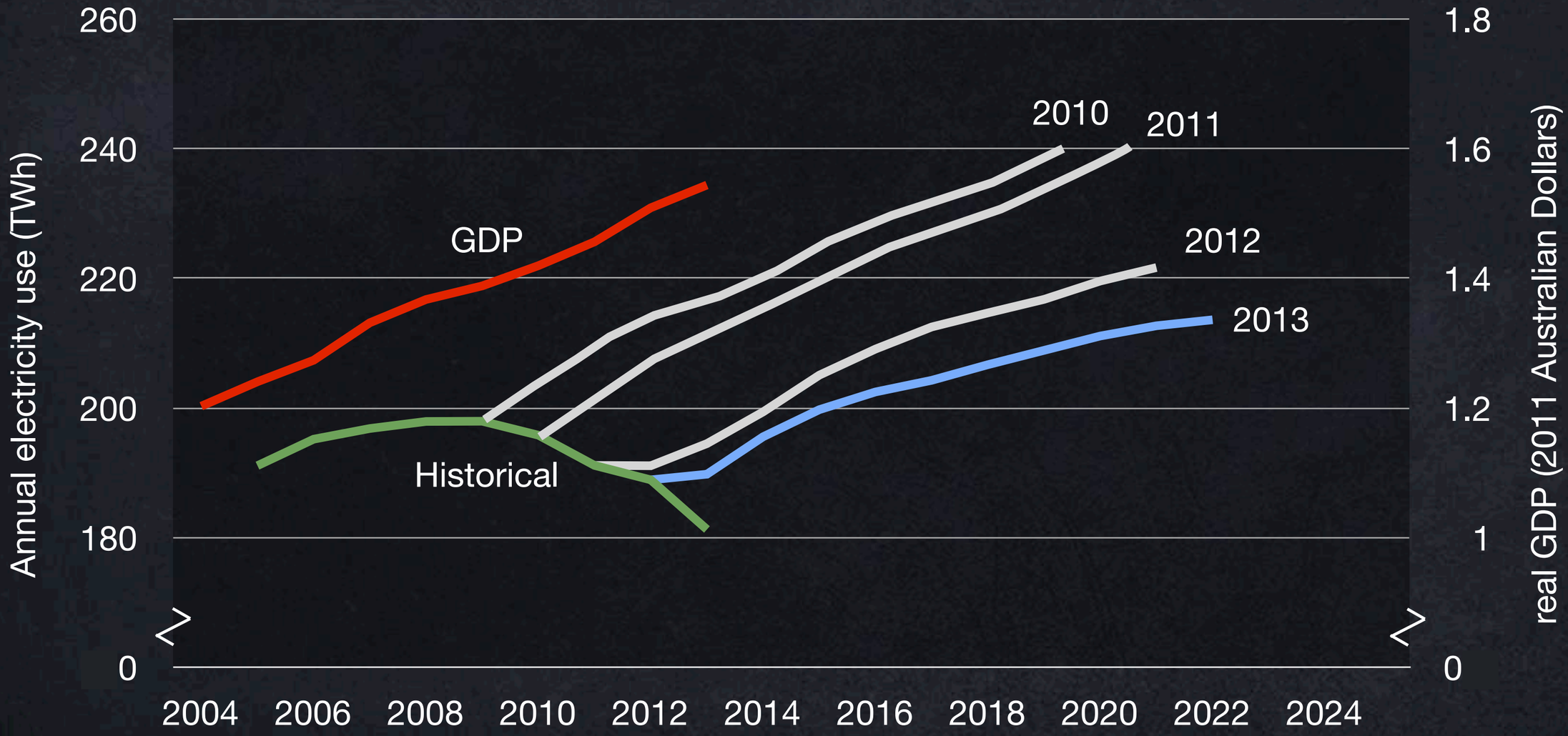
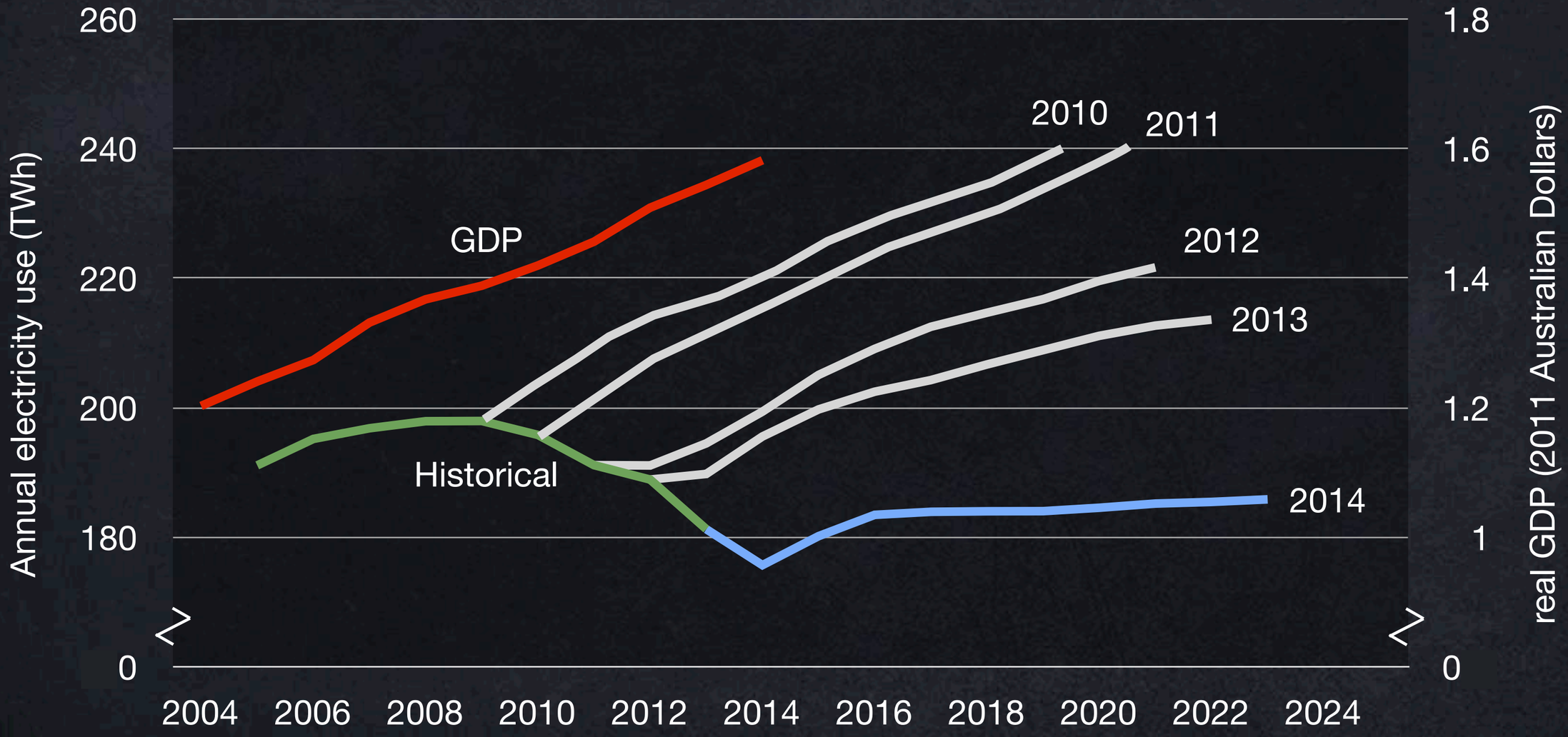
Actual vs. forecast electricity demand



Australia national electricity market

Actual vs. forecast electricity demand



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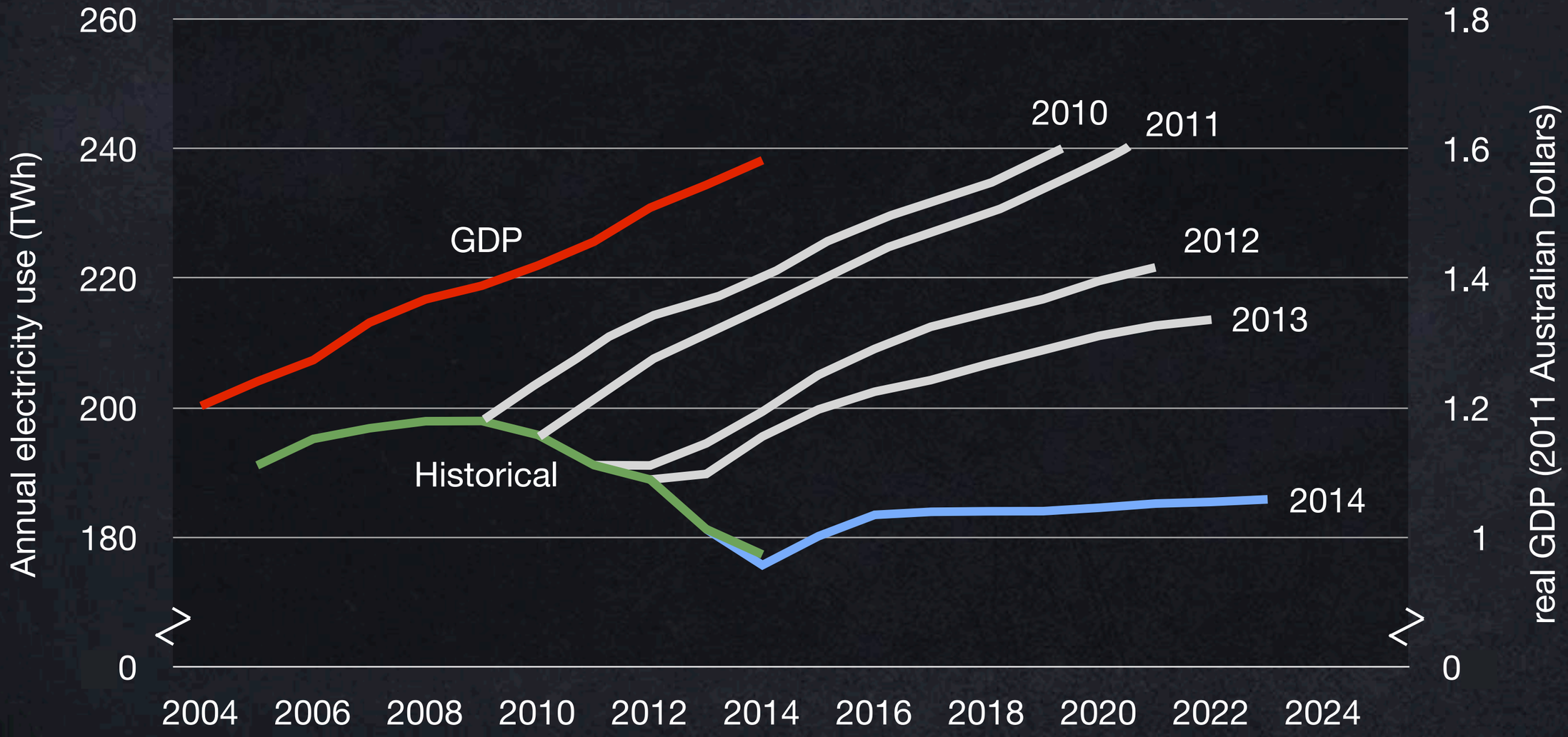

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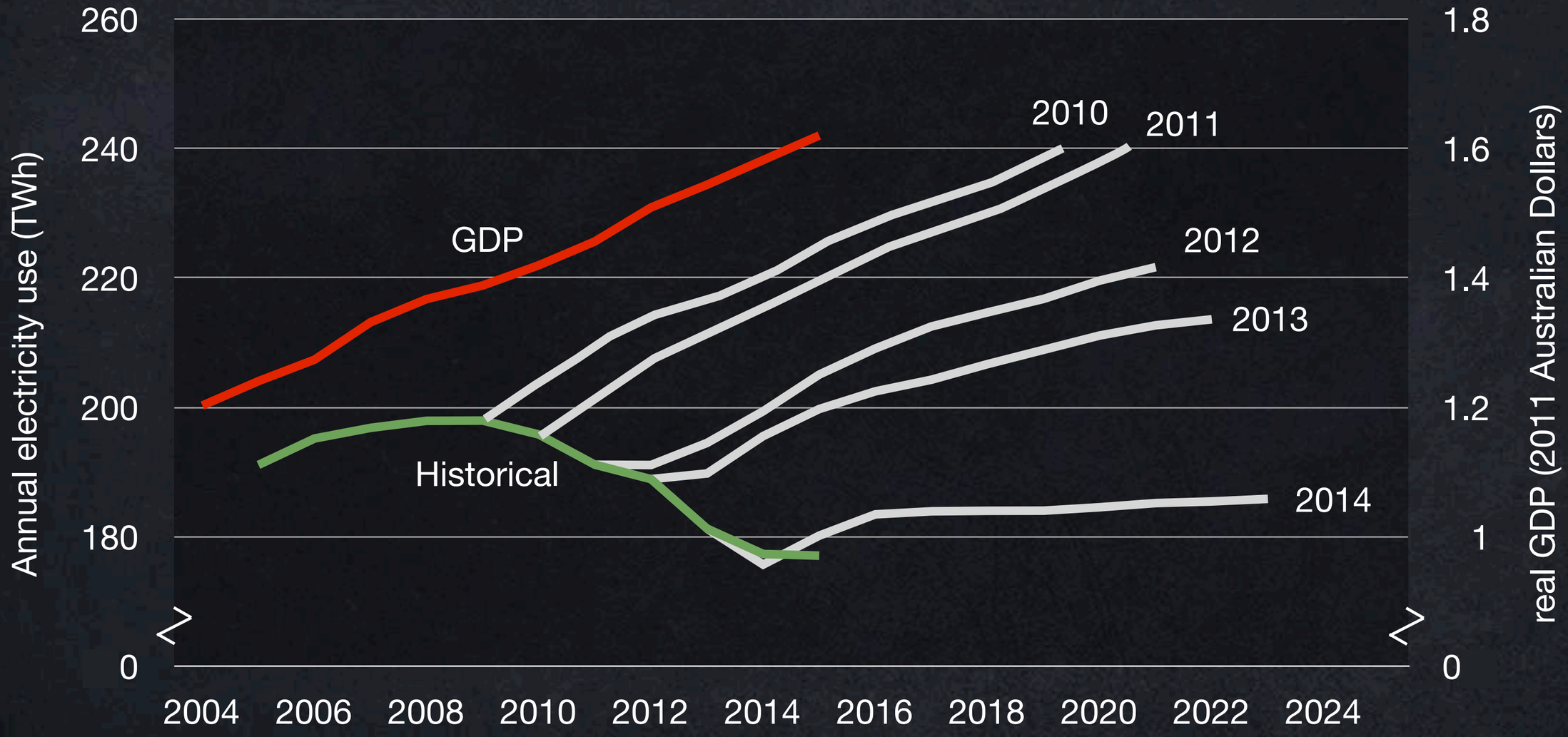


Flexible demand

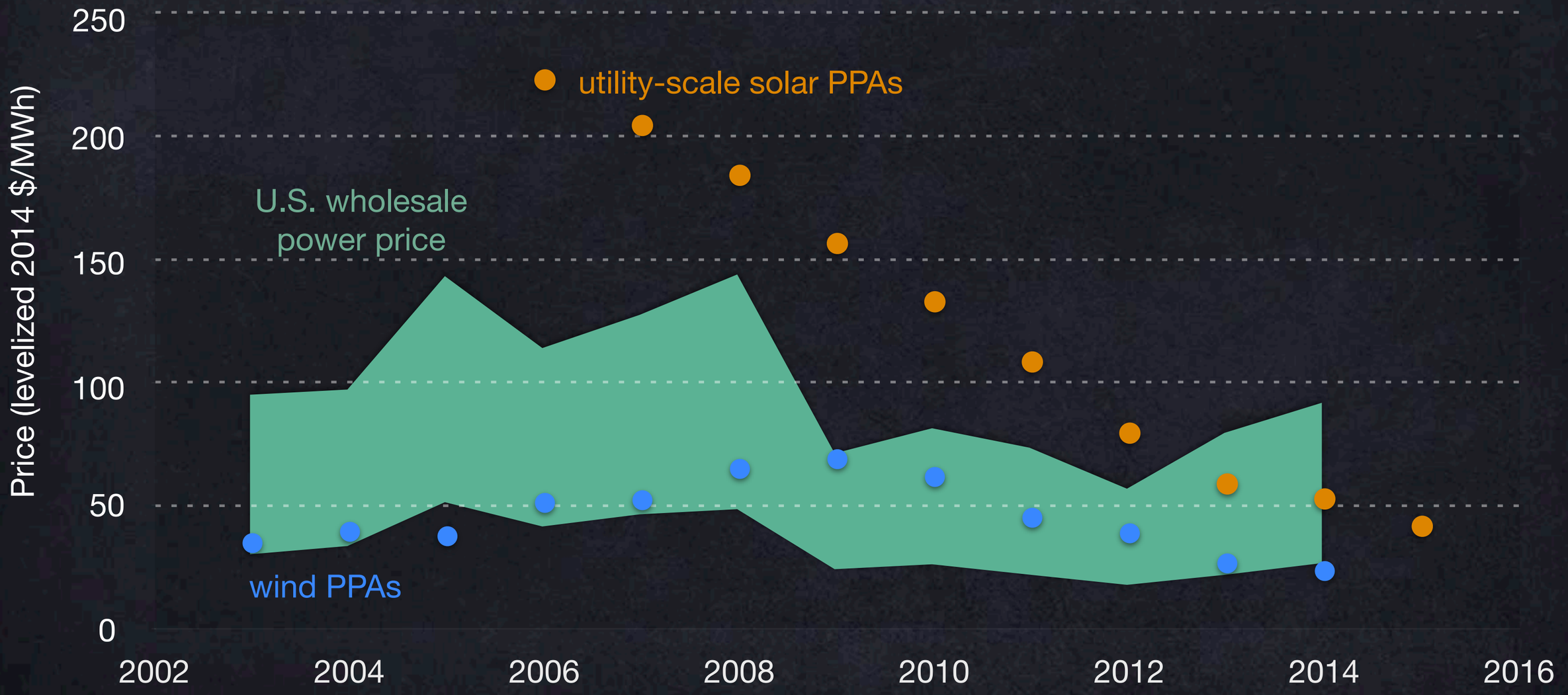
Utility revenues

Distributed renewables

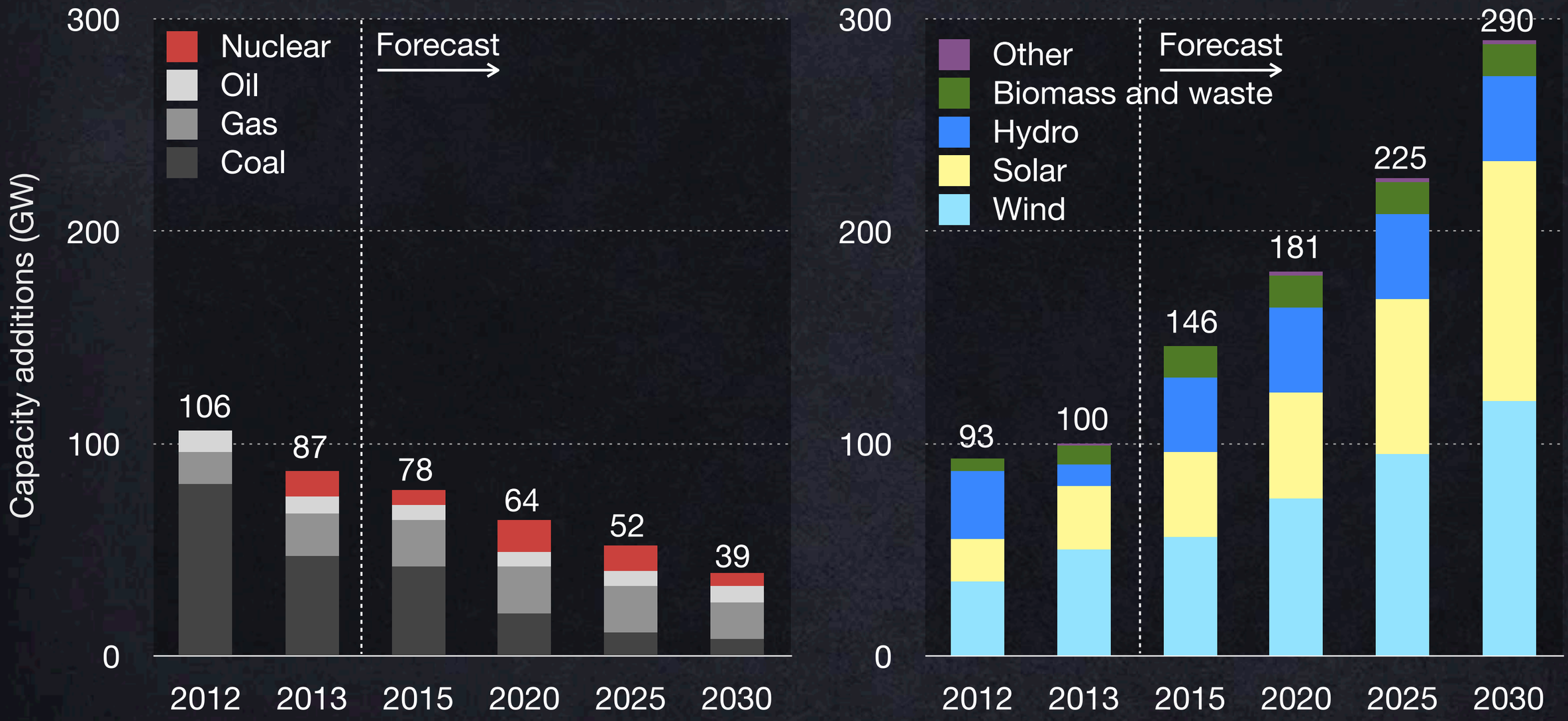
Storage (including EVs)

Renewable Energy's Costs Continue to Plummet

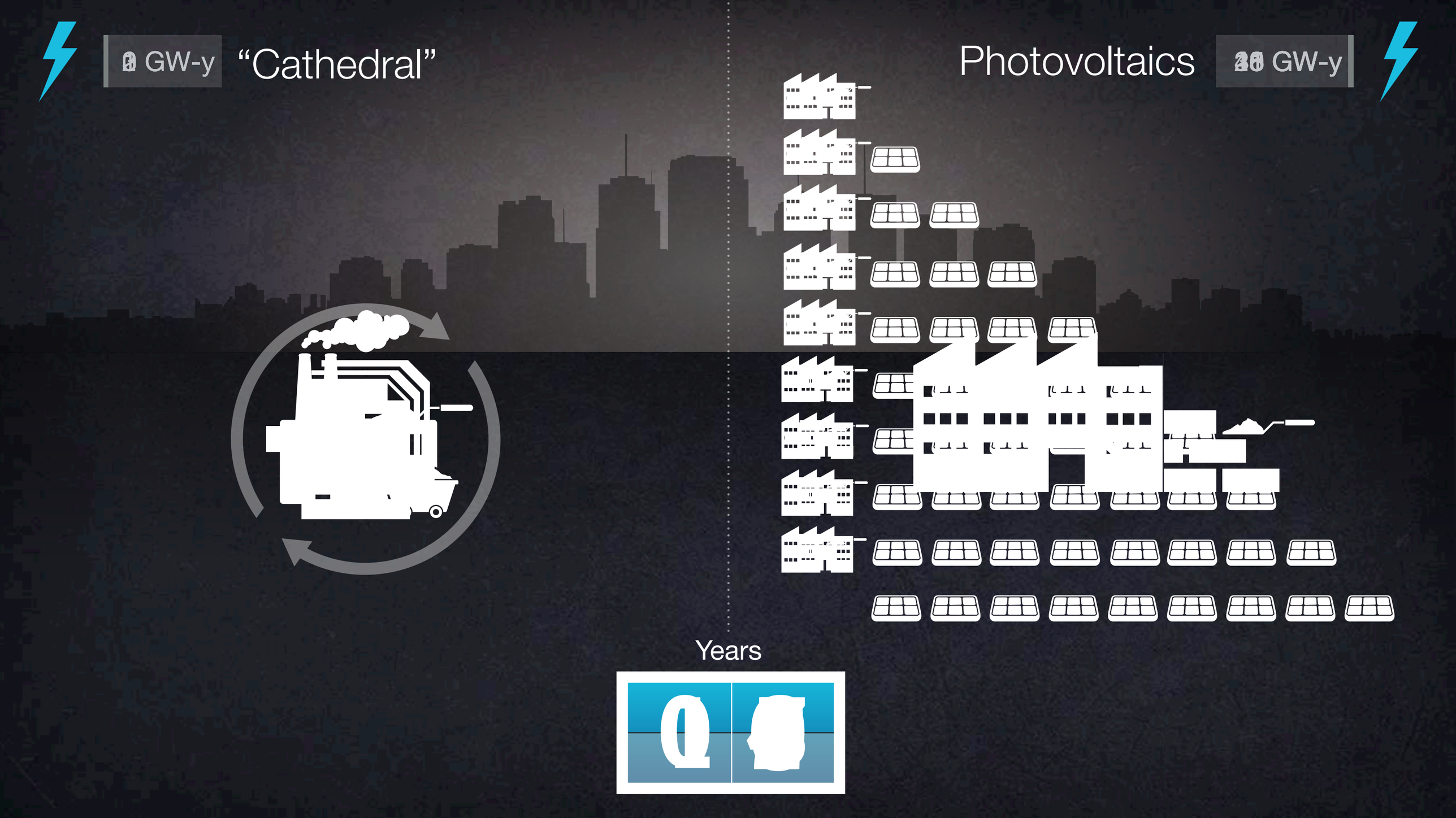
Wind and photovoltaics: U.S. generation-weighted-average Power Purchase Agreement prices, by year of signing

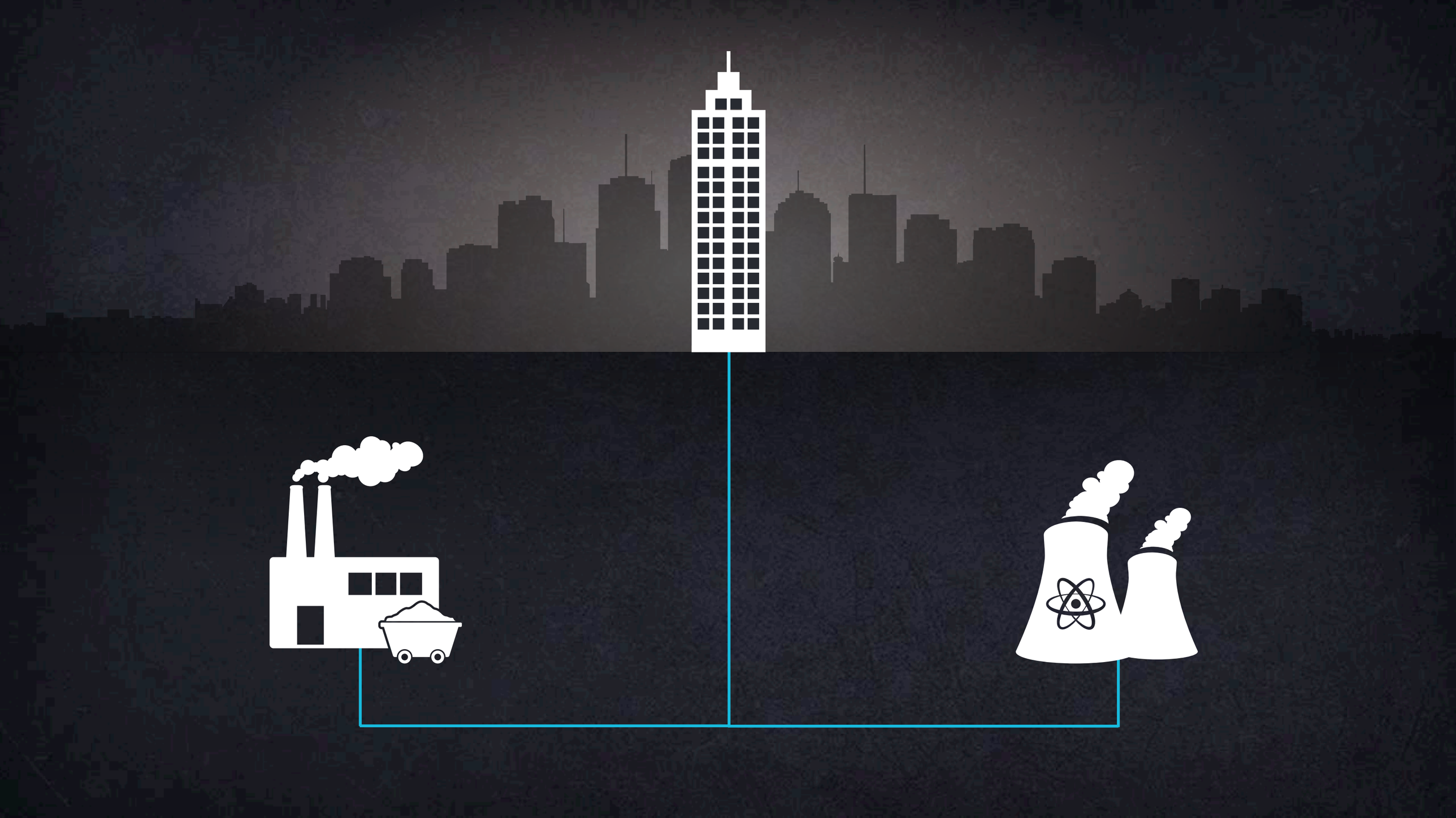


Global power generation capacity additions, 2012–30



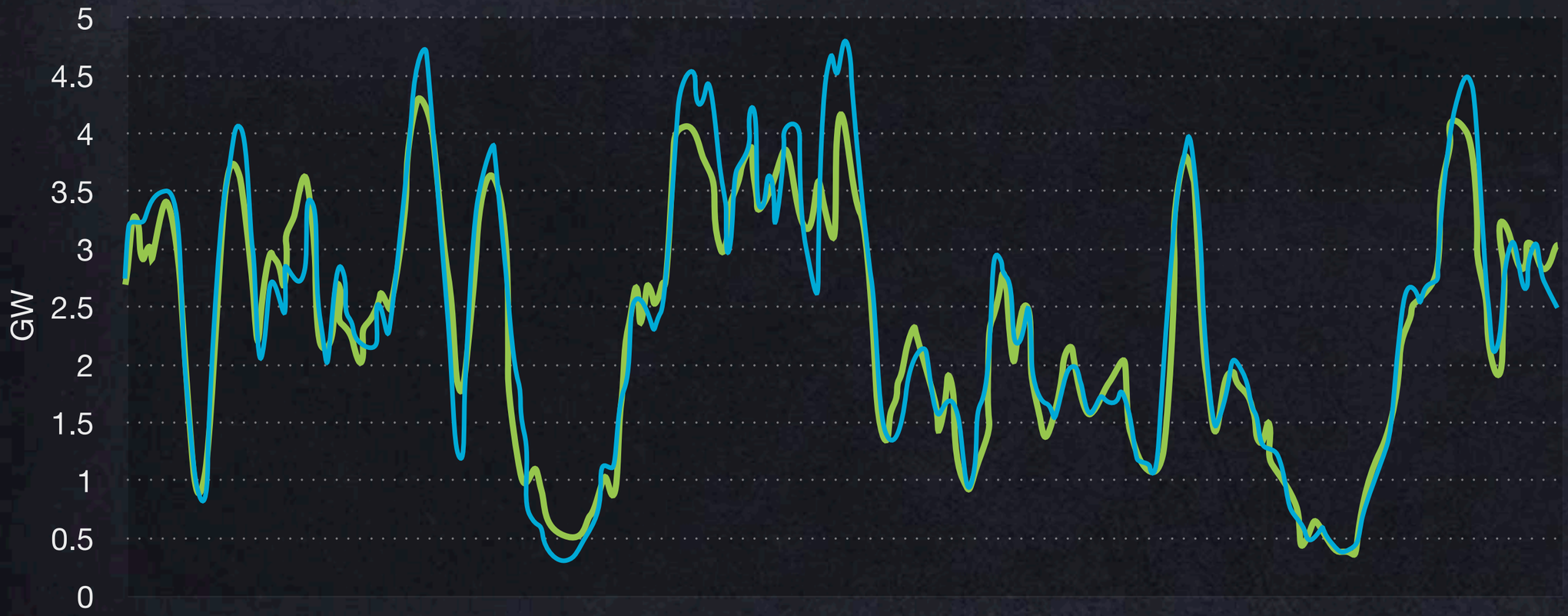
Source: Bloomberg New Energy Finance, redrawn from Michael Liebreich's Summit Keynote, 7 April 2014


GW-y
“Cathedral”
Photovoltaics
GW-y
Years

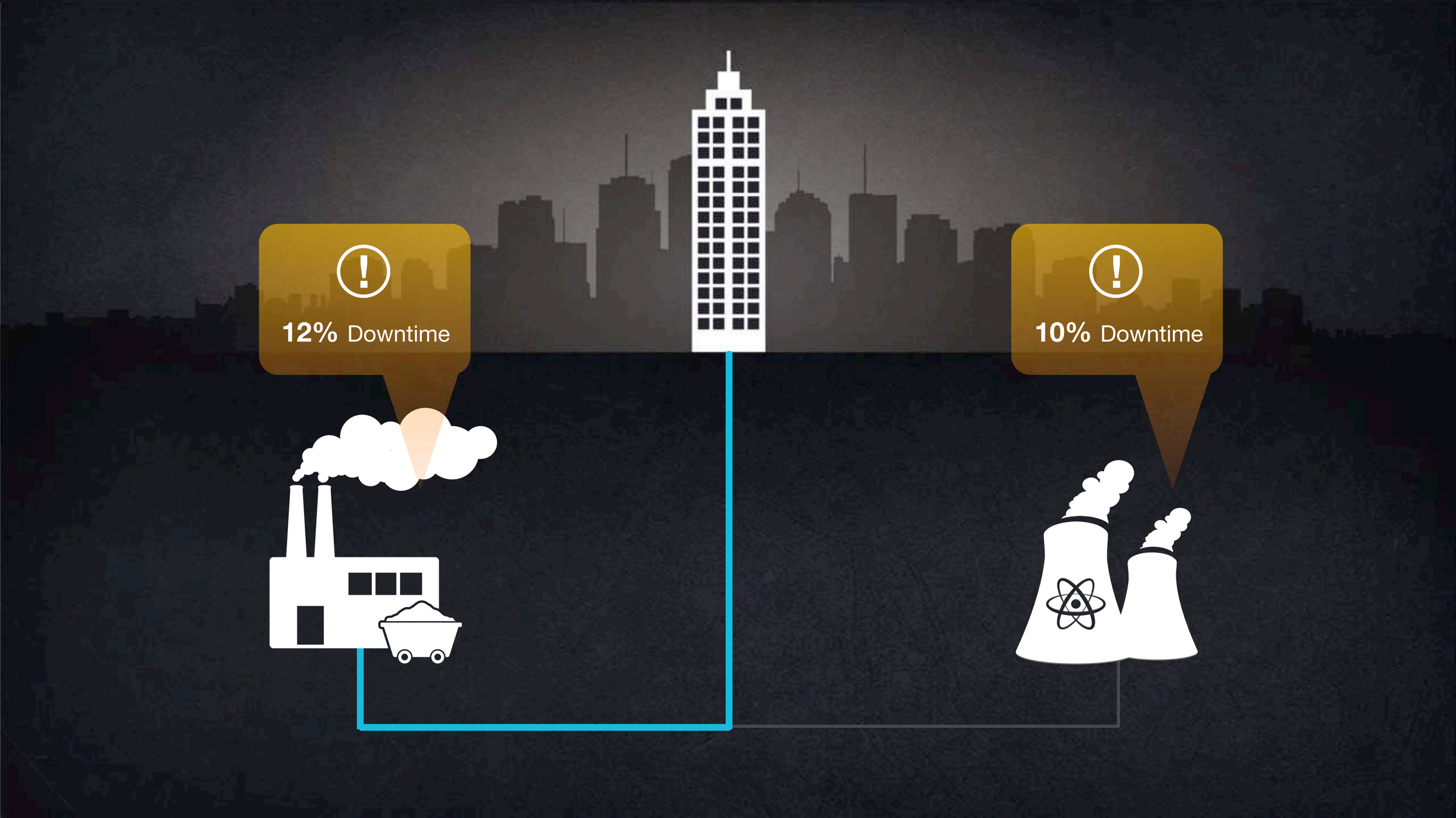


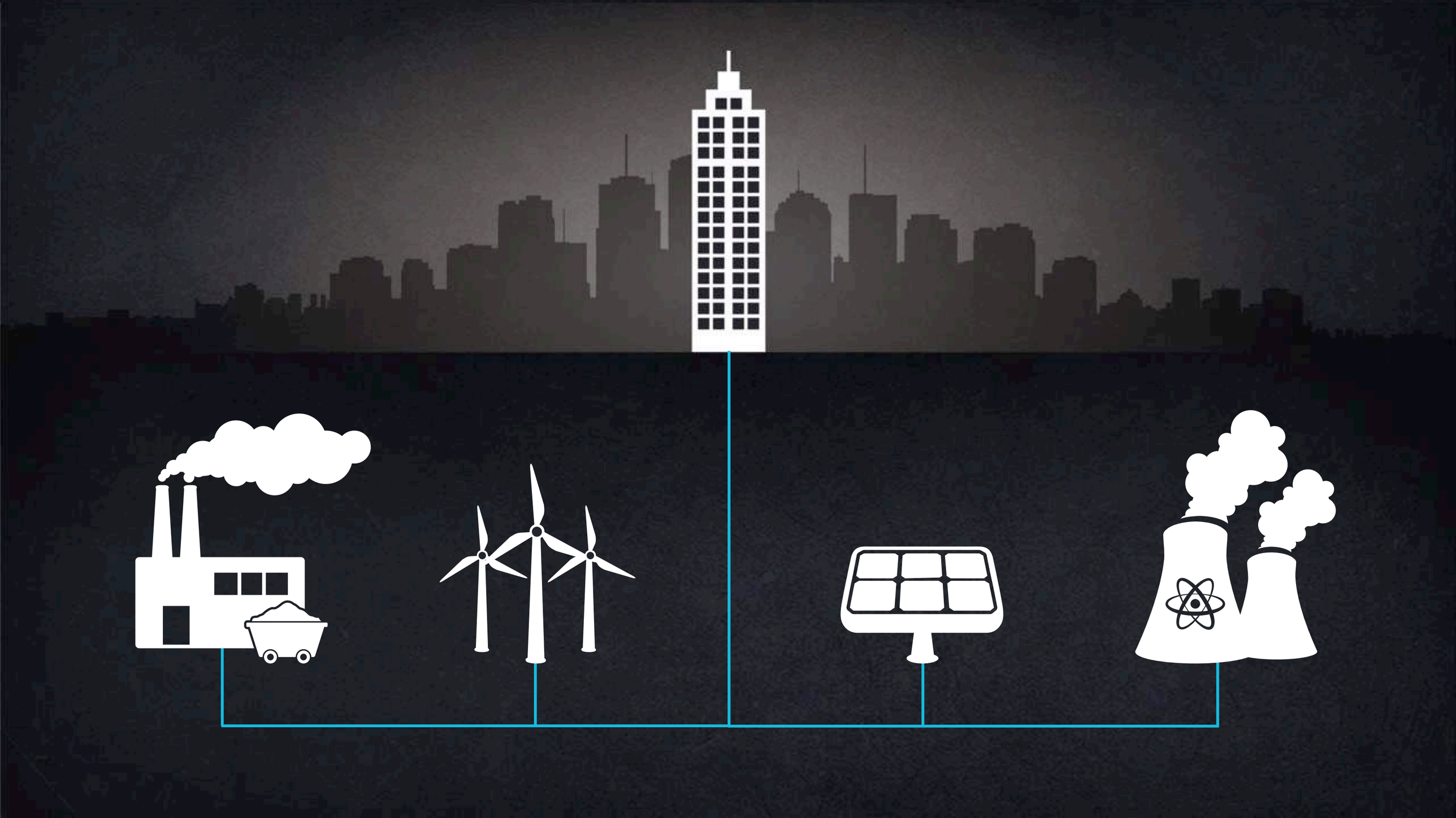
Variable Renewables Can Be Forecasted At Least as Accurately as Electricity Demand

French windpower output, December 2011: forecasted one day ahead vs. actual



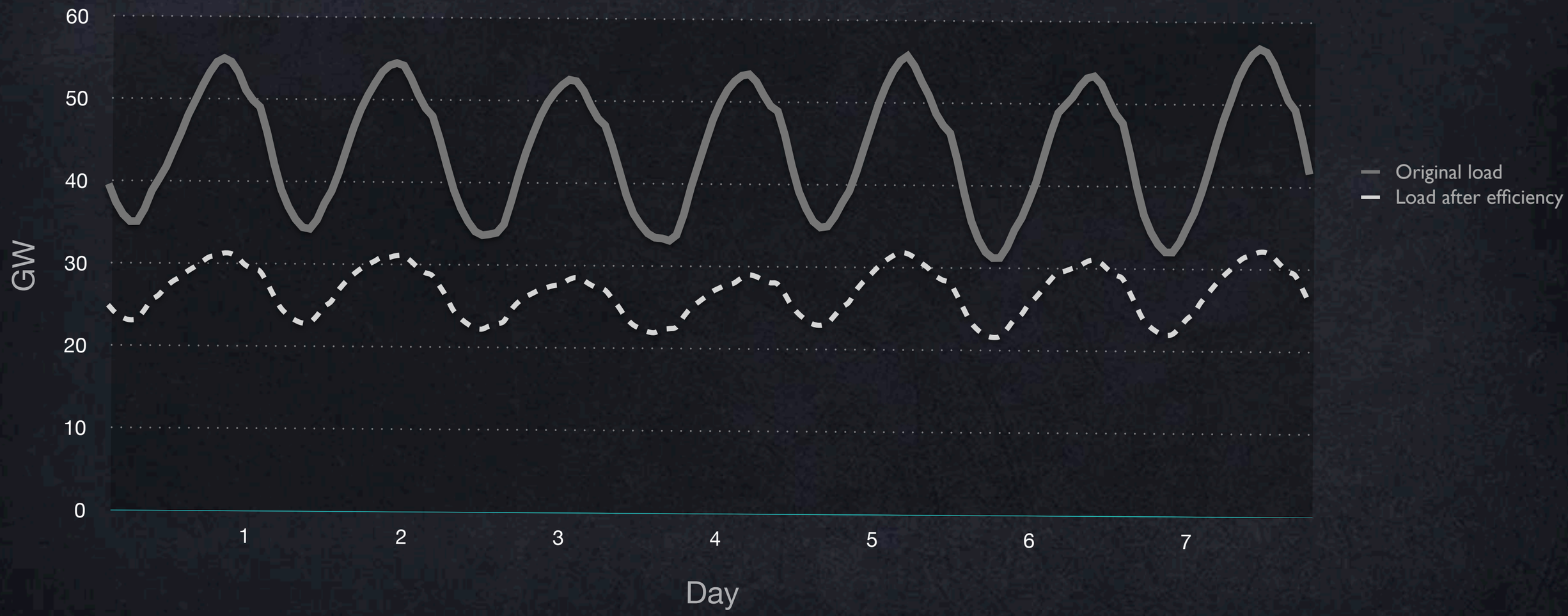
Source: Bernard Chabot, 10 April 2013, Fig. 7, www.renewablesinternational.net/wind-power-statistics-by-the-hour/150/505/61845/, data from French TSO RTE


12% Downtime
10% Downtime



Choreographing Variable Renewable Generation

ERCOT power pool, Texas summer week, 2050 (RMI hourly simulation)



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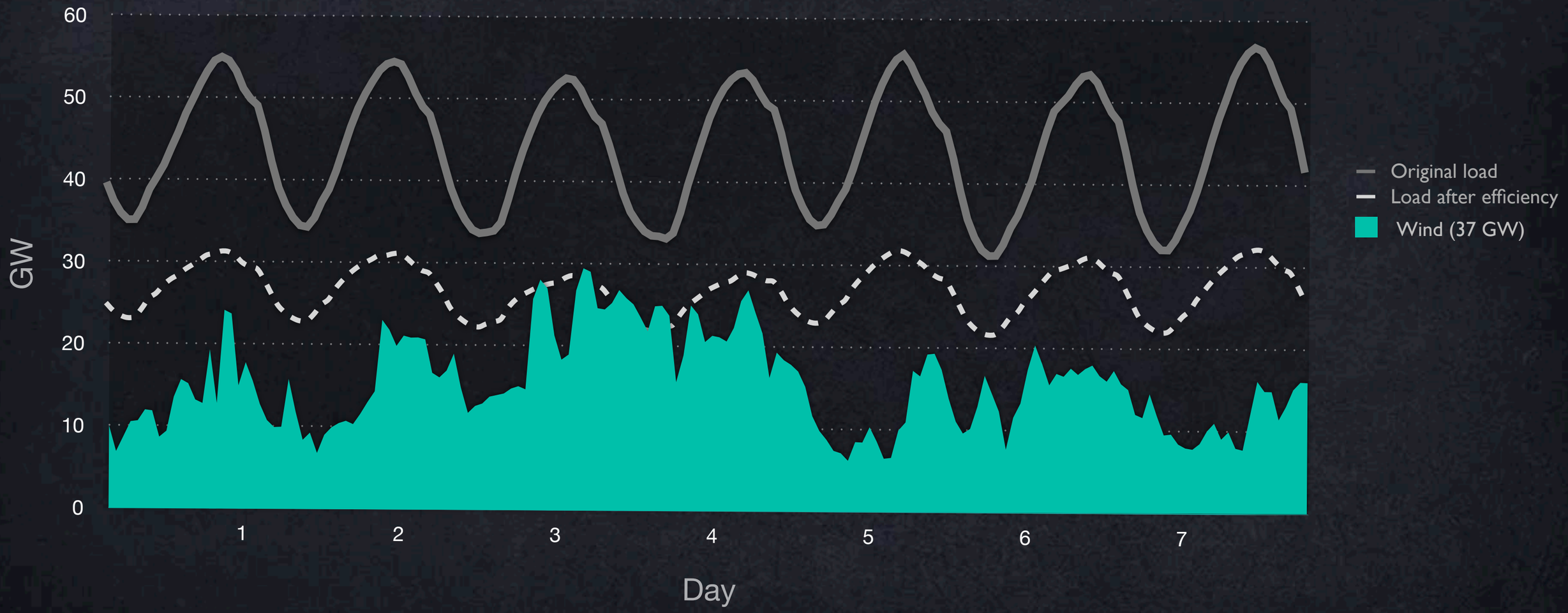

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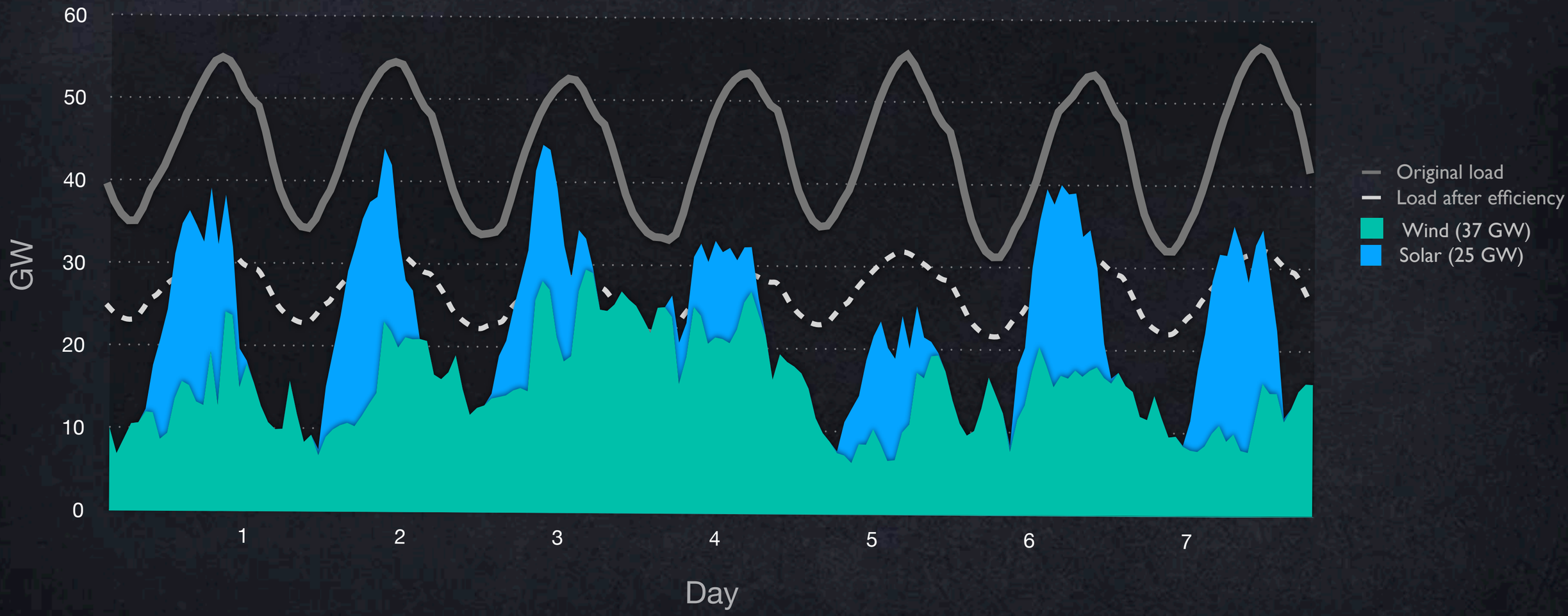

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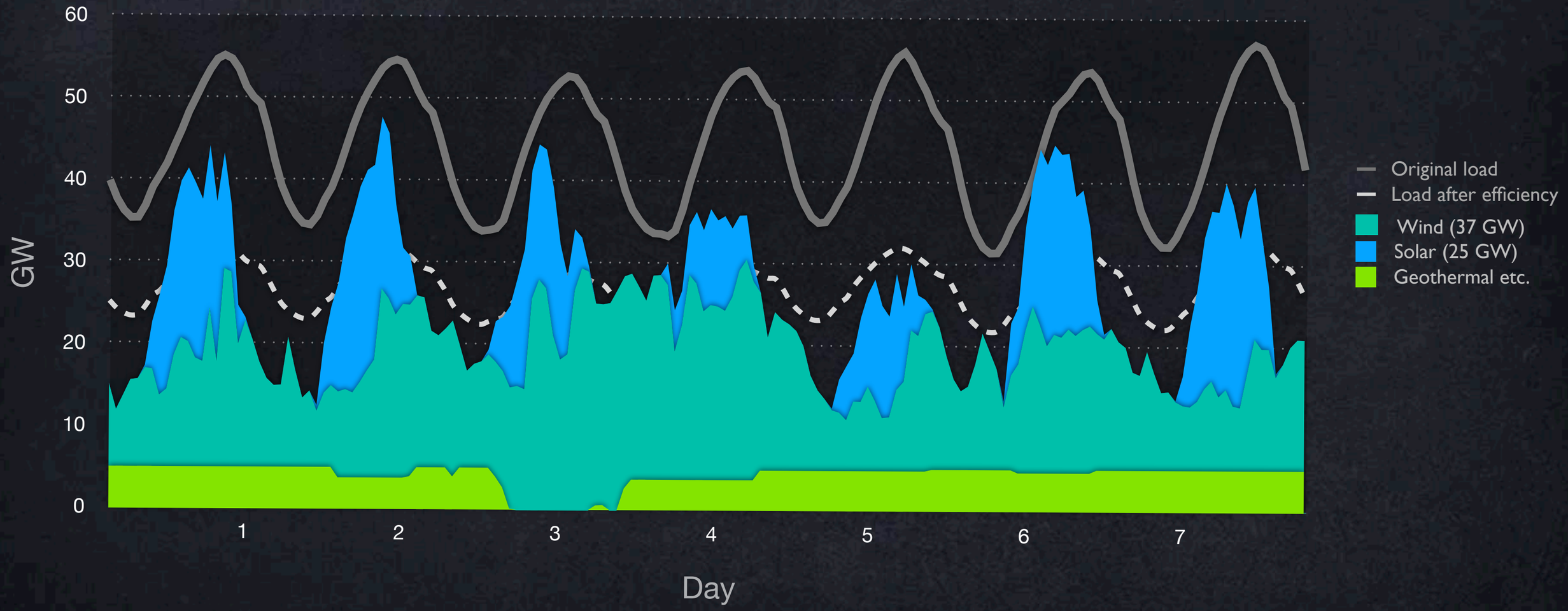

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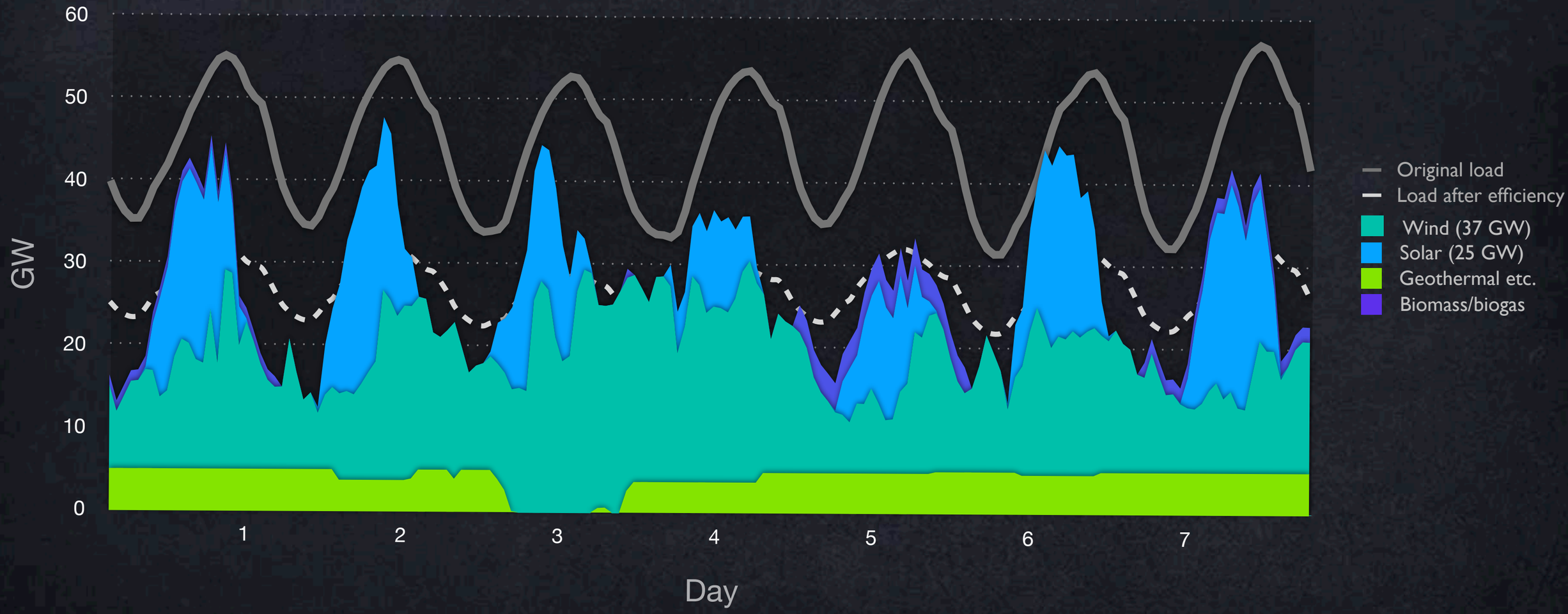

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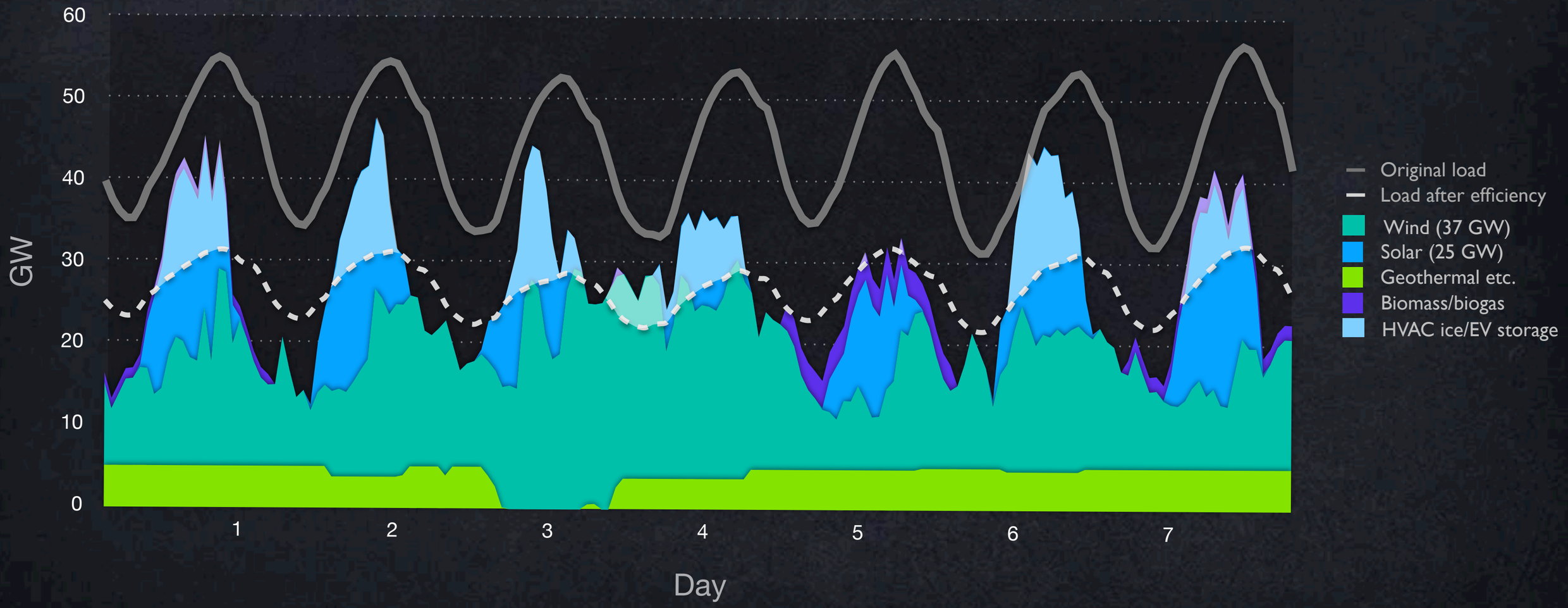

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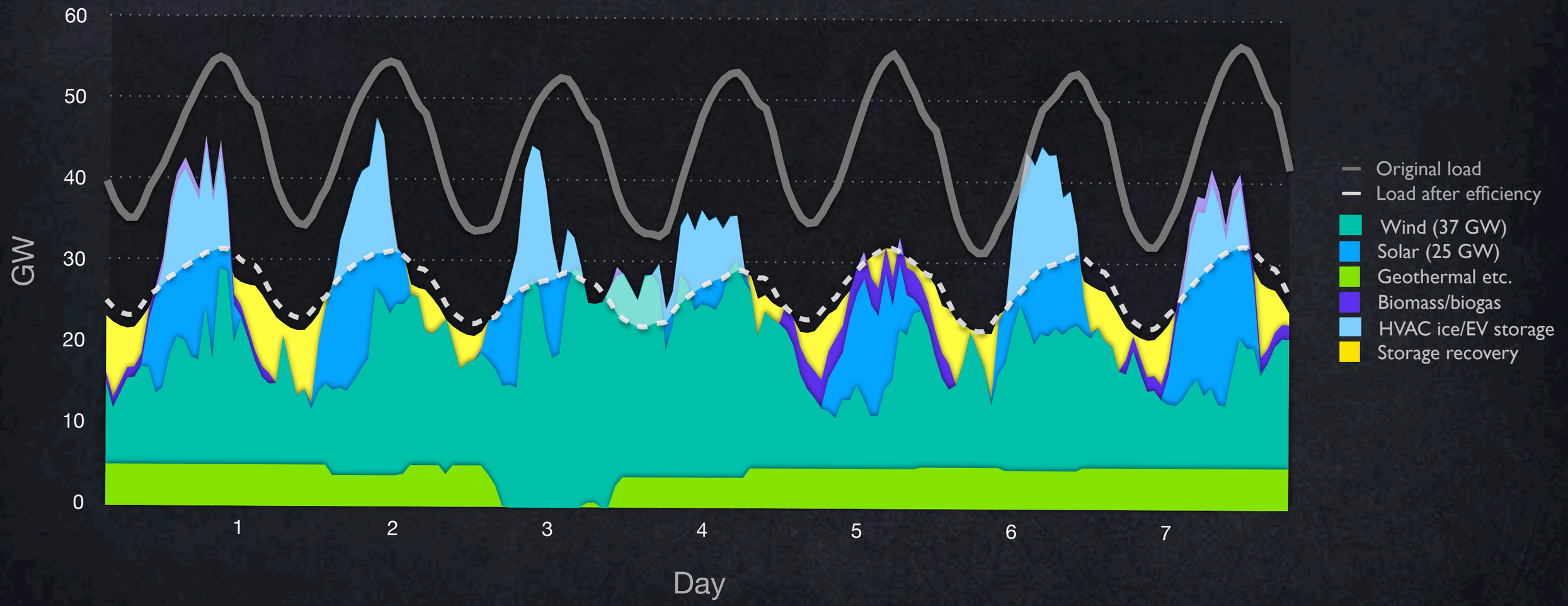

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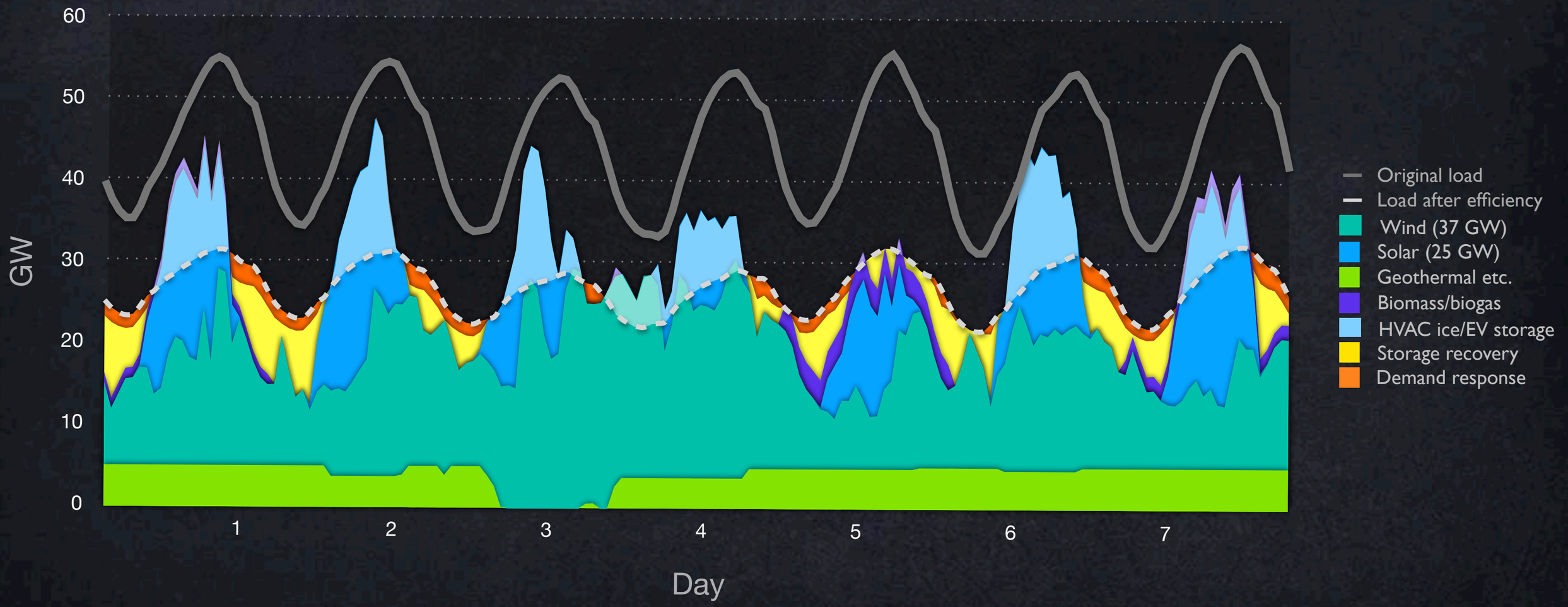

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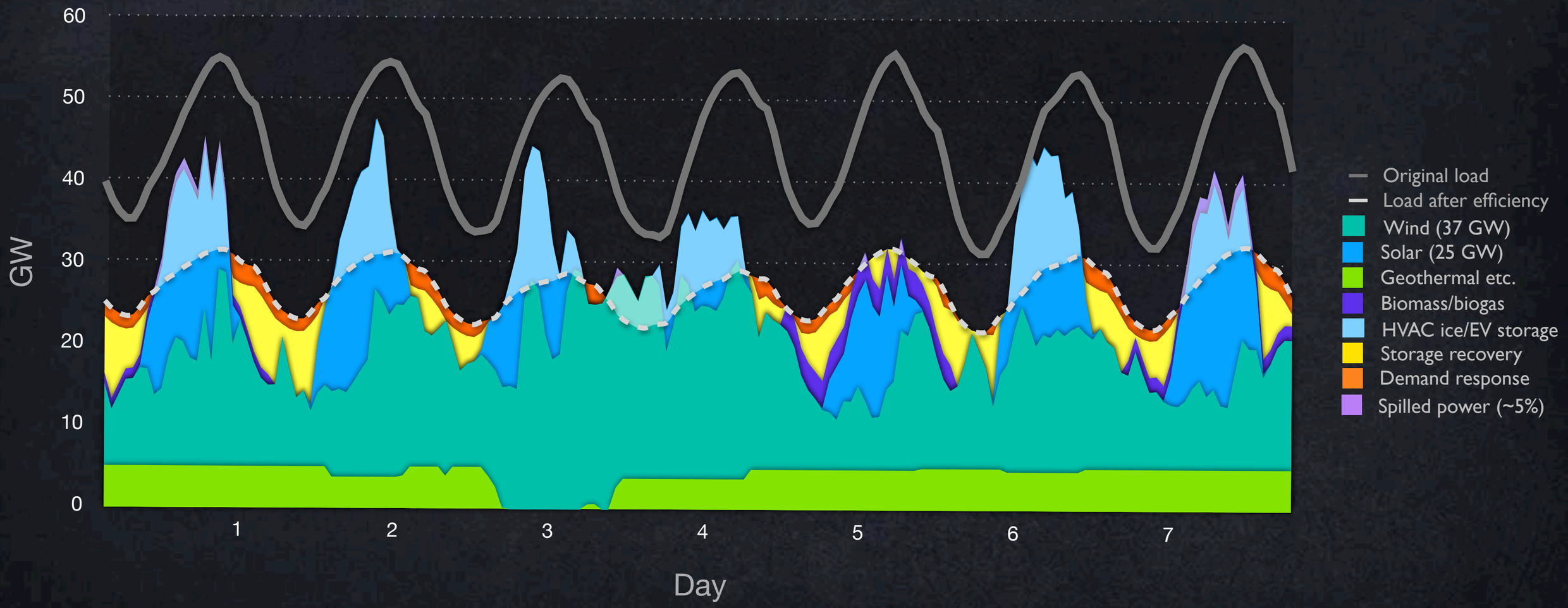
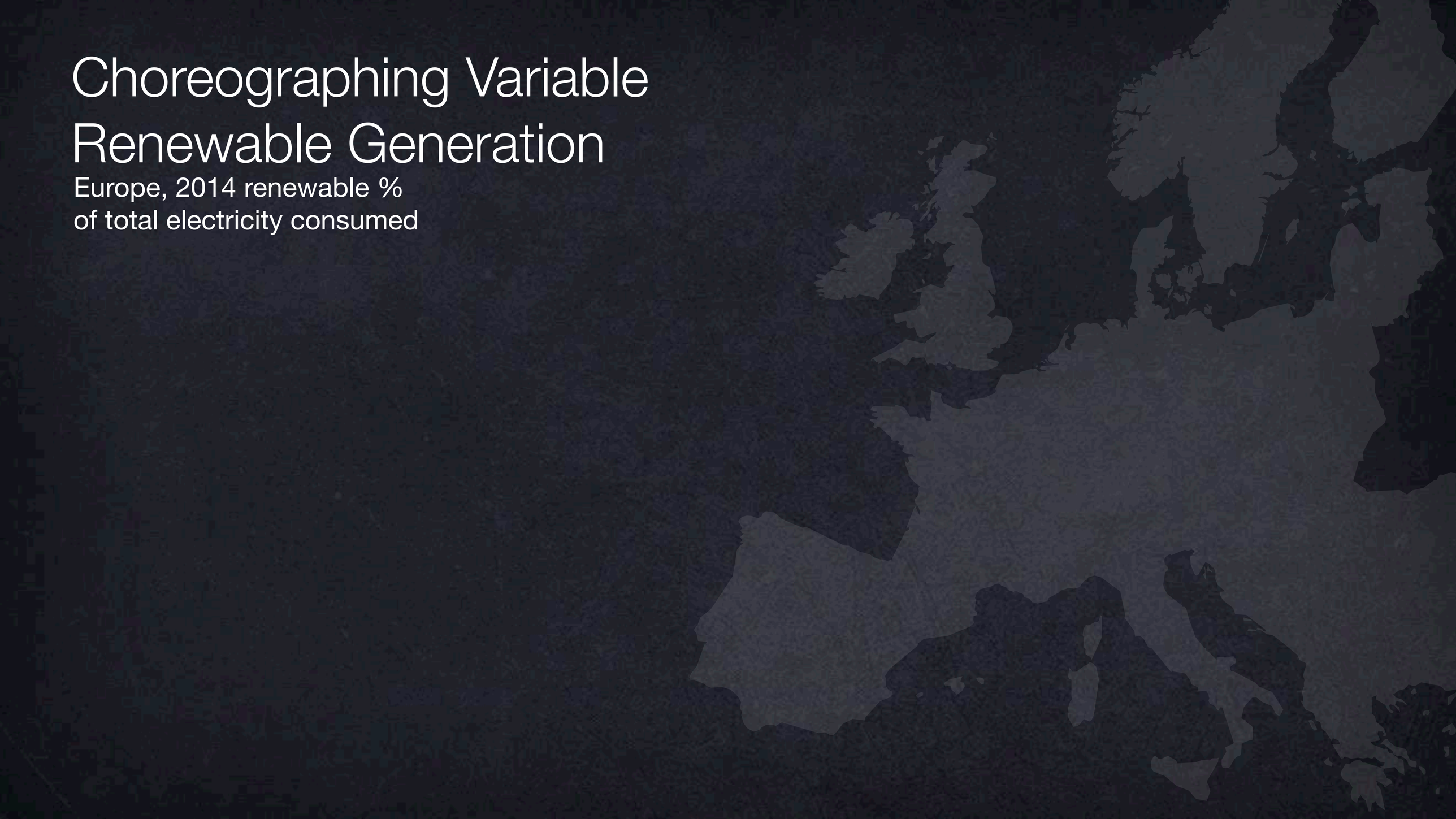


Choreographing Variable Renewable Generation

Europe, 2014 renewable %
of total electricity consumed



50%

Scotland

≥55%

Denmark (33% wind; 2013 windpower peak 136%—55% for all December)

27%

Germany (2013 peak 70%)

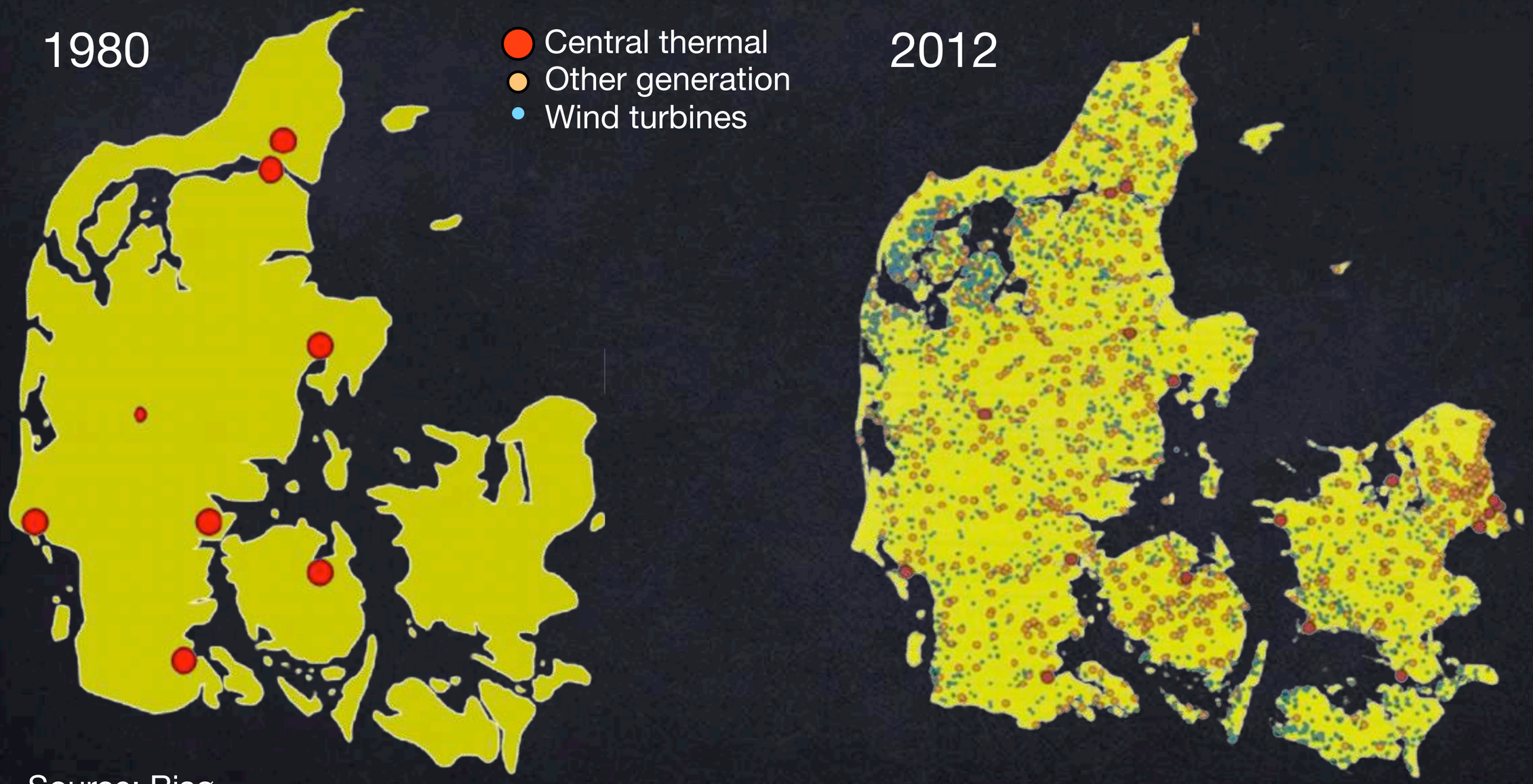
64%

Portugal (peak 100% in 2011; 70% for the whole first half of 2013, incl, 26% wind & 34% hydro; 17% in 2005)

46%

Spain (including 21% wind, 14% hydro, 5% solar)

Denmark’s transition to distributed electricity, 1980–2012



Source: Risø

Customer preferences

$

Utility revenues

Cascading blackouts threaten security

New Jersey, United States: resilience

Costs

Risks

India: air, reliable electricity, and development

Beijing, China: air

Germany: prosperity, climate, democracy

www.earthzine.org/wp-content/uploads/2013/08/solar-power.jpg

Stephen Glassman, https://stevenglassman.files.wordpress.com/2014/07/ballooning-10.jpg

Stork near Schöneck, Frank Rumpenhorst/EPA, www.theguardian.com/environment/gallery/2014/may/02/the-beauty-of-windfarms-in-pictures

Hawai‘i, United States: affordability and independence

Flexible demand

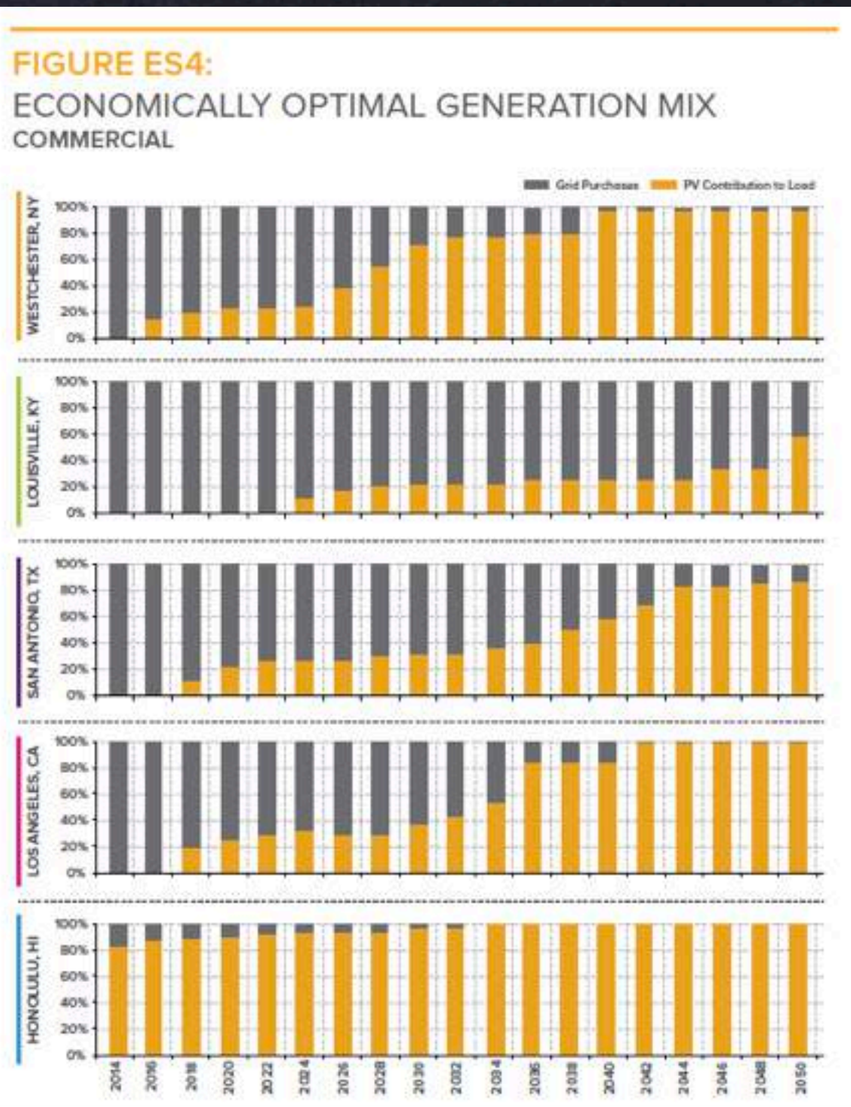
Utility revenues

Distributed renewables

Storage (including EVs)

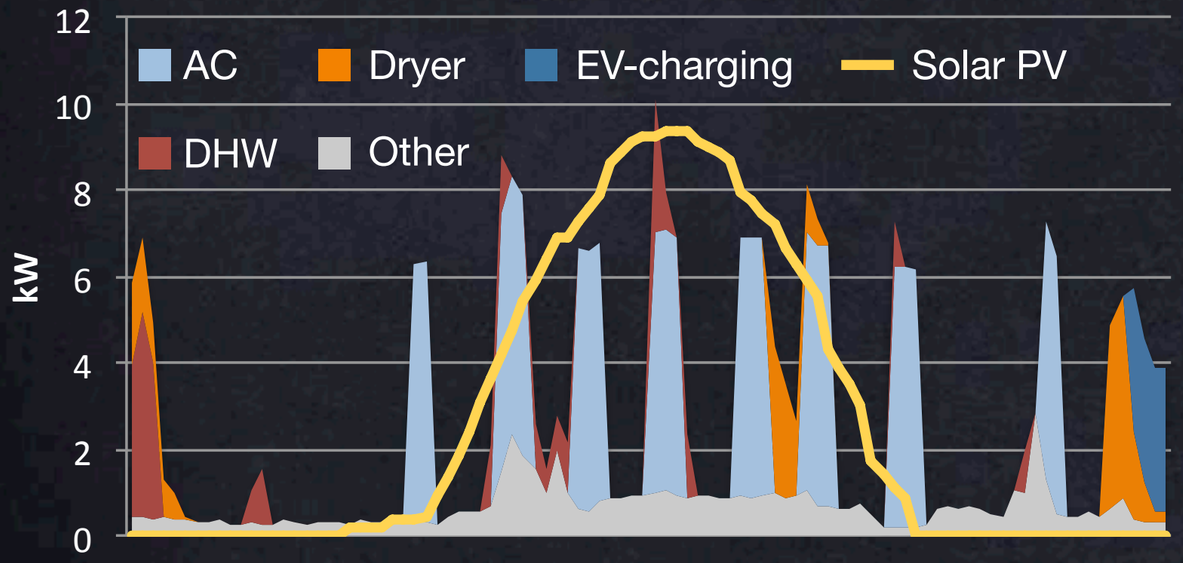
Cheaper renewables *and* batteries change the game

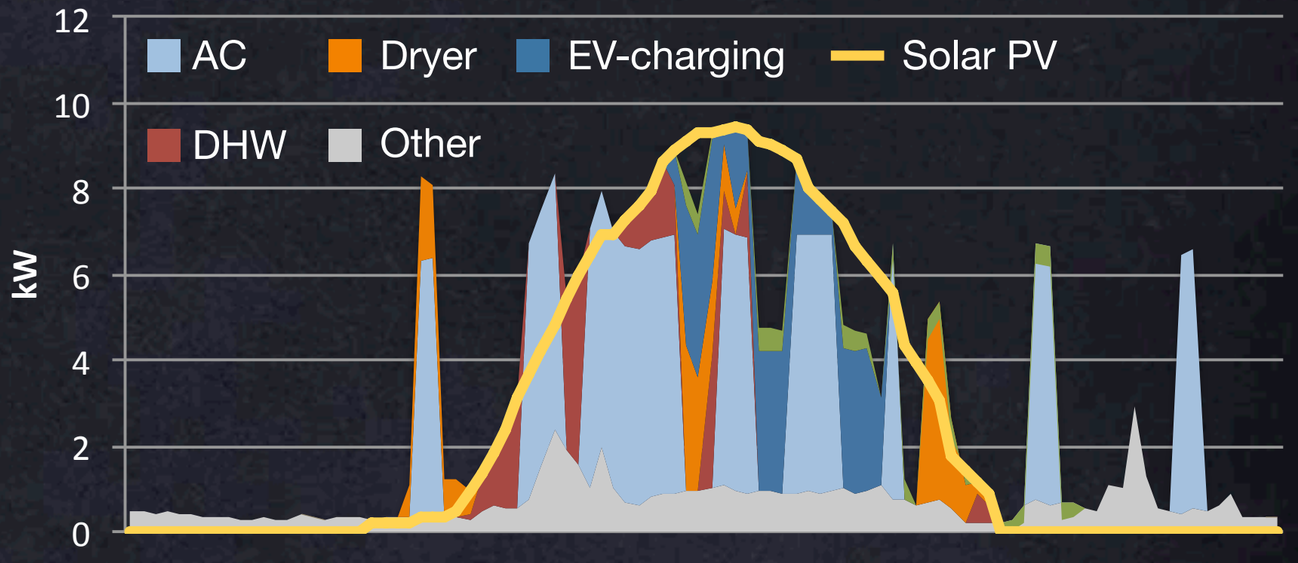
In Westchester, NY, 60% of residential consumption in the next decade could come more cheaply from PV



Source: RMI analysis “The Economics of Load Defection,” 2015

Load control + PVs = grid optional





Uncontrolled: ~50% of solar PV production is sent to the grid, but if the utility doesn't pay for that energy, how could customers respond?

Controlled: flexible load enables customers to consume >80% of solar PV production onsite. The utility loses nearly all its windfall and most of its ordinary revenue.

Source: RMI analysis "The Economics of Load Flexibility," 2015


$
Utility revenues
Regulatory shifts
New financial and business models

How can incumbents respond to the electricity shift?

http://recruitingdaily.com/wp-content/uploads/sites/6/2014/09/ostrich-in-sand.jpg

The Koch Attack on Solar Energy

By THE EDITORIAL BOARDAPRIL 26, 2014

No Free Sun for You! Why Arizona Wants to ‘Tax’ Solar Power

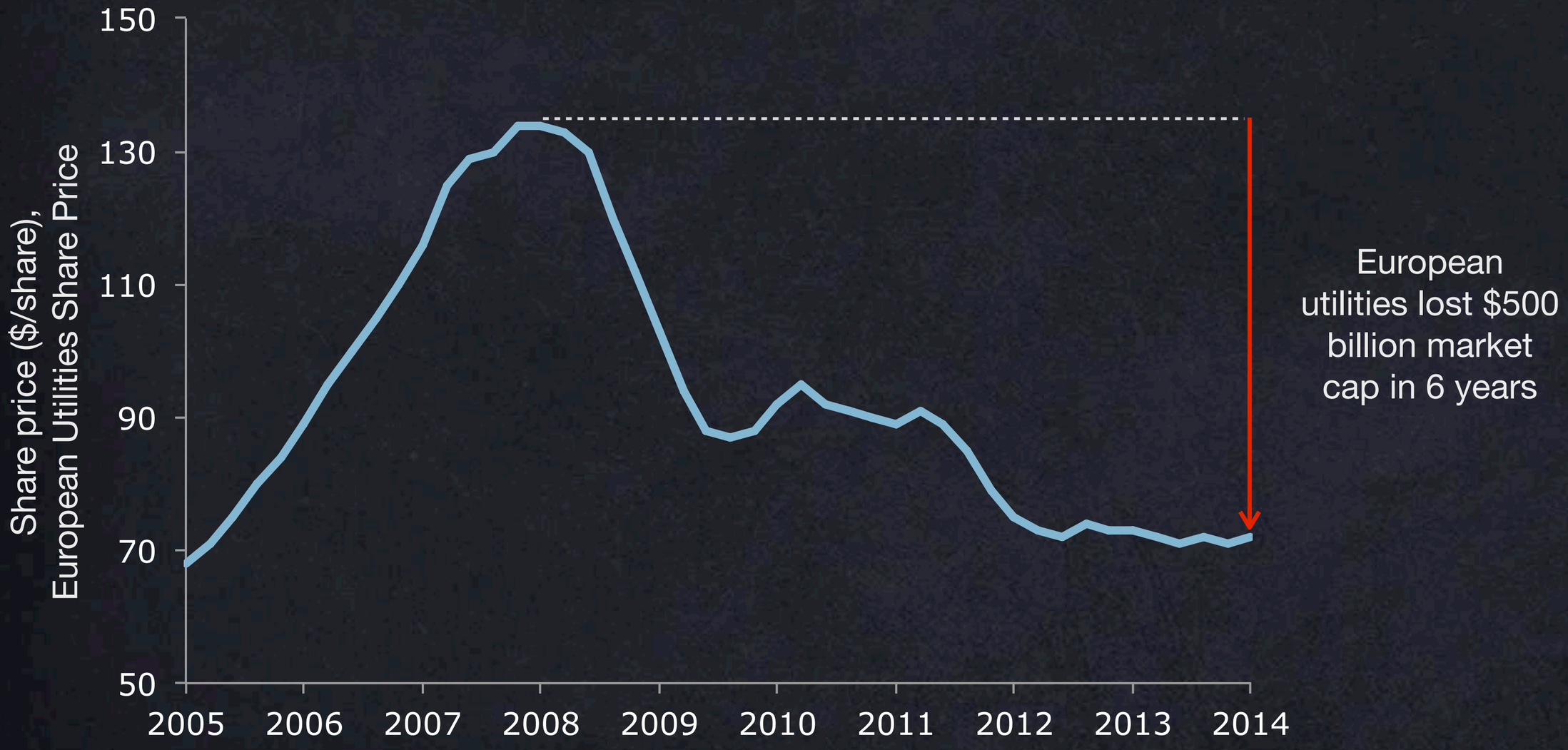
A new proposal would slap existing solar-paneled homeowners with a fee of up to $100 per month for the privilege of selling excess power back to the grid.

Solar Companies Sue Over New Rooftop Solar Tax In Arizona

The world's dumbest idea: Taxing solar energy

Conservative group ALEC pushes stealth tax on homeowners who install solar panels

The German example



Source: Morgan Stanley Capital International

The German example

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重塑能源：中国

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Value > Price > Cost

Easter Parades on Fifth Avenue, New York, 13 years apart

1900: where's the first car?

1913: where's the last horse?

Images: L, National Archive, www.archives.gov/research/american-cities/images/american-cities-101.jpg; R, shorpy.com/node/204.
Inspiration: Tona Seba's keynote lecture at AltCar, Santa Monica CA, 28 Oct 2014, http://tonyseba.com/keynote-at-altcar-expo-100-electric-transportation-100-solar-by-2030/

A new and old utility

A new and old automaker

WHERE WOULD YOU INVEST YOUR MONEY?

WHERE WOULD YOU INVEST YOUR MONEY?

From the Age of Carbon to the Age of Silicon

Renewables replacing $38b/y kerosene market

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www.ted.com/talks/amory_lovins_a_50_year_plan_for_energy.html

www.rmi.org/Knowledge-Center/Library/2012-01_FarewellToFossilFuels