Disruptive Electricity Futures

革命的な電力事業の未来

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REF, Tōkyō, 9 September 2016

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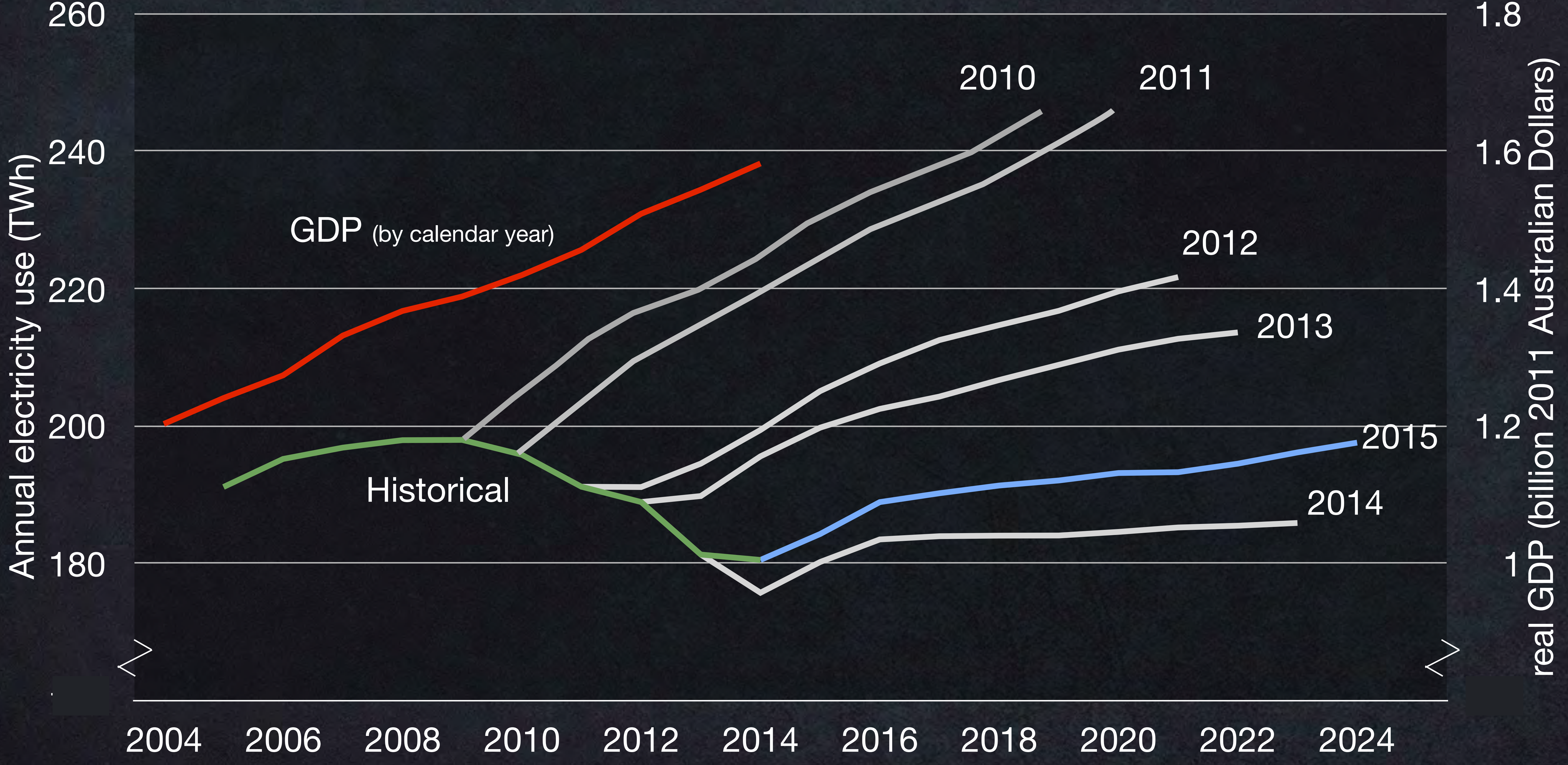
Australia national electricity market

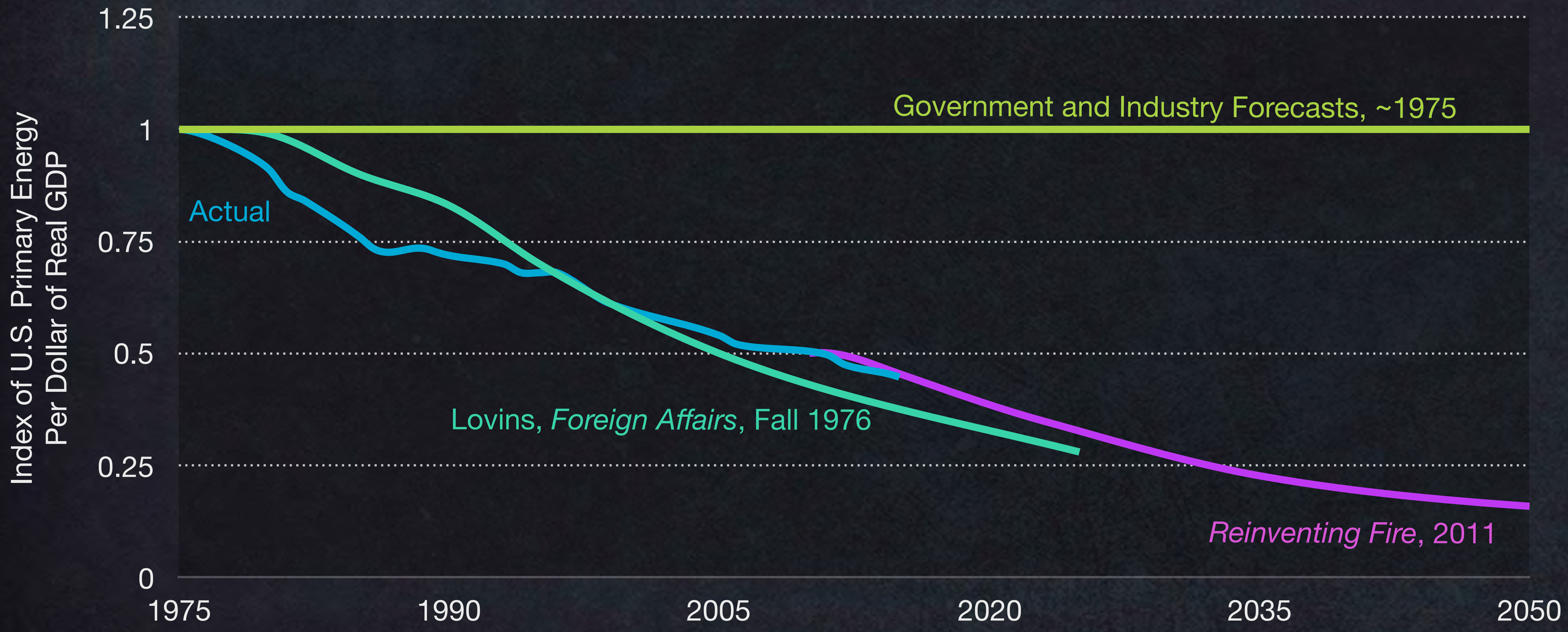
Actual vs. forecast electricity demand



Inspiration: M. Liebreich, keynote, Bloomberg New Energy Finance summit, April 2015. GDP data: International Monetary Fund, World Economic Outlook database, http://www.imf.org/external/pubs/ft/weo/2015/02/weodata/download.aspx Historical and forecast electricity use: Australian Energy Market Operator, National Electricity Forecasting Report 2010–2015, http://www.aemo.com.au/AEMO%20Home/Electricity/Planning/Forecasting

Heresy Happens

U.S. energy intensity



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

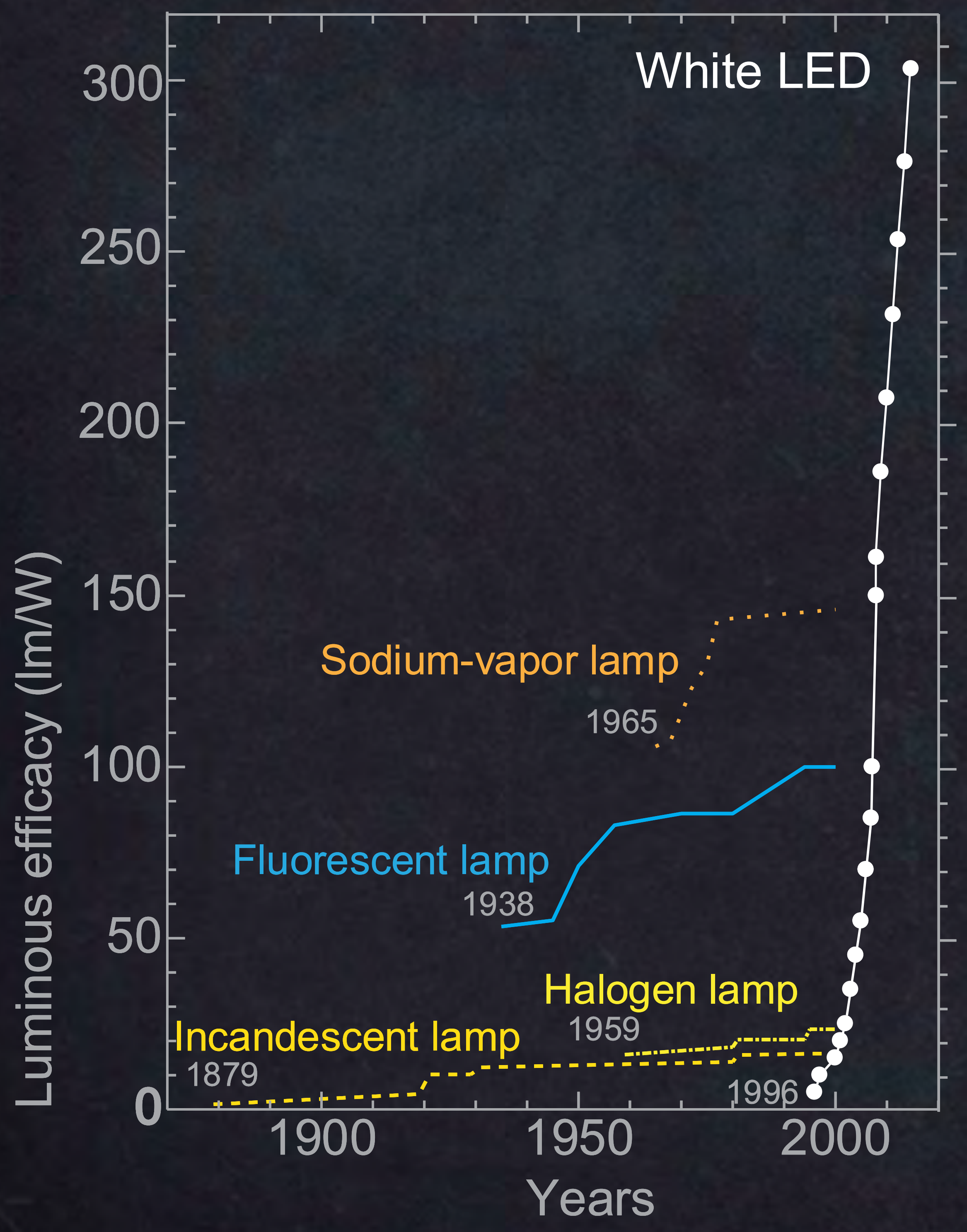
284→85 (–70%)
2013 retrofit

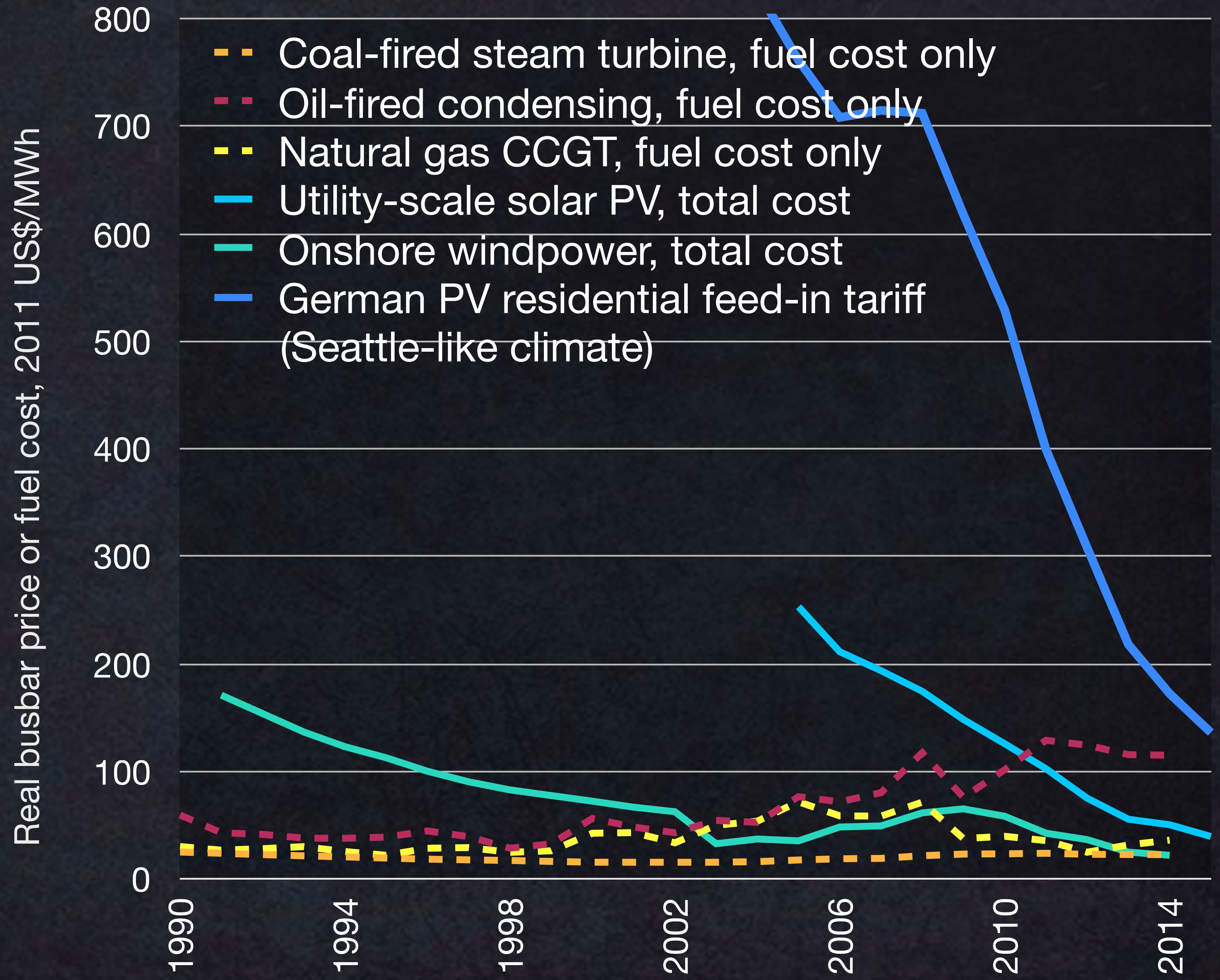
...→108 (–63%)
2010–11 new

...→≤50 (–83% to –85%)
2015 new

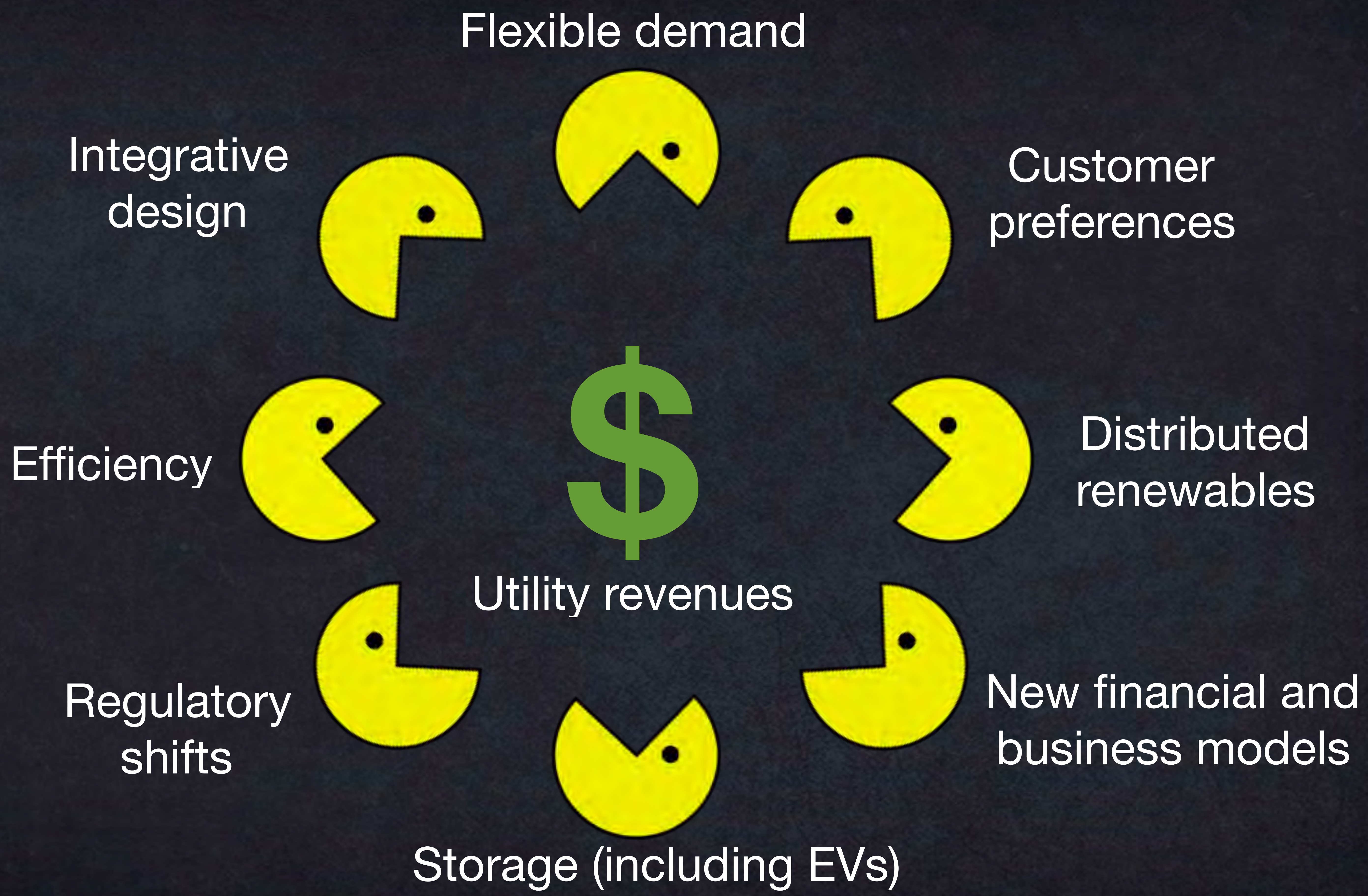
Yet all the technologies in the 2015 example existed well before 2005!

LED and PV



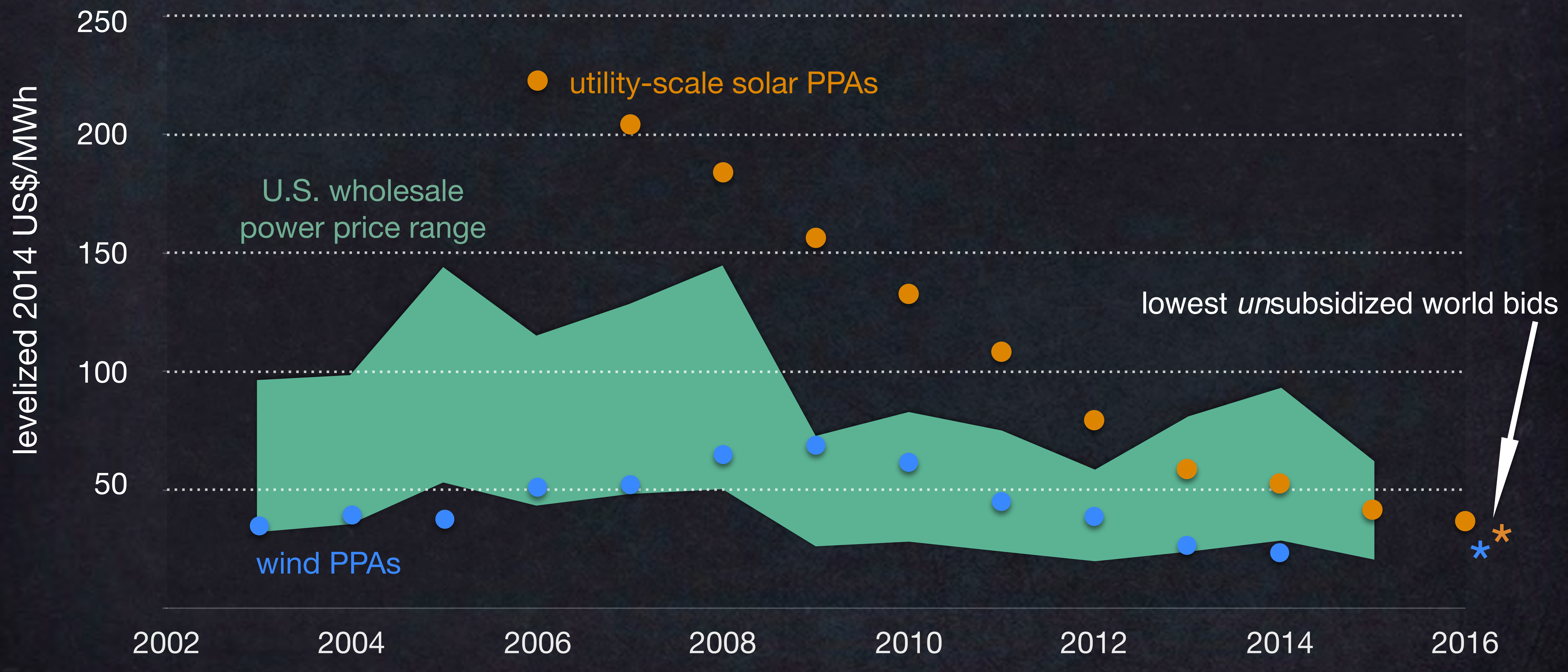


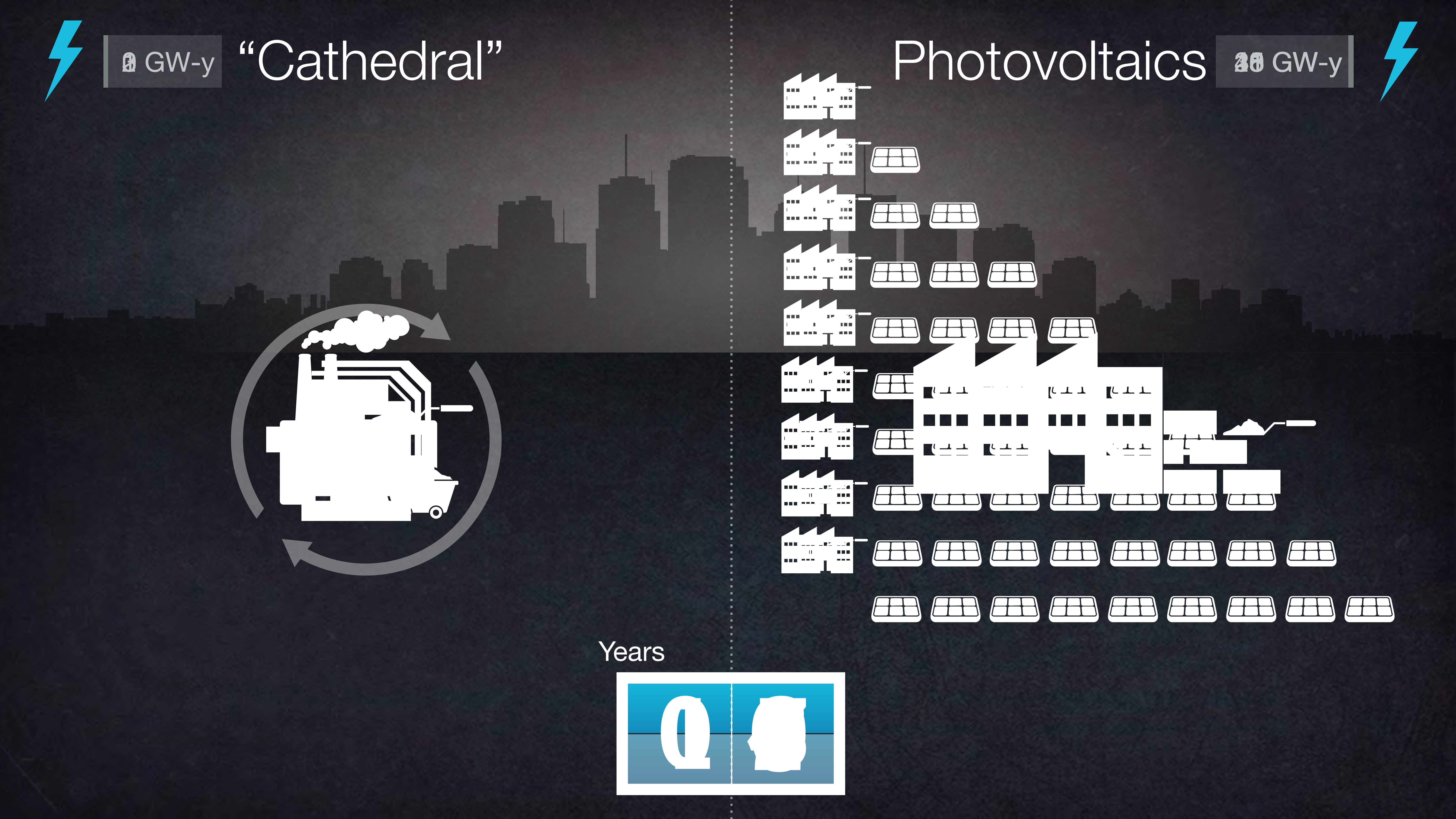
Sources: L: courtesy of Dr. Yukio Narukawa (Nichia Corp., Tokushima, Japan) from *J. Physics. D: Appl. Phys.* ***43***(2010) 354002, doi:10.1088/0022-3727/43/35/354002, updated by RMI with CREE lm/W data, 2015, www.cree.com/News-and-Events/Cree-News/Press-Releases/2014/March/300LPW-LED-barrier;. R: RMI 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


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

Renewable Energy's Costs Continue to Plummet

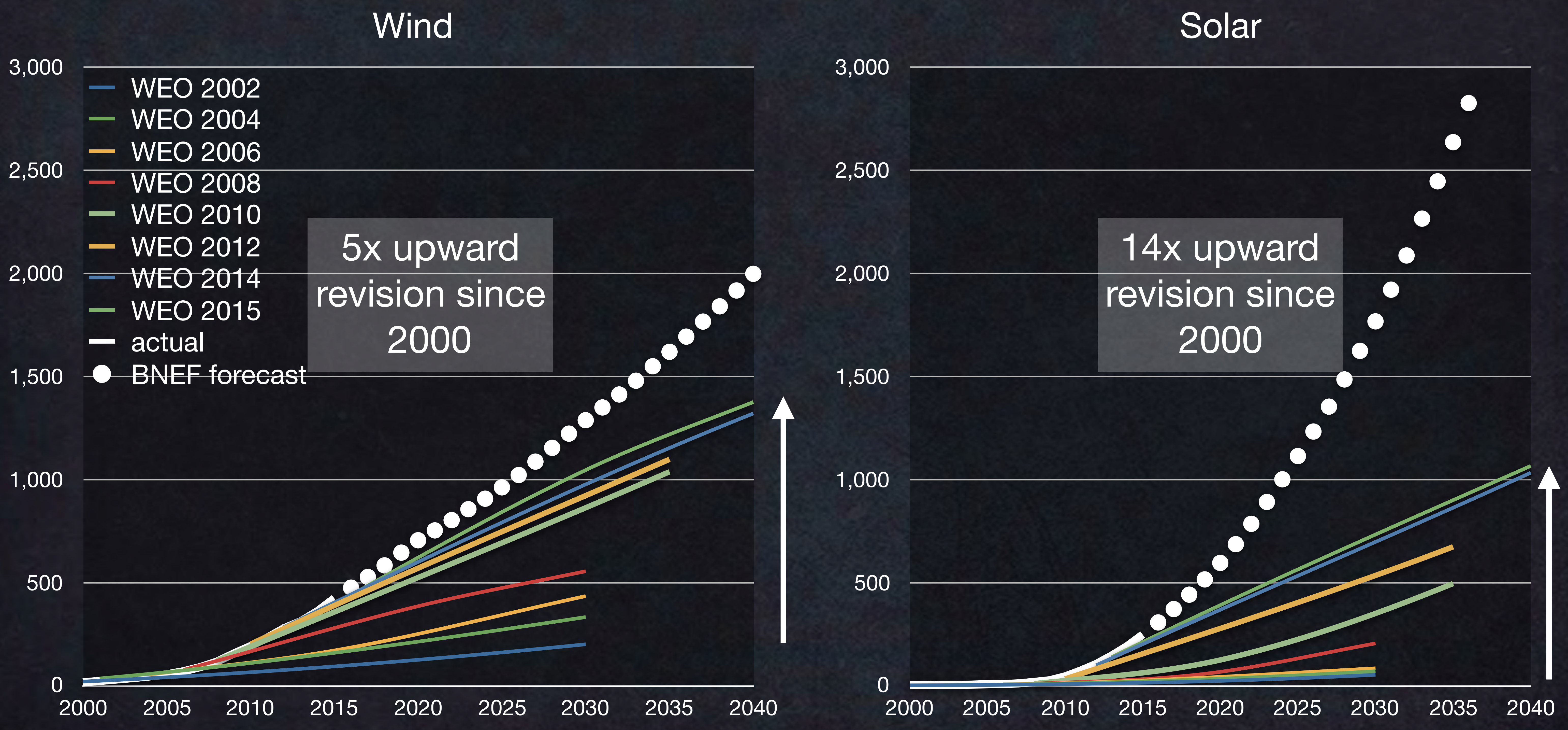
Wind and photovoltaics: U.S. generation-weighted-average Power Purchase Agreement prices, by year of signing



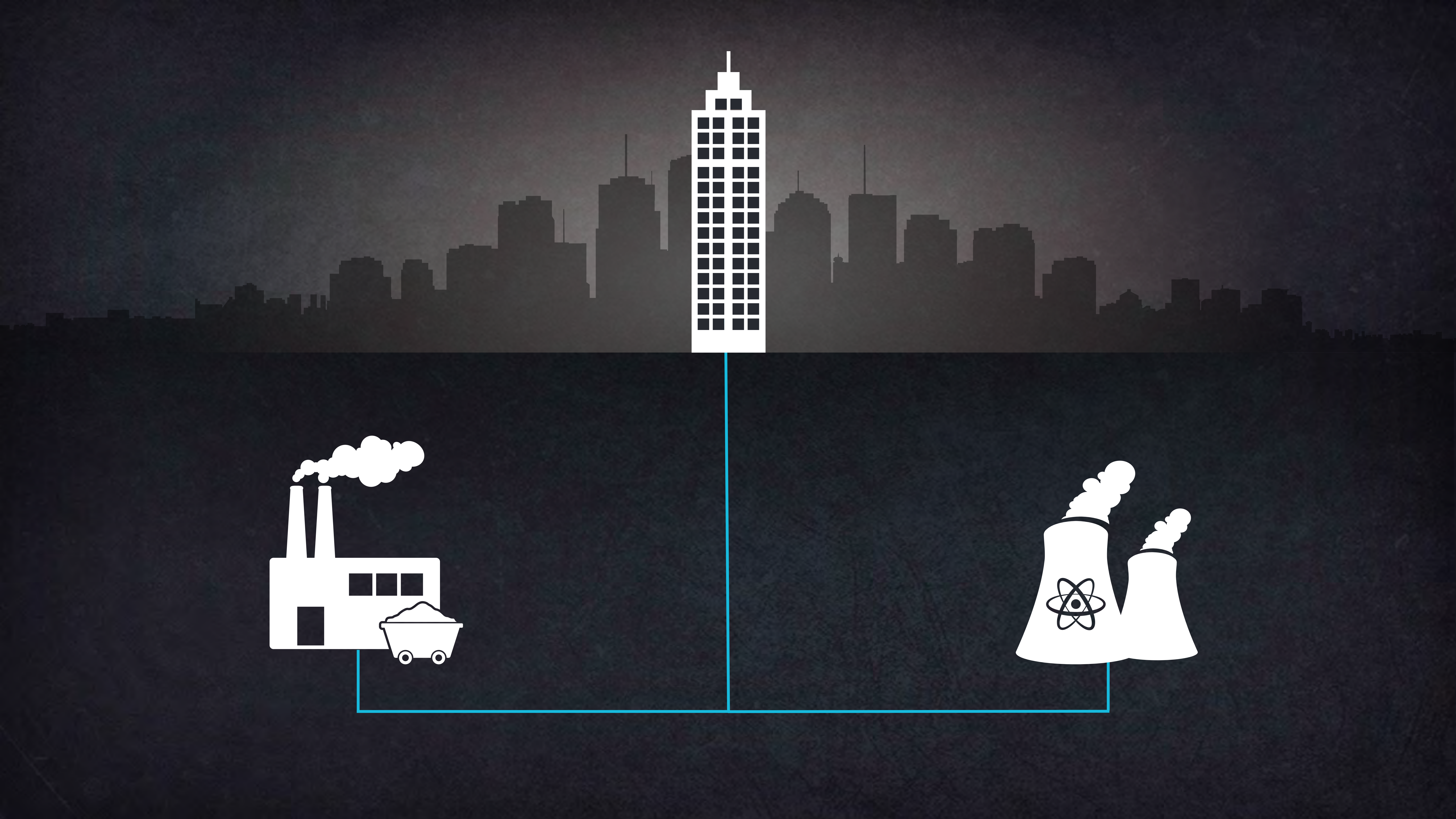

GW-y
“Cathedral”
Photovoltaics
GW-y
Years

International Energy Agency global wind and solar forecasts

Cumulative GW installed

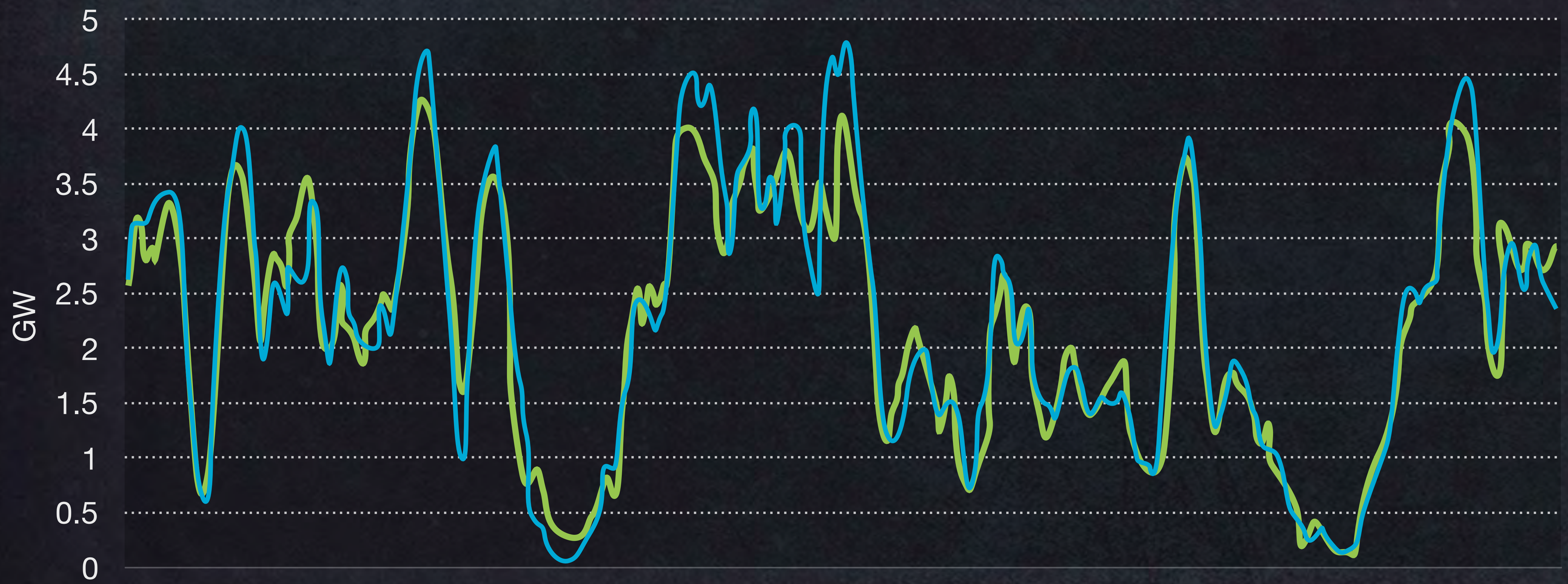


Source: IEA WEO, BNEF (forecast from June 2015), slide inspired by Michael Liebreich's 2016 BNEF Summit keynote

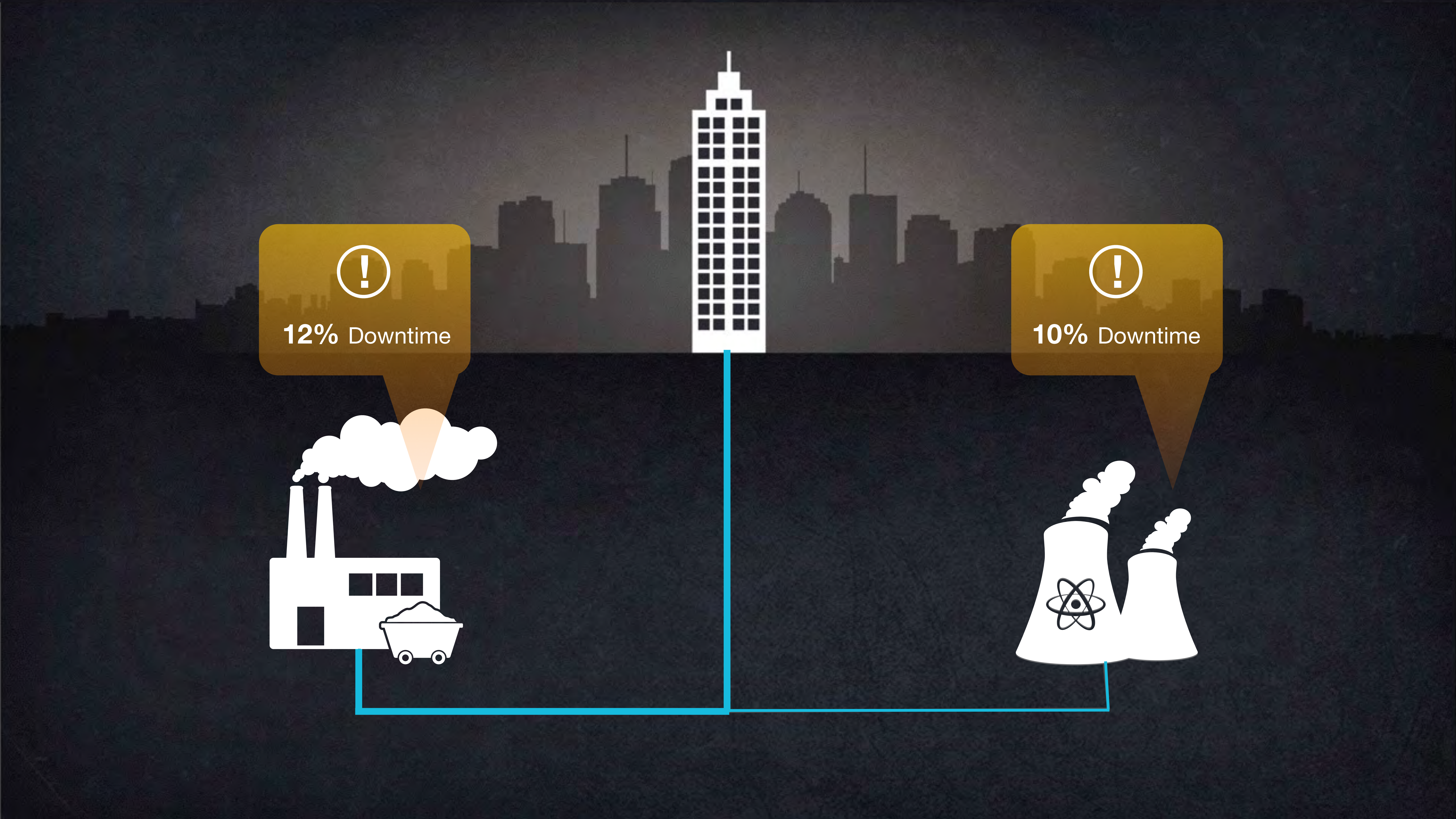


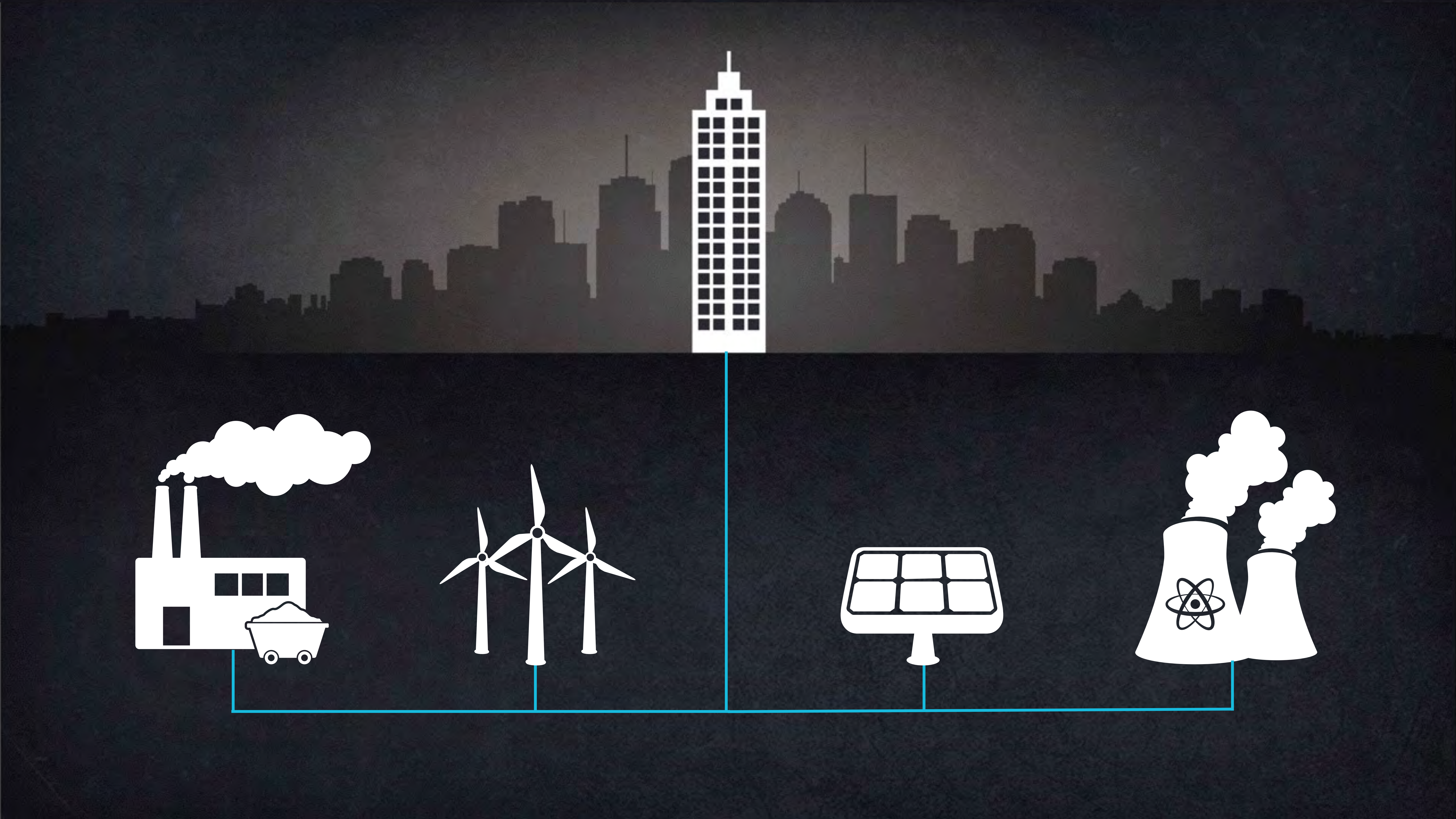
Variable Renewables Can Be Forecasted At Least as Accurately as Electricity Demand

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



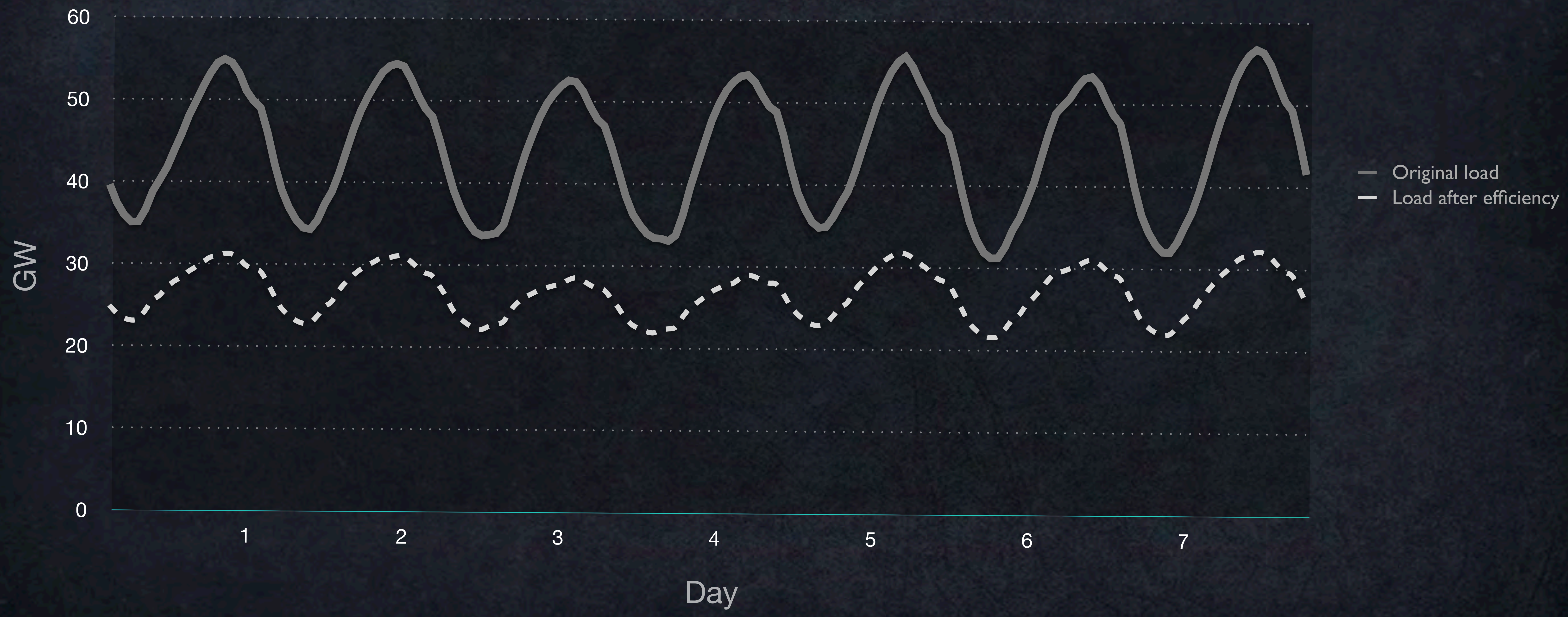
Source: Bernard Chabot, 10 April 2013, Fig. 7, www.renewablesinternational.net/wind-power-statistics-by-the-hour/150/505/61845/, data from French TSO RTE


12% Downtime
10% Downtime



Choreographing Variable Renewable Generation

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



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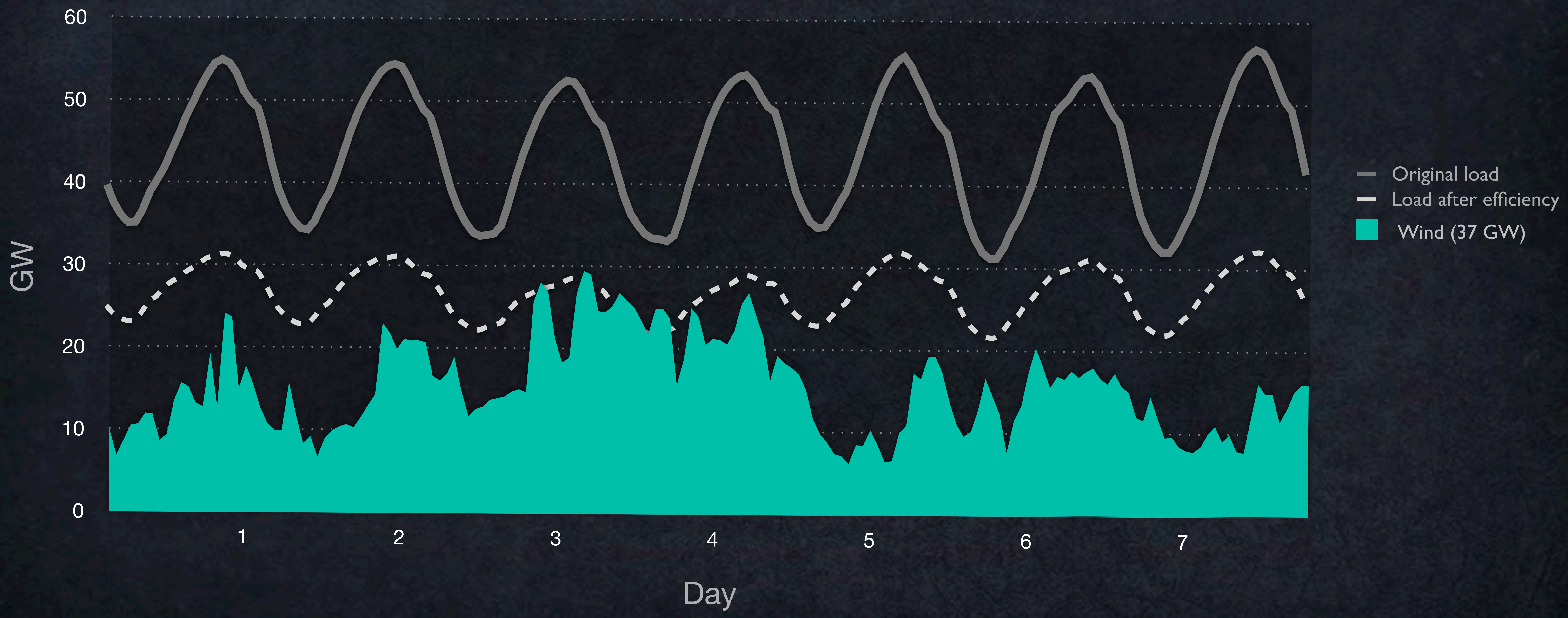

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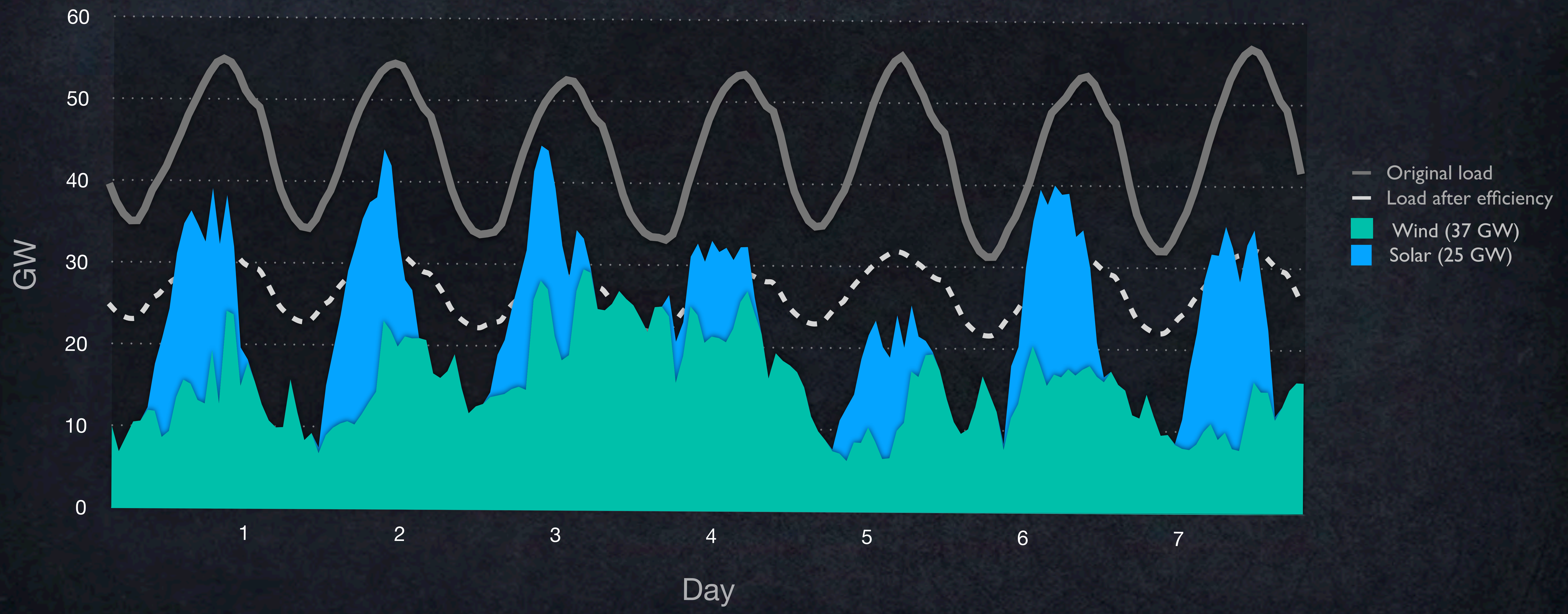

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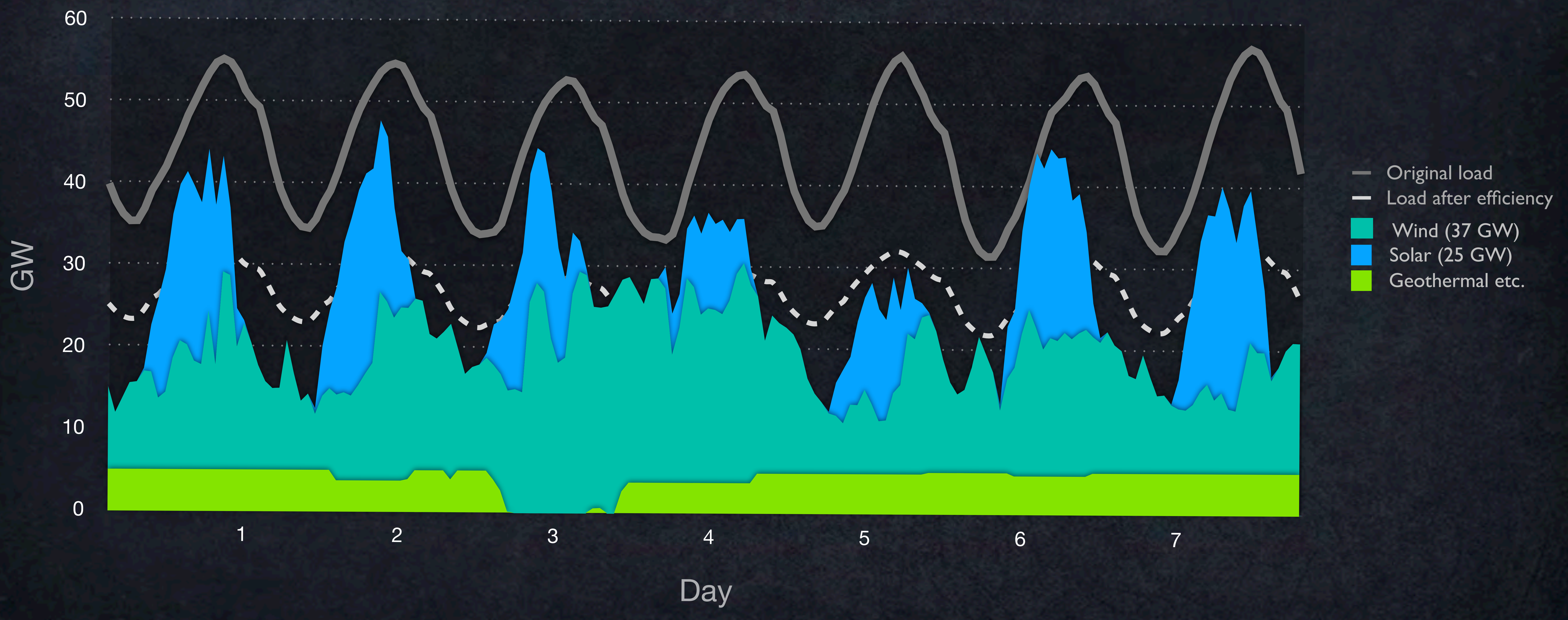

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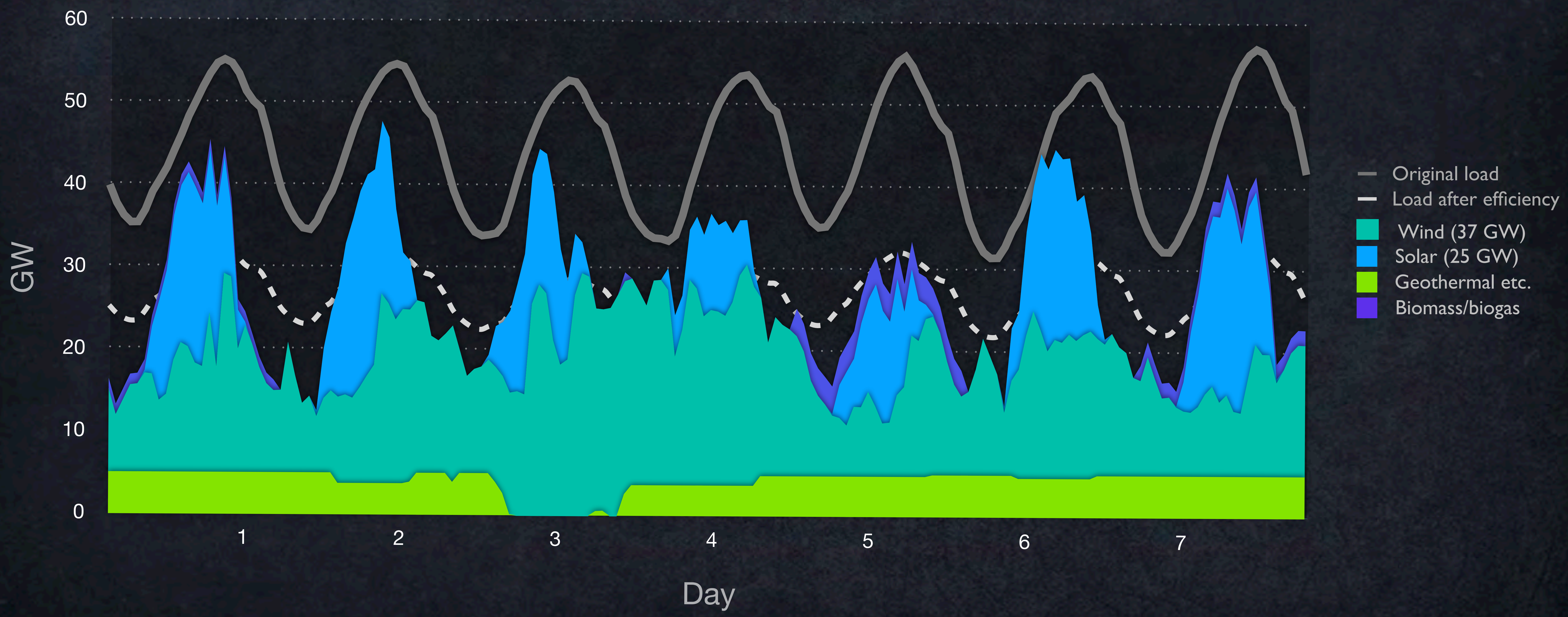

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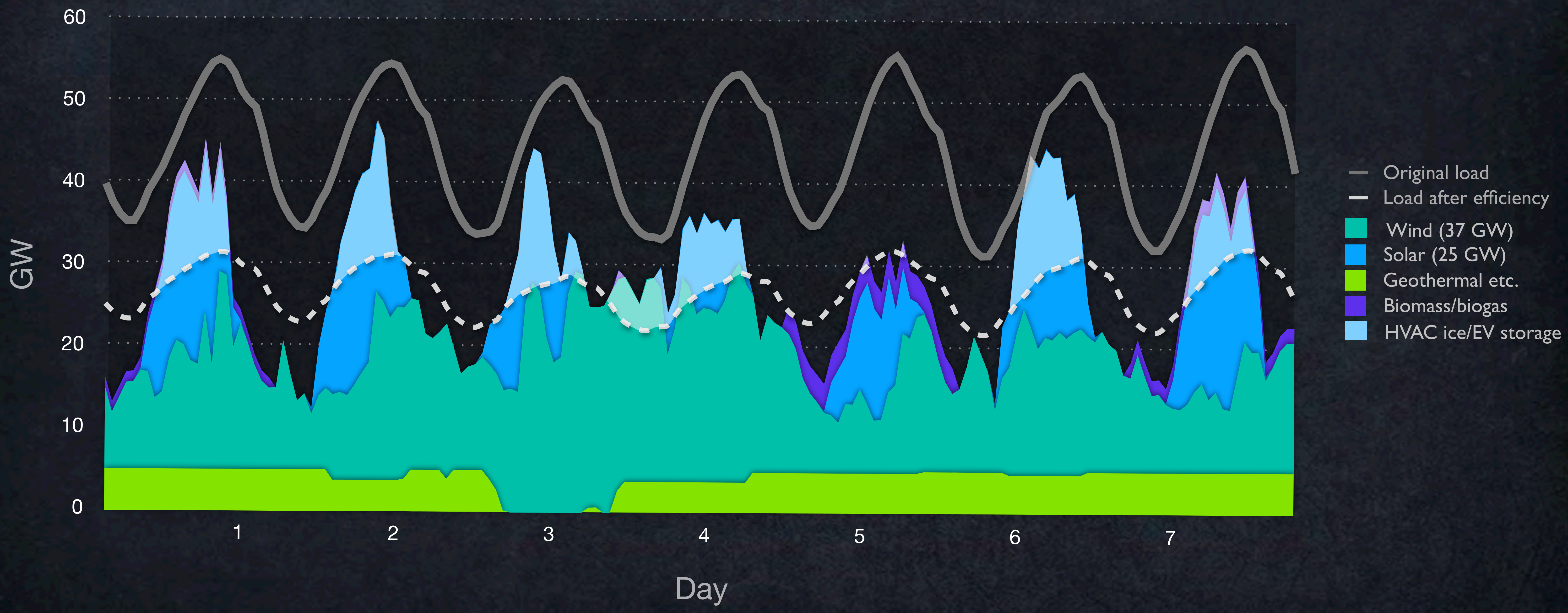

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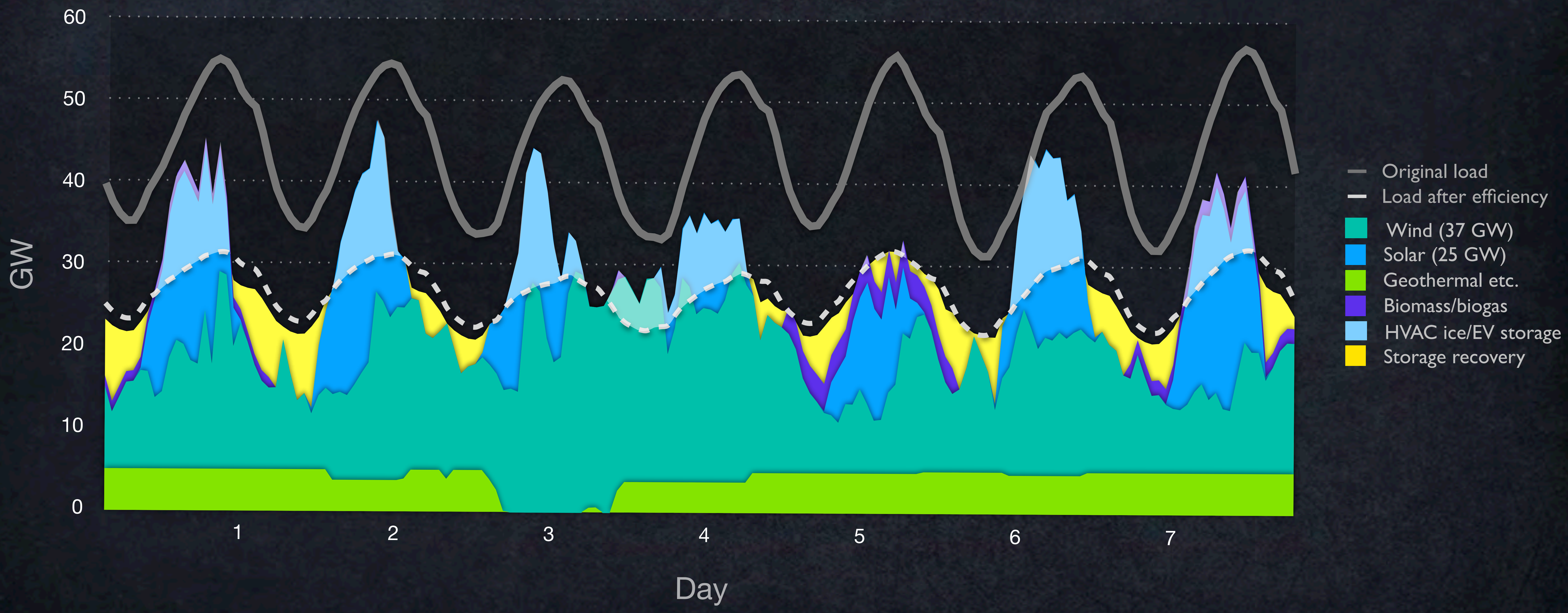

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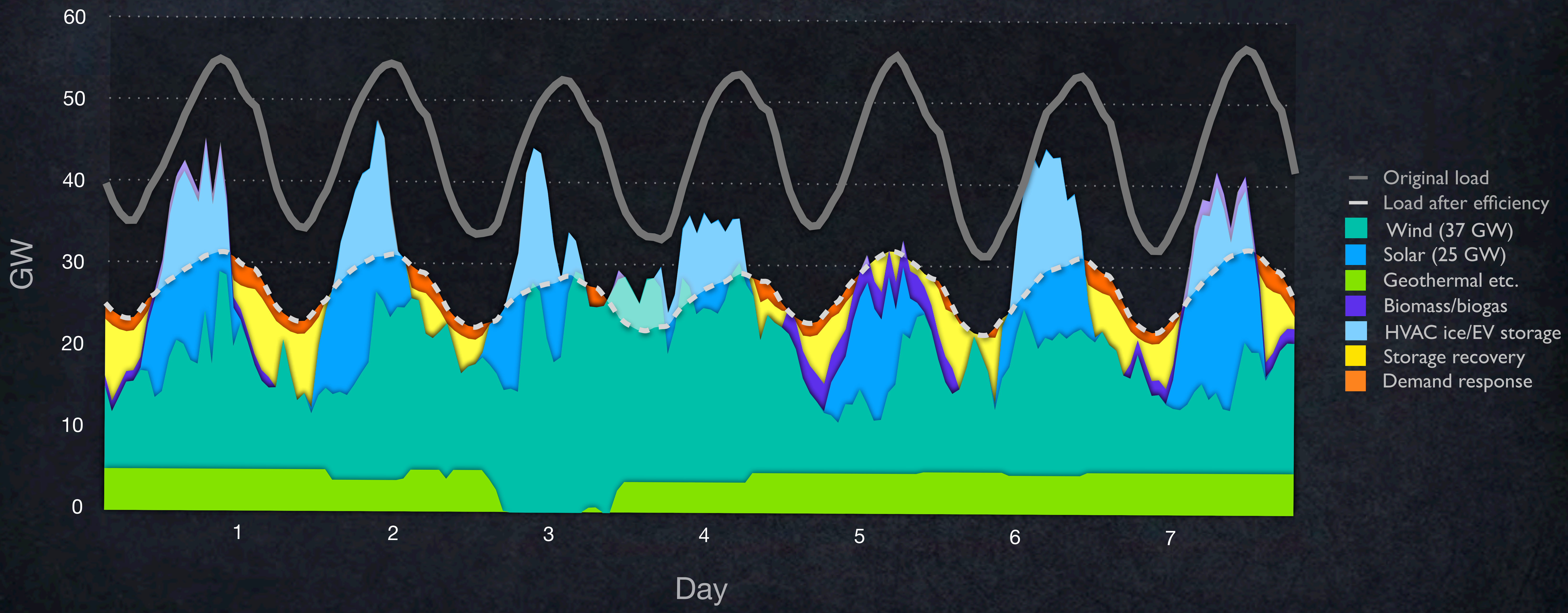

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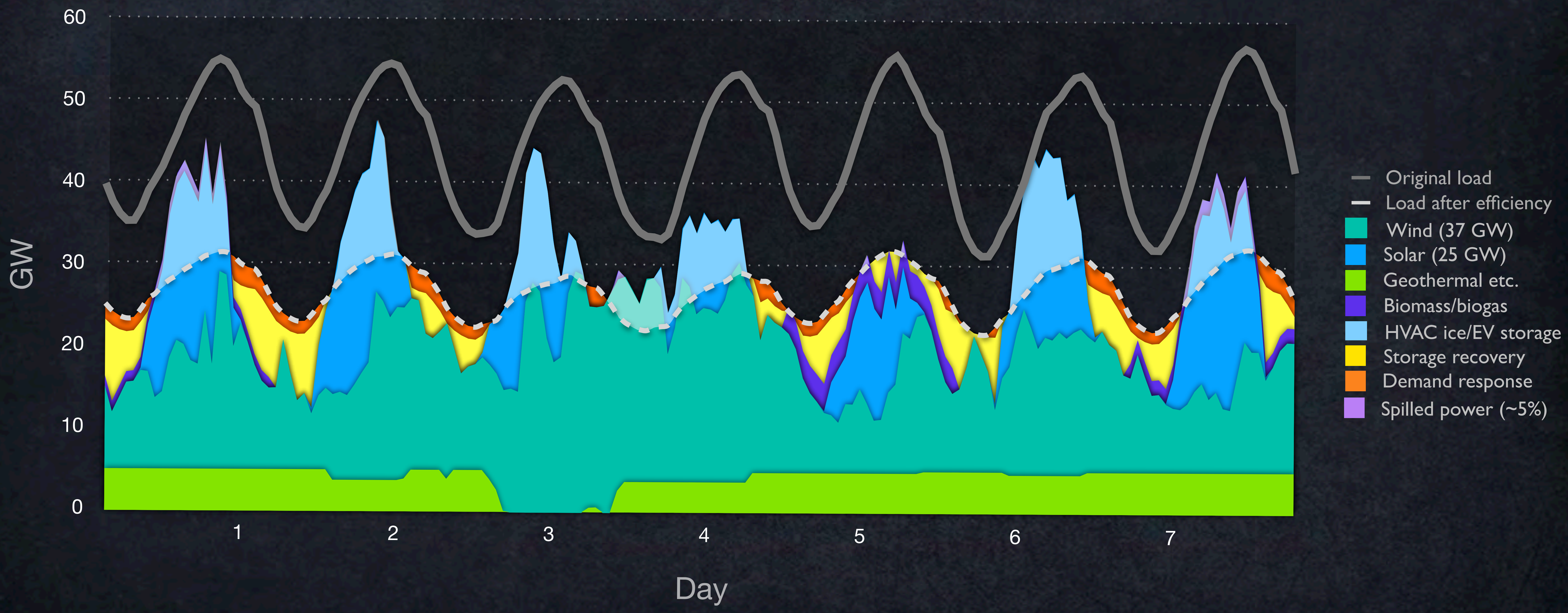


Choreographing Variable Renewable Generation

Europe, 2014 renewable %
of total electricity consumed

50%

Scotland

59%

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

27%

Germany (2015 peak 78%)

64%

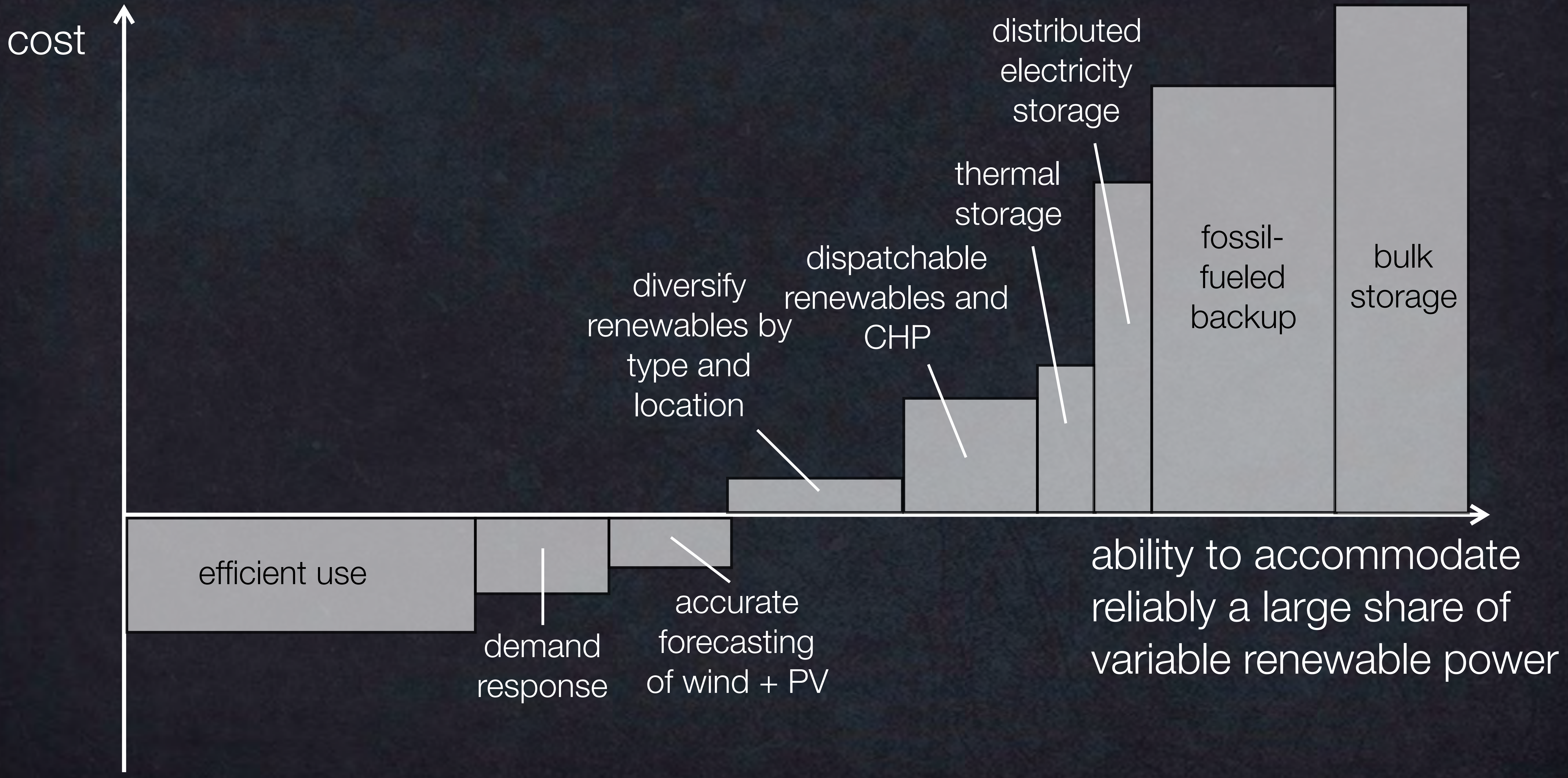
Portugal (peak 100% in 2011; 70% for the whole first half of 2013, incl, 26% wind & 34% hydro; 17% in 2005)

46%

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

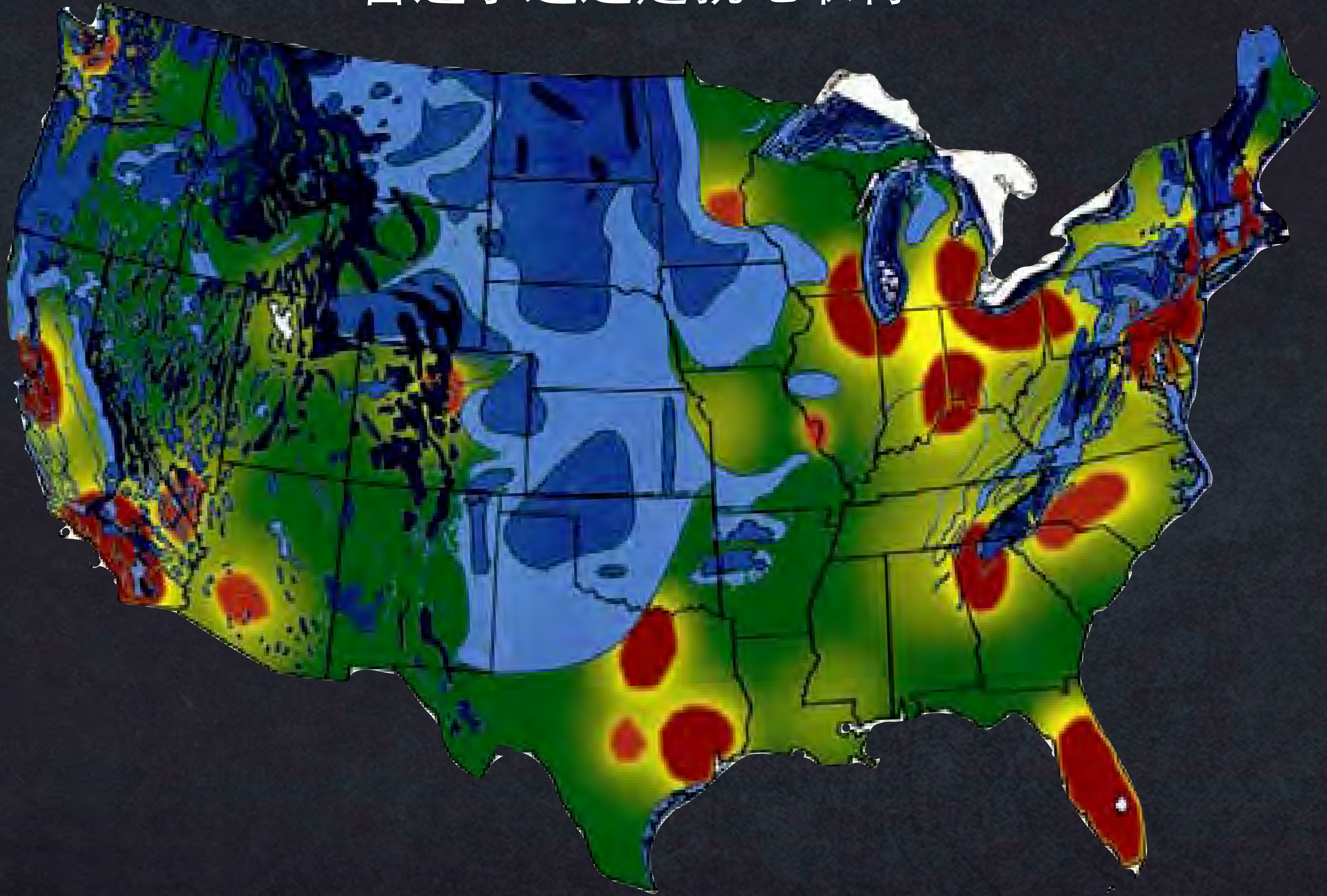
Grid flexibility supply curve

(all values shown are conceptual and illustrative)



Best resources far away, or adequate resources nearby?

舍近求远还是就地取材

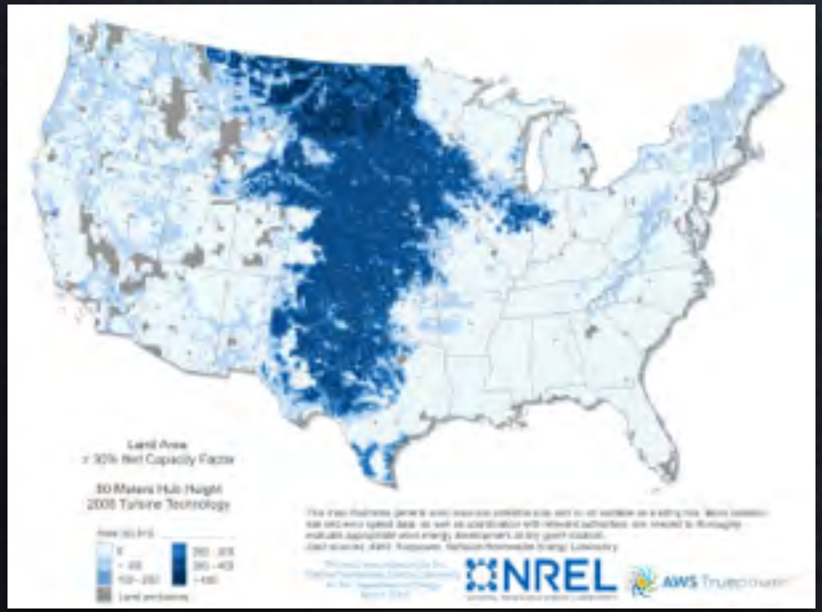


Source: NERC 2009 LTRA p 72

Best resources far away, or adequate resources nearby?

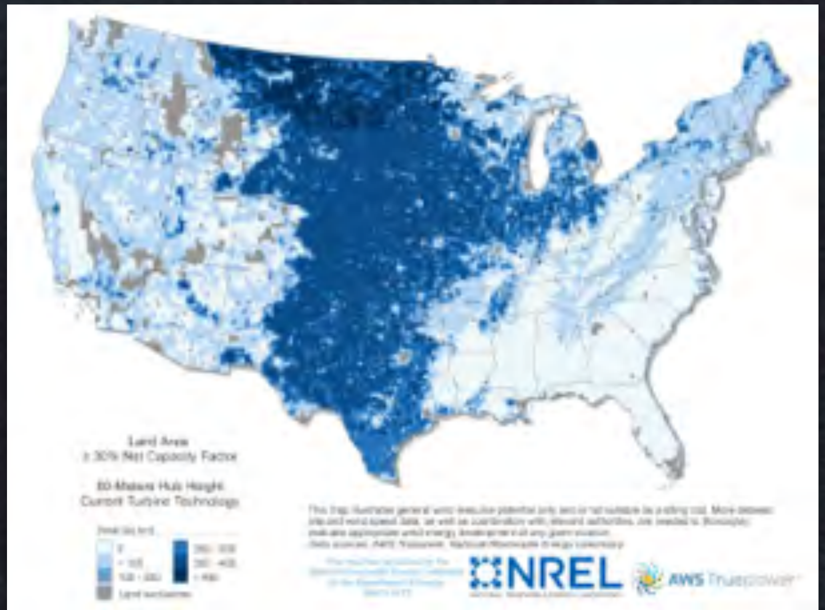
舍近求远还是就地取材

2008



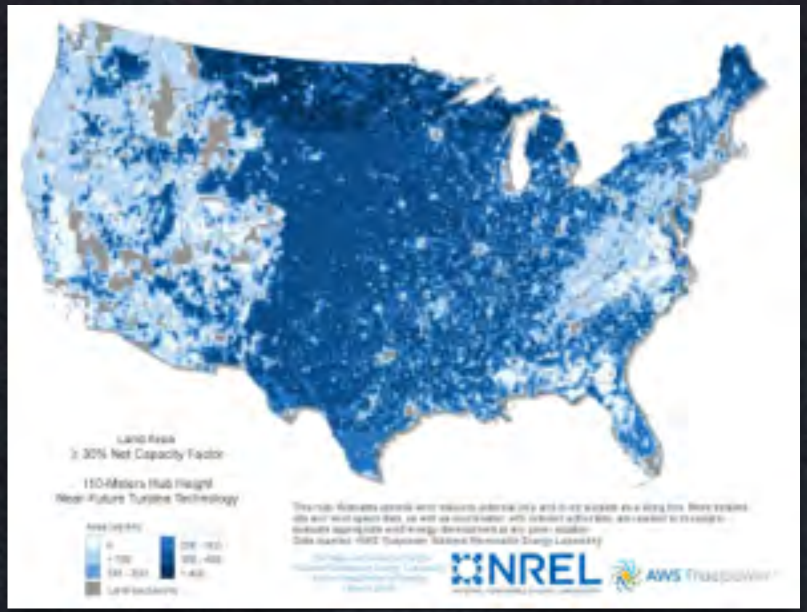
400 W/m², 80m

2013



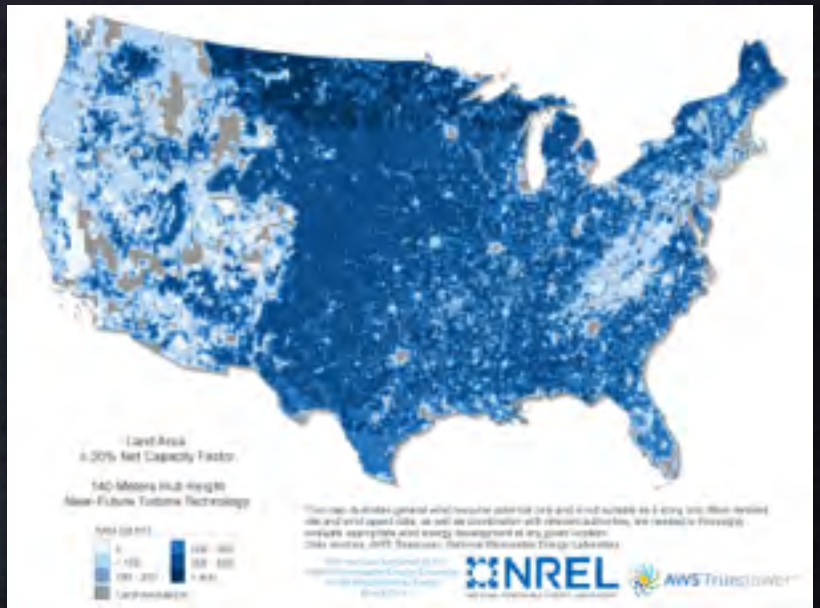
210–320 W/m², 80m

2013



150 W/m², 110m

2015



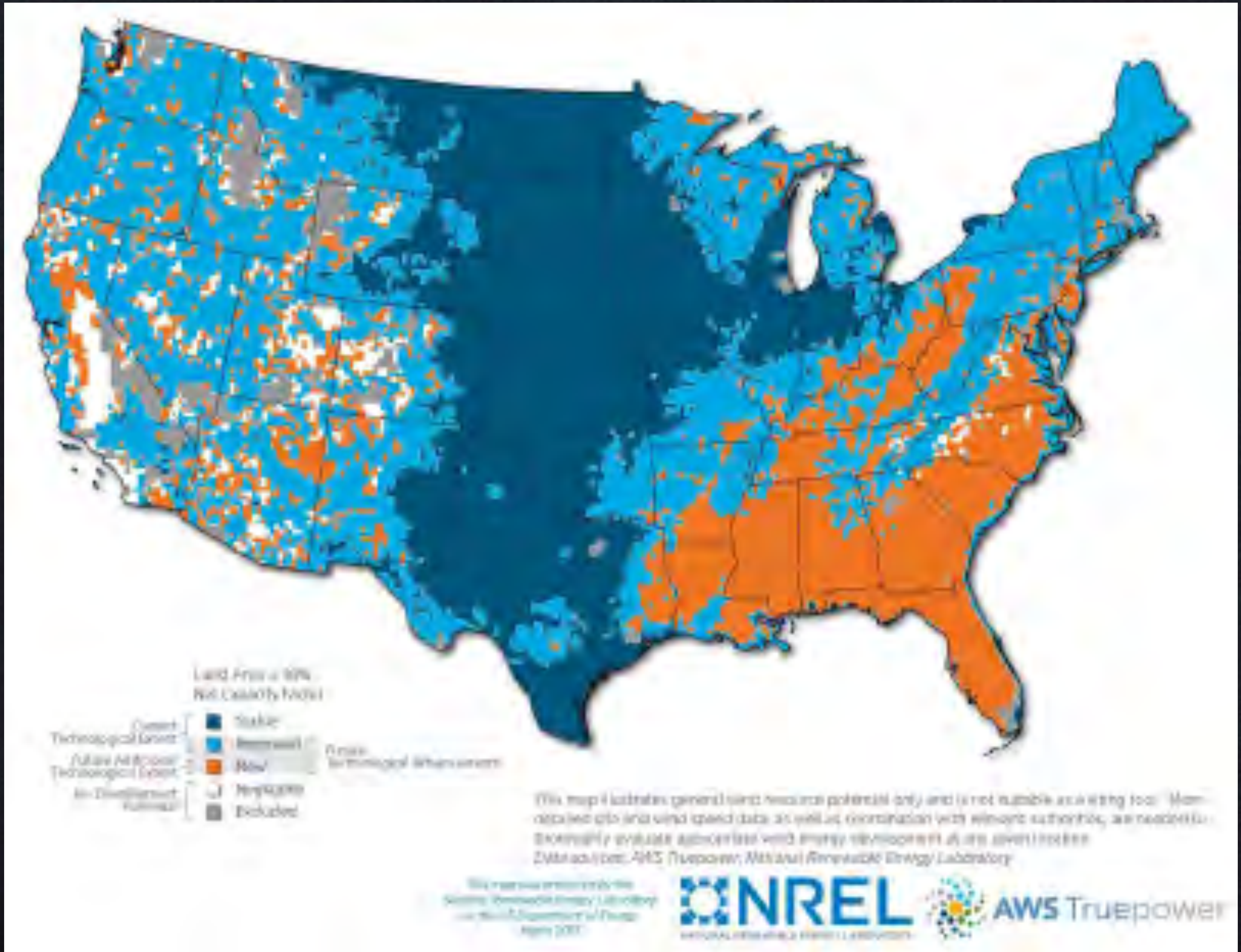
150 W/m², 140m

2008–15: TWh/y +67%

US Department of Energy, *Enabling Wind Power Nationwide*, May 2015, DOE/EE-1218

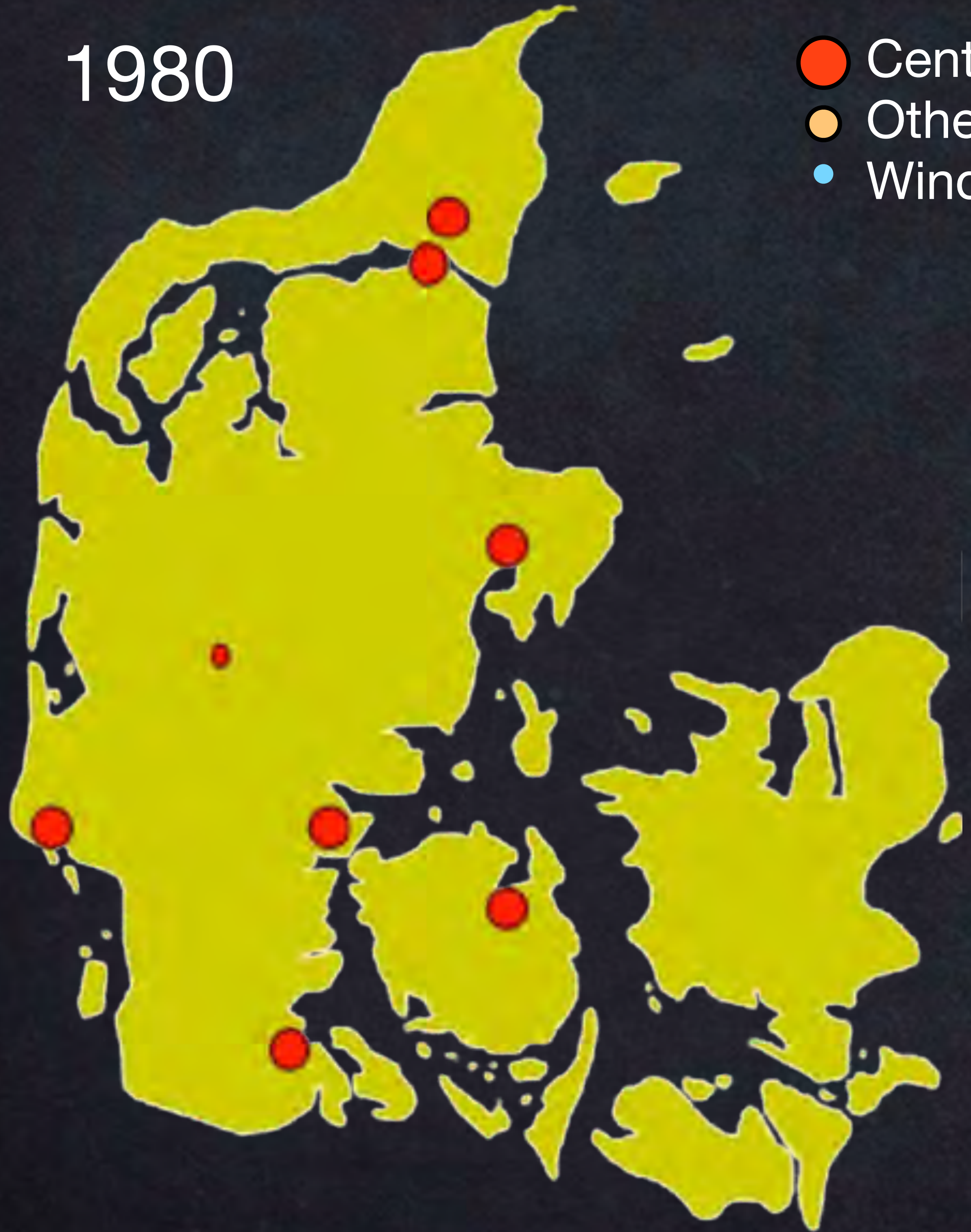
Best resources far away, or adequate resources nearby?

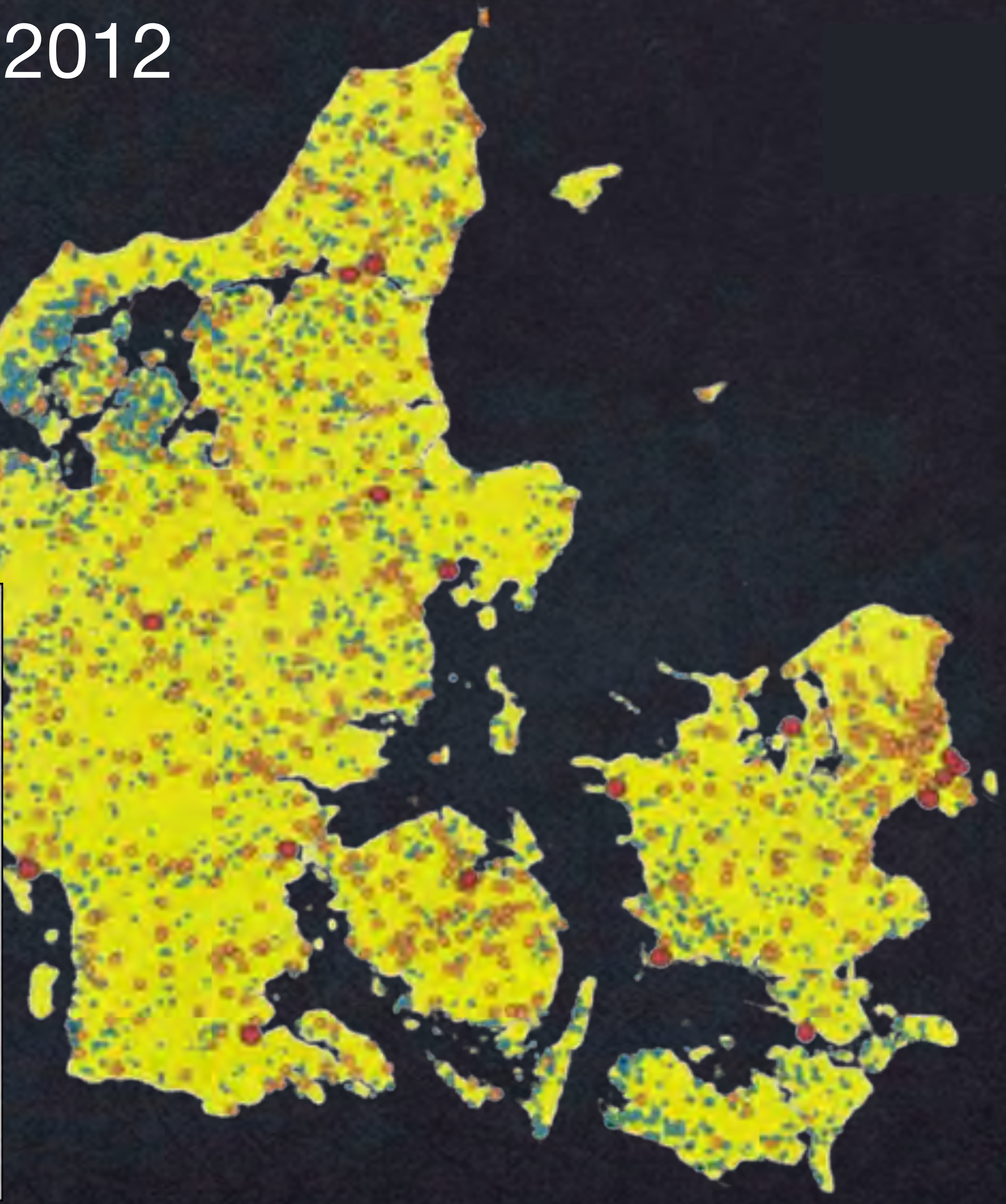
舍近求远还是就地取材



US Department of Energy,
Enabling Wind Power Nationwide,
May 2015, DOE/EE-1218

Denmark’s transition to distributed electricity, 1980–2012

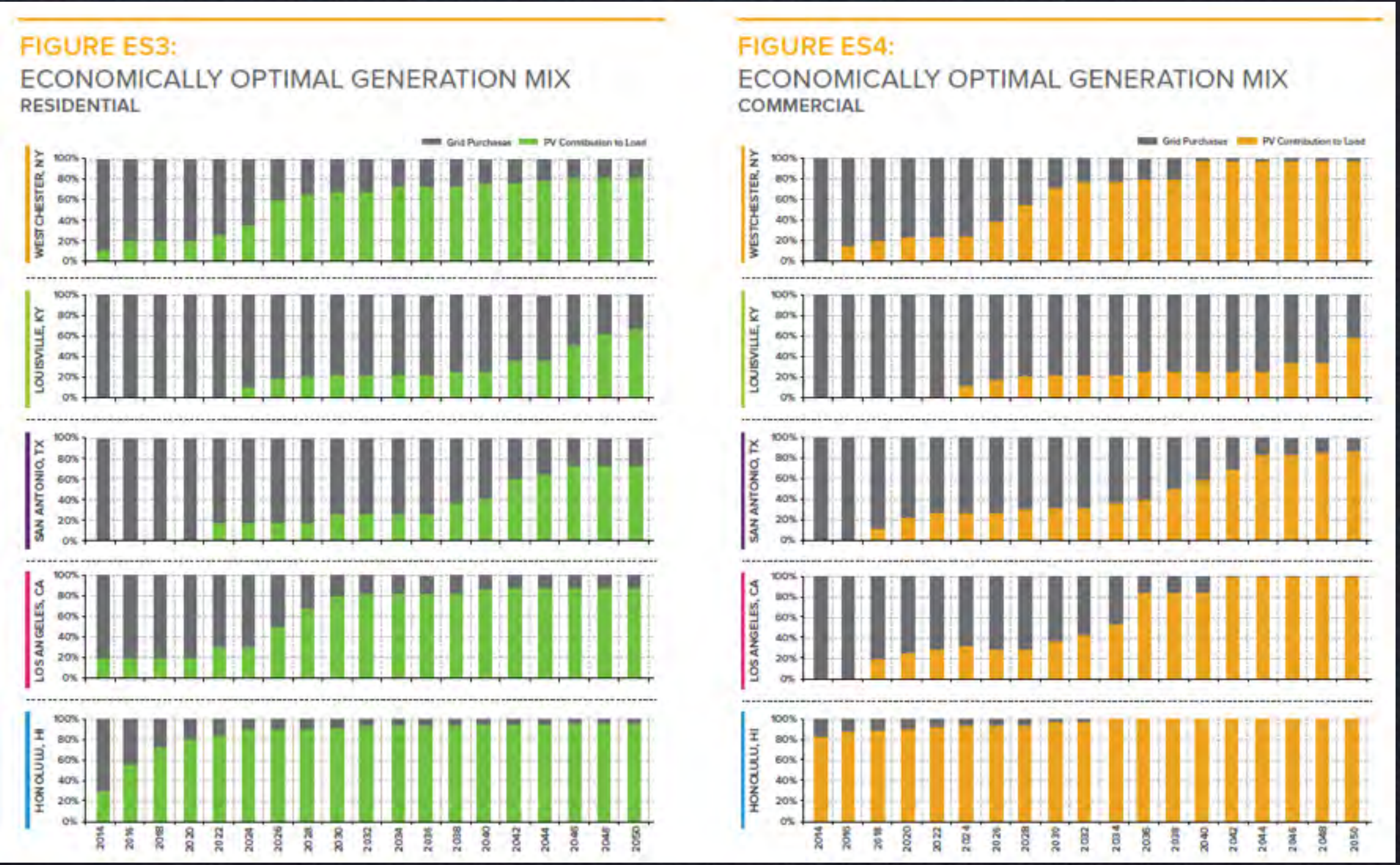




Source: Risø

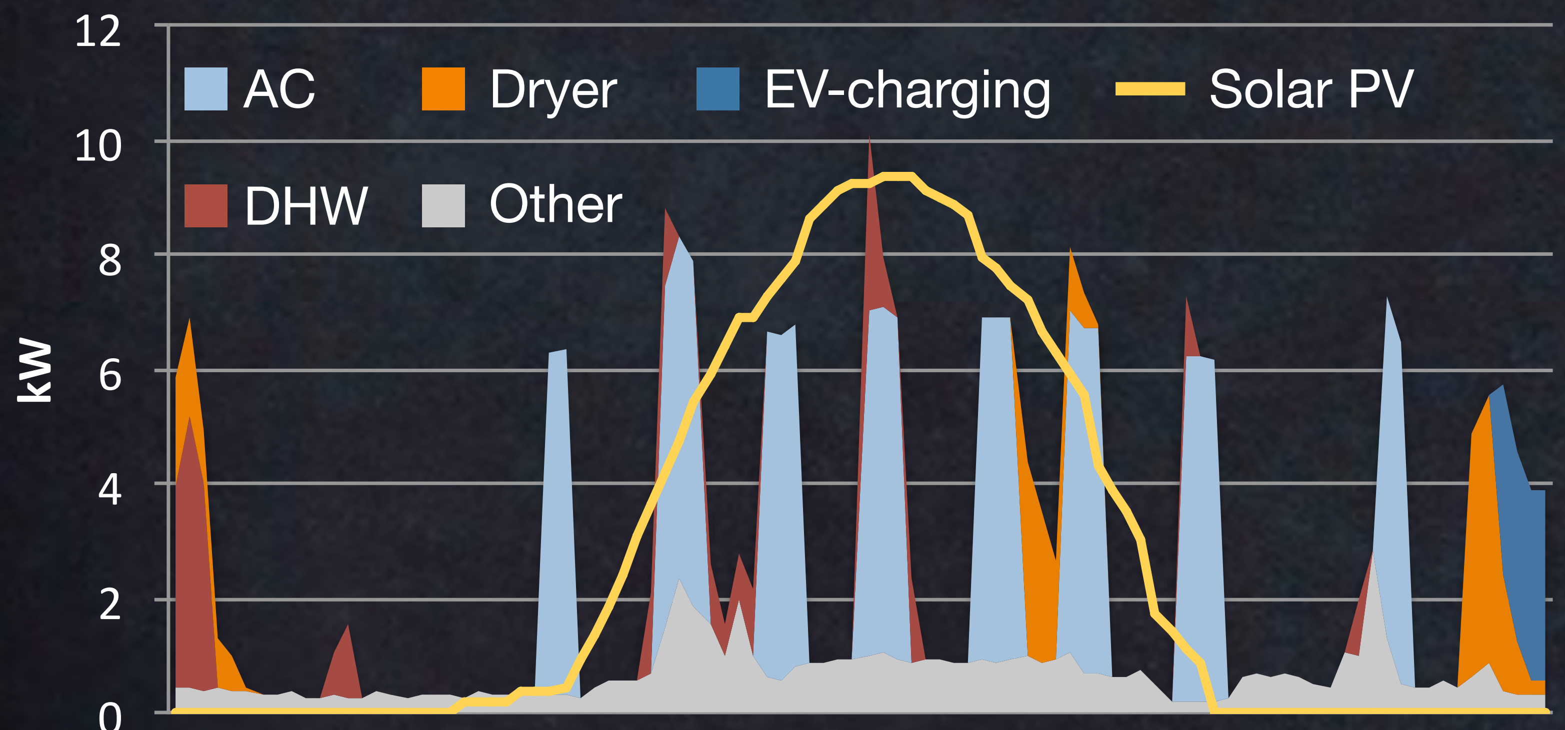
Cheaper renewables *and* batteries change the game

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

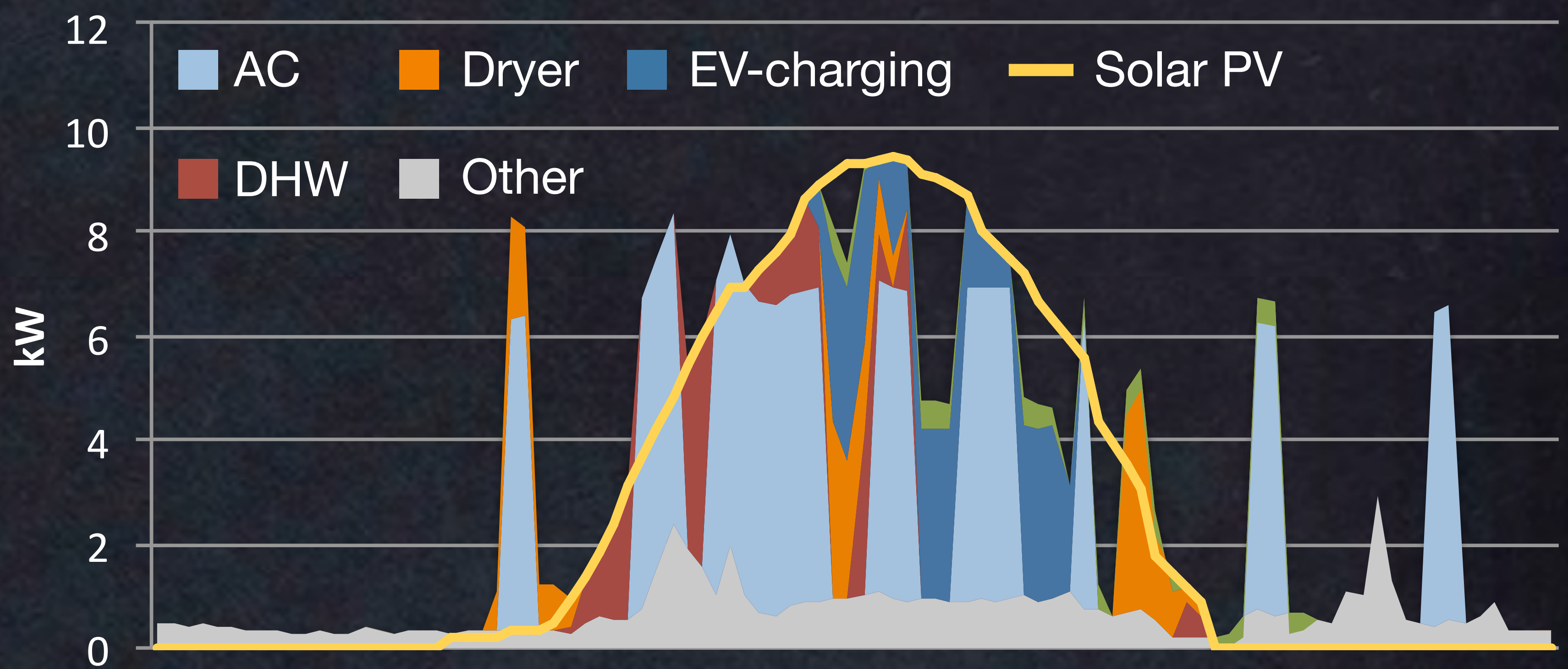


Source: RMI analysis “The Economics of Load Defection,” 2015

Load control + PVs = grid optional



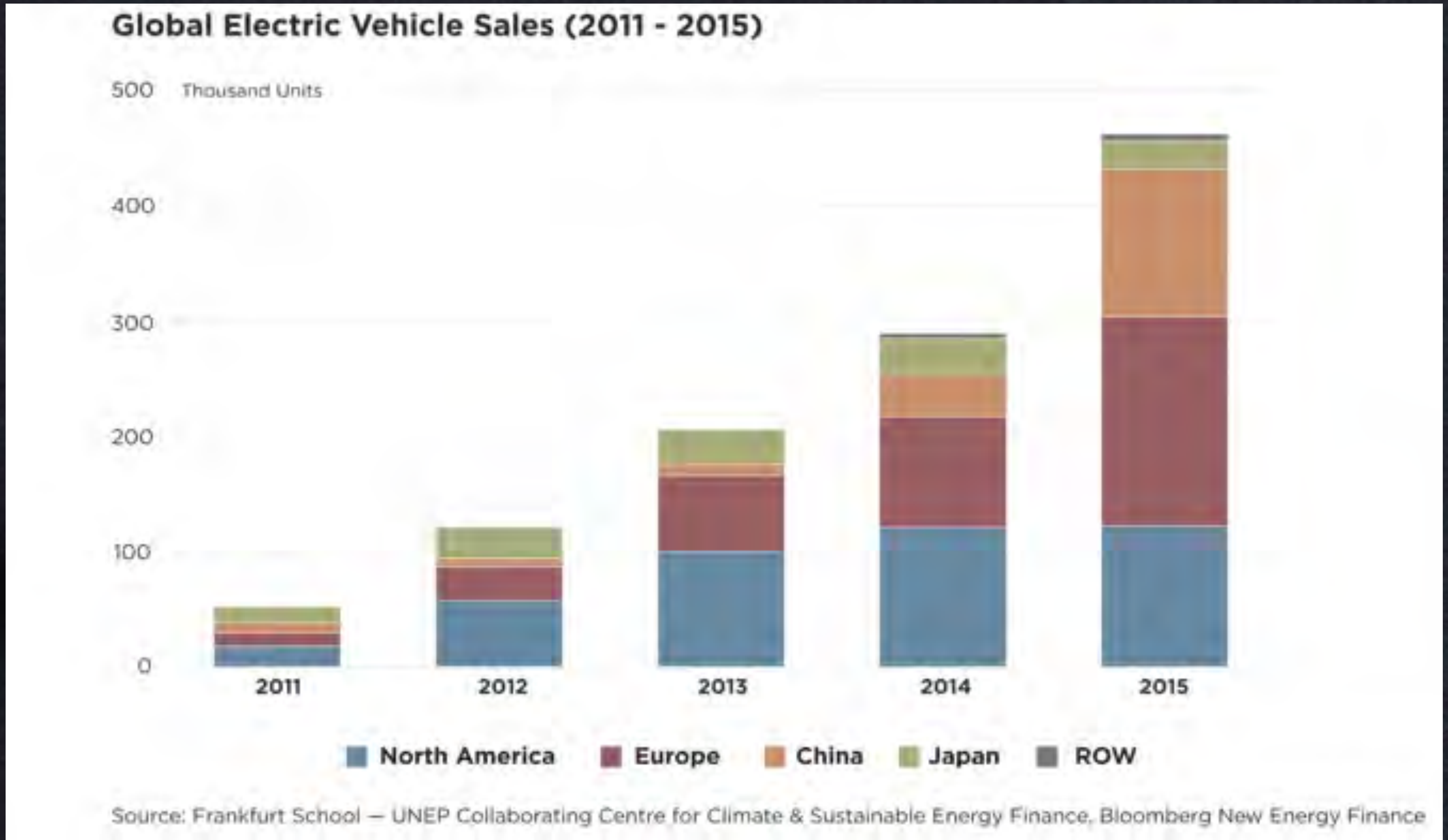
Uncontrolled: ~50% of solar PV production is sent to the grid, but if the utility doesn't pay for that energy, how could customers respond?

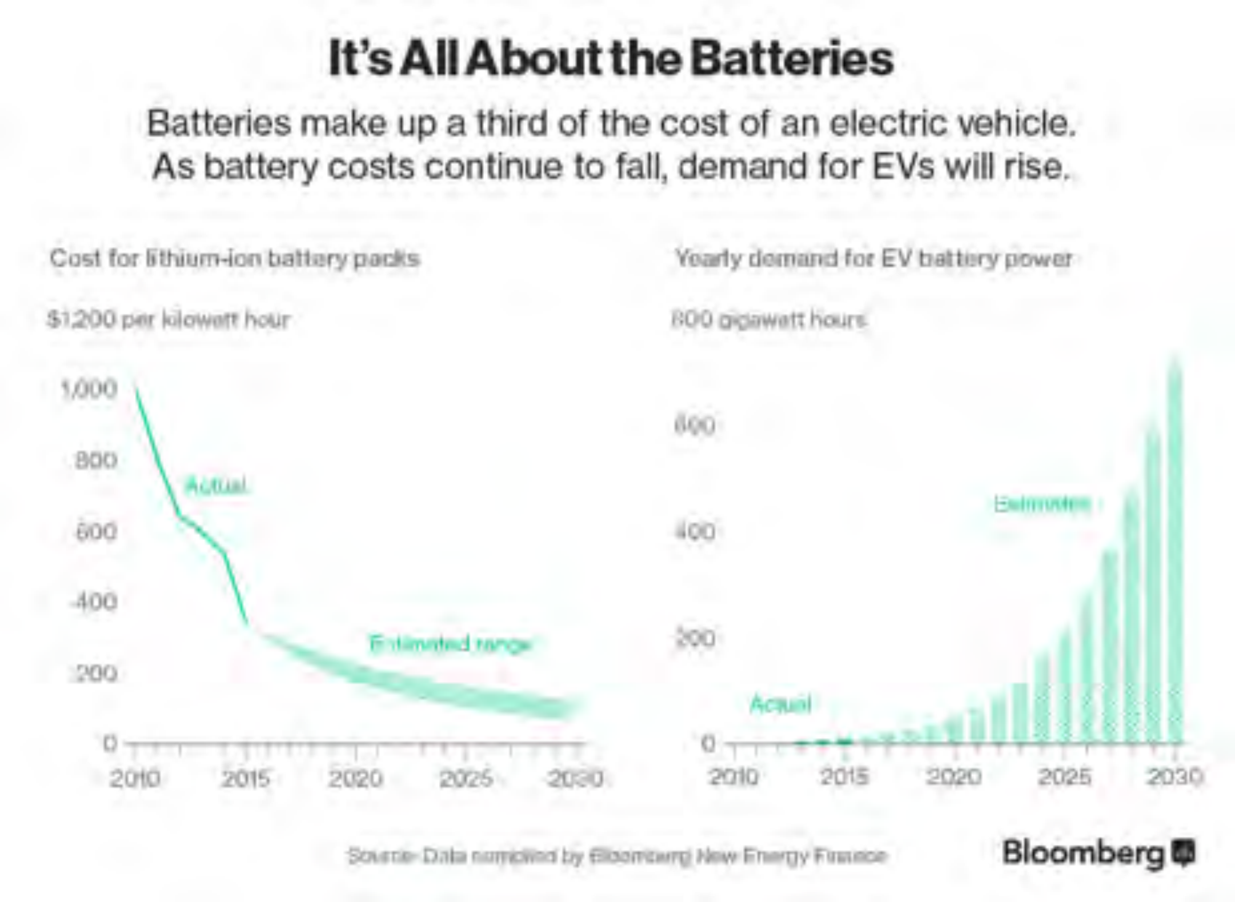


Controlled: flexible load enables customers to consume >80% of solar PV production onsite. The utility loses nearly all its windfall and most of its ordinary revenue.

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

Rapid Growth of Electrified Cars





U.S. EV sales flattened—but *global* sales are growing ~60%/y, and at least four ways to accelerate that growth are emerging

Source: Tom Randall (Bloomberg), "Here's How Electric Cars Will Cause the Next Oil Crisis," 25 Feb 2016, http://www.bloomberg.com/features/2016-ev-oil-crisis/; see also RMI, "Electric Vehicle Charging as a Distributed Energy Resource," in press, spring 2016

REINVENTING FIRE®

BOLD BUSINESS SOLUTIONS FOR THE NEW ENERGY ERA

$5T

in savings
(2009 $,
net present value,
private internal cost)

+158%

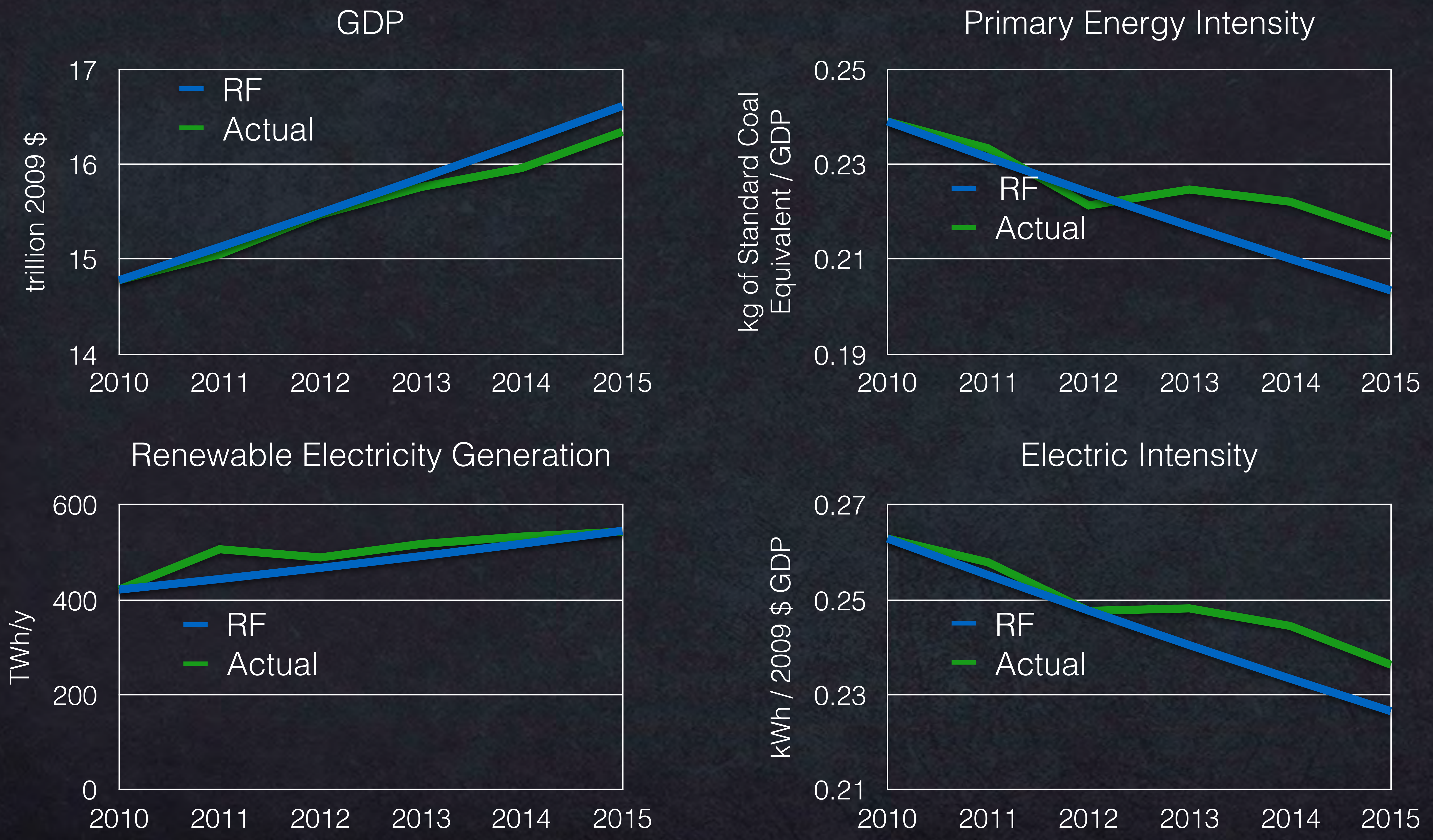
bigger GDP

0

oil, coal, nuclear

2010–2015 U.S. progress toward *Reinventing Fire's* 2050 goals

Actuals (USEIA) are not weather-adjusted. *Reinventing Fire* progression based on constant exponential growth rate.



Solutions to :




面向2050年能源消费和生产革命路线图研究

RMB22T	+587%	38%
in savings	bigger GDP	less carbon
经济节约	经济规模	碳排放减少

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

From the Age of Carbon to the Age of Silicon

Japan can lead this global energy *hiyaku* (飛躍)

日本は、世界のエネルギー業界の飛躍を牽引することができる

Japanese frogs jump too!
日本の蛙も飛躍する!

The old pond
frog jumps in
plop
—*Bashō, 1686,* 松尾芭蕉

古池
蛙飛び込む
水の音