Disruptive energy futures

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“I can’t wait to see what happens when our industries merge.”
Designing to save ~90% of pipe and duct friction—equivalent to about half the world’s coal-fired electricity
	hin, long, crooked

fat, short, straight

Typical paybacks ≤1 y retrofit, ≤0 new-build

But not yet in any textbook, official study, or industry forecast
LED and PV


Graph: White LED efficiency over time. Key: Sodium-vapor lamp (1965), Incandescent lamp (1879), Halogen lamp (1959), Fluorescent lamp (1938).

Y-axis: Luminous efficacy (lm/W).
X-axis: Years.

Legend:
- Coal-fired steam turbine, fuel cost only
- Oil-fired condensing, fuel cost only
- Natural gas CCGT, fuel cost only
- Utility-scale solar PV, total cost
- Onshore windpower, total cost
- German PV residential feed-in tariff (Seattle-like climate)

Sources:
- 10.1088/0022-3727/43/35/354002
- USEIA fossil-fueled generation efficiencies and each year’s real fuel costs (no O&M)
- LBNL, Utility-Scale Solar 2013 (Sep 2014), Fig. 18
- Fraunhofer ISE, Cost Perspective, Grid and Market Integration of Renewable Energies, p 6 (Jan 2014)
- Michael Parker, Bernstein Alliance

Graph: Real busbar price or fuel cost, 2011 US$/MWh.
X-axis: Years from 1990 to 2015.
Y-axis: Real busbar price or fuel cost (US$/MWh).

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Netherlands: trade electricity with fellow-customers
Renewable energy’s costs continue to plummet

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

Levelized 2014 US$/MWh

* = lowest unsubsidized auction bids worldwide

Updated through Mar 2017; solar asterisks: Chile (2.91¢/kWh, Aug 2016) and Mexico (2.7 ¢/kWh, Feb 2017); wind asterisk: Morocco (Jan 2016)
Grid flexibility supply curve

- Grid flexibility supply curve
- cost
- efficient use
- demand response
- accurate forecasting of wind + PV
- diversify renewables by type and location
- dispatchable renewables and cogeneration
- distributed electricity storage incl. EVs
- thermal storage
- fossil-fueled backup
- bulk storage
- ability to accommodate reliably a large share of variable renewable power

(all values shown are conceptual and illustrative)
$5T$ in savings

$+158\%$ bigger economy

0 oil, coal, nuclear
RMB 21T
2010 NPV

in savings
经济节约

+ 587%
bigger GDP
经济规模

42%
less carbon
碳排放减少
Easter Parades on Fifth Avenue, New York, 13 years apart

1900: where’s the first car?

1913: where’s the last horse?


Corporate Renewable Deals
2013 – 2018 YTD

Publicly announced contracted capacity of corporate Power Purchase Agreements, Green Power Purchases, Green Tariffs, and Outright Project Ownership in the US and Mexico, 2013 – 2018 (YTD). Excludes on-site generation (e.g., rooftop solar PV) and deals with operating plants. Last updated: February 13, 2018.

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All through cities, up and down the supply chain
From the Age of Carbon to the Age of Silicon
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