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Observations on Fusion Power Market Attractiveness

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The electricity market is a competitive place

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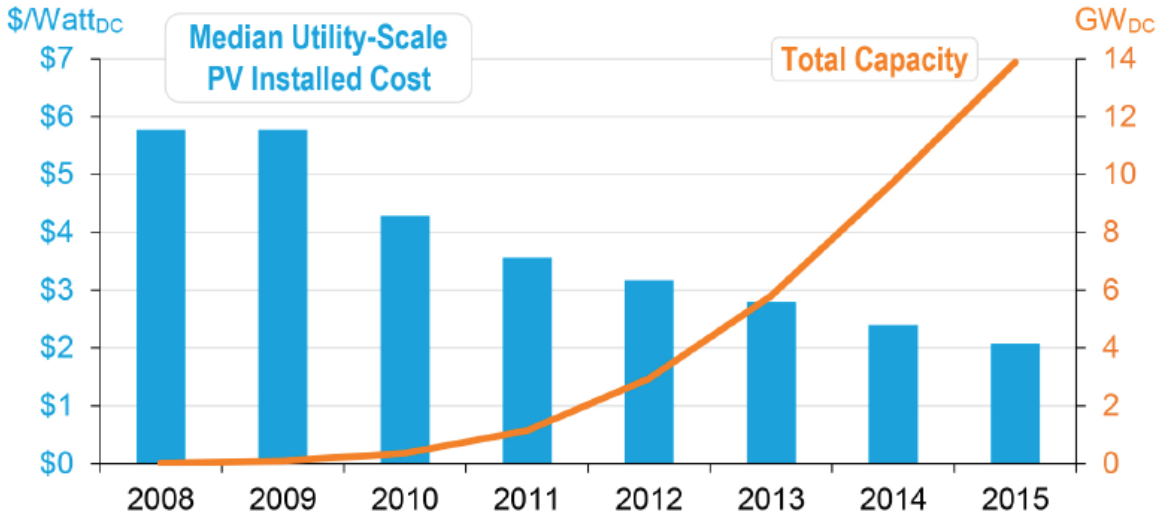
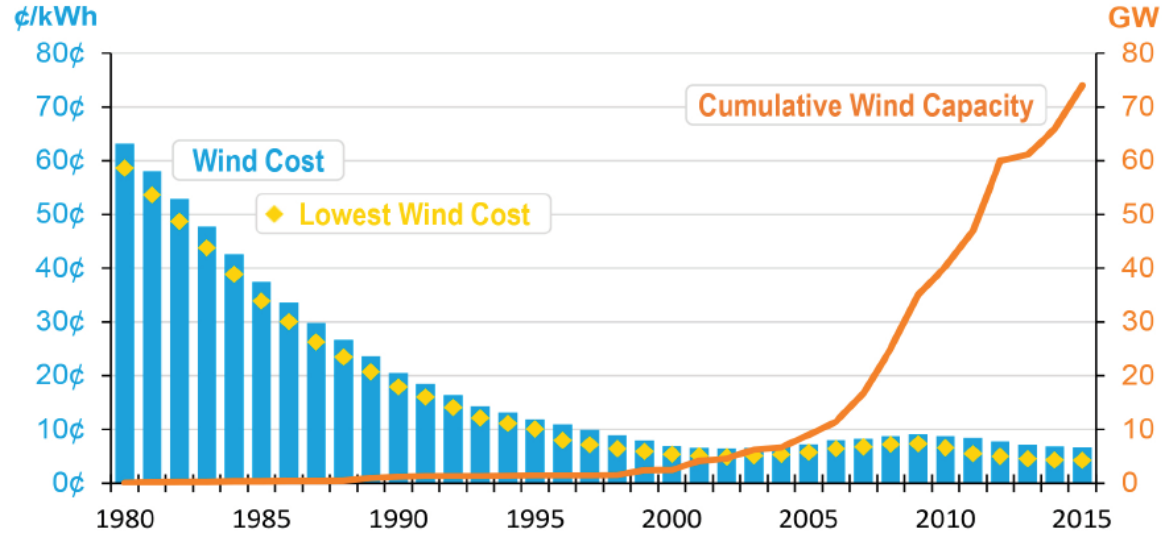
Solar PV: Utility-Scale



Costs from reference [4]; Deployment from reference [16]. Costs shown are the median costs and exclude the effect of the Investment Tax Credit. 1 gigawatt (GW) = 1,000 megawatts (MW). Costs and capacity are reported as DC power.

Wind



Cost data from references are inflation adjusted to dollar year 2015, and exclude the production tax credit. "Wind Cost" data estimates the levelized cost of energy from a representative wind site from references [1] and [2] and "Lowest Wind Cost" represents costs derived from power purchase agreements from good to excellent wind resource sites in the interior of the country as reported in reference [9]. ¹ Deployment data also from reference [9]. 1 gigawatt (GW) = 1,000 megawatts (MW).

- Signed power purchase agreements exist at or below $0.035/kWh (PV) and $0.02/kWh (Wind)
- …but challenges remain for PV or Wind to serve as a merchant generator

https://www.energy.gov/eere/downloads/revolutionnow-2016-update

But intermittent renewables are no panacea

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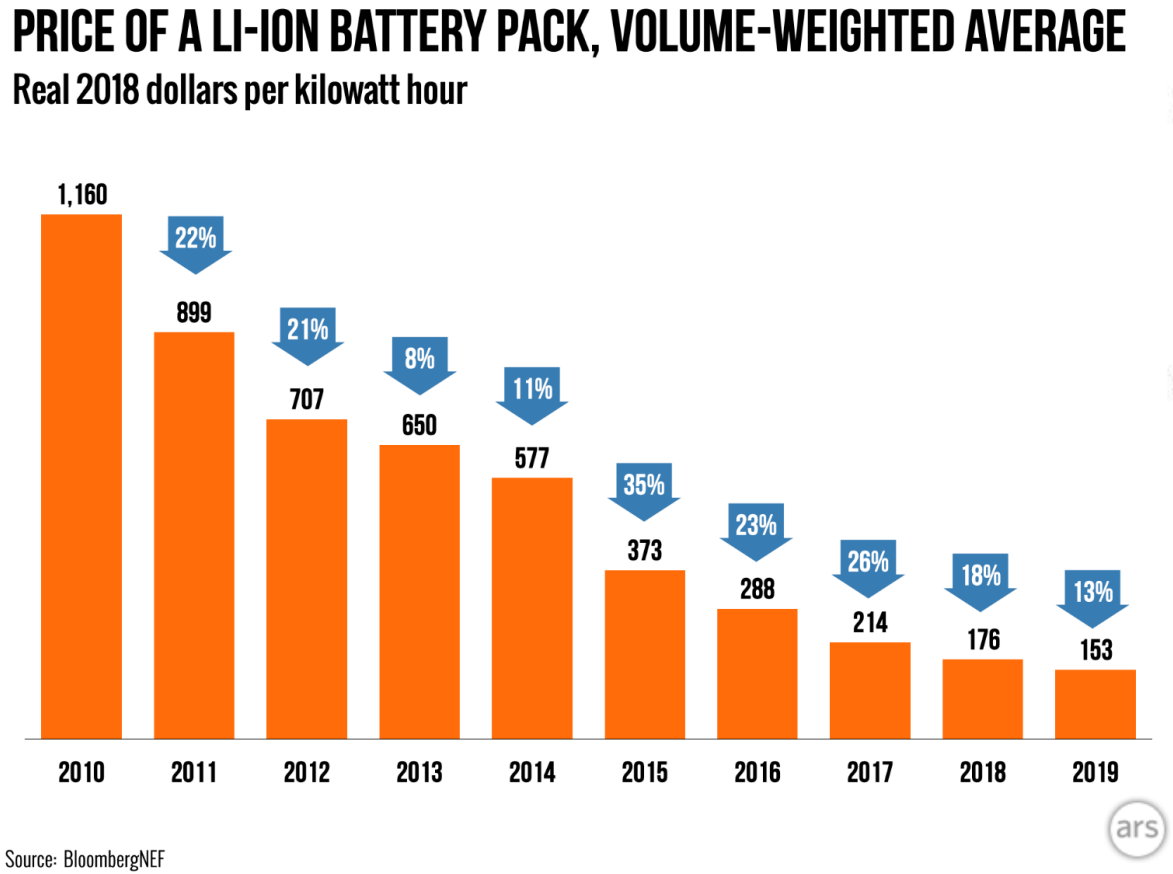
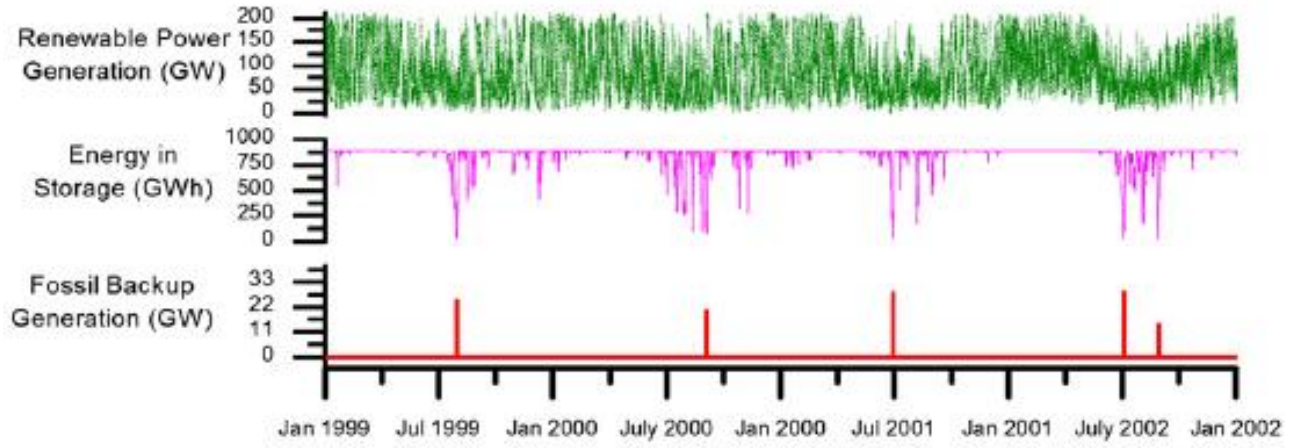


Source: BloombergNEF



Load was met with renewable generation and storage 99.9% of hours over 4 years; fossil backup needed on five occasions

Table 4
Cost to make load using renewables, storage, and fossil backup, ¢/kWh in 2010 dollars.

Hours covered by all renewables (%)	Hydrogen		Central batteries		GIV	
	2008	2030	2008	2030	2008	2030
30	11	09	11	09	11	11
90	22	10	23	15	28	09
99.9	36	17	45	25	32	17

Budischak, et al Journal of Power Sources 225 (2013) 60–74

- Fusion-specific benefits:
  - power density and geographic / seasonal independence
- …but can fusion deliver re: cost and load-following?

Power plant footprints

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Mumbai or Tokyo electricity demand: 1 MW / 60 acres

Fuel-based power plant:
13 Acres / MW

Solar:
44 Acres / MW

Wind:
71 Acres / MW

L. Stevens et al, “The footprint of energy: land use of U.S. electricity production,” Strata 2017

The scale of U.S. power plants today

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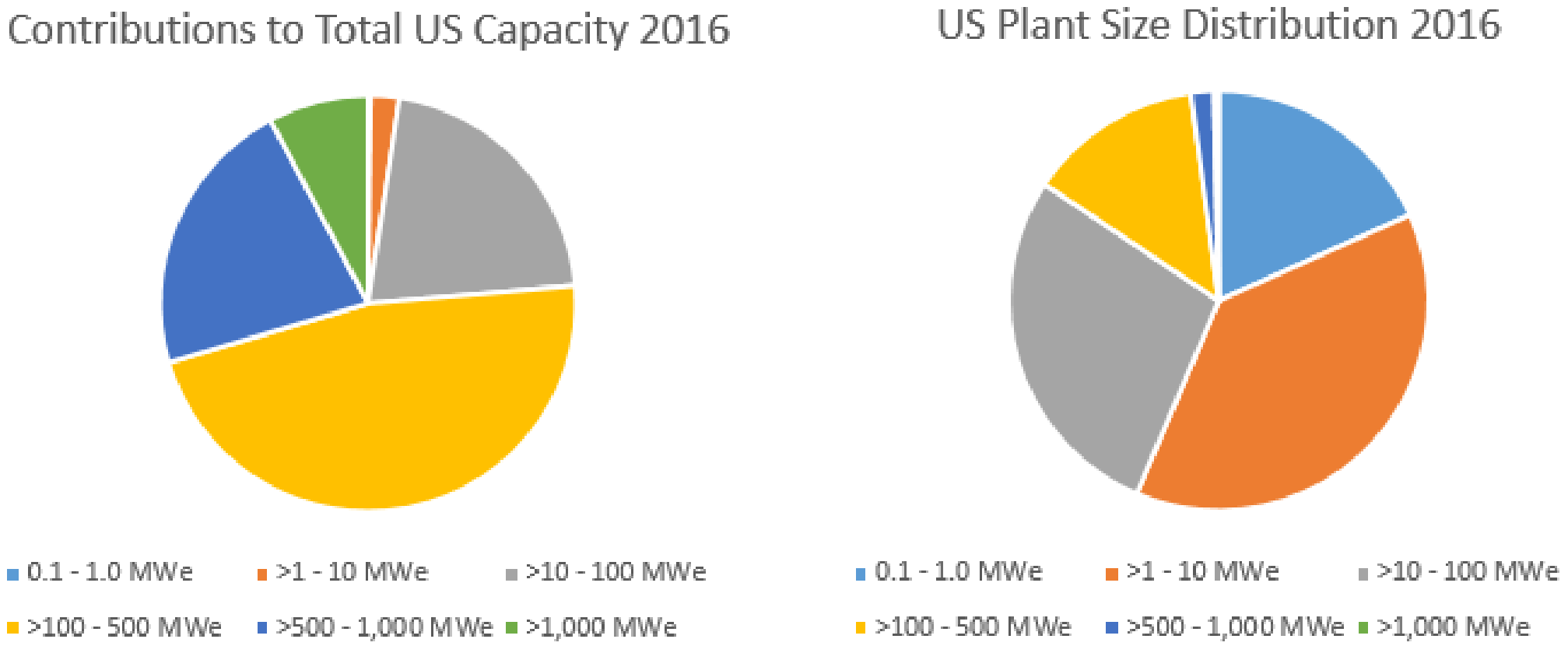

- In 2016, plants larger than 1 GWe were responsible for 8% of U.S. electricity generation capacity
- Of the ~17,000 plants with > 1MWe capacity, only 76 are > 1 GWe

All data from Form EIA-860 -- https://www.eia.gov/electricity/data/eia860/

Evolution of the U.S. power plant fleet

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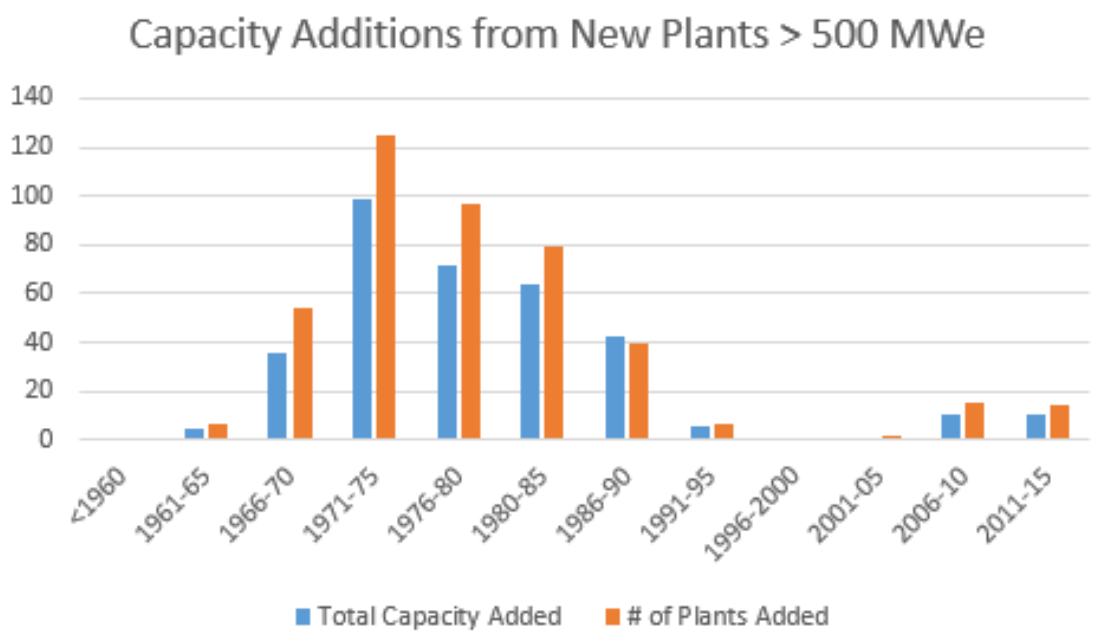
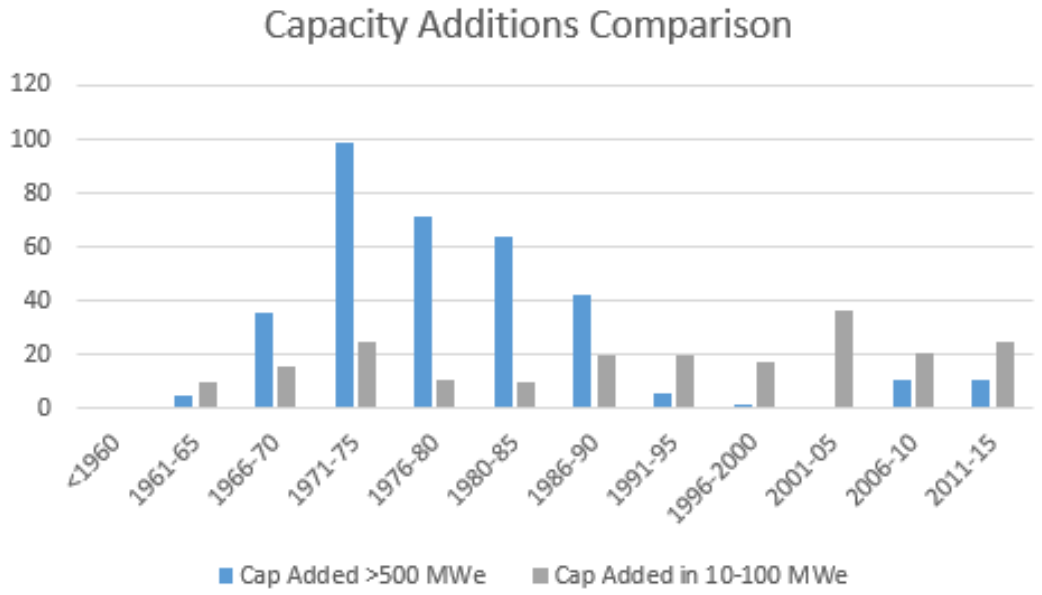
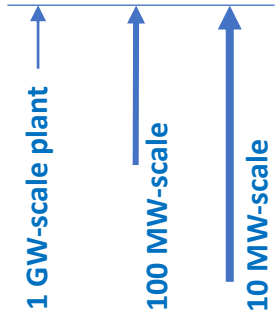
All data from Form EIA-860 -- https://www.eia.gov/electricity/data/eia860/





- Large scale plants are the exception rather than the rule
- Smaller plants offer greater flexibility in:
  - financing options (to build)
  - matching load changes (in operation)

Population	# of high-density cities/towns
1,000,000+	3
100,000 – 999,999	14
50,000 – 99,999	29
10,000 – 49,999	48
1,000 – 9,999	26
0 – 999	5



https://en.wikipedia.org/wiki/List_of_United_States_cities_by_population_density

Things we've heard from utilities

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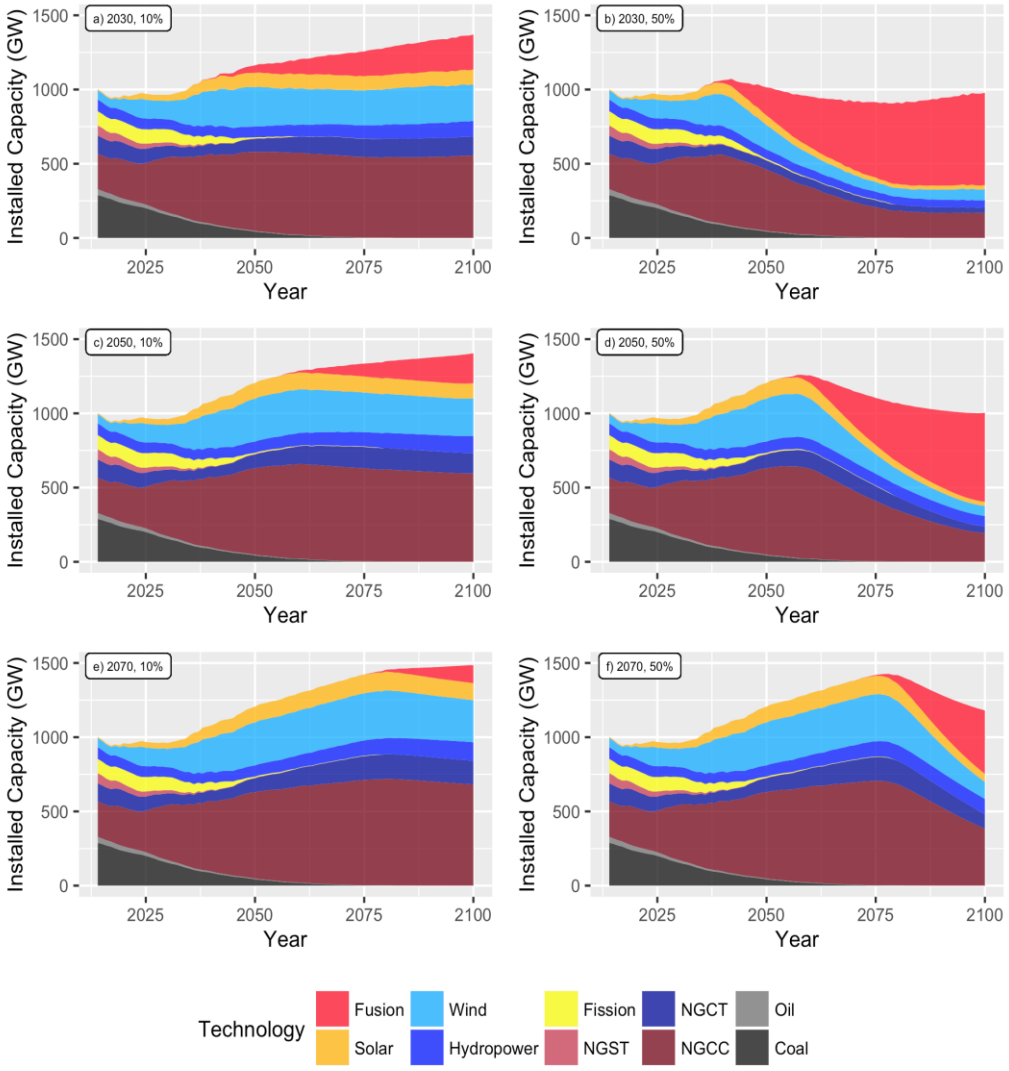
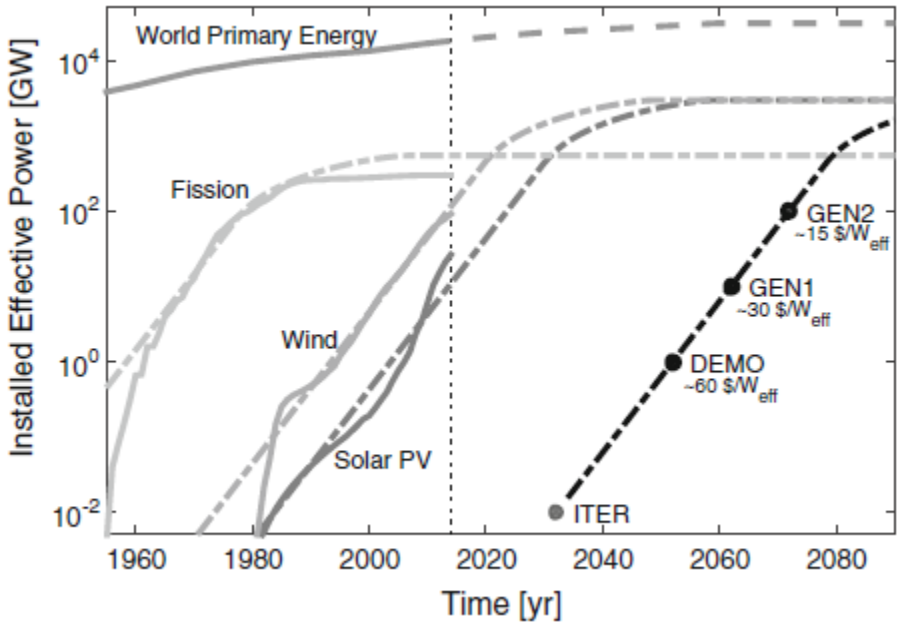
- Load-following capability and frequency support
- Sized to match load growth
- Lower capital cost capacity additions
- More distributed / incremental
- Smaller footprint
- More siting options
- Enhanced safety / security
- Shorter construction timeline
- Smaller operational staff

Fusion adoption scenarios



- Key takeaways:
  - Later fusion entry generally equates to larger initial fusion plant additions due to larger total electricity demand
  - Depending on market share, fusion ramps up to approx. 3-15 GWe / yr capacity additions in U.S.

Cordozo, Lange, Kramer, JFE 2016



L. Spangher, J. S. Vitter and R. Umstattd, "Characterizing Fusion Market Entry via an Agent-based Power Plant Fleet Model," *Energy Strategy Reviews* **26**, 100404 (Nov 2019)

Opportunities overseas

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Figure 5-1. OECD and non-OECD net electricity generation, 1990–2040 (trillion kilowatthours)

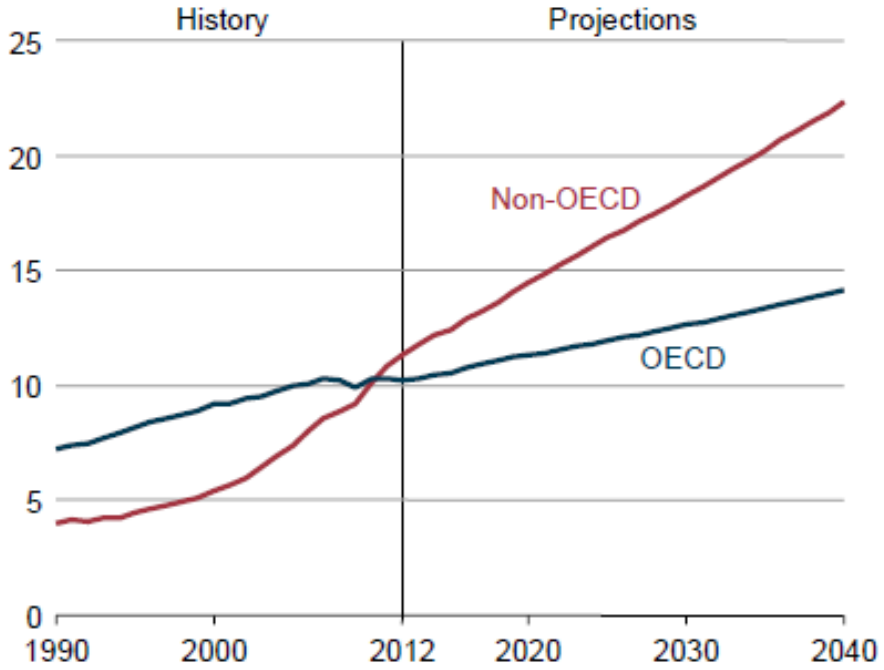

Figure 5-14. World electricity transmission and distribution losses by selected countries and regions, 2001 and 2013 (percent of total generation)

- Net electricity generation in non-OECD countries rises twice as fast as in the OECD
- Transmission & distribution infrastructure still maturing in some markets

EIA International Energy Outlook 2016 -- DOE/EIA-0484(2016)

Getting there from here: can private financing support fusion development?

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- Attributes for matching investors with fusion development
  - The investors: philanthropic, mission-oriented, patient (a small but growing subset of general venture capital) OR energy sector strategic / corporate venture
  - The technology: development path needs well-defined stage gates
    - Demonstrate step-changes in valuation during development
    - Demonstrate quantified risk-reduction

- Portfolio approach for both the investors and the technologies
  - To manage technology risk, need diverse, independent approaches
  - Need tiers of investors matched to each stage of tech risk / capital requirements

- Opportunities for early revenue streams consistent with path to fusion energy

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The Voice of a new Industry

The Fusion Industry Association is an international coalition of companies working to electrify the world with fusion - the unparalleled power of the stars. Energy from fusion will provide clean power for everyone that's safe, affordable, and limitless.