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Nuclear Power Industry

NEI International Uranium Fuel Seminar
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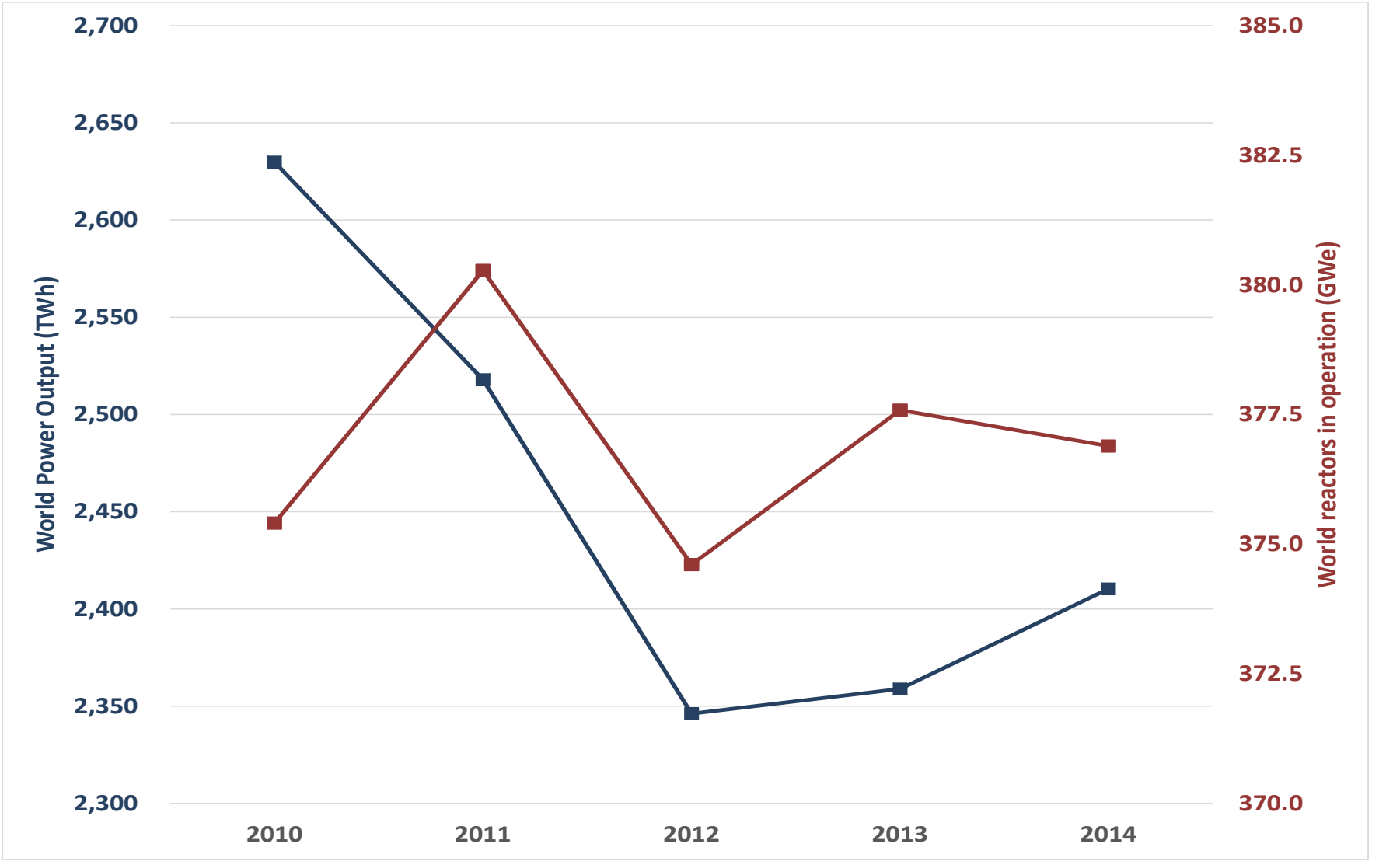
Last five years



What happened?

- Great East Japan Earthquake and Tsunami
  - Fukushima Dai-ichi accident
  - Japanese shutdown of all nuclear units
  - German decision to phase out nuclear
- New units
  - COD - China, Korea, India, Russia, Argentina, Iran
  - Construction starts – 40 units (25 after FD)
- Retirements - US, UK, Spain, and Quebec

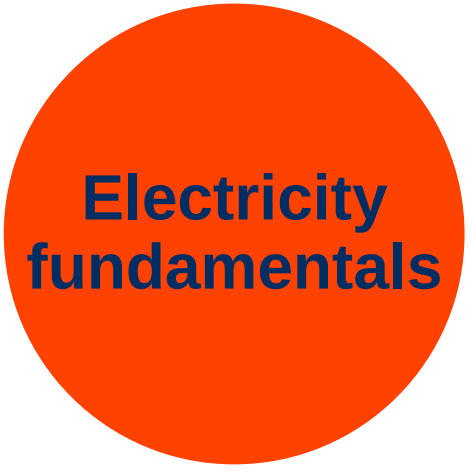
Nuclear units

	2011	2012	2013	2014
Entered Service	Ling Ao 4 Qinshan 2-4 Kaiga 4 Bushehr 1 Chasnupp 2 Kalinin 4	Bruce 1 & 2 Pt Lepreau Ningde 1 Shin Kori 2 Shin Wolsong 1	Hongyanhe 1 & 2 Yangjiang 1 Kudankulam 1	Atucha 2 Fangjiashan-1 Fuqing 1 Ningde 2 Rostov 3
Retired or closed	*Japan* • Fleet shutdown • Fukushima I-1-4 *Germany* • Biblis A & B • Brunsbuettel • Isar 1 • Kruemmel • Neckarwestheim 1 • Philippsburg 1 • Unterweser Oldbury A-2	Gentilly 2 Oldbury A-1 Wylfa 2	Garoña Crystal River 3 Kewaunee SONGS 2 & 3	Fukushima I-5&6 Vermont Yankee

Nuclear power ≡ electricity production

- Nuclear power closely linked to
  - Availability & cost of other power generation options
  - Electricity industry structure (traditional vs markets)
  - Nuclear business model and role of government
- New nuclear build in traditional electricity approach where nuclear has relative value
- Little new nuclear (and closures) in electricity markets and where nuclear has low relative value

Electricity fundamentals



- Electricity system
  - Long-term investments
  - Real-time dispatch
- Value of nuclear electricity
  - Linked to other generation options
  - Availability of alternate fuels is key

China

Electricity fundamentals

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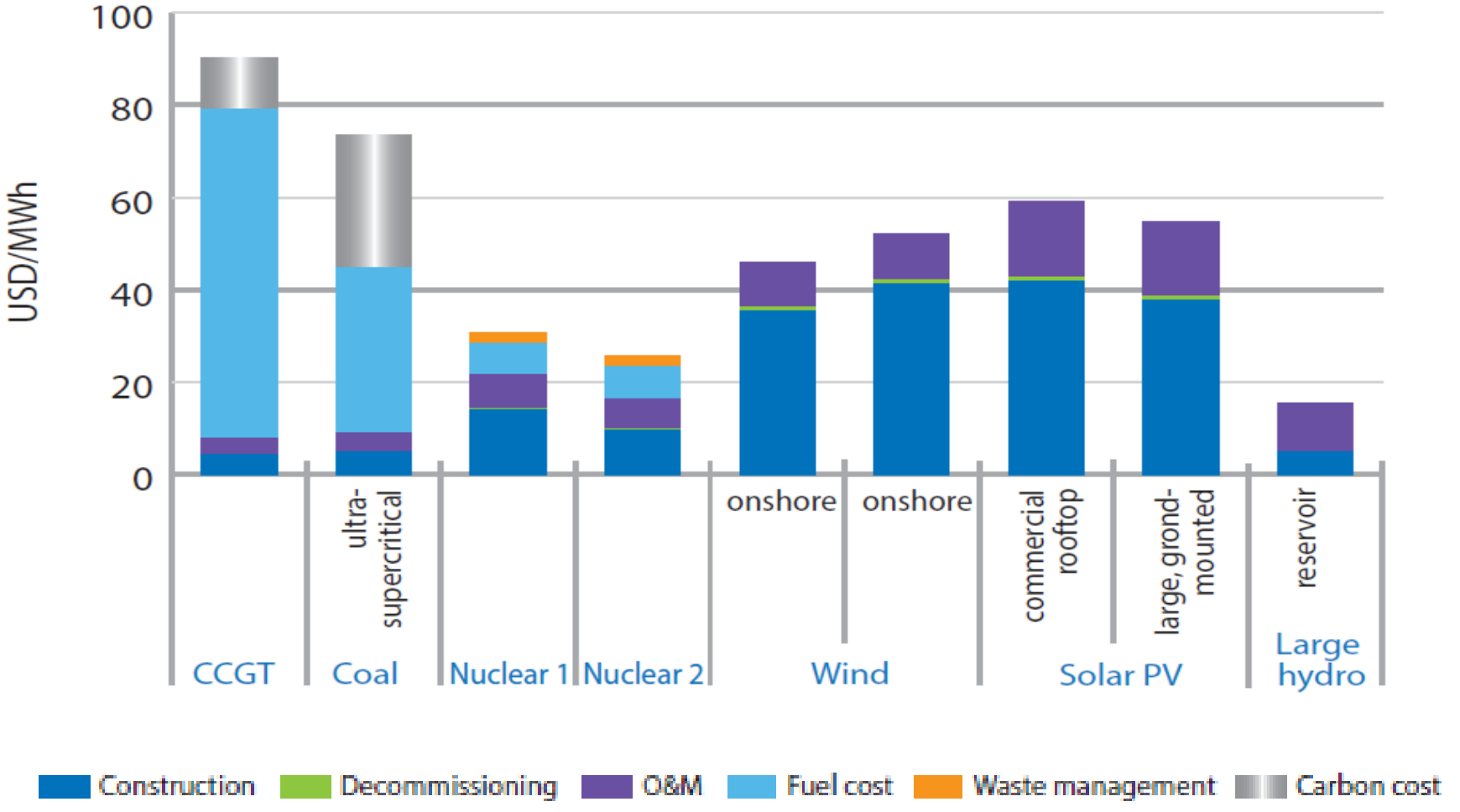
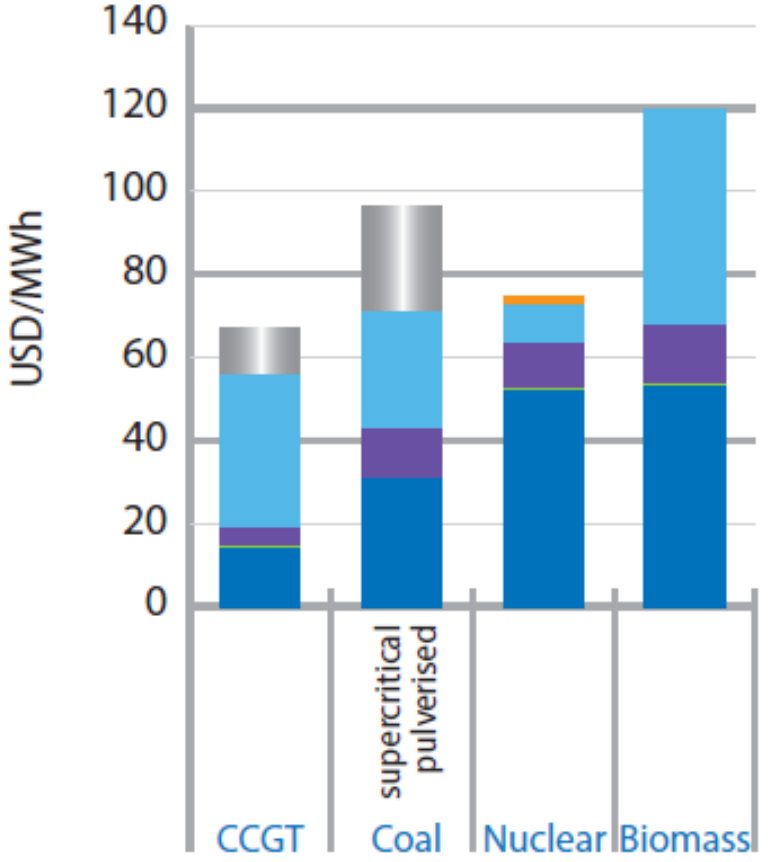


Source: Figure 4.21; OECD Generating Costs 2015, LCOE - China; 3% discount rate

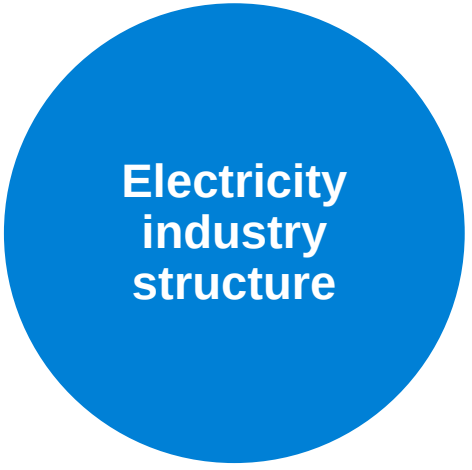
USA



- EIA / AEO 2015
  - CCGT $64.4 - $66.3
  - Coal $95.6
  - Adv. nuclear $96.1
  - Biomass $102.6

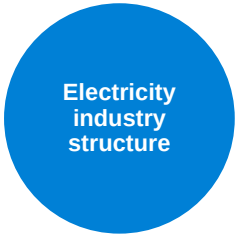
Source: Figure 4.19; OECD Generating Costs 2015, LCOE – United States; 7% discount rate

Electricity industry structure



- Traditional
  - Government-owned electricity sector
  - Investor-owned regulated utility
  - Cooperatives
- New - electricity markets

Different economic drivers



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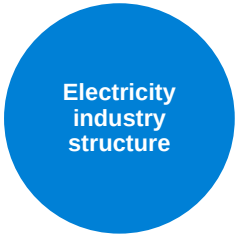
- Traditional electricity industry approach – regulated/government utilities plan and build a portfolio of generation units to:

minimize long-term total cost of electricity

- New market-based electricity industry approach - electricity markets manage system dispatch to

minimize short-term marginal cost of electricity

Market Risk



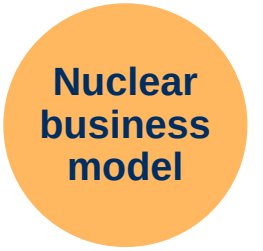
- Short-term
  - Prices vary hourly/daily/monthly
  - Decisions by multiple parties
  - No spot market revenue for key nuclear attributes
- Long-term
  - Fuel costs (e.g., shale gas)
  - Technology shifts (e.g., CCGT; renewables)
  - Policy/subsidy actions (e.g., renewable mandate)

Nuclear business models

Nuclear business model

- Traditional
  - Government or regulated utility
  - IPP with power contracts
  - Energy user cooperatives
- New - merchant nuclear

Revenue certainty key to new nuclear



- Traditional approaches to electricity industry cover nuclear project/market risk
- Long-term PPA may be feasible
- Merchant nuclear approach difficult
  - Multiple approaches for revenue adequacy/certainty
  - Power contracts add revenue certainty
  - Project design/operation flexibility for market risk
  - Careful analysis of project economics needed

Uncertain electricity market revenue

Nuclear business model

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- Future electricity market revenue hard to predict
  - Market simulations with range of assumptions (entry/exit, fuel prices, demand, market rules, etc.)
  - Micro issues and macro issues
  - Scenarios to reflect major uncertainties
  - Bilateral power markets harder to predict
- Nuclear time-lines make this even more difficult
  - Revenue starts at COD (~10 years after project start)
  - Project operates for 60 years (or more)

Nuclear capacity forecasts

Nuclear capacity forecasts

- IAEA 2015 RDS-1
- WNA 2015 Nuclear Fuel Report
- How do these forecasts of nuclear capacity reflect the issues just covered?

IAEA 2015 RDS-1

Nuclear capacity forecasts

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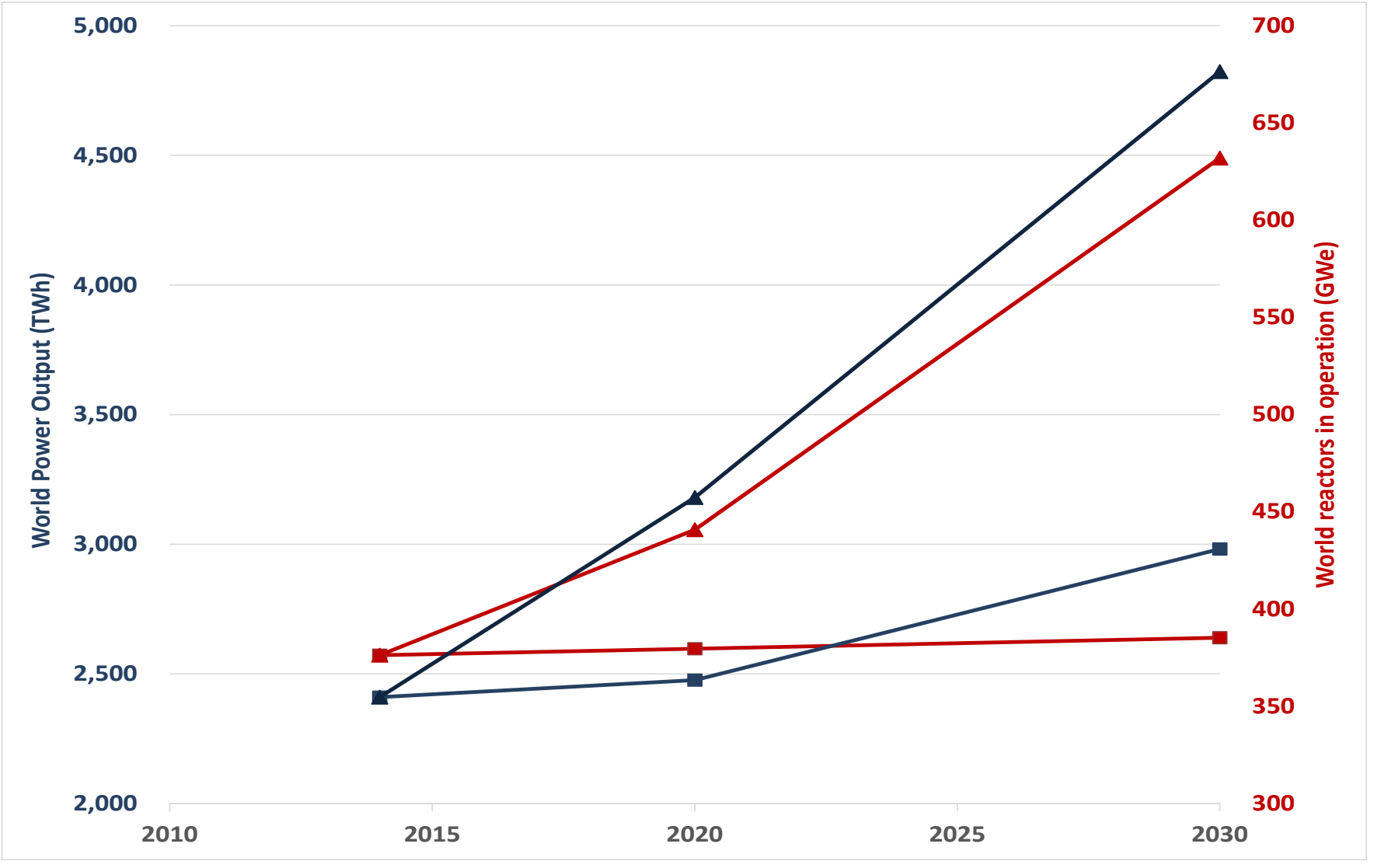
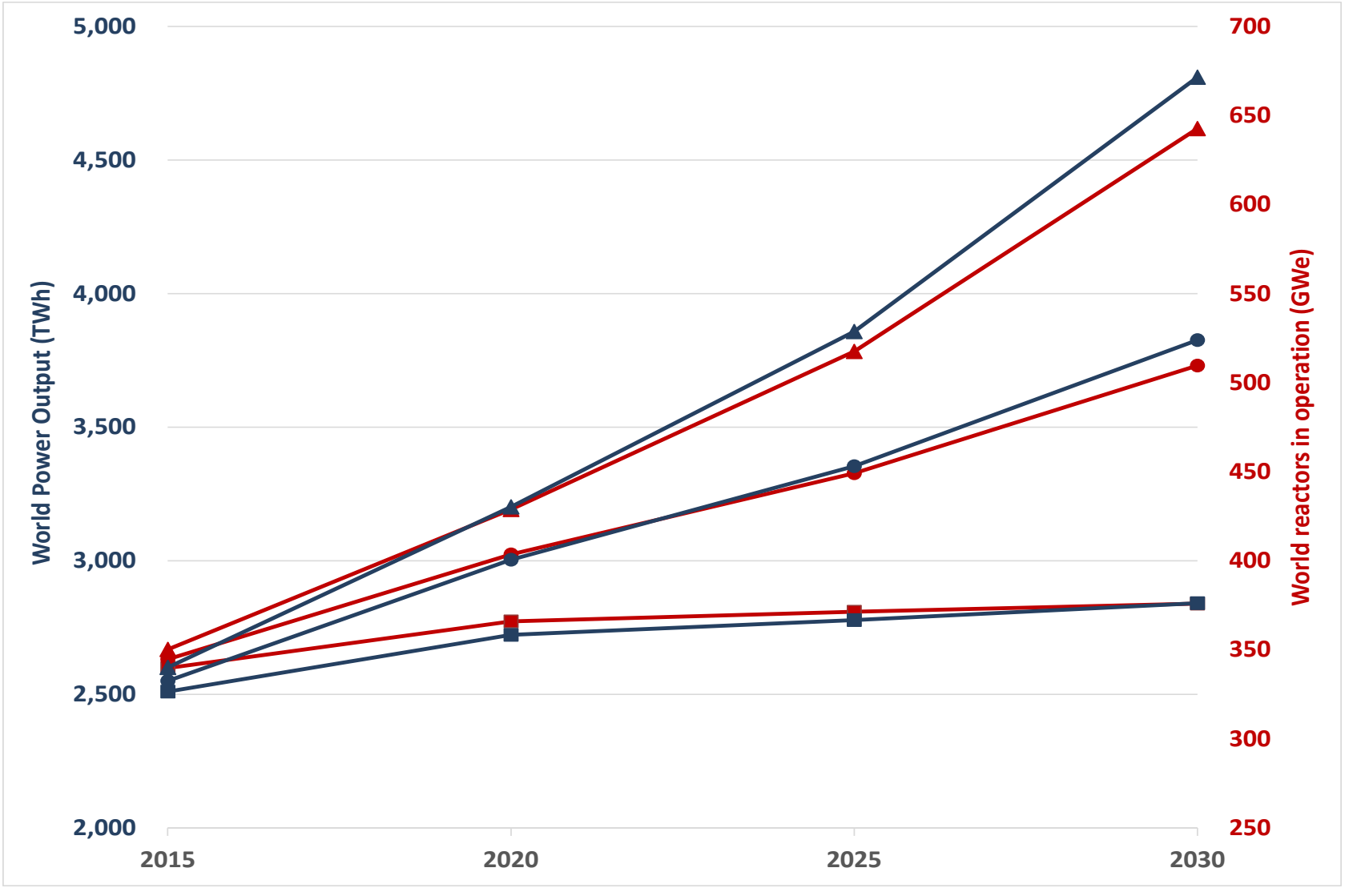


WNA 2015 Nuclear Fuel Report

Nuclear capacity forecasts

NECG



2020 IAEA GW increase from 2014

Nuclear capacity forecasts

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	Low	High
Far East	+ 11.6	+ 35.8
Eastern Europe	+ 5.5	+ 13.0
Middle East and South Asia	+ 5.1	+ 10.5
North America	- 3.8	+ 6.1
Latin America	- 0.3	+ 1.0
Africa	0.0	0.0
SE Asia and Pacific	0.0	0.0
Western Europe	- 14.7	- 1.8
TOTAL	+ 3.4	+ 64.6

2020 WNA GW increase from 2015

Nuclear capacity forecasts

NECG

	Lower	Reference	Upper
China	+ 22.0	+ 25.3	+ 27.1
Asia	+ 13.3	+ 28.9	+ 41.3
Russia	+ 1.9	+ 2.9	+ 2.9
Other	- 1.0	+ 2.9	+ 3.4
Latin America	- 0.3	-	-
USA	- 4.1	+ 2.4	+ 5.0
Eastern Europe	-	-	+ 1.2
Canada	-	-	-
Europe	- 7.7	- 3.4	- 2.1
TOTAL	+ 26.1	+ 58.8	+ 78.6

2030 IAEA GW increase from 2014

Nuclear capacity forecasts

NECG

	Low	High
Far East	+ 44.7	+ 131.9
Eastern Europe	+ 14.4	+ 43.8
Middle East and South Asia	+ 19.0	+ 36.9
North America	- 20.1	+ 27.6
Latin America	+ 2.0	+ 8.6
Africa	-	+ 4.6
SE Asia and Pacific	-	+ 4.0
Western Europe	- 51.0	- 1.7
TOTAL	+ 9.0	+ 255.7

WNA - 2030 GW increase from 2015

Nuclear capacity forecasts

NECG

	Lower	Reference	Upper
China	+ 68.6	+ 98.4	+ 127.1
Asia	+ 21.4	+ 48.2	+ 67.8
Other	+ 7.9	+ 22.0	+ 52.6
Russia	+ 1.2	+ 6.3	+ 10.9
Eastern Europe	+ 1.2	+ 5.2	+ 4.8
Canada	- 1.0	-	+ 1.4
Latin America	- 1.5	+ 3.8	+ 9.6
USA	- 6.0	+8.7	+ 12.2
Europe	- 55.4	- 27.7	+ 6.2
TOTAL	+ 36.1	+ 164.9	+ 292.5

Future of nuclear power

- Significant growth in some countries (e.g., China)
  - Strong role of government
  - Strong demand growth
  - High relative value for nuclear
- Electricity markets not good fit for nuclear
  - US merchant nuclear threatened
  - Market-based new nuclear really hard
- Climate change?
- Western Europe moving away from nuclear

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