georguensberg
Politik- und Strategieberatun

The role of climate change and nuclear in major energy scenarios

Climate Crisis: Why Nuclear is not Helping

October 7&8, 2019

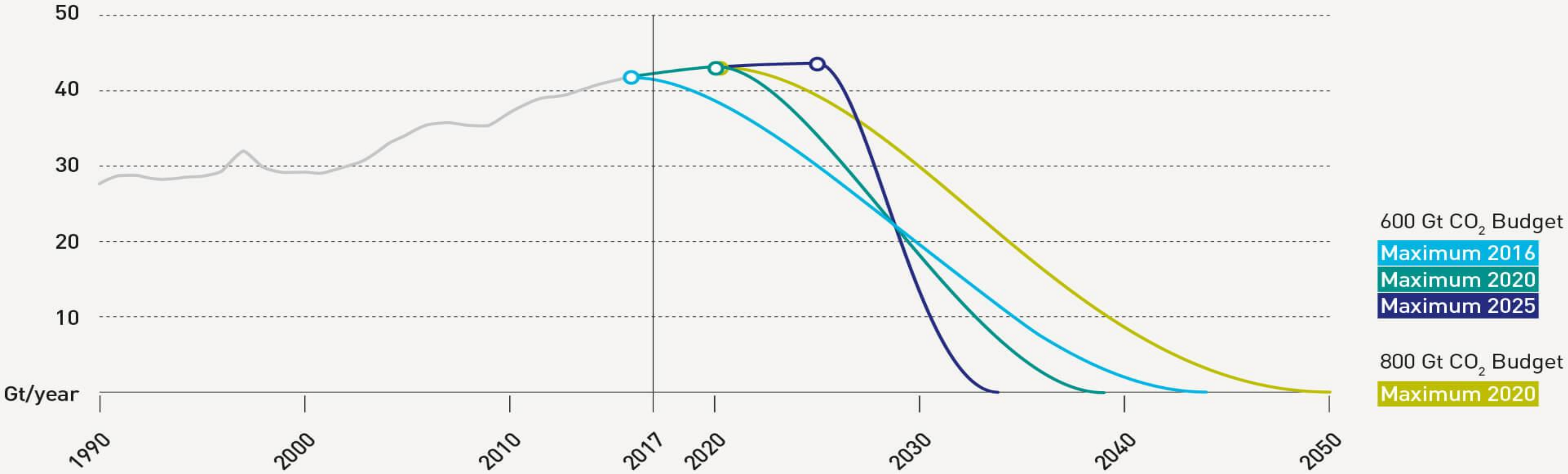
Vienna

Some structure

- The climate change challenge and a new energy world
- The role of scenarios for decision makers
- Looking back at forecasts
- Key aspects
- Battlefield„sustainable finance“

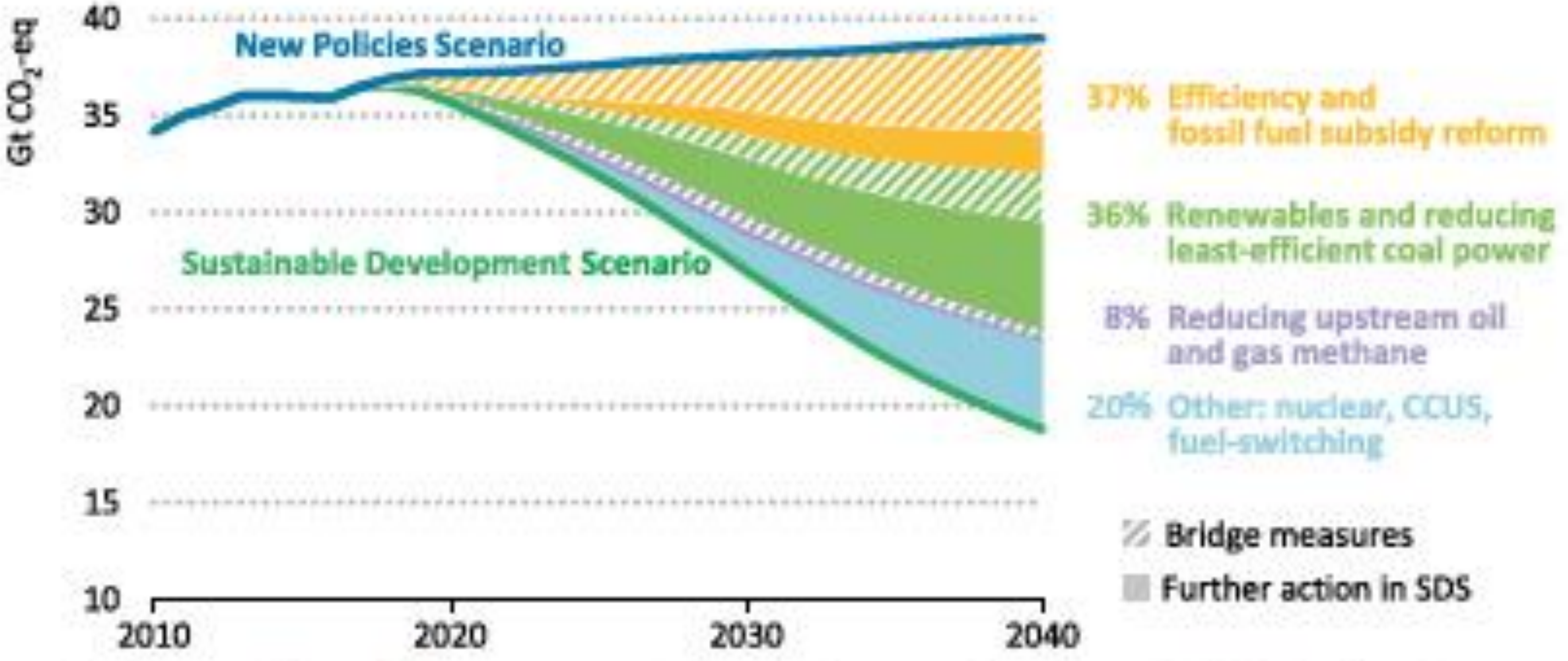
The later greenhouse gas emissions are reduced, the faster they need to drop

Global CO_2 emission scenarios to comply with the 1.5°C and 2°C temperature limit



Source: The Global Carbon Project 2016, Nature 2017

Figure 2.16 ▷ CO_2 and methane emissions reductions by measure in the Sustainable Development Scenario relative to the New Policies Scenario



Implementation of five measures at no net economic cost would bridge less than half of the gap between current trends and a Paris Agreement trajectory

Notes: Gt CO_2-eq = gigatonnes of CO_2 equivalent; CCUS = Carbon, Capture, Utilisation and Storage; SDS = Sustainable Development Scenario; 100-year global warming potential of methane = 30.

IEA WEO 2018

The new energy world:
A wide range of trends are linked to energy

- Decarbonisation
- Disruption
- Divest-Invest
- Decentralization
- Digitalisation
- Democratization

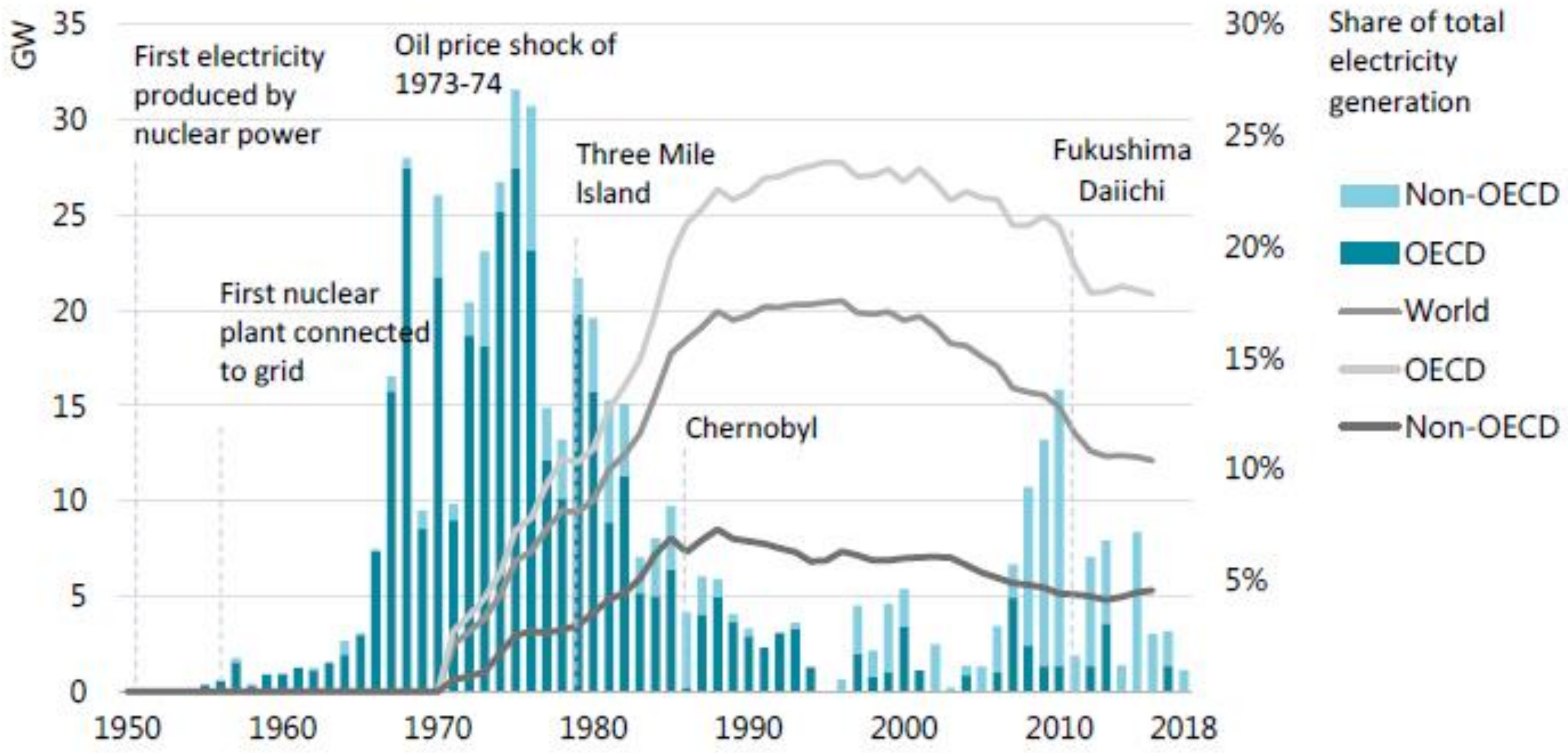
Theses on the new energy world in a resilience perspective

- **Disruption**: breakthrough technologies, innovation and dramatic costs reduction (PV, EV) will change many industries on global scale. Conventional energy scenarios do not reflect the transformation process in a sufficient way.
- **Decarbonisation**: will become a key element for all industries. EU discussion on long term strategy on GHG reduction. Inaction will bring even more disruption to economy and society.
- **Divest-Invest:** finance markets have sent a signal. But policies have to deliver on instruments (carbon tax) and measures.

Theses on the new energy world in a resilience perspective

- **Decentralisation**: An energy system based on renewable energy will be more decentralised, requires more flexibility and demand-side management. Current instruments (and institutions) and rules are based on the old, conventional system.
- **Digitalisation**: is a key driver for the transformation and creates new business models. But: negative effects to be taken into account.
- **Democratization & transparency**: Civil society will play a key element in the transformation but is threatened by shrinking space and ineffective instruments. Undermining democracy and nationalism is a threat to climate and energy strategies.

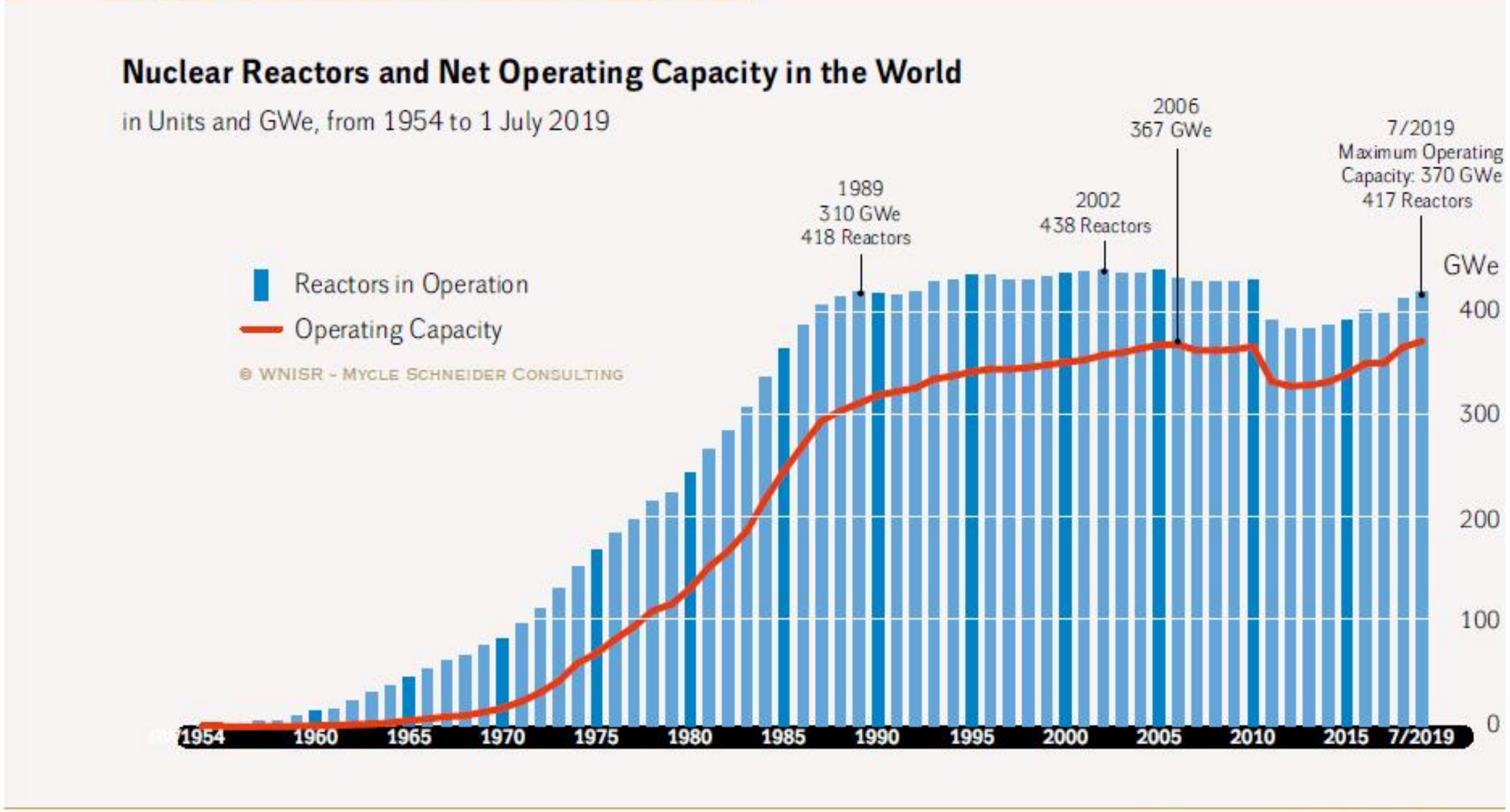
Figure 5. Reactor construction starts and share of nuclear power in total electricity generation



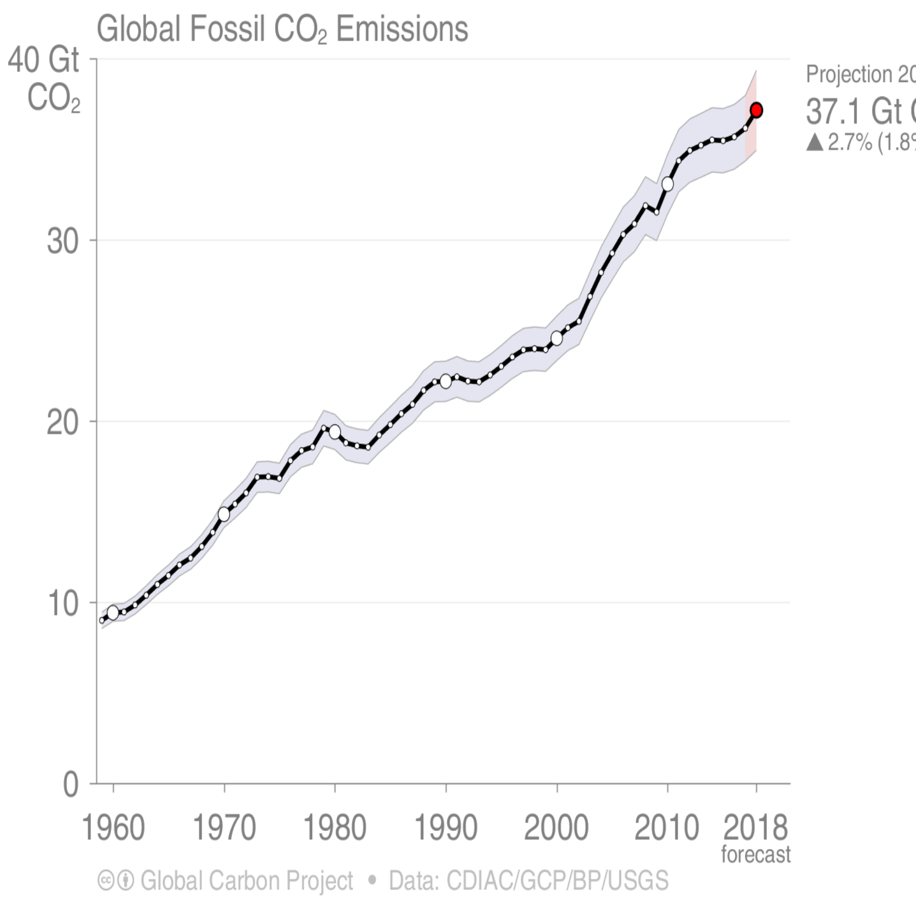
Note: OECD = Organisation for Economic Co-operation and Development.

Sources: IAEA (2019), Power Reactor Information System (PRIS) (database); IEA (2018a), Electricity Information 2018 (database).

Figure 7 | World Nuclear Reactor Fleet, 1954–2019

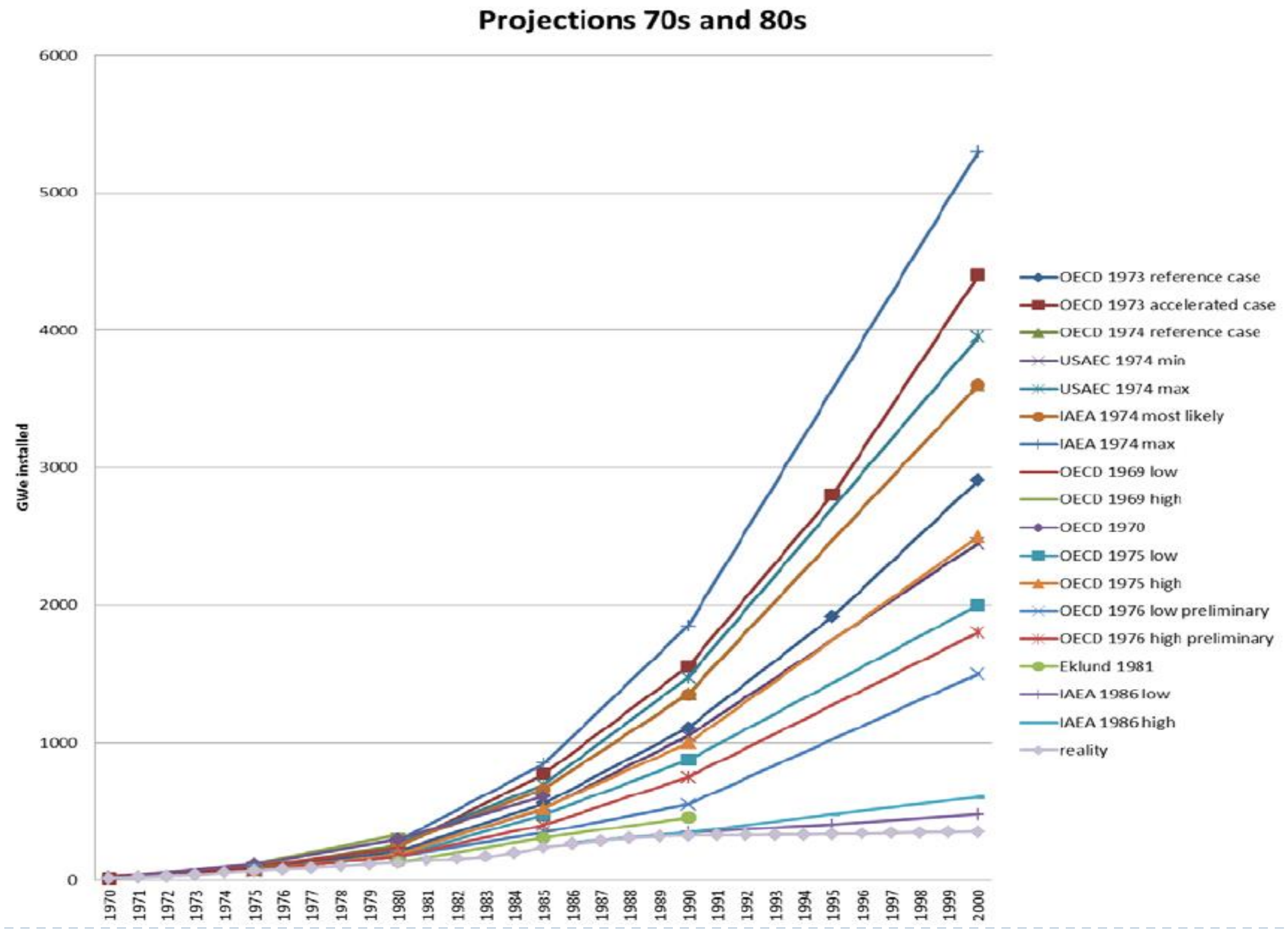


Sources: WNISR, with IAEA-PRIS, 2019



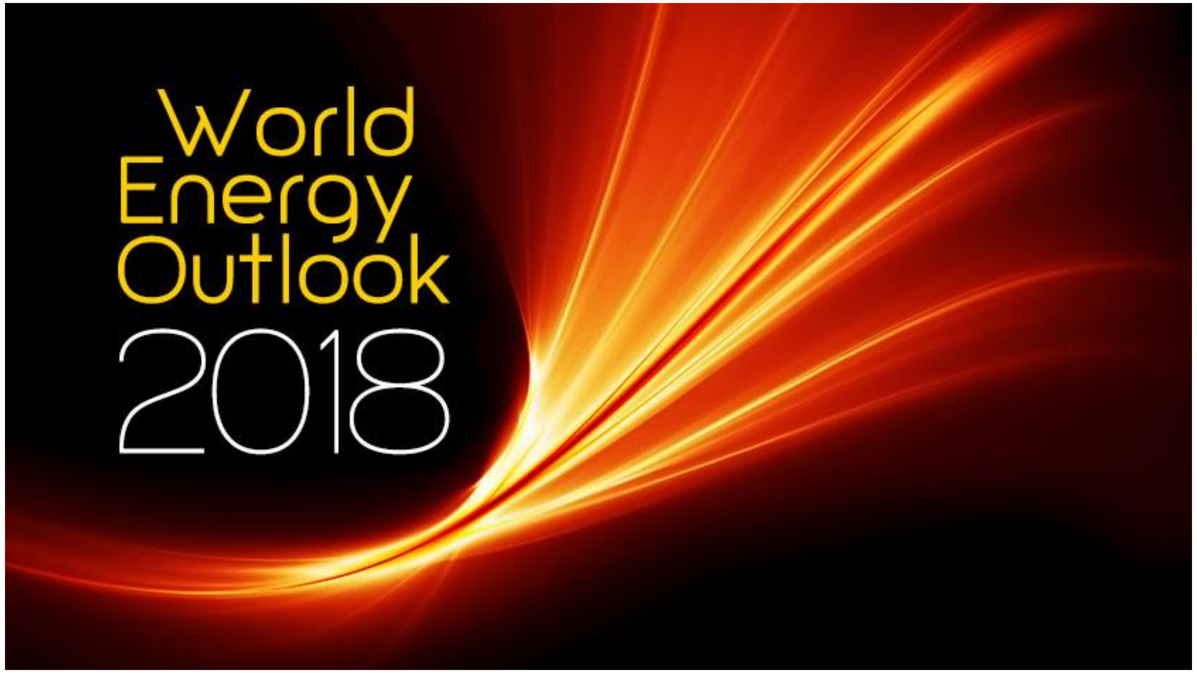
Note
Changes in the database regarding closing dates of reactors or LTO status slightly change the shape of this graph from previous editions. In particular, the previous "maximum operating capacity" of 2006 (overtaken in July 2019) is now at 367 GW.

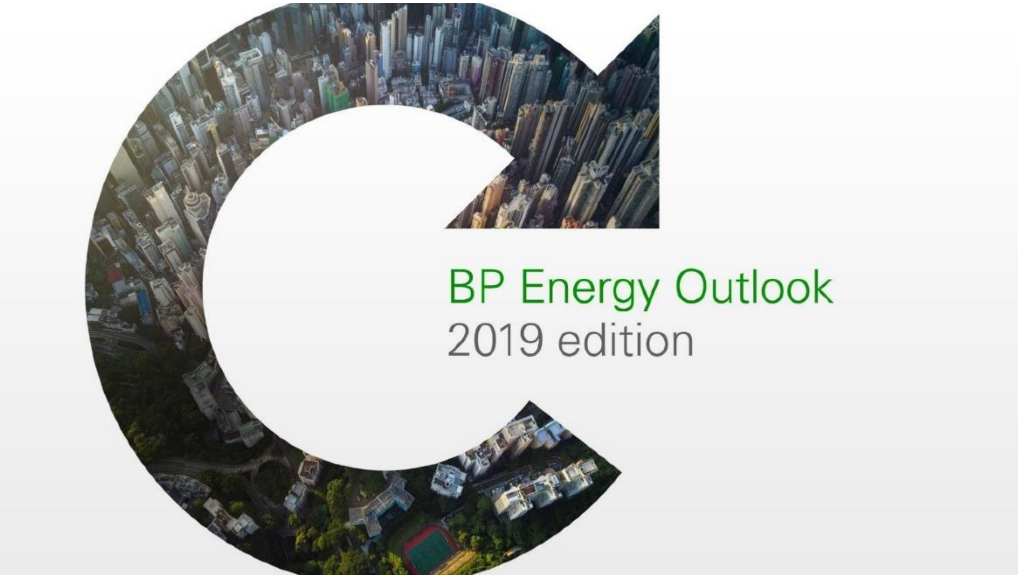
Earlier projections creating expectations



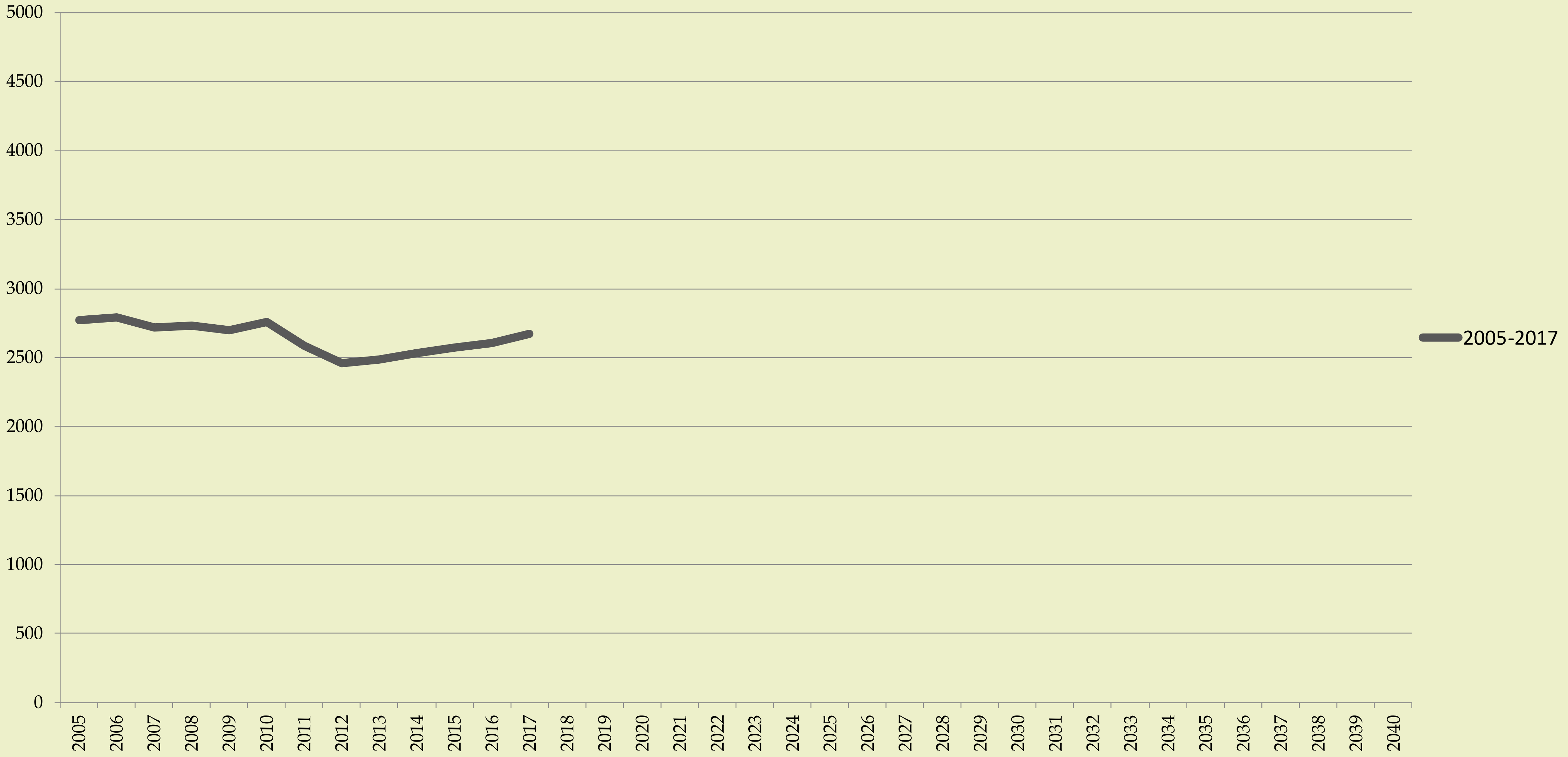
Klaus Gufler, "Short and Mid-term Trends of the Development of Nuclear Energy", 2013

The role of scenarios (forecasts?)

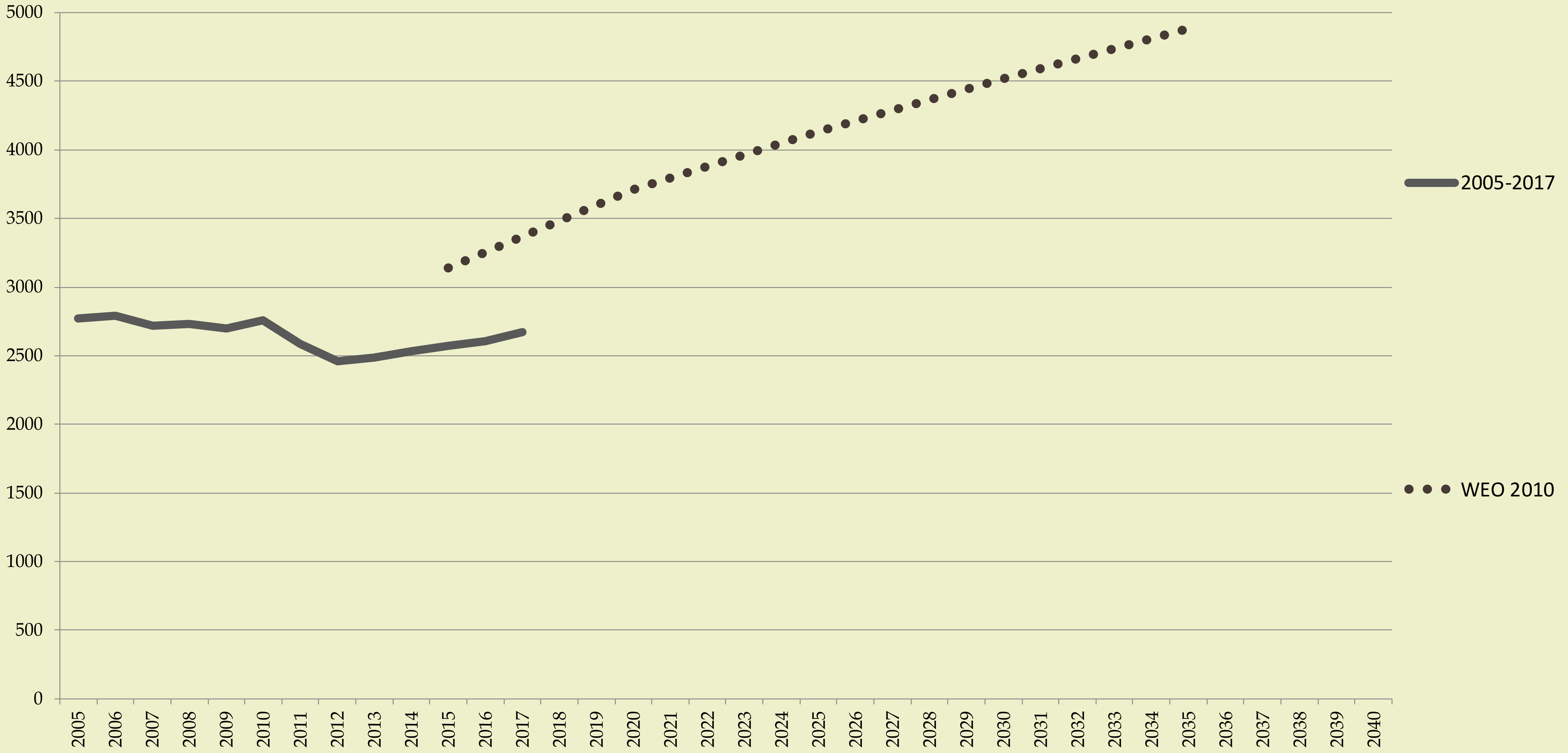




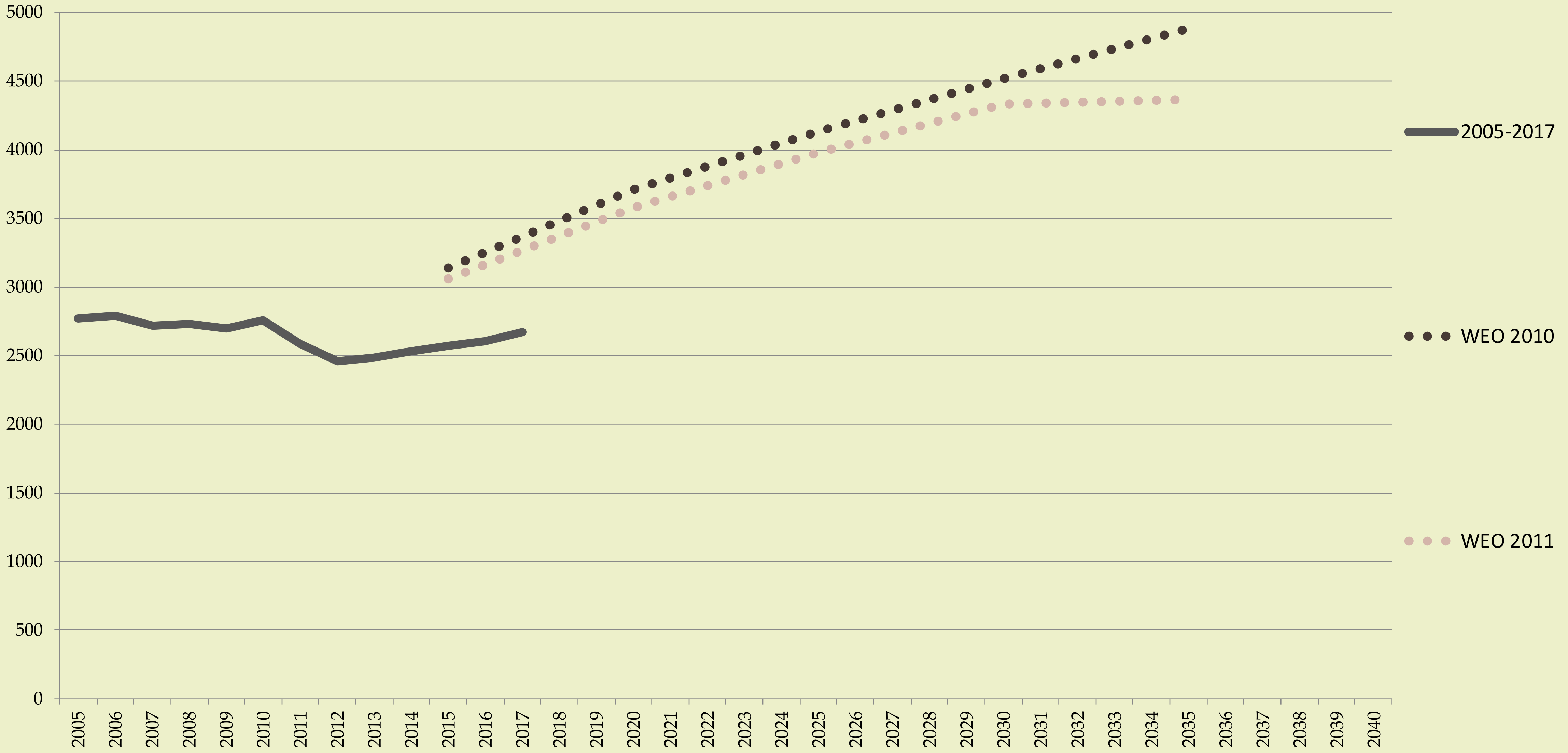
Nuclear: Declining development vs. projected increase in IEA WEO in TWh

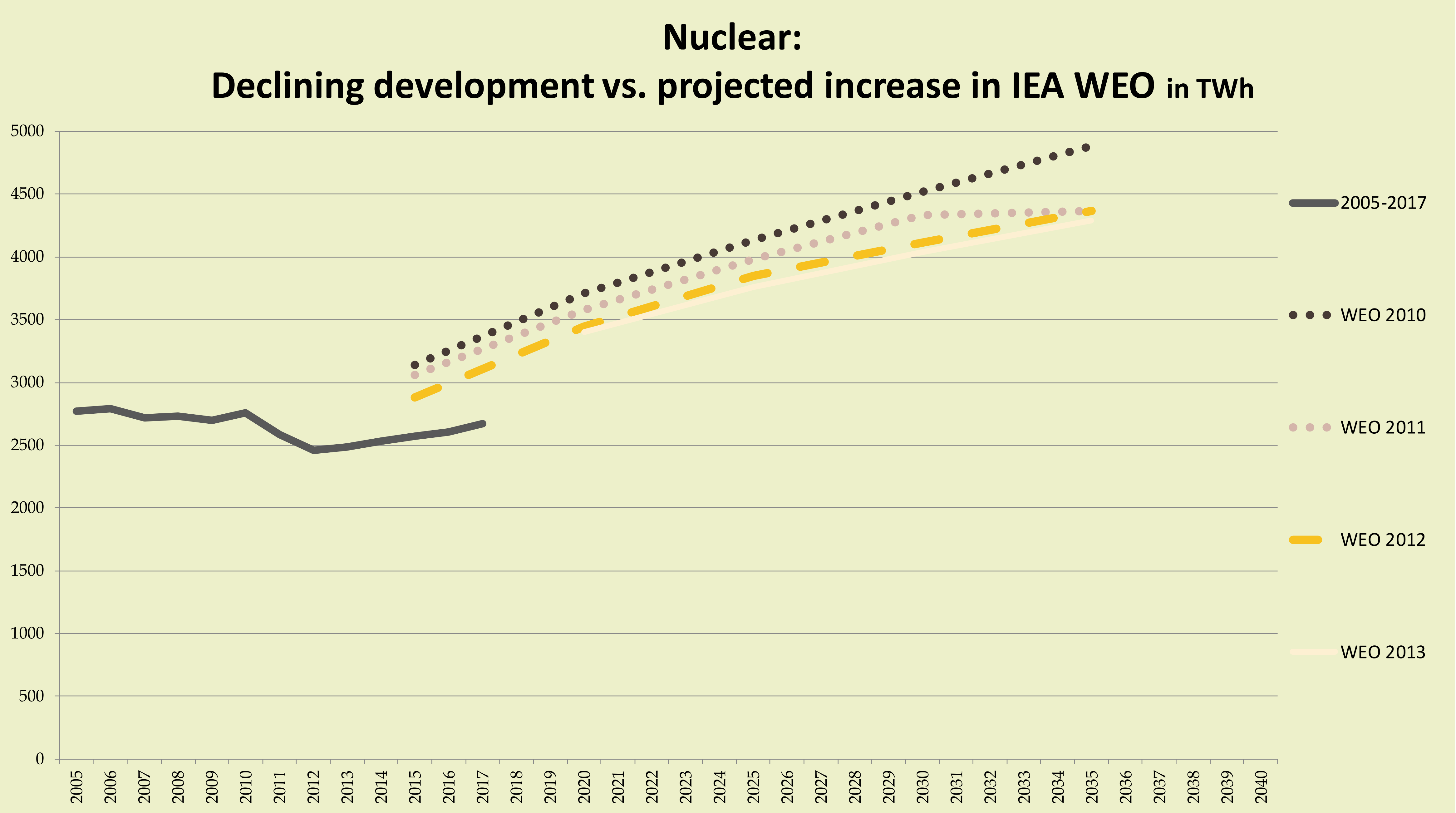


Nuclear:
Declining development vs. projected increase in IEA WEO in TWh



Nuclear: Declining development vs. projected increase in IEA WEO in TWh





Nuclear:
Declining development vs. projected increase in IEA WEO in TWh
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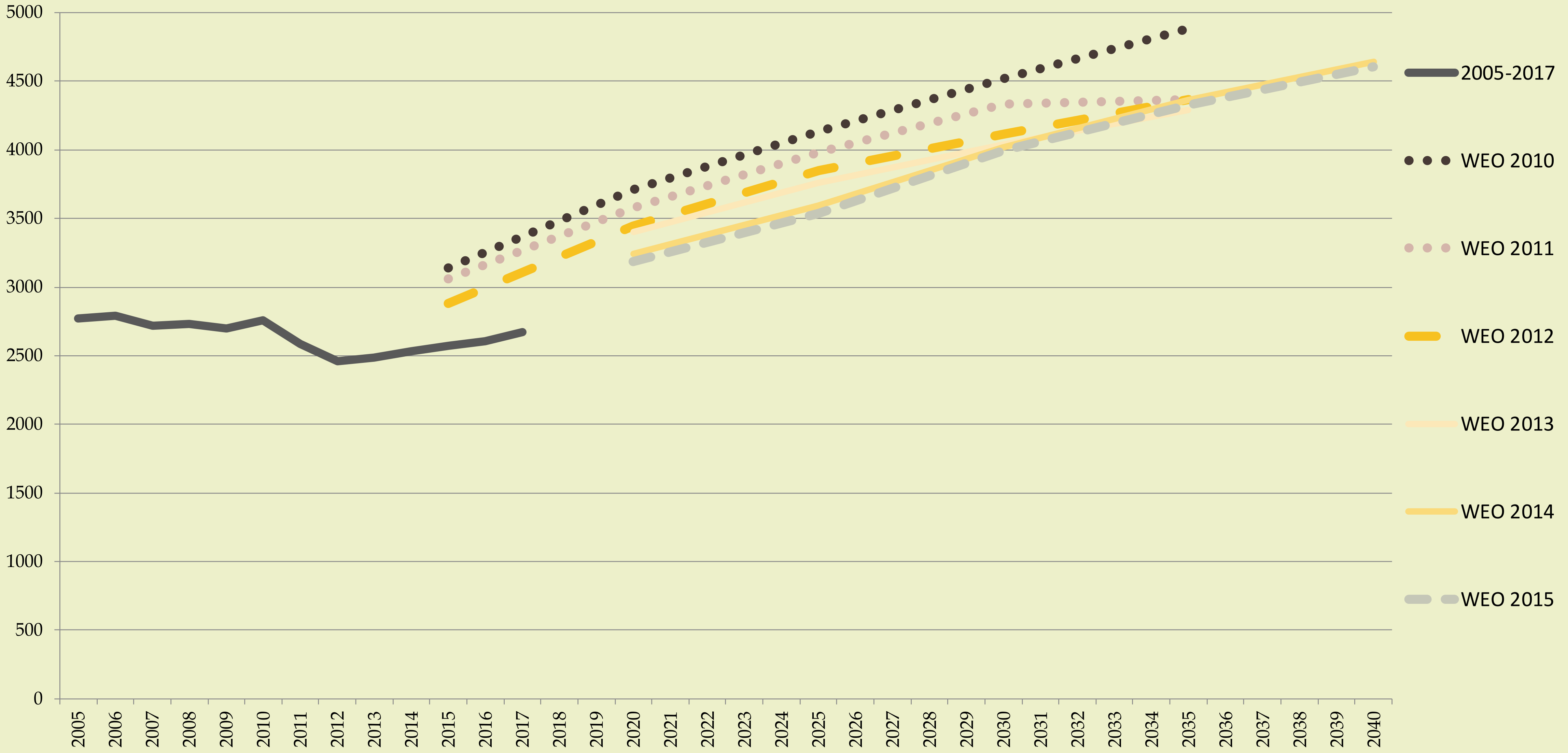
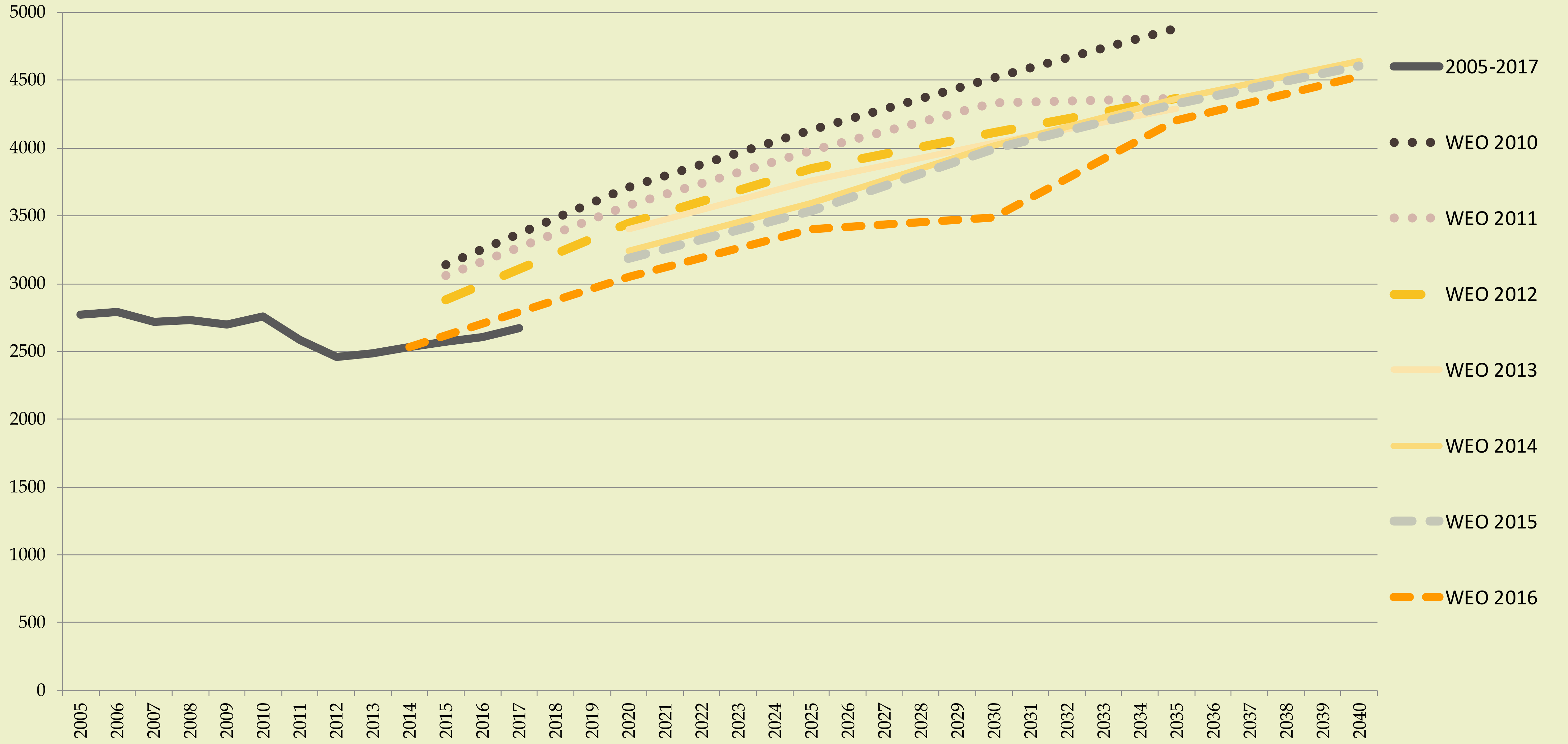
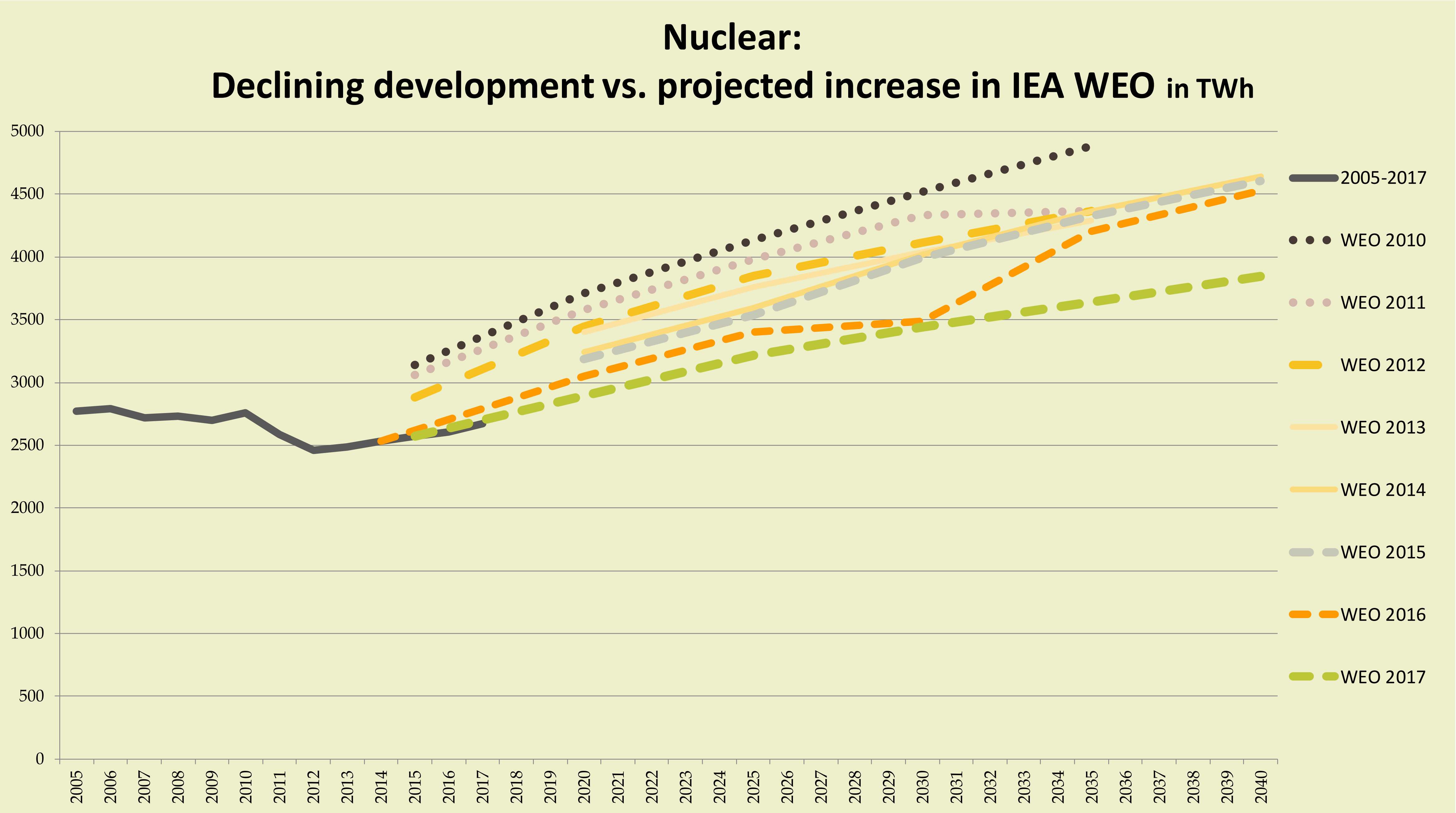
Nuclear:
Declining development vs. projected increase in IEA WEO in TWh



Nuclear:
Declining development vs. projected increase in IEA WEO in TWh





Nuclear:
Declining development vs. projected increase in IEA WEO in TWh
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WEO 2016
WEO 2017

Nuclear:
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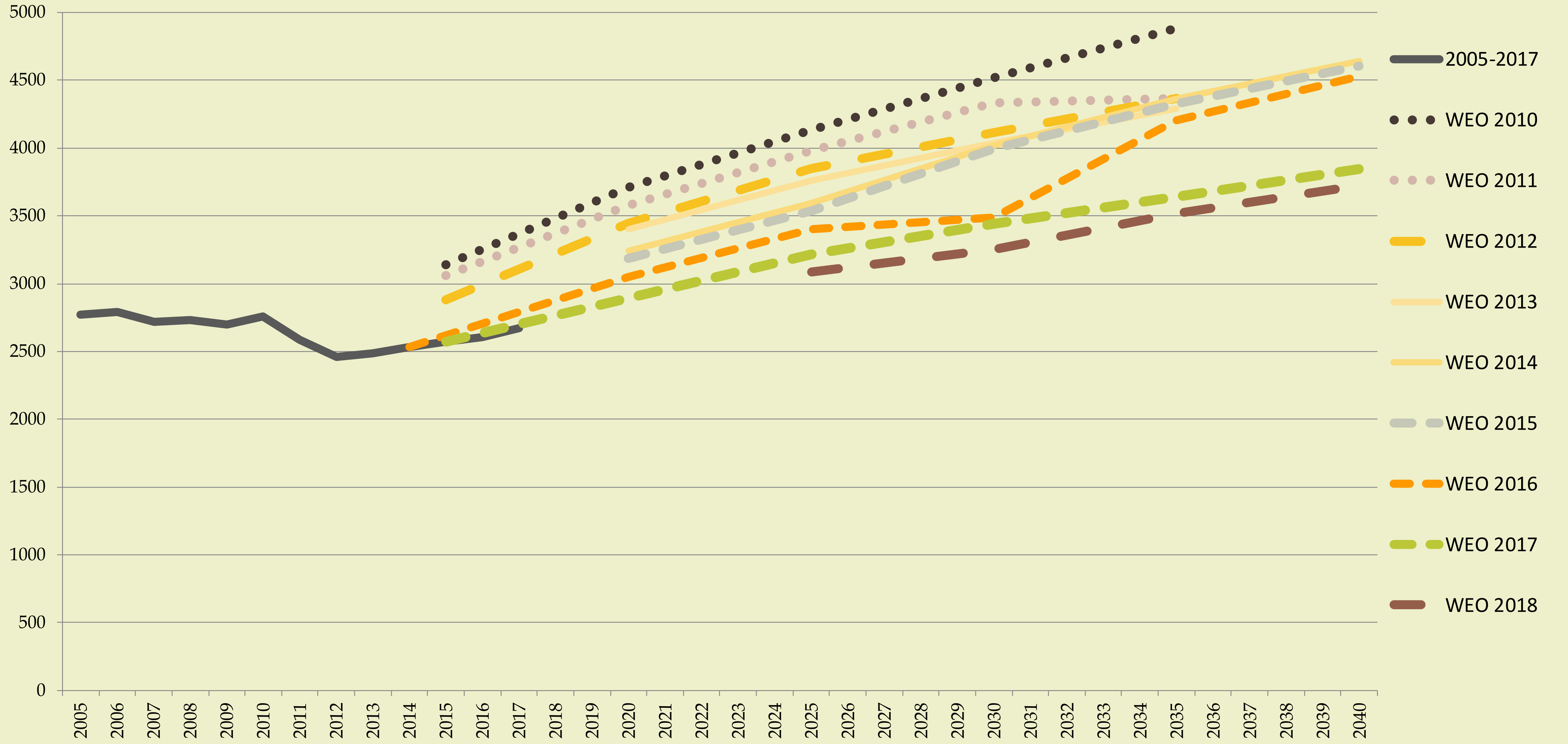
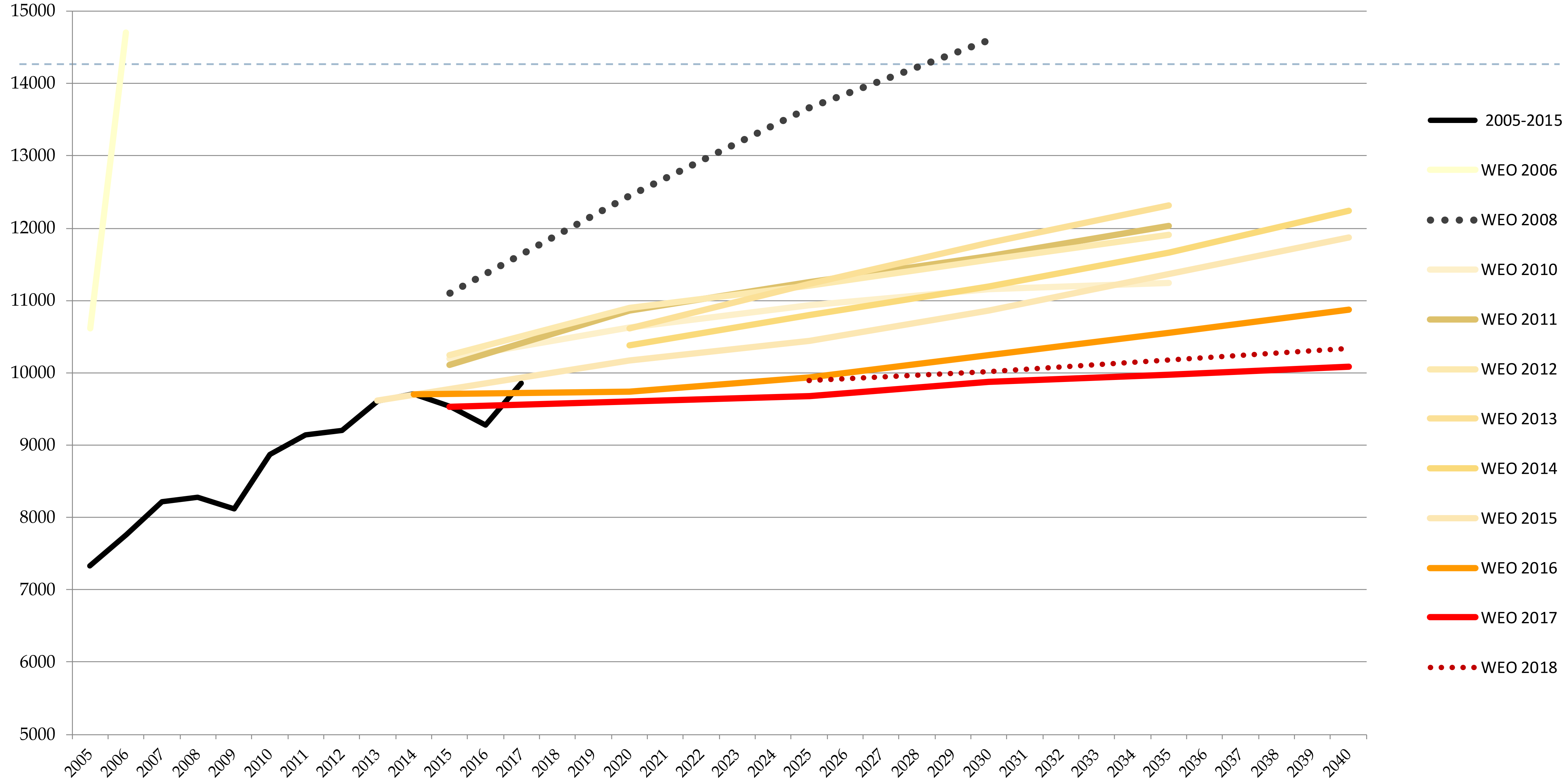
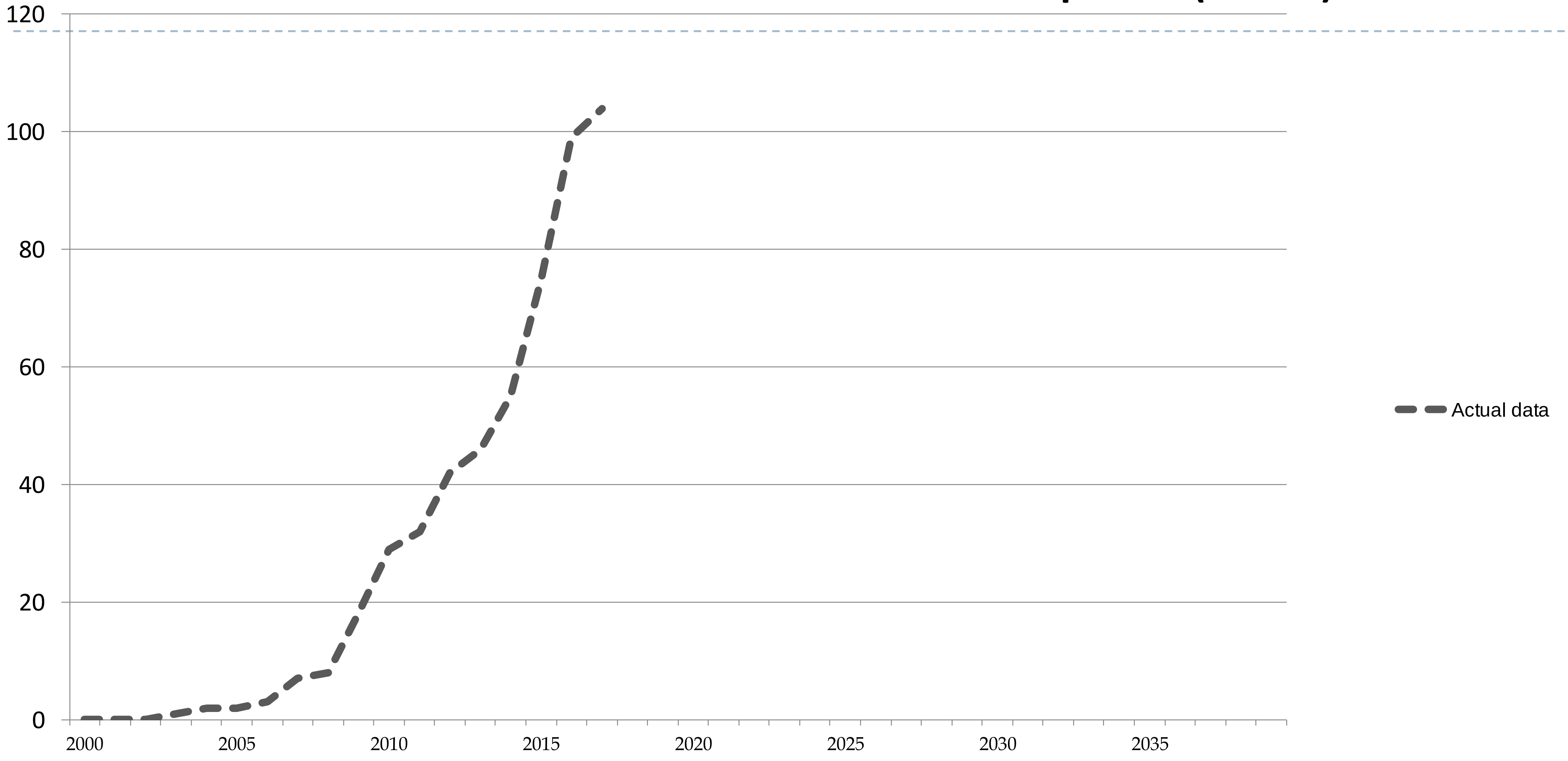


Coal-fired electricity development and IEA WEO main scenario in TWh



Solar power: new capacity added per year:
IEA-WEO main scenarios and actual development (in GW)



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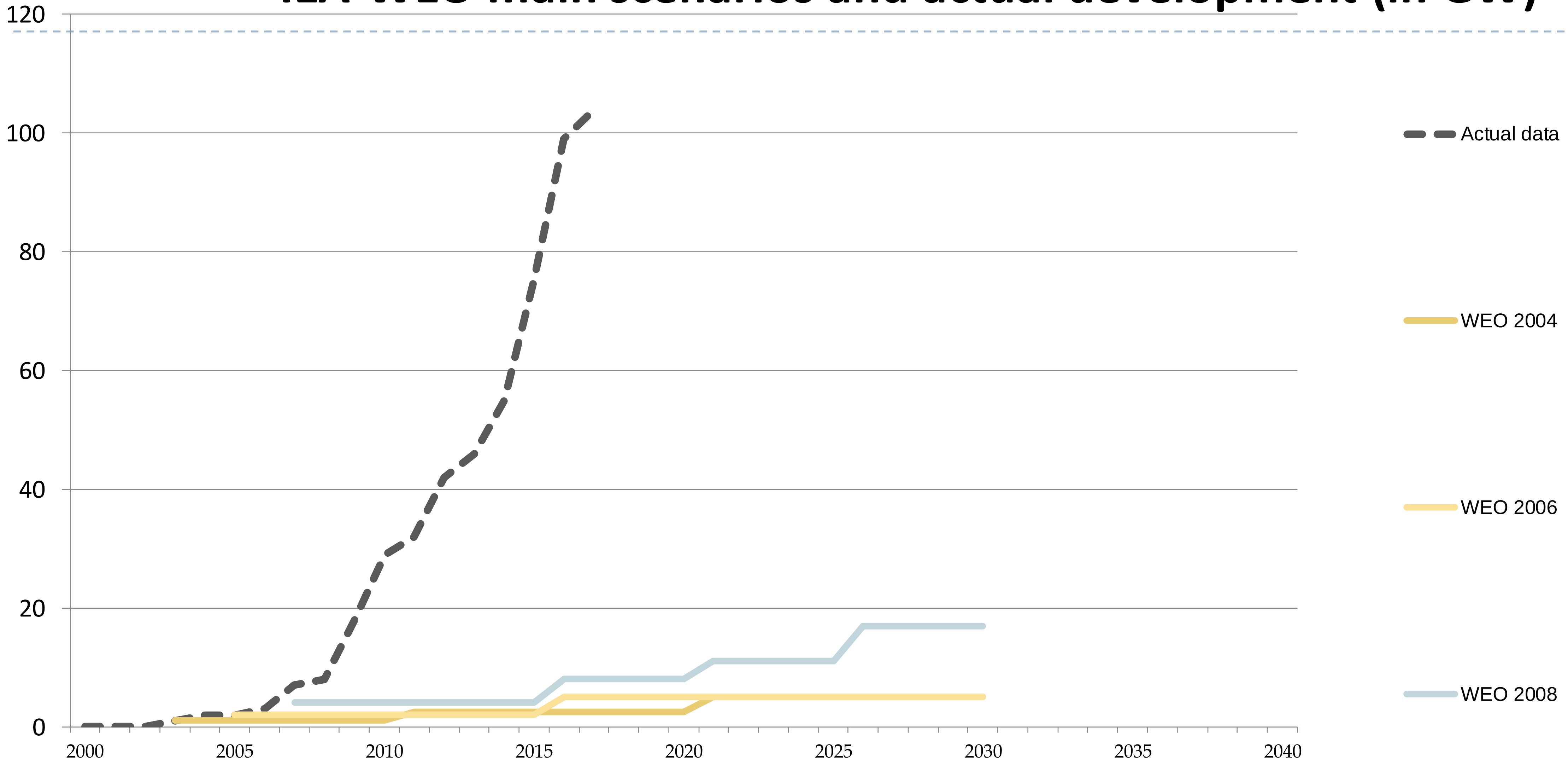

Solar power:
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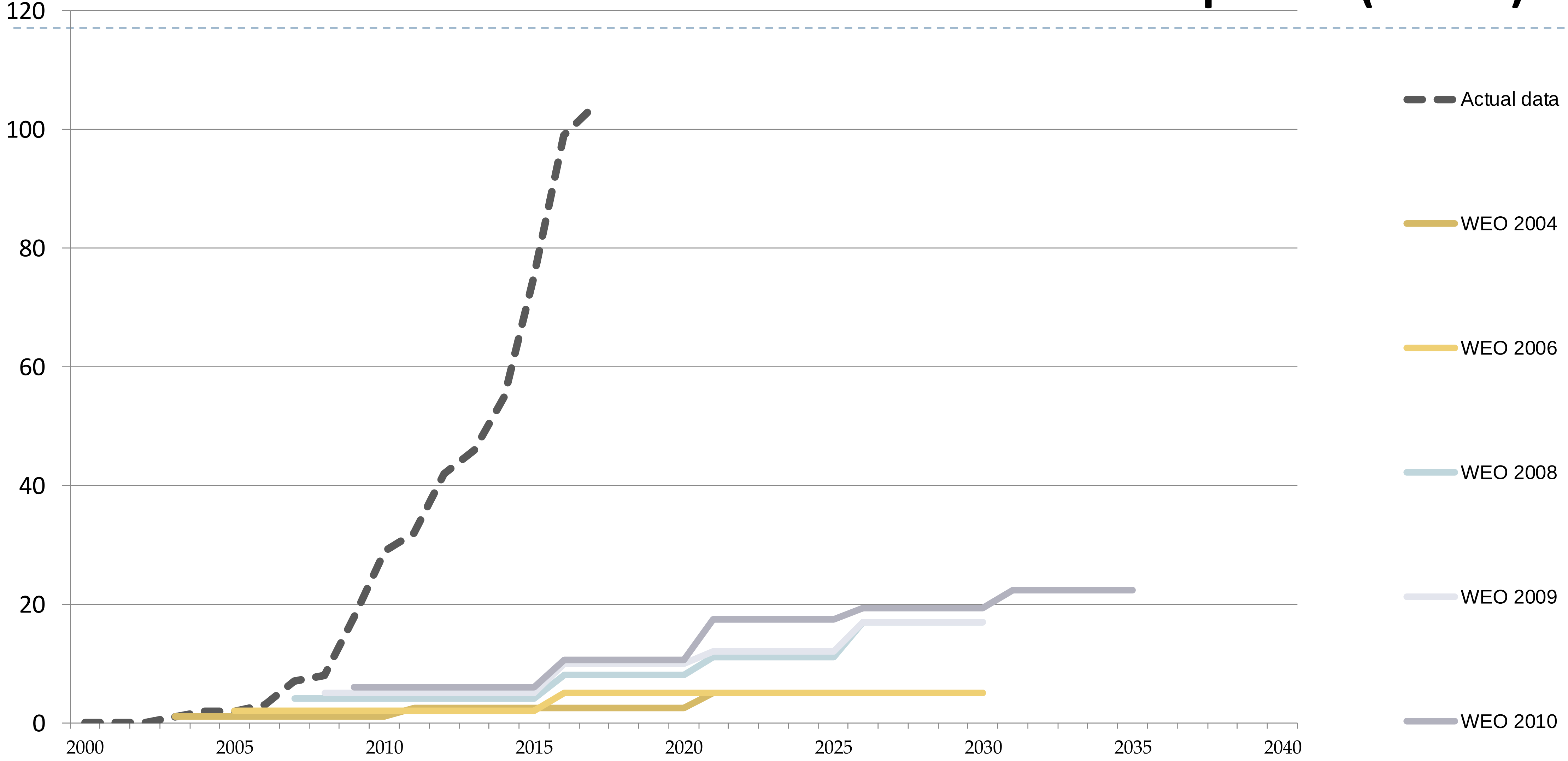

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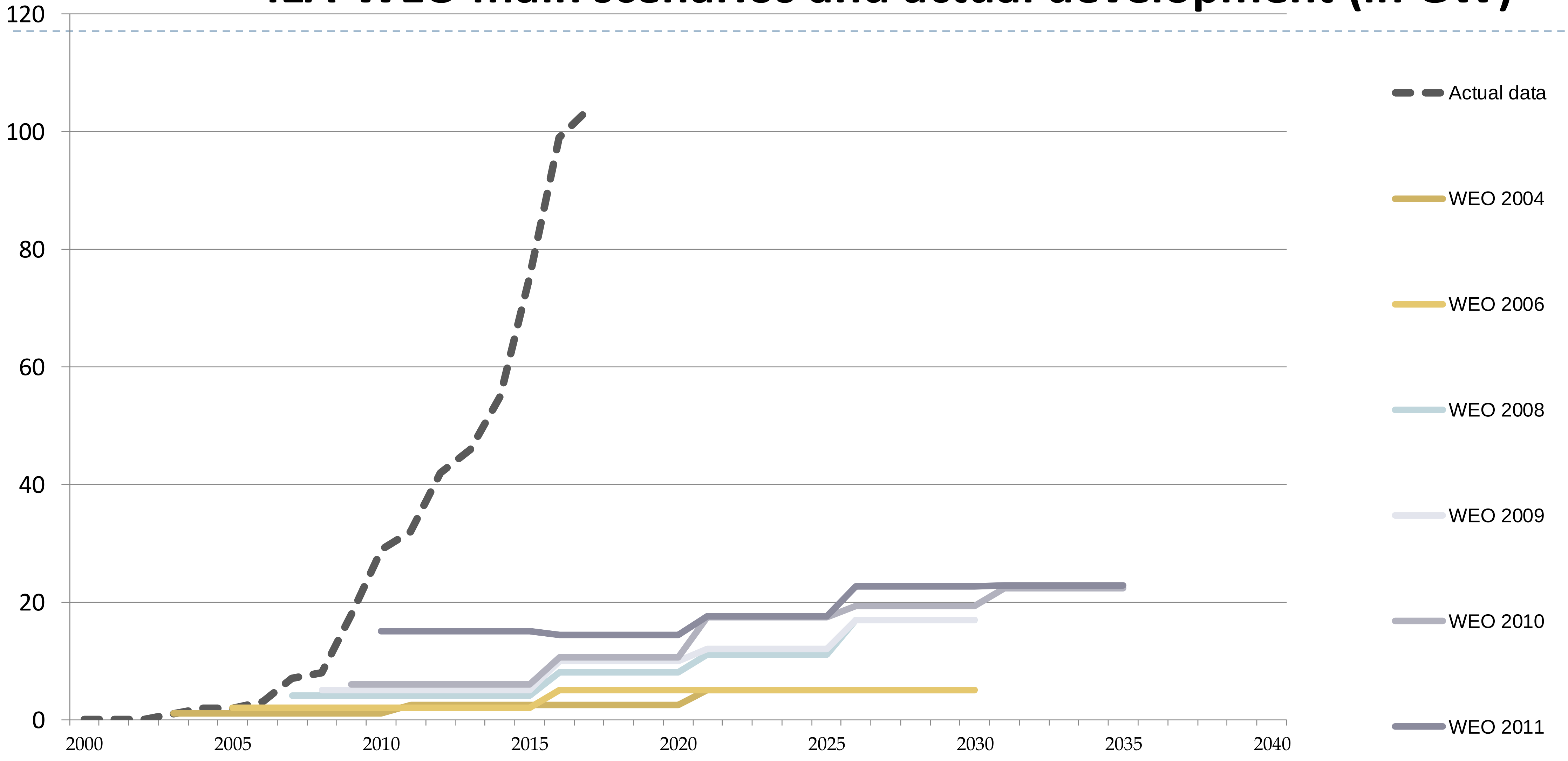

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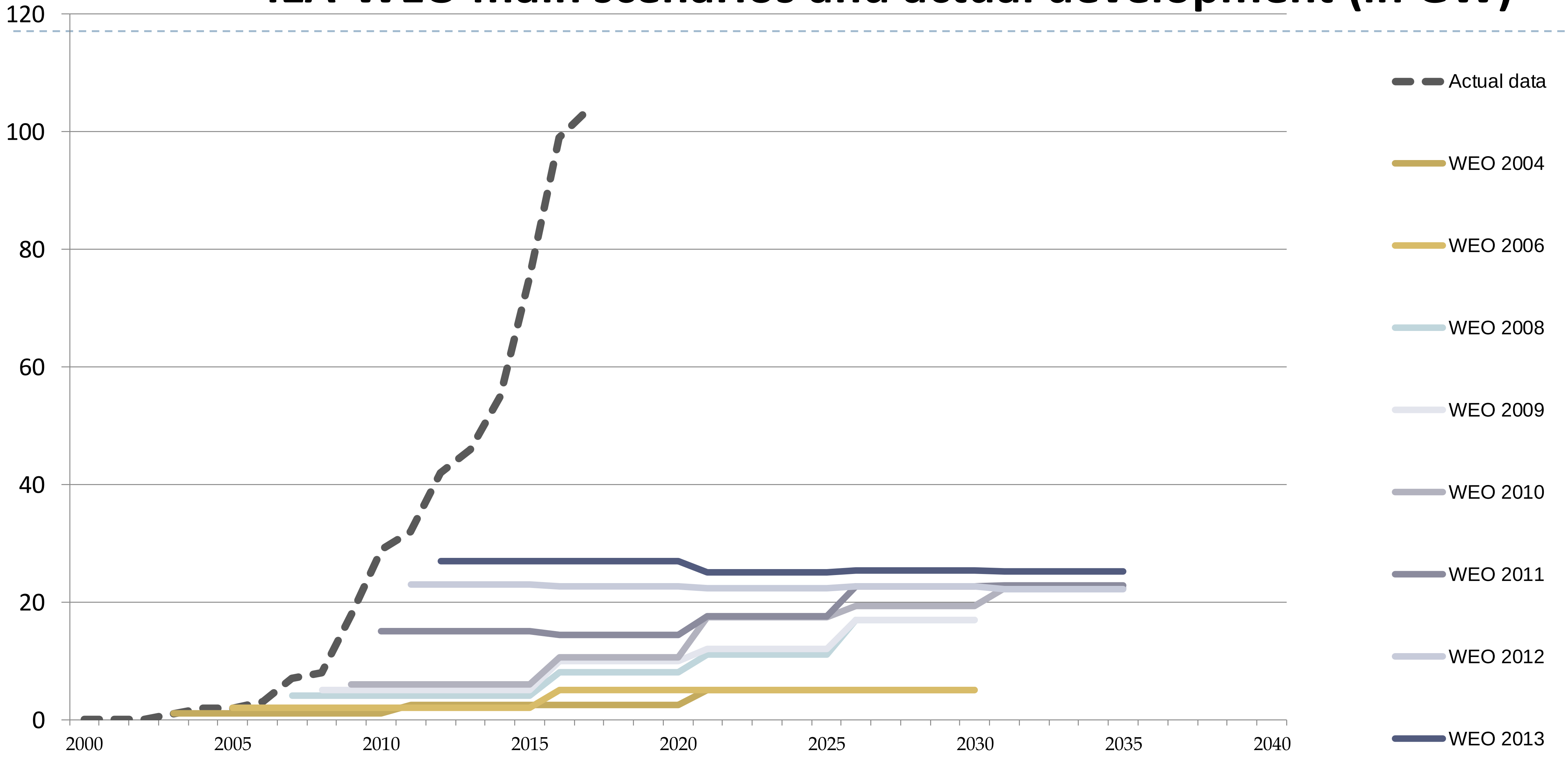

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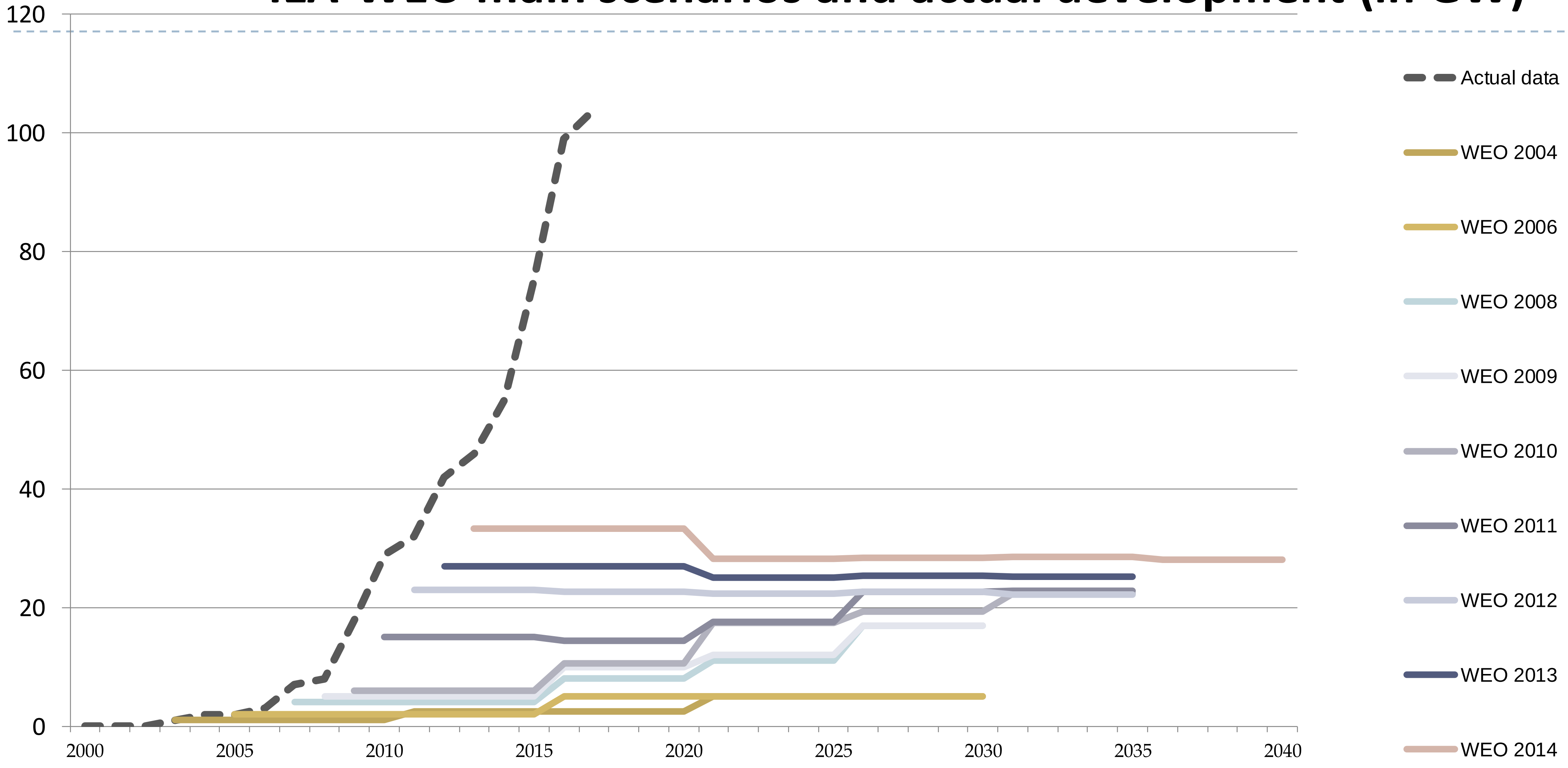

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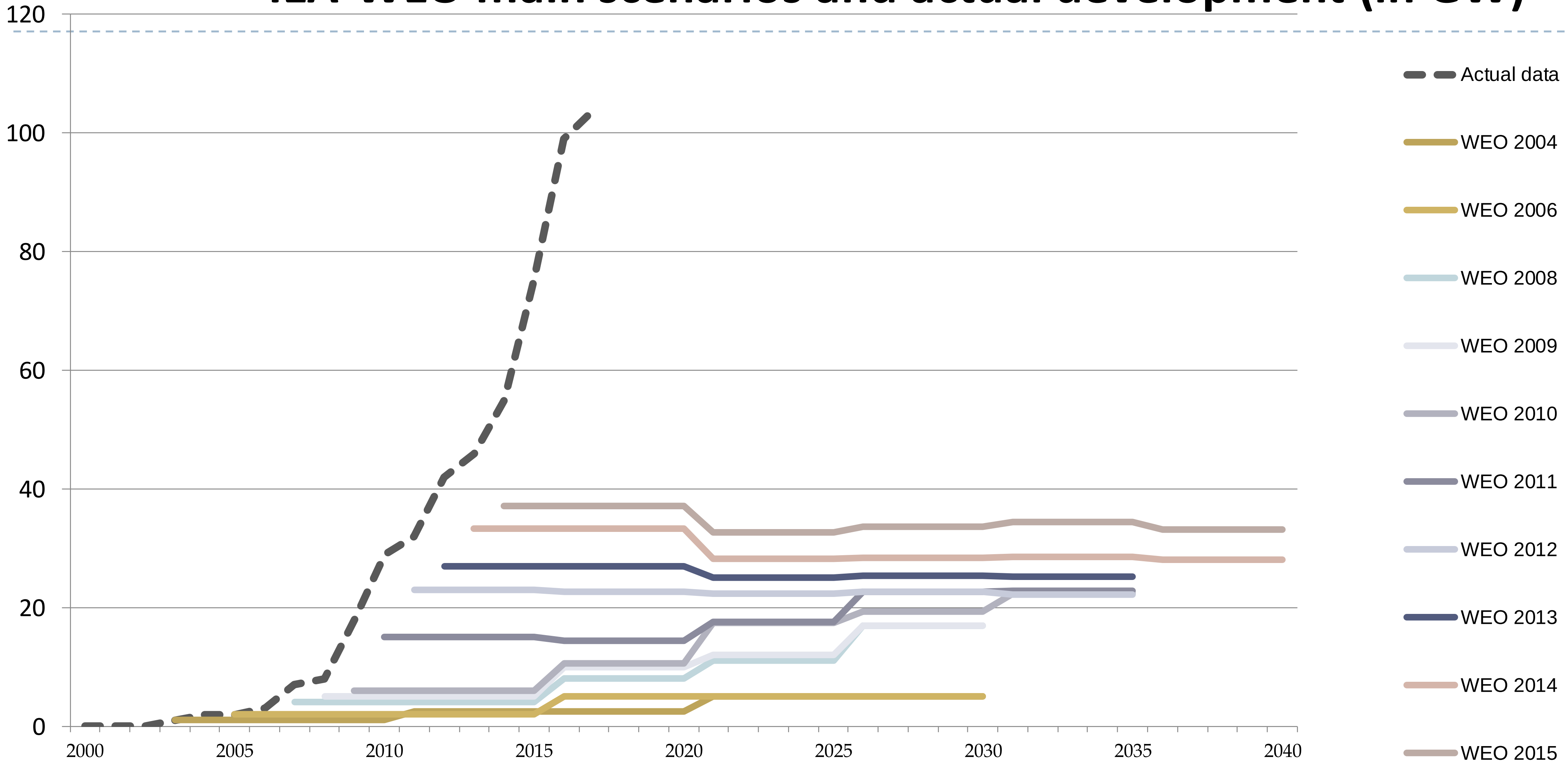

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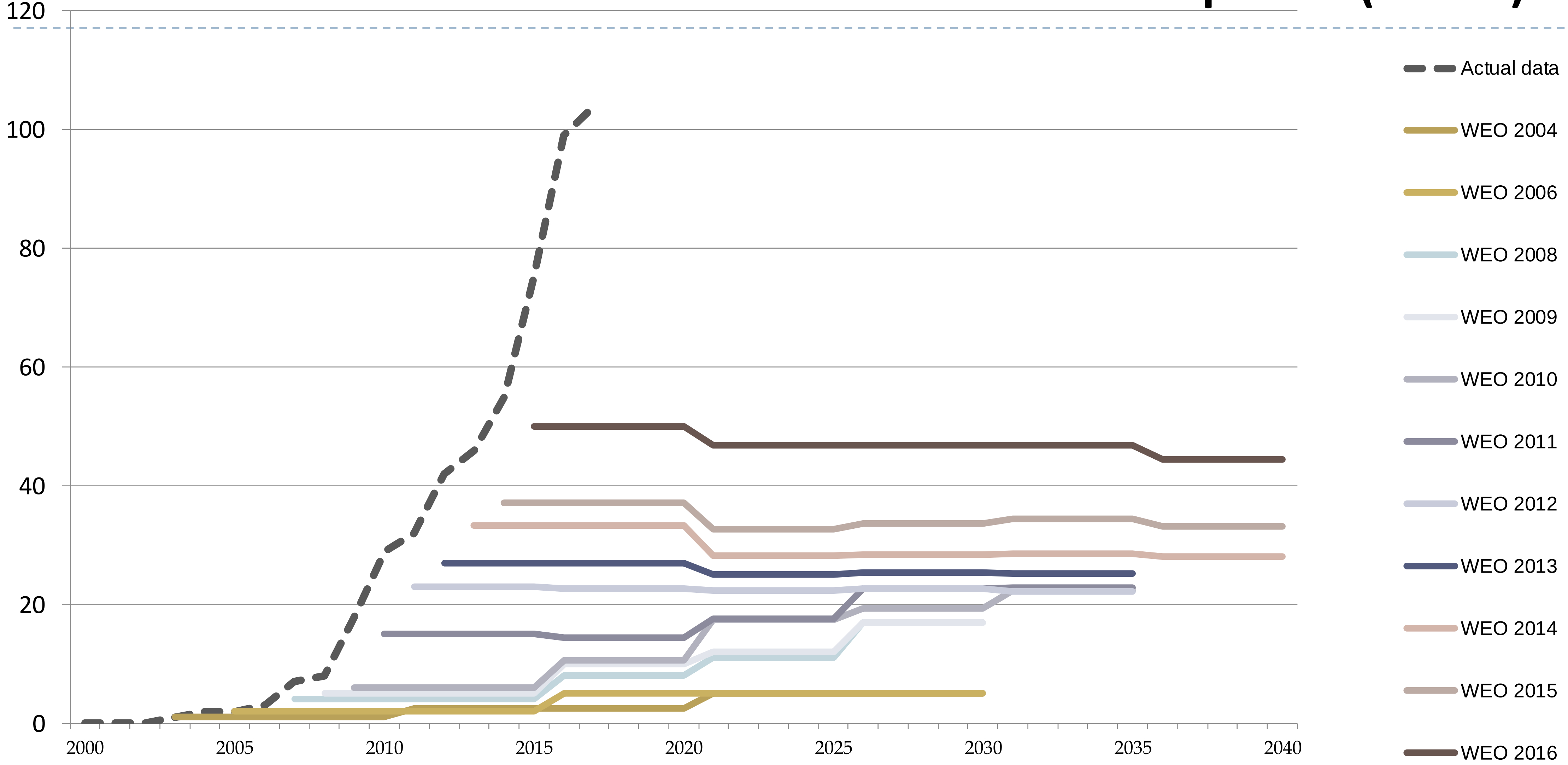

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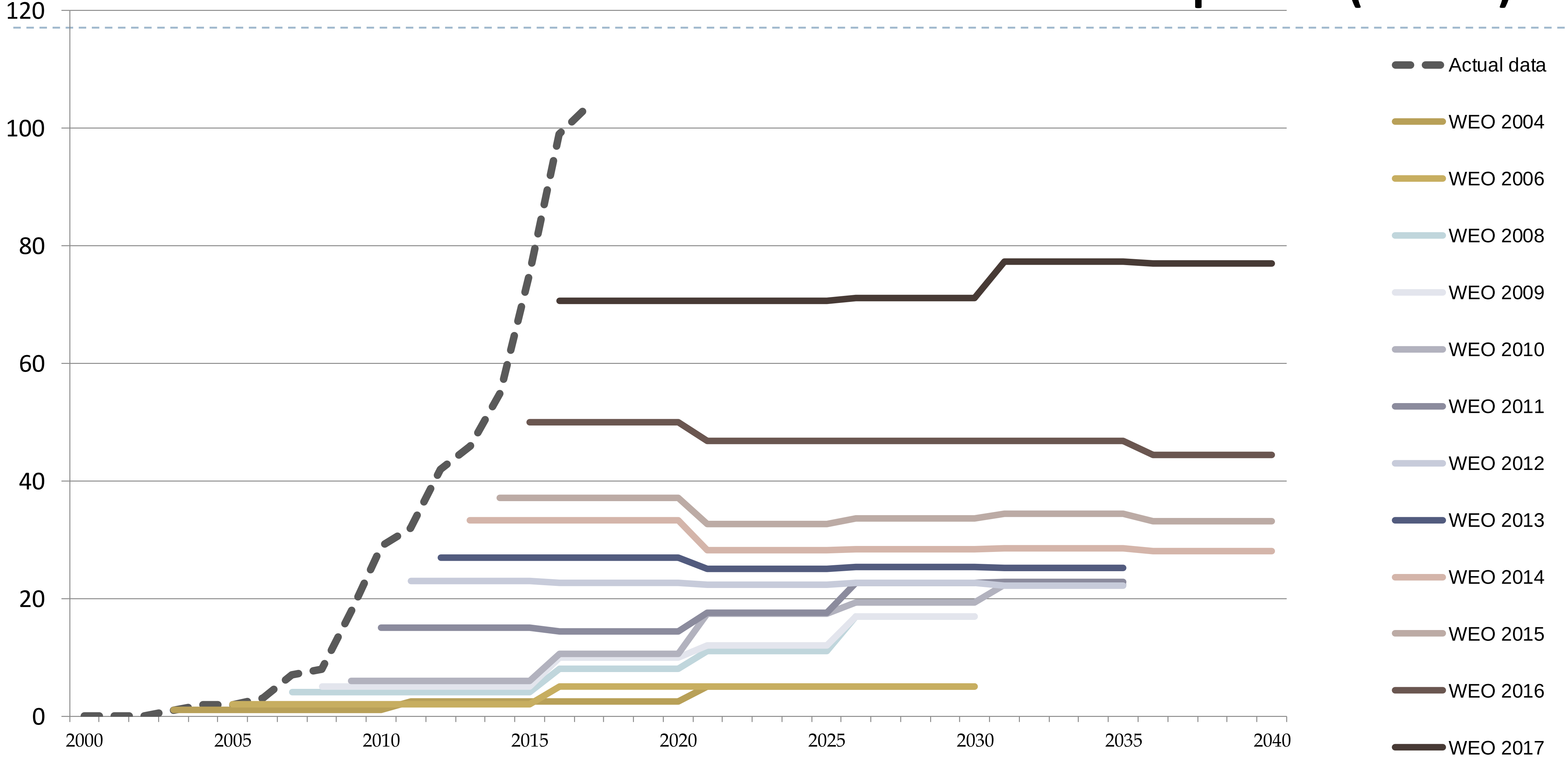

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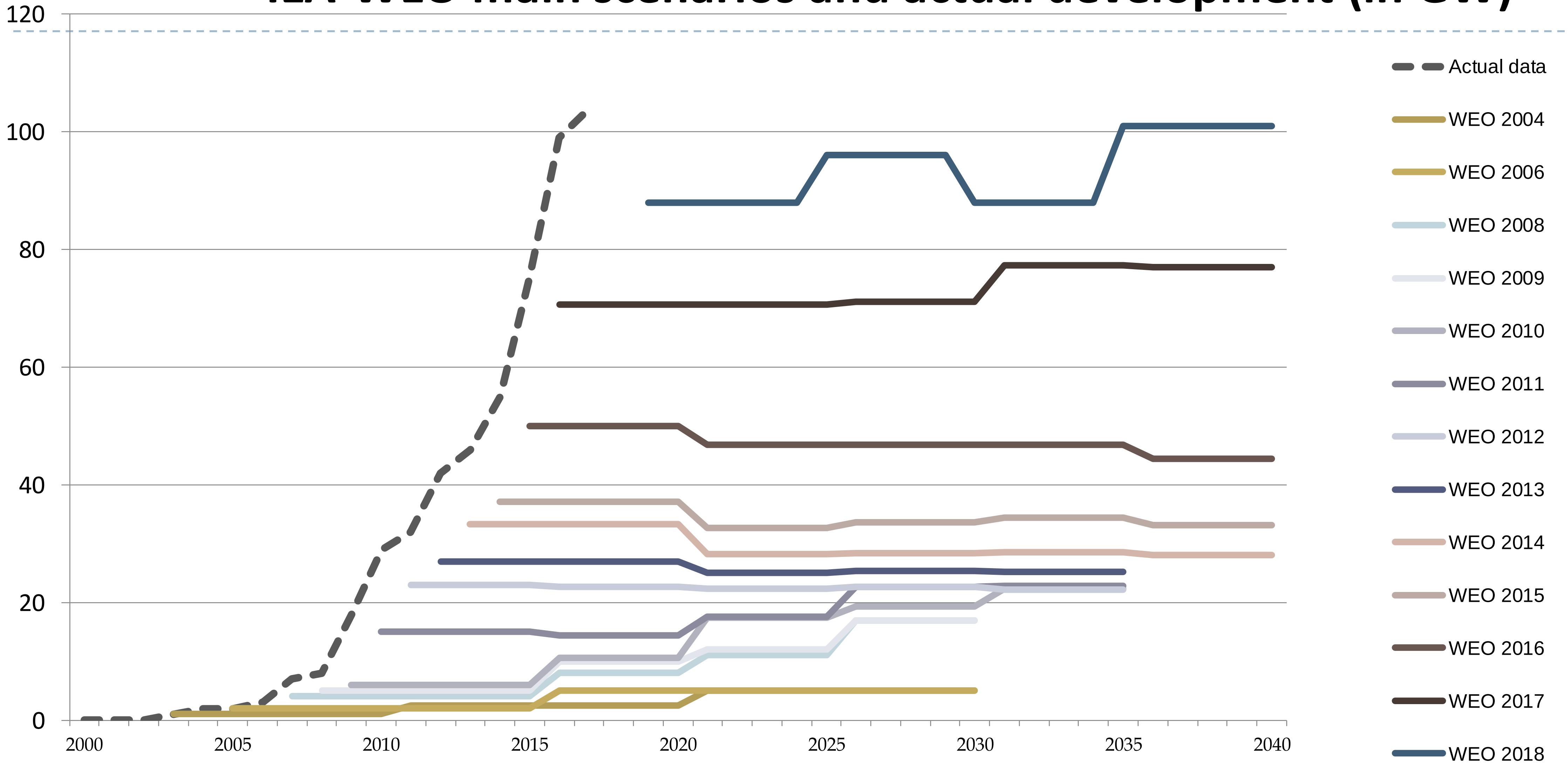
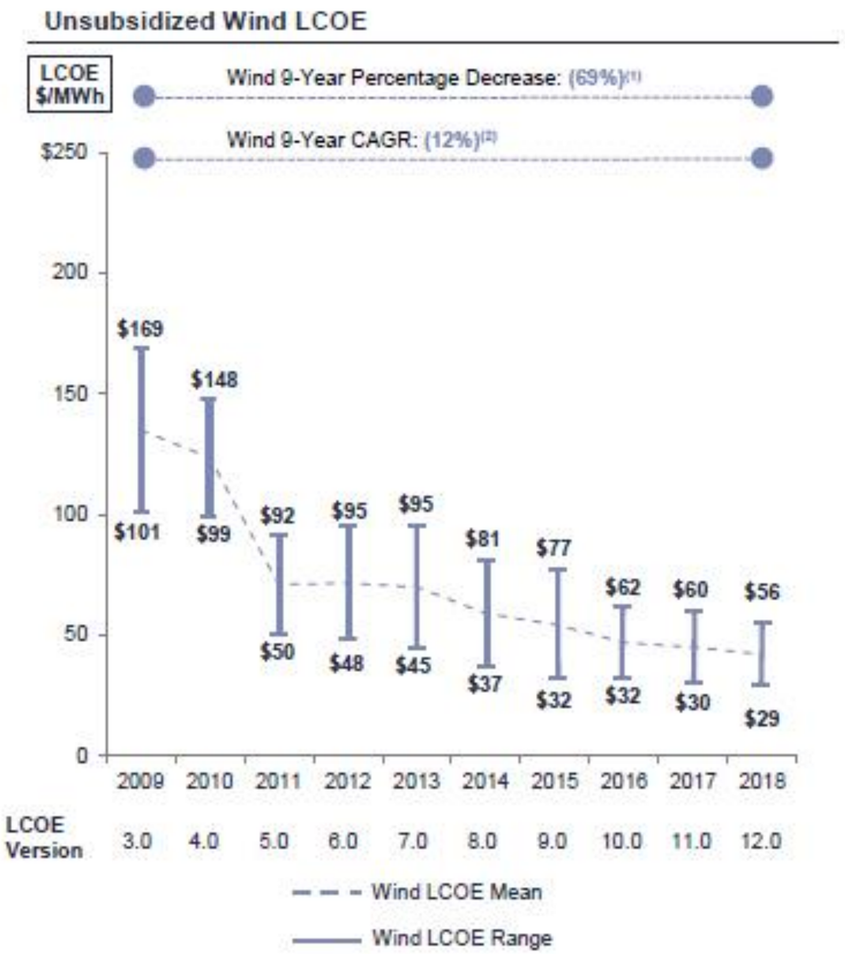
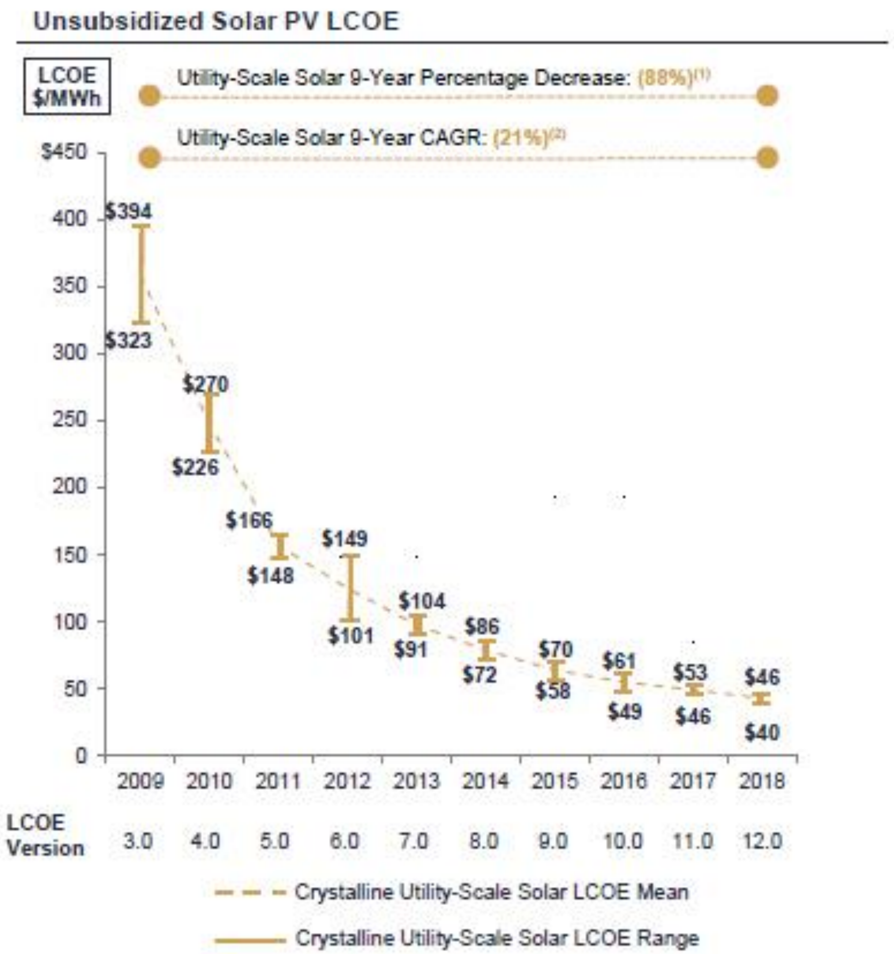






LAZARD

Source: Lazard estimates.
(1) Represents the average percentage decrease of the high end and low end of the LCOE range.
(2) Represents the average compounded annual rate of decline of the high end and low end of the LCOE range.

Table 1 Definitions and objectives of the *WEO-2018* scenarios

	Current Policies Scenario	New Policies Scenario	Sustainable Development Scenario	Future is Electric Scenario
Definitions	Government policies that had been enacted or adopted by mid-2018 continue unchanged.	Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted, are implemented in a cautious manner.	An integrated scenario specifying a pathway aiming at: ensuring universal access to affordable, reliable, sustainable and modern energy services by 2030 (SDG 7); substantially reducing air pollution (SDG 3.9); and taking effective action to combat climate change (SDG 13).	Assume that electric technologies will be widely taken up in this sector as soon as they become cost-competitive, because policy makers remove non-economic barriers.
Objectives	To provide a baseline that shows how energy markets would evolve if underlying trends in energy demand and supply are not changed.	To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy.	To demonstrate a plausible path to concurrently achieve universal energy access, set a path towards meeting the objectives of the Paris Agreement on climate change and significantly reduce air pollution	To explore what would happen if specific policies and technology cost reductions were to lead to a faster pace of electricity demand growth.

Table B.1 ▷ Population assumptions by region

	Compound average annual growth rate			Population (million)		Urbanisation share	
	2000-17	2017-25	2017-40	2017	2040	2017	2040
North America	1.0%	0.8%	0.7%	487	571	81%	87%
United States	0.9%	0.7%	0.6%	327	376	82%	87%
Central and South America	1.2%	0.8%	0.6%	516	599	81%	86%
Brazil	1.0%	0.6%	0.4%	209	232	86%	91%
Europe	0.3%	0.1%	0.1%	690	700	75%	81%
European Union	0.3%	0.1%	0.0%	512	513	75%	82%
Africa	2.6%	2.4%	2.3%	1 256	2 100	42%	54%
South Africa	1.4%	1.1%	0.9%	57	69	66%	76%

Power generation technology costs

Table B.6 ▷ Technology costs by selected region in the New Policies Scenario

		Capital costs ($/kW)		Capacity factor (%)		Fuel and O&M ($/MWh)		LCOE ($/MWh)		VALCOE ($/MWh)	
		2017	2040	2017	2040	2017	2040	2017	2040	2017	2040
United States	Nuclear	5 000	4 500	90	90	30	30	105	100	105	100
	Coal	2 100	2 100	60	60	30	35	75	75	75	75
	Gas CCGT	1 000	1 000	50	50	30	40	50	65	45	60
	Solar PV	1 560	860	20	23	10	5	105	50	105	55
	Wind onshore	1 620	1 480	42	44	10	10	60	50	70	60
	Wind offshore	4 720	2 960	45	49	40	25	180	105	190	115
European Union	Nuclear	6 600	4 500	75	75	35	35	150	110	150	110
	Coal	2 000	2 000	40	40	45	45	120	145	105	120
	Gas CCGT	1 000	1 000	40	40	55	75	90	120	80	95
	Solar PV	1 300	760	12	13	20	15	160	85	165	105
	Wind onshore	1 820	1 700	28	30	20	15	100	90	105	105
	Wind offshore	4 260	2 820	50	55	35	25	150	90	160	105
China	Nuclear	2 320	2 500	75	75	25	25	60	65	60	65

Table B.2 ▷ Real gross domestic product (GDP) growth assumptions by region

	Compound average annual growth rate			
	2000-17	2017-25	2025-40	2017-40
North America	1.9%	2.1%	2.1%	2.1%
United States	1.8%	2.0%	2.0%	2.0%
Central and South America	2.7%	2.6%	3.0%	2.9%
Brazil	2.3%	2.3%	3.0%	2.8%
Europe	1.8%	2.1%	1.6%	1.8%
European Union	1.5%	1.8%	1.4%	1.6%
Africa	4.4%	4.1%	4.4%	4.3%
South Africa	2.8%	1.9%	2.8%	2.5%
Middle East	4.1%	3.3%	3.5%	3.4%
Eurasia	4.0%	2.2%	2.5%	2.4%
Russia	3.4%	1.6%	2.1%	1.9%
Asia Pacific	6.0%	5.4%	4.0%	4.5%
China	9.1%	5.8%	3.7%	4.4%
India	7.2%	7.8%	5.7%	6.5%
Japan	0.8%	0.7%	0.7%	0.7%

CO_2 prices

Table B.5 ▷ CO_2 prices in selected regions by scenario ($2017 per tonne)

Region	Sector	2025	2040
Current Policies Scenario			
Canada	Power, industry, aviation, others*	35	39
Chile	Power	5	5
China	Power	15	31
European Union	Power, industry, aviation	22	38
Korea	Power, industry	22	39
New Policies Scenario			
Canada	Power, industry, aviation, others*	35	39
Chile	Power	8	20
China	Power, industry, aviation	17	36

Power generation technology costs

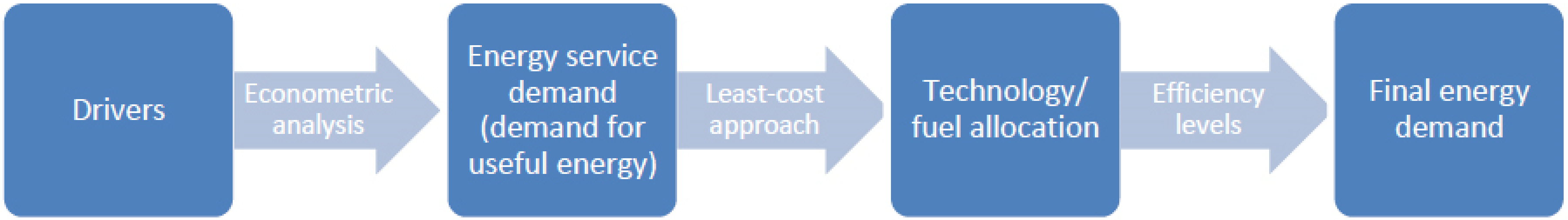
Table B.6 ▷ Technology costs by selected region in the New Policies Scenario

		Capital costs ($/kW)		Capacity factor (%)		Fuel and O&M ($/MWh)		LCOE ($/MWh)		VALCOE ($/MWh)	
		2017	2040	2017	2040	2017	2040	2017	2040	2017	2040
United States	Nuclear	5 000	4 500	90	90	30	30	105	100	105	100
	Coal	2 100	2 100	60	60	30	35	75	75	75	75
	Gas CCGT	1 000	1 000	50	50	30	40	50	65	45	60
	Solar PV	1 560	860	20	23	10	5	105	50	105	55
	Wind onshore	1 620	1 480	42	44	10	10	60	50	70	60
	Wind offshore	4 720	2 960	45	49	40	25	180	105	190	115
European Union	Nuclear	6 600	4 500	75	75	35	35	150	110	150	110
	Coal	2 000	2 000	40	40	45	45	120	145	105	120
	Gas CCGT	1 000	1 000	40	40	55	75	90	120	80	95
	Solar PV	1 300	760	12	13	20	15	160	85	165	105
	Wind onshore	1 820	1 700	28	30	20	15	100	90	105	105
	Wind offshore	4 260	2 820	50	55	35	25	150	90	160	105
China	Nuclear	2 320	2 500	75	75	25	25	60	65	60	65
	Coal	800	800	70	70	35	30	50	70	50	65
	Gas CCGT	560	560	50	50	70	90	85	115	80	105
	Solar PV	1 120	640	17	19	10	10	90	45	90	65
	Wind onshore	1 200	1 180	25	27	15	15	70	65	70	70
	Wind offshore	4 120	2 740	46	50	35	25	145	90	150	95
India	Nuclear	2 800	2 800	80	80	30	30	70	70	70	70
	Coal	1 200	1 200	60	60	35	35	60	55	60	50
	Gas CCGT	700	700	50	50	80	90	95	105	90	80
	Solar PV	1 120	620	19	22	10	10	80	40	80	65
	Wind onshore	1 080	1 040	25	30	10	10	60	50	65	55
	Wind offshore	3 320	2 220	40	44	40	25	155	95	160	100

Notes: O&M = operation and maintenance; LCOE = levelised cost of electricity; VALCOE = value-adjusted LCOE; kW = kilowatt; MWh = megawatt-hour; CCGT = combined-cycle gas turbine. LCOE and VALCOE figures are rounded. Lower figures for VALCOE indicate improved competitiveness. Coal refers to supercritical, except China that refers to ultra-supercritical.

Sources: IEA analysis; IRENA Renewable Cost Database; Bolinger and Seel (2018).

Figure 2: General structure of demand modules



IEA WEO central scenario (NPS): growth for everyone

Table 1.1 ▷ World primary energy demand by fuel and scenario (Mtoe)

			New Policies		Current Policies		Sustainable Development	
	2000	2017	2025	2040	2025	2040	2025	2040
Coal	2 308	3 750	3 768	3 809	3 998	4 769	3 045	1 597
Oil	3 665	4 435	4 754	4 894	4 902	5 570	4 334	3 156
Gas	2 071	3 107	3 539	4 436	3 616	4 804	3 454	3 433
Nuclear	675	688	805	971	803	951	861	1 293
Renewables	662	1 334	1 855	3 014	1 798	2 642	2 056	4 159
Hydro	225	353	415	531	413	514	431	601
Modern bioenergy	377	727	924	1 260	906	1 181	976	1 427
Other	60	254	516	1 223	479	948	648	2 132
Solid biomass	646	658	666	591	666	591	396	77
Total	10 027	13 972	15 388	17 715	15 782	19 328	14 146	13 715
Fossil fuel share	*80%*	*81%*	*78%*	*74%*	*79%*	*78%*	*77%*	*60%*
CO_2 emissions (Gt)	23.1	32.6	33.9	35.9	35.5	42.5	29.5	17.6

Notes: Mtoe = million tonnes of oil equivalent; Gt = gigatonnes. Solid biomass includes its traditional use in three-stone fires and in improved cookstoves.

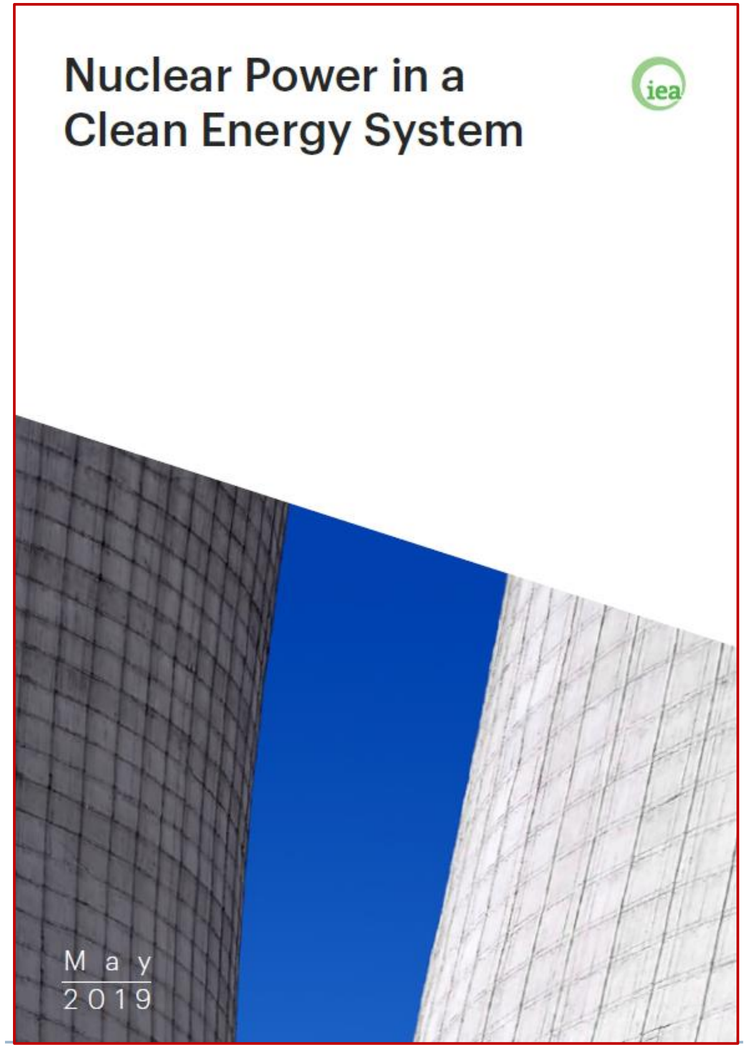
1.4 Power generation and energy supply

Table 1.4 ▷ World electricity generation by fuel, technology and scenario (TWh)

			New Policies		Current Policies		Sustainable Development	
	2000	2017	2025	2040	2025	2040	2025	2040
Coal	6 001	9 858	9 896	10 335	10 694	13 910	7 193	1 982
Oil	1 212	940	763	527	779	610	605	197
Gas	2 747	5 855	6 829	9 071	7 072	10 295	6 810	5 358
Nuclear	2 591	2 637	3 089	3 726	3 079	3 648	3 303	4 960
Hydro	2 618	4 109	4 821	6 179	4 801	5 973	5 012	6 990
Wind and solar PV	32	1 519	3 766	8 529	3 485	6 635	4 647	14 139
Other renewables	217	722	1 057	2 044	1 031	1 653	1 259	3 456
Total generation	15 441	25 679	30 253	40 443	30 971	42 755	28 859	37 114
Electricity demand	*13 156*	*22 209*	*26 417*	*35 526*	*26 950*	*37 258*	*25 336*	*33 176*

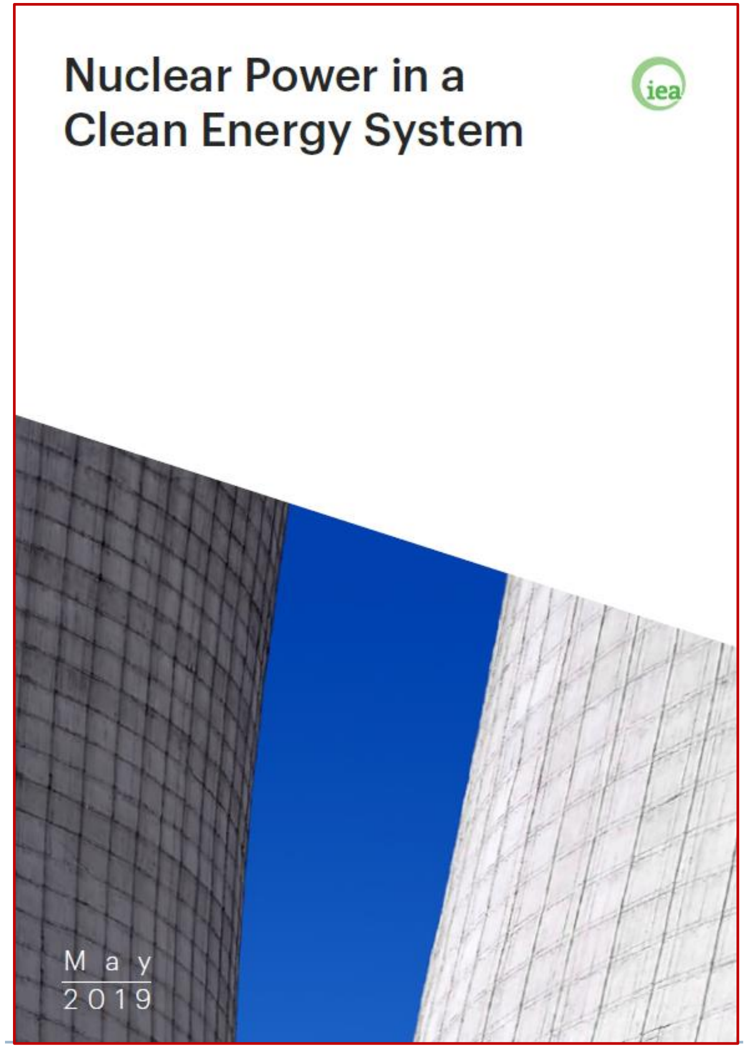
Notes: TWh = terawatt-hours. Electricity demand equals total generation minus own use (for generation) and transmission and distribution losses. Total generation includes other sources.

IEA Nuclear report May 2019



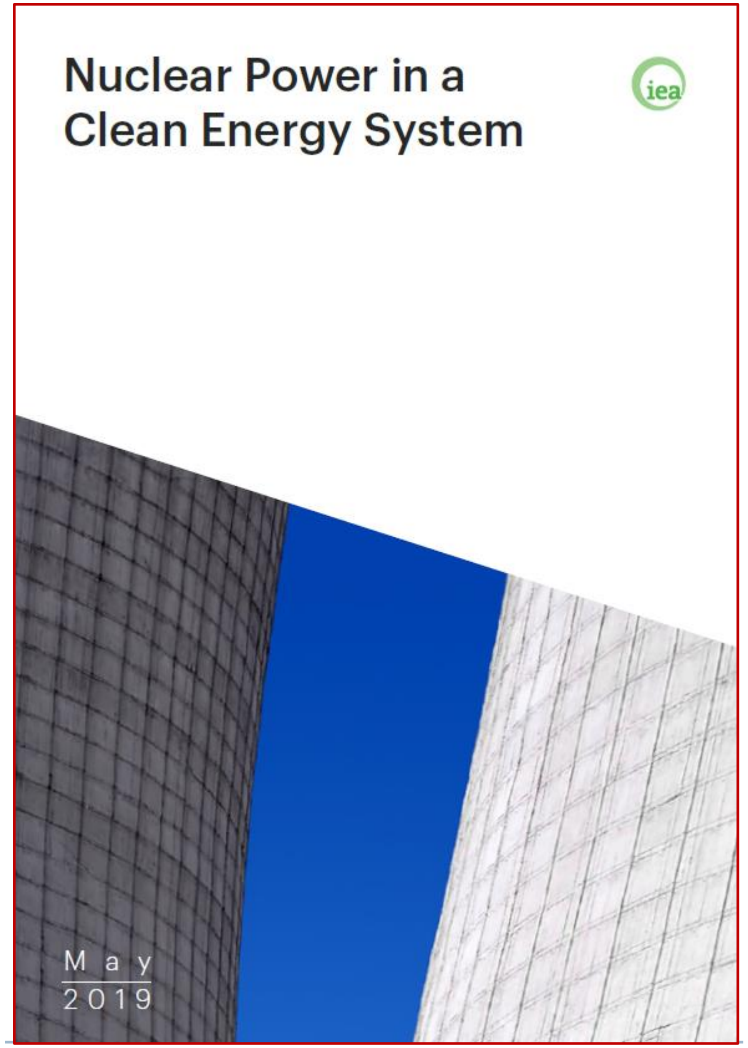
- Nuclear power can play an important role in clean energy transitions
- Achieving the clean energy transition with less nuclear power is possible but would require an extraordinary effort.
- Lifetime extensions of nuclear power plants are crucial to getting the energy transition back on track
- Policy and regulatory decisions remain critical to the fate of ageing reactors in advanced economies.
- Offsetting less nuclear power with more renewables would cost more
- Despite recent declines in wind and solar costs, adding new renewable capacity requires considerably more capital investment than extending the lifetimes of existing nuclear reactors.

Well yes….



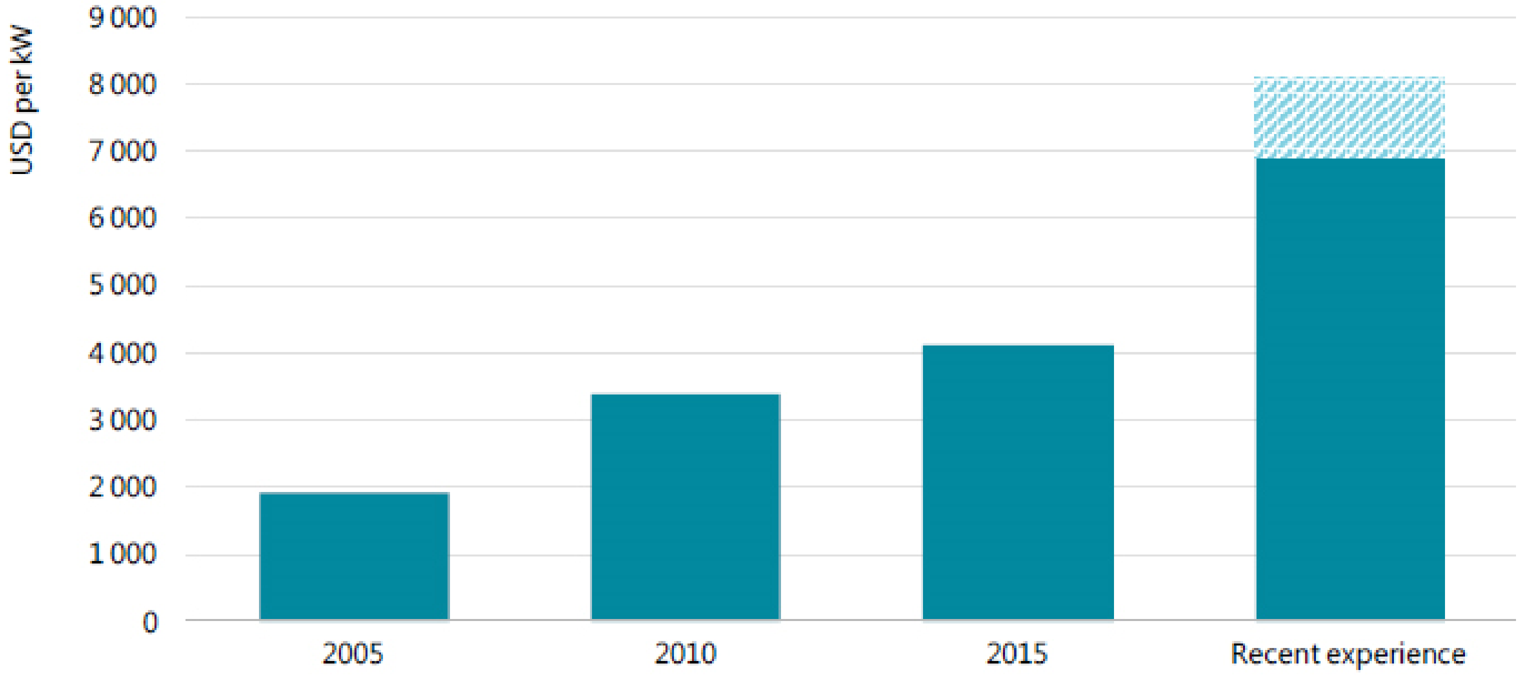
- The biggest barrier to new nuclear construction is mobilising investment. Plans to build new nuclear
- Plants face concerns about competitiveness with other power generation technologies and the very large
- Size of nuclear projects that require billions of dollars in upfront investment. Those doubts are especially strong in countries that have introduced competitive wholesale markets.
- A number of challenges specific to the nature of nuclear power technology may prevent investment
- The main obstacles relate to the sheer scale of investment and long lead times; the risk of construction problems, delays and cost overruns; and the possibility of future changes in policy or the electricity system itself. There have been long delays in completing advanced reactors. They have turned out to cost far more than originally expected and dampened investor interest in new projects.

The political wish list



- Countries that have kept the option of using nuclear power need to reform their policies to ensure competition on a level playing field. They also need to address barriers to investment in lifetime extensions and new capacity.
- The focus should be on designing electricity markets in a way that values the clean energy and energy security attributes of low-carbon technologies, including nuclear power.
- Securing investment in new nuclear plants would require more intrusive policy intervention given the very high cost of projects and unfavourable recent experiences in some countries. Investment policies need to overcome financing barriers through a combination of long-term contracts, price guarantees and direct state investment.

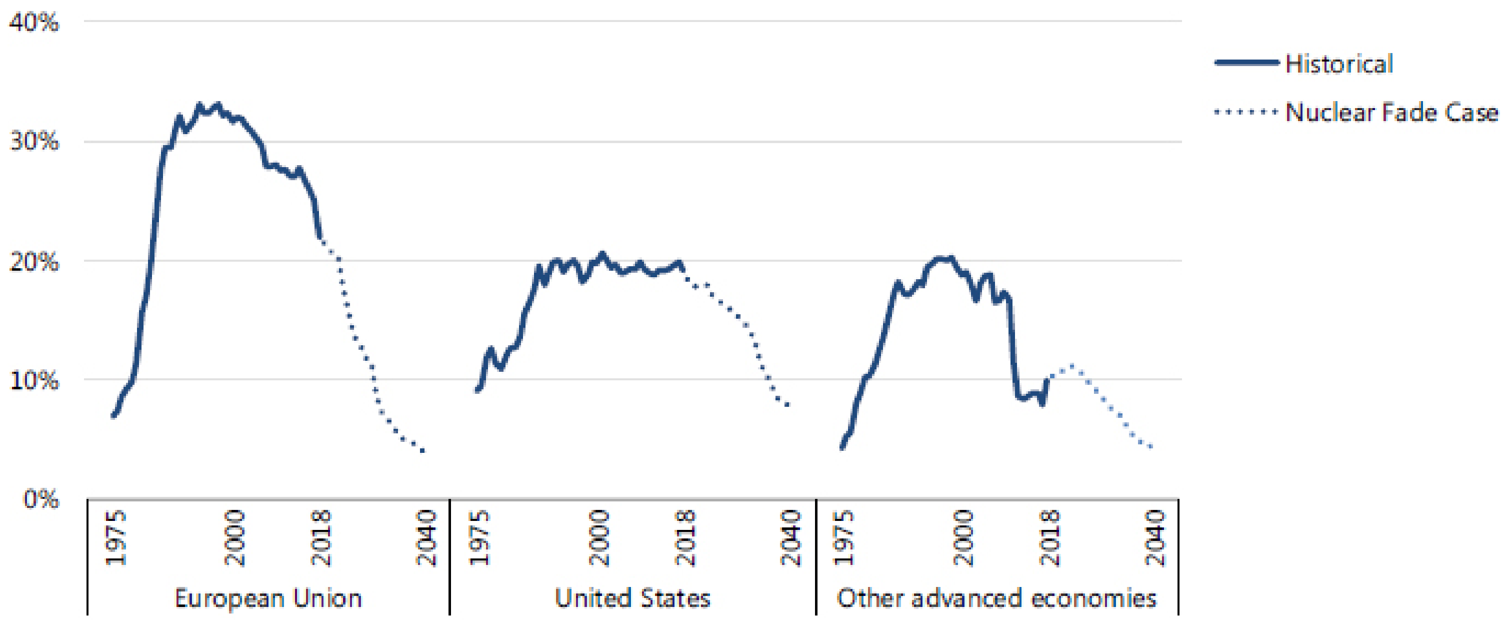
Figure 9. Projected overnight construction cost of nuclear power capacity and recent United States and Western European experience



Source: IEA analysis based on IEA/NEA (2005, 2010 and 2015 editions), Projected Costs of Generating Electricity.

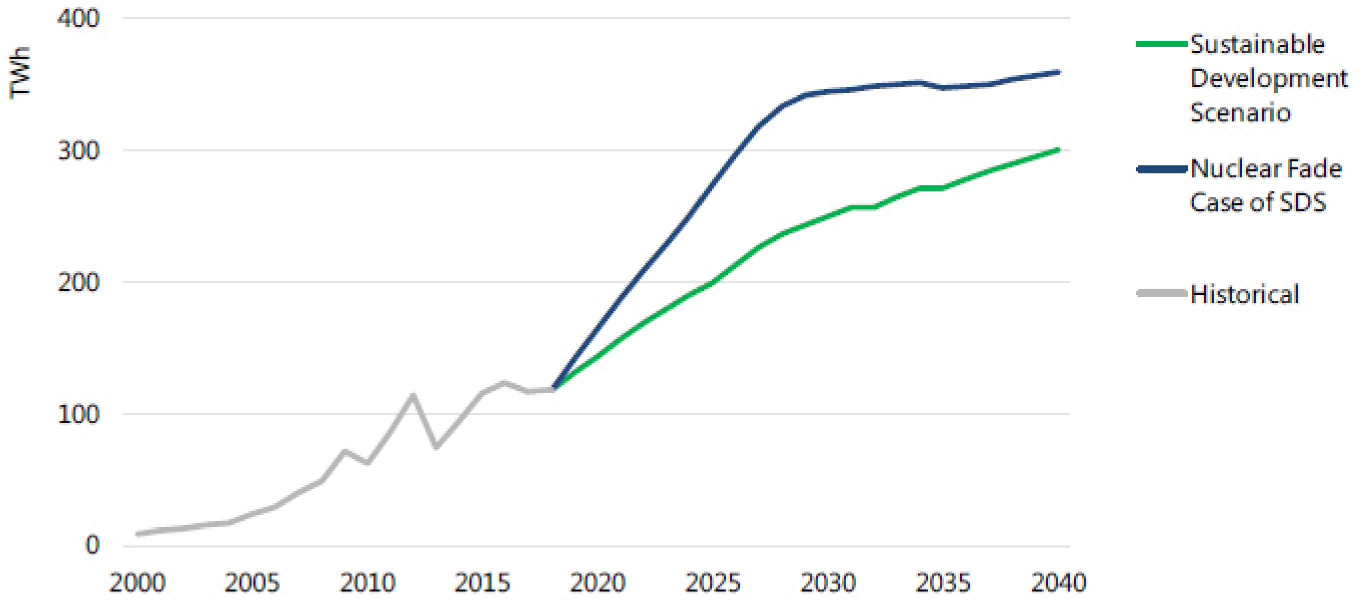
Construction costs of new nuclear power plants in the United States and Western Europe have turned out to be much higher than projected.

Figure 22. Share of nuclear power in electricity supply in advanced economies in the Nuclear Fade Case of the New Policies Scenario



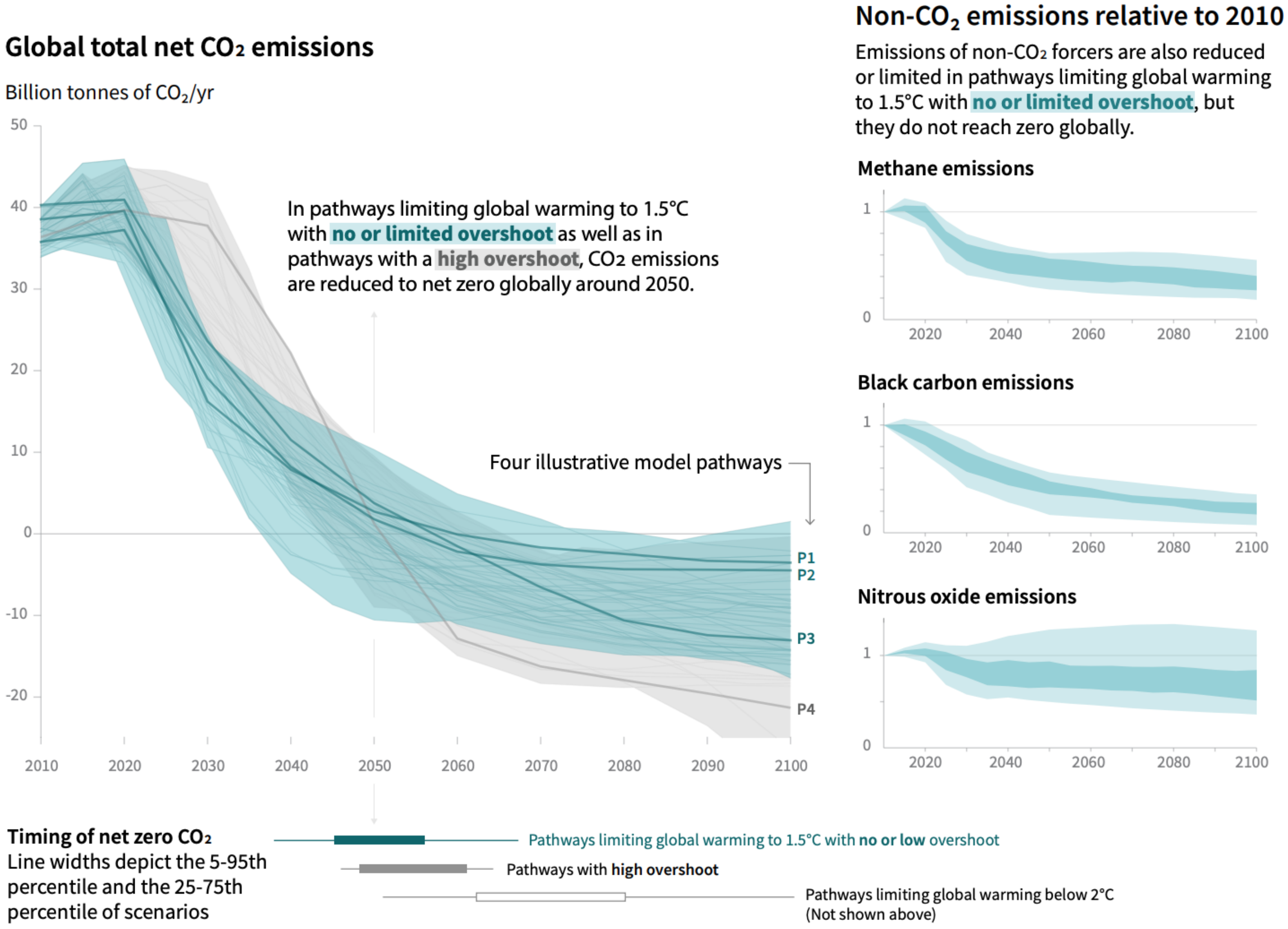
Without further investment, nuclear power will lose its position as the leading source of electricity in advanced economies, providing 6% of electricity supply in 2040 compared with 18% today.

Figure 31. Combined wind and solar power production growth in advanced economies in the Sustainable Development Scenario and the Nuclear Fade Case



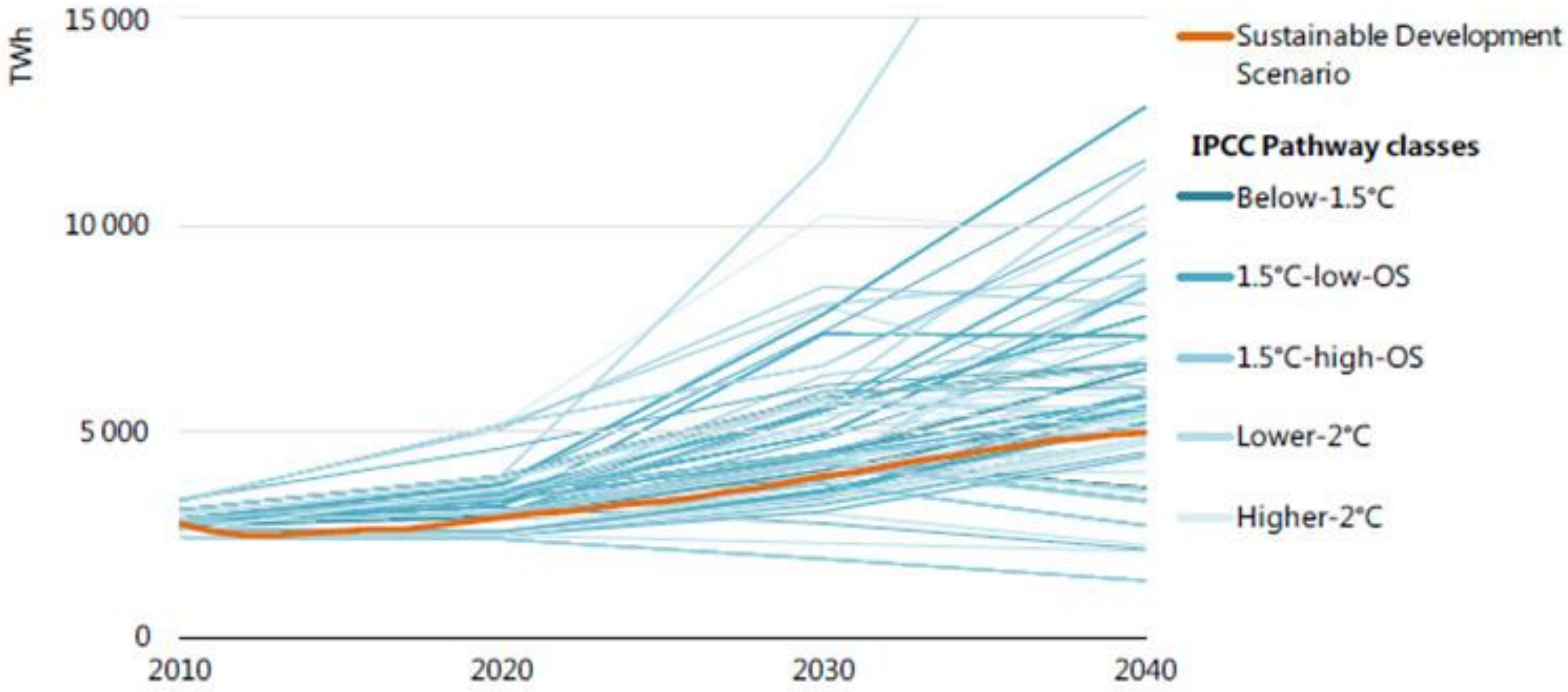
To achieve sustainable energy development, output from wind and solar power would need to expand twice as fast as in the past, and three times as fast in the absence of new nuclear investment.

IPCC 1.5



Global total net CO_2 emissions
Billion tonnes of CO_2/yr
50
40
30
20
10
0
-10
-20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a high overshoot, CO_2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4
Non-CO_2 emissions relative to 2010
Emissions of non-CO_2 forcers are also reduced or limited in pathways limiting global warming to 1.5°C with no or limited overshoot, but they do not reach zero globally.
Methane emissions
Black carbon emissions
Nitrous oxide emissions
1
0
2020
2040
2060
2080
2100
Timing of net zero CO_2
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios
Pathways limiting global warming to 1.5°C with no or low overshoot
Pathways with high overshoot
Pathways limiting global warming below 2°C
(Not shown above)

Figure 28. Global nuclear power production in the Sustainable Development Scenario compared with IPCC scenarios consistent with 2°C warming



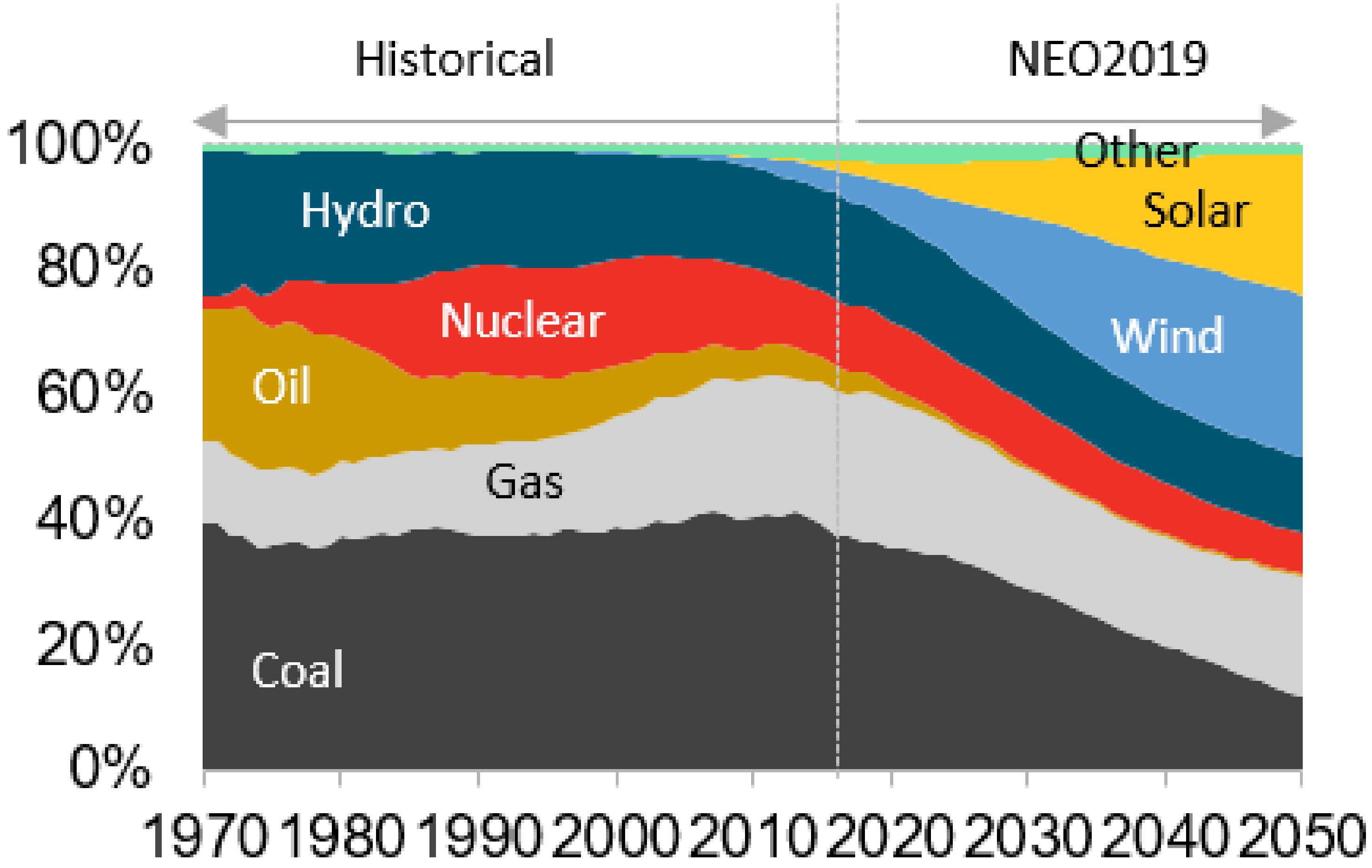
Note: All IPCC scenarios included for 4 pathway classes: Below-1.5°C, 1.5°C-low-OS, 1.5°C-high-OS and Lower-2°C and Higher-2°C.
Source: Huppmann et al. (2018), release 1.1.

IPCC and nuclear energy

- Nuclear power increases its share in most 1.5°C pathways with no or limited overshoot by 2050, but in some pathways both the absolute capacity and share of power from nuclear generators decrease.
- There are large differences in nuclear power between models and across pathways
- Nuclear generation increases, on average by around 2.5 times by 2050 in the 89 mitigation scenarios considered by the IPCC.
- One of the reasons for this variation is that the future deployment of nuclear can be constrained by societal preferences assumed in narratives underlying the pathways
- In the chapter on mitigation, the IPCC review the role of different energy technologies and are clear that in order to have a high degree of confidence in meeting a 1.5 degree target, the share of primary energy from renewables (including bioenergy, hydro, wind, and solar) needs to increase by 2050, so that they supply 52–67 percent of primary energy. Solar and wind together are expected to provide 28–343 EJ930 (with a median of 121 EJ) by 2050, while the role for nuclear power is much less certain, with the suggestion that by 2050 primary energy supplied by nuclear would range from 3 to 66 EJ/year (median of 24 EJ).
- IPCC 1.5 Summary for Policymakers: Nuclear energy, the share of which increases in most of the 1.5ºC-compatible pathways (see Chapter 2, 43 Section 2.4.2.1), can increase the risks of proliferation (SDG 16), have negative environmental effects (e.g., 44 for water use, SDG 6),

Sectoral mitigation measures	Effect on additional objectives/concerns		
	Economic	Social	Environmental
Energy Supply	*For possible upstream effects of biomass supply for bioenergy, see AFOLU.*		
Nuclear replacing coal power	Energy security (reduced exposure to fuel price volatility) (*m*/*m*); local employment impact (but uncertain net effect) (*l*/*m*); legacy/cost of waste and abandoned reactors (*m*/*h*)	Mixed health impact via reduced air pollution and coal mining accidents (*m*/*h*), nuclear accidents and waste treatment, uranium mining and milling (*m*/*l*); safety and waste concerns (*r*/*h*); proliferation risk (*m*/*m*)	Mixed ecosystem impact via reduced air pollution (*m*/*h*) and coal mining (*l*/*h*), nuclear accidents (*m*/*m*)

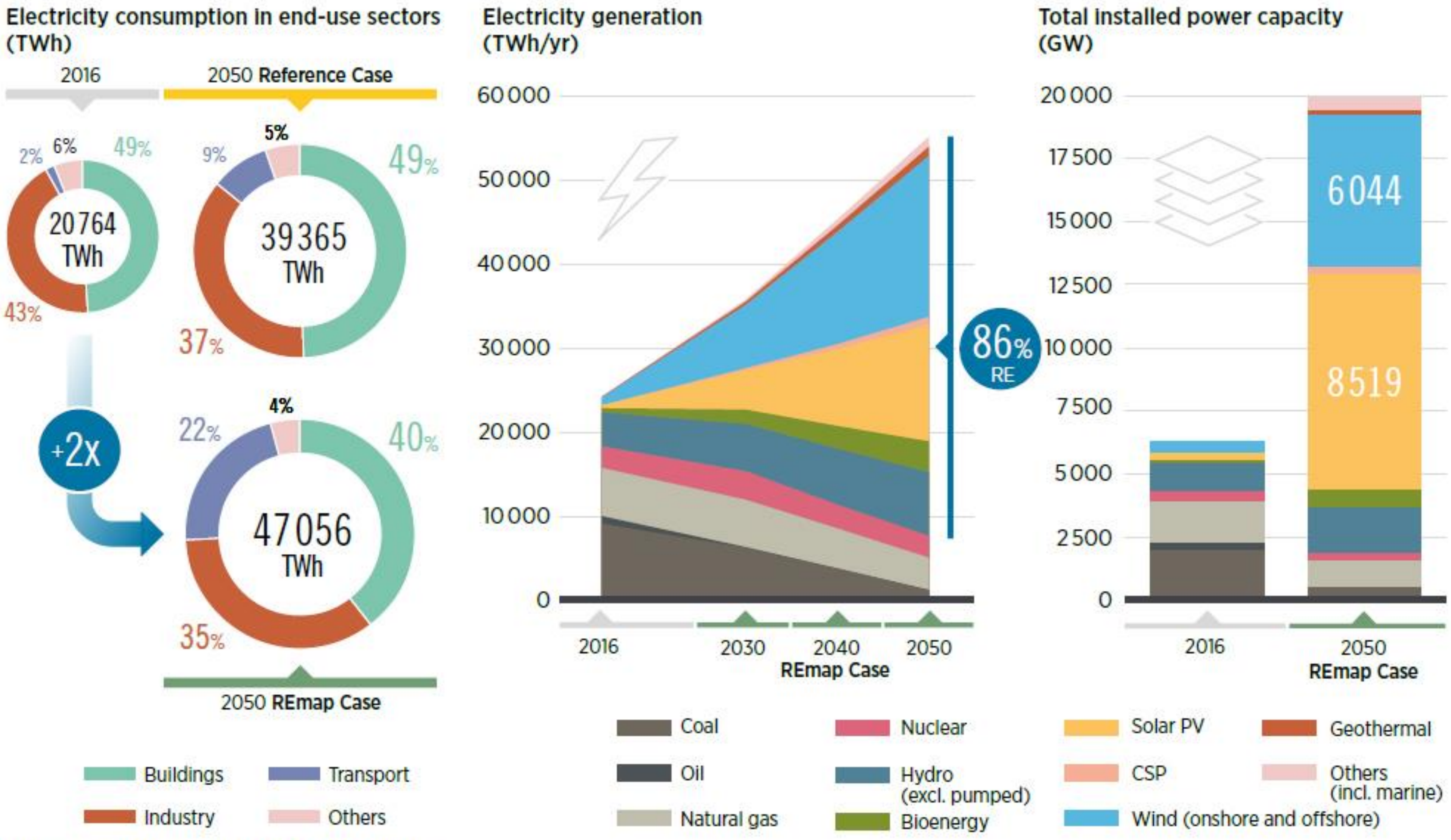
Other scenarions: BNEF NEO 2019



IRENA Scenario

Figure 7. Wind and solar will dominate electricity generation

Electricity consumption by sector, electricity generation (TWh/yr) and power capacity mix (GW)

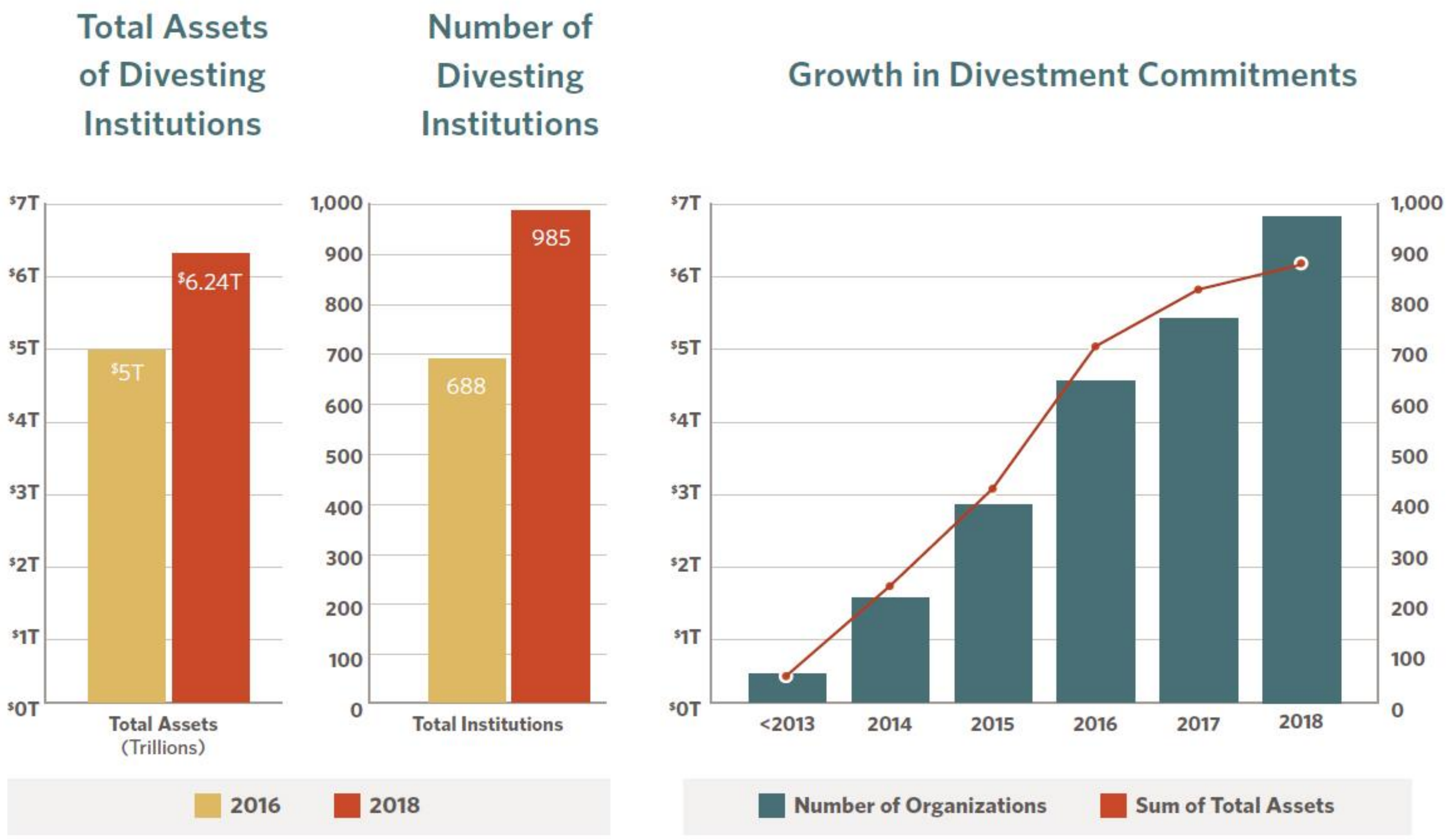


Note: CSP refers to concentrated solar power

Nuclear and CO_2: wide range

- Nuclear: Intergovernmental Panel on Climate Change (IPCC)'s range of 4-110 g-CO_2e/kWh (Bruckner et al., 2014)
- Jacobson (2009): The range of 9-70 g-CO_2e/kWh
- Sovacool (2008) 66 (1.4-288) g-CO_2e/kWh

Commitments to fossil fuel divestment: what about nuclear?



Arabelle
Advisory
Sept 2018

Data accurate as of September 5, 2018.

Taxonomy: what is green/sustainable?

Definition

A classification system identifying economic activities that deliver on EU sustainability goals

Scope

Environmental taxonomy, but with intention to extend to social objectives in the long-term

Key features

Granular to minimise ambiguity about "greenness" of an activity

Flexible to cater to technological and market developments

Stakeholders

Built on existing initiatives (HLEG, CBI, EIB) and additional scientific, technical and financial expertise

Benefits

Common language for financial markets

A basis for transperency: Product disclosures and labelling schemes

Resumée

- Crucial moment for combating climage change and for the future of nuclear industry: no indications for going hand-in-hand
- Scenarios are very often dominated by conventional thinking and in the struggle of interpretational sovereignity
- Key aspects in debate:
  - Costs (investments) and opportunity costs
  - Time factor: peak CO_2 to be reached now. Minus 50% GHG 2030 (for 1.5°)
  - Life time extension depend on politics
  - Systemic risk analysis and the definition of what is sustainable

Table 5
Summary statistics of qualified studie

(gCO_2e/kWh)	Frontend	Decommissioning	Total
Min	0.58	0.01	1.36
Max	118	54.5	288.25
Mean	25.09	12.01	66.08
N	17	13	

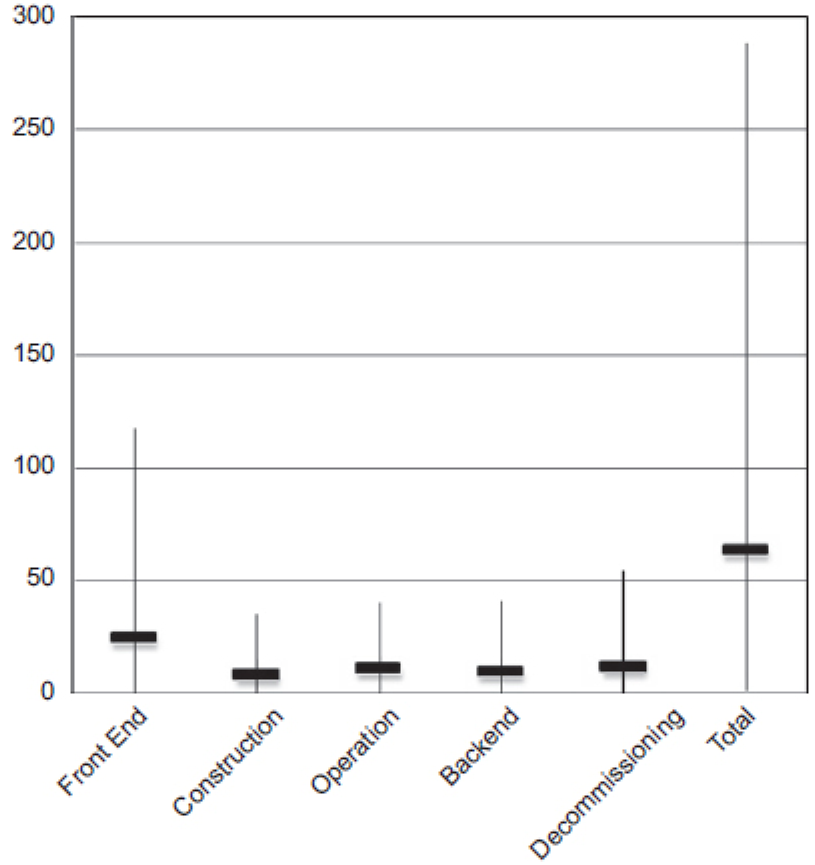


Fig. 3. Range and mean emissions reported from qualified studies for the nuclear fuel cycle (gCO_2e/kWh)