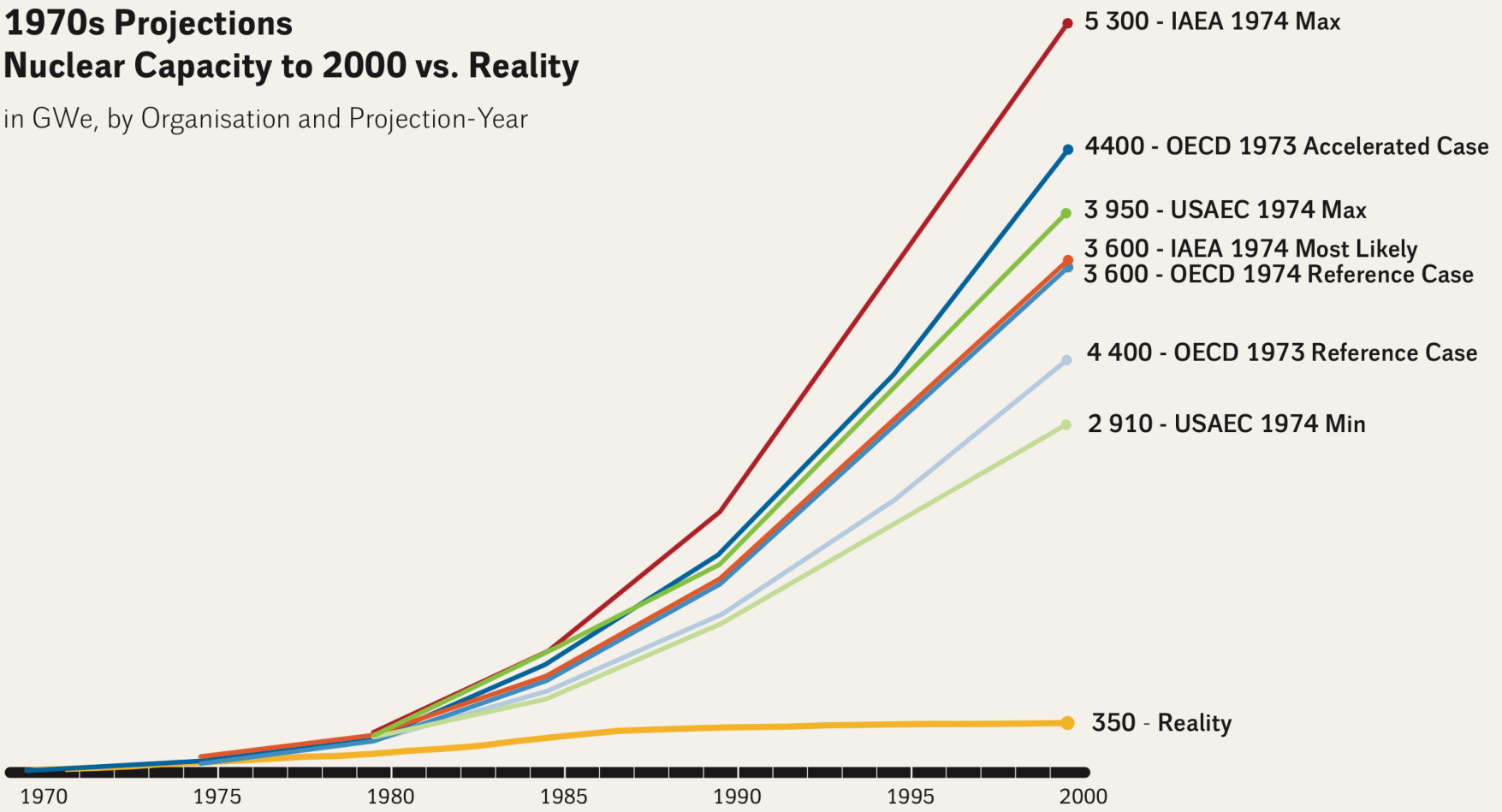
The World Nuclear Industry Status Report 2019

(WNISR2019)

www.WorldNuclearReport.org

Antony Froggatt

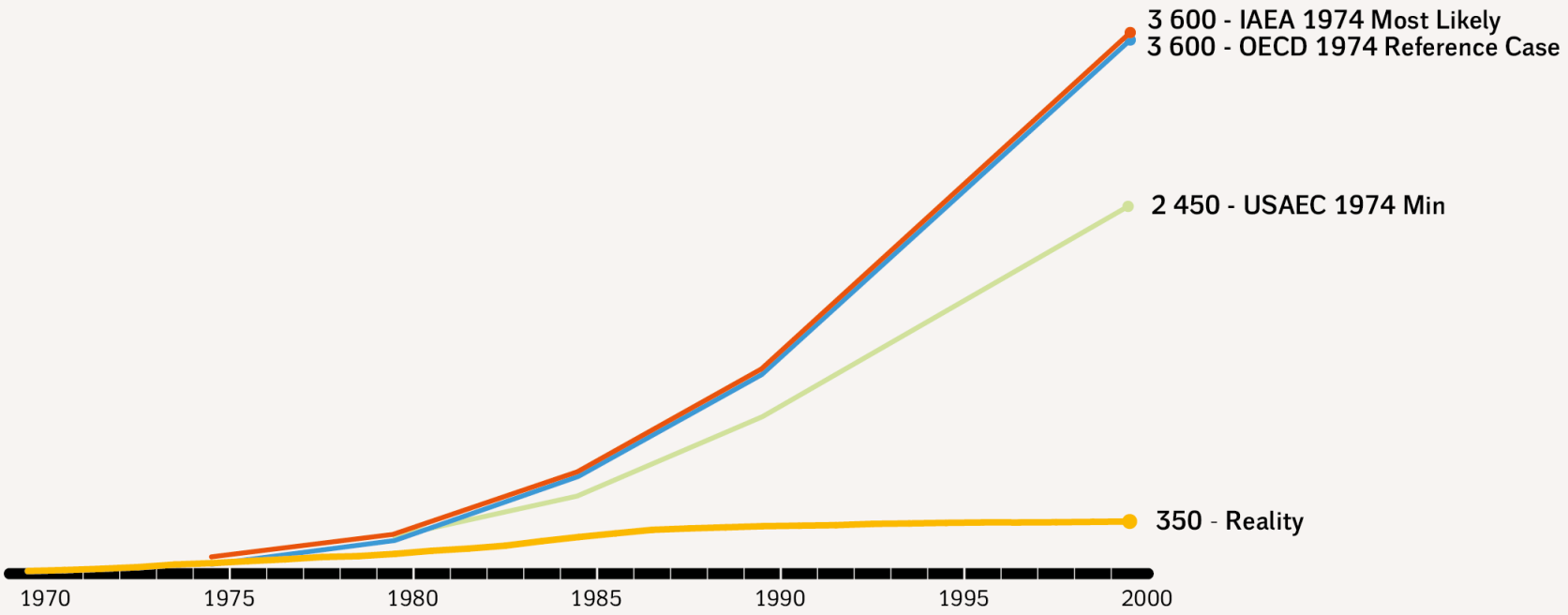
23rd REFORM Group Meeting, Salzburg 15 October 2019



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

1970s Projections
Nuclear Capacity to 2000 vs. Reality

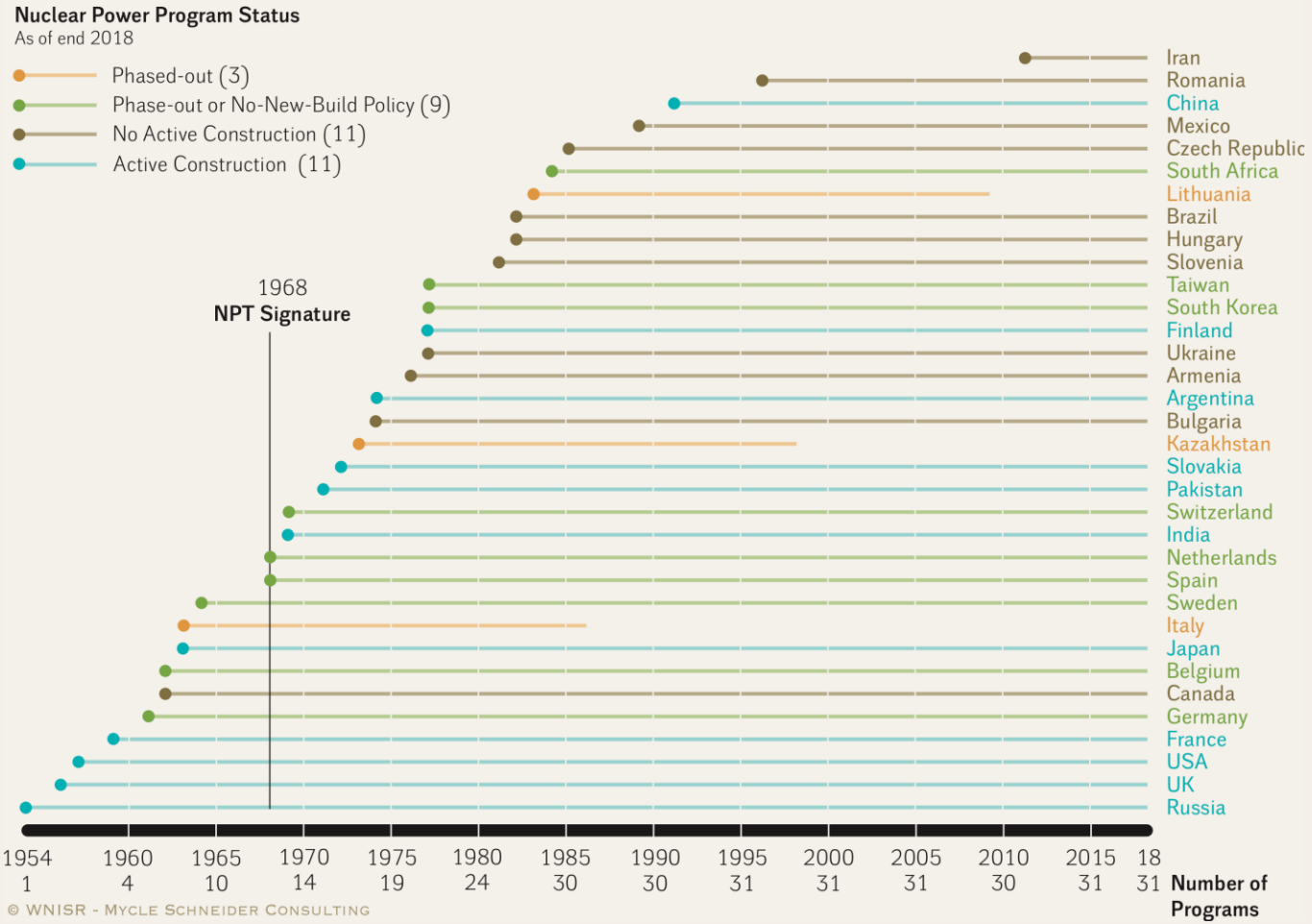
in GWe, by Organisation and Projection-Year



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

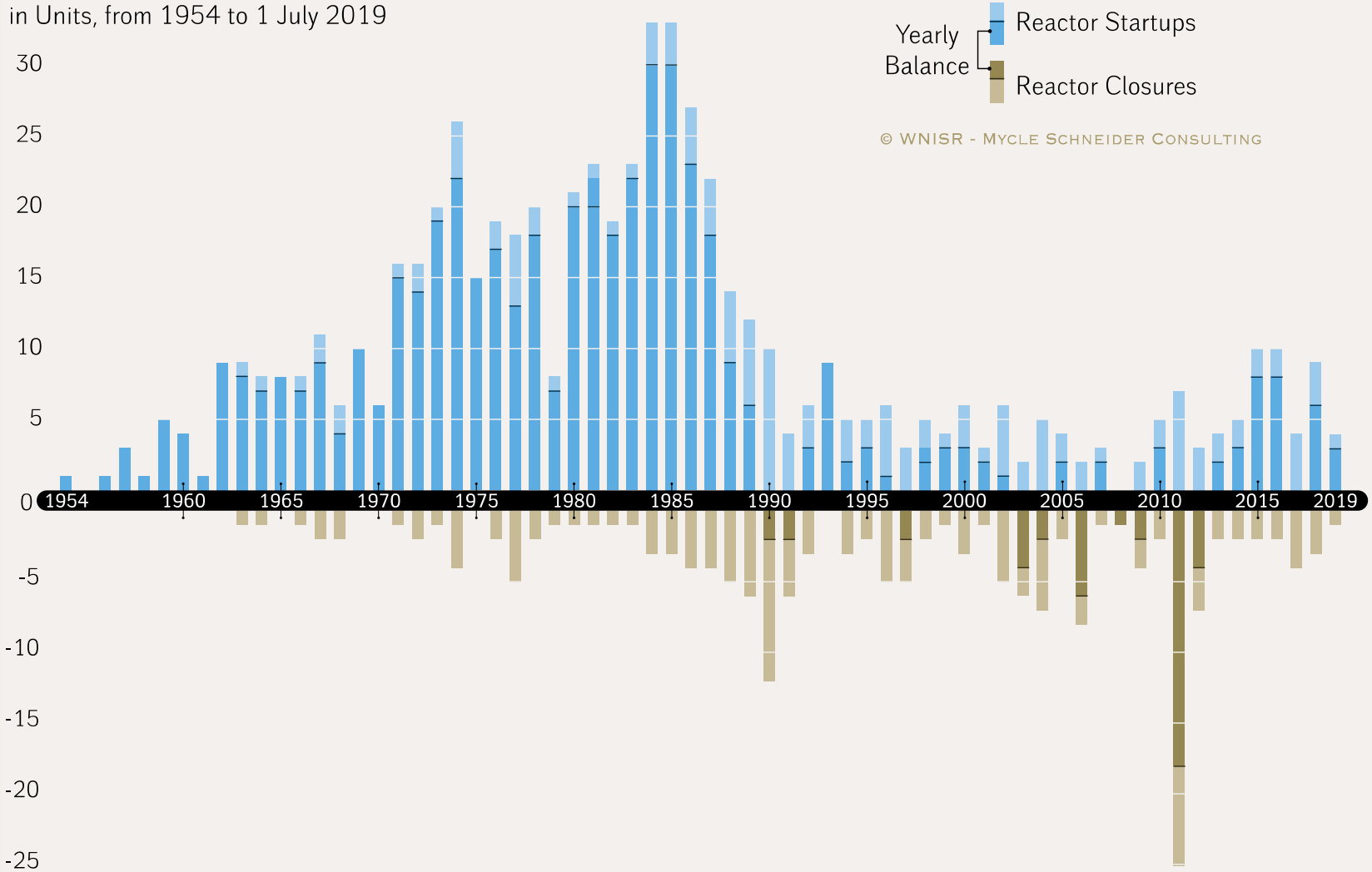
National Nuclear Power Program Startup and Phase-out

Cumulated Number of National Programs, from 1954 to 2018



Reactor Startups and Closures in the World

in Units, from 1954 to 1 July 2019



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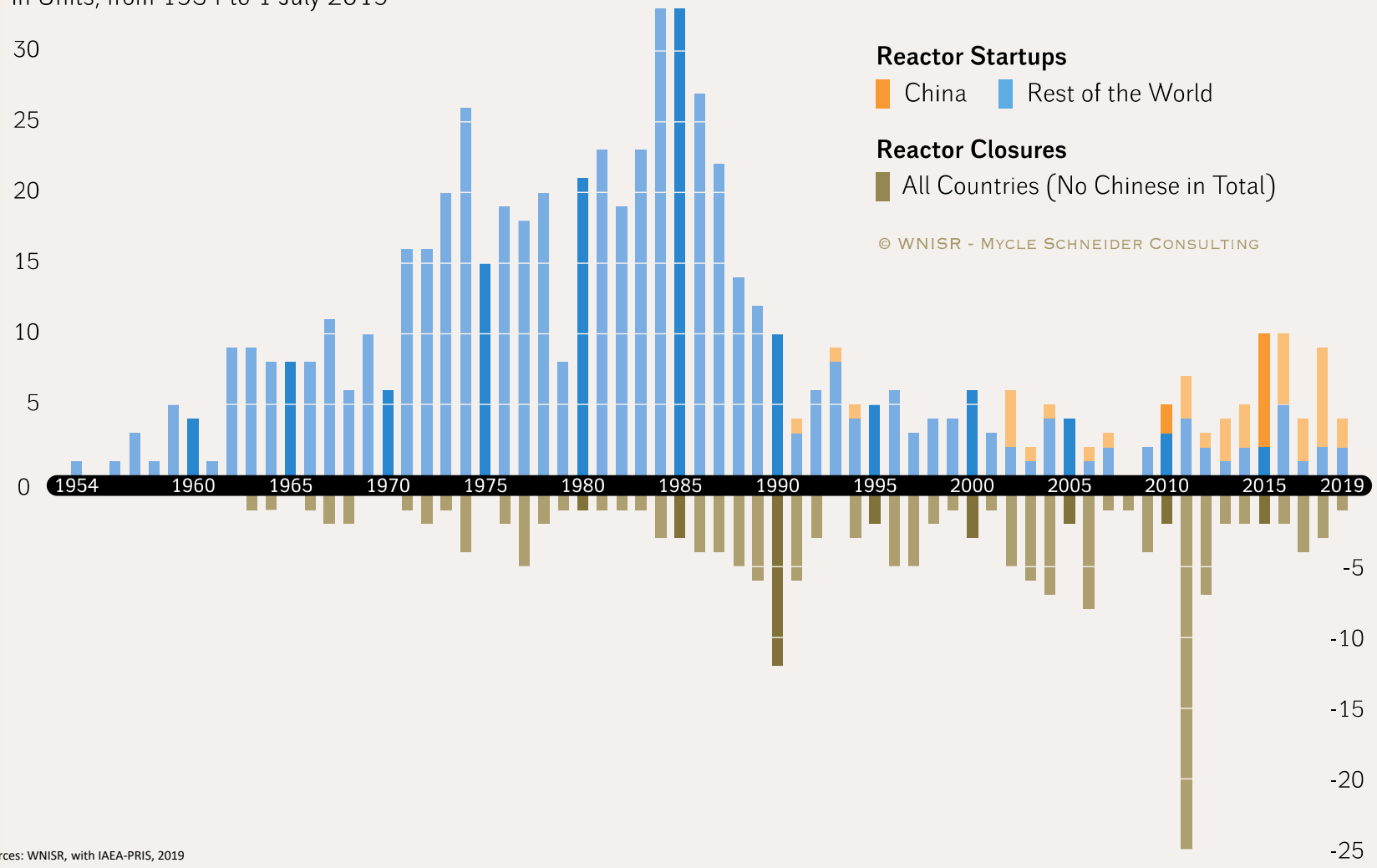
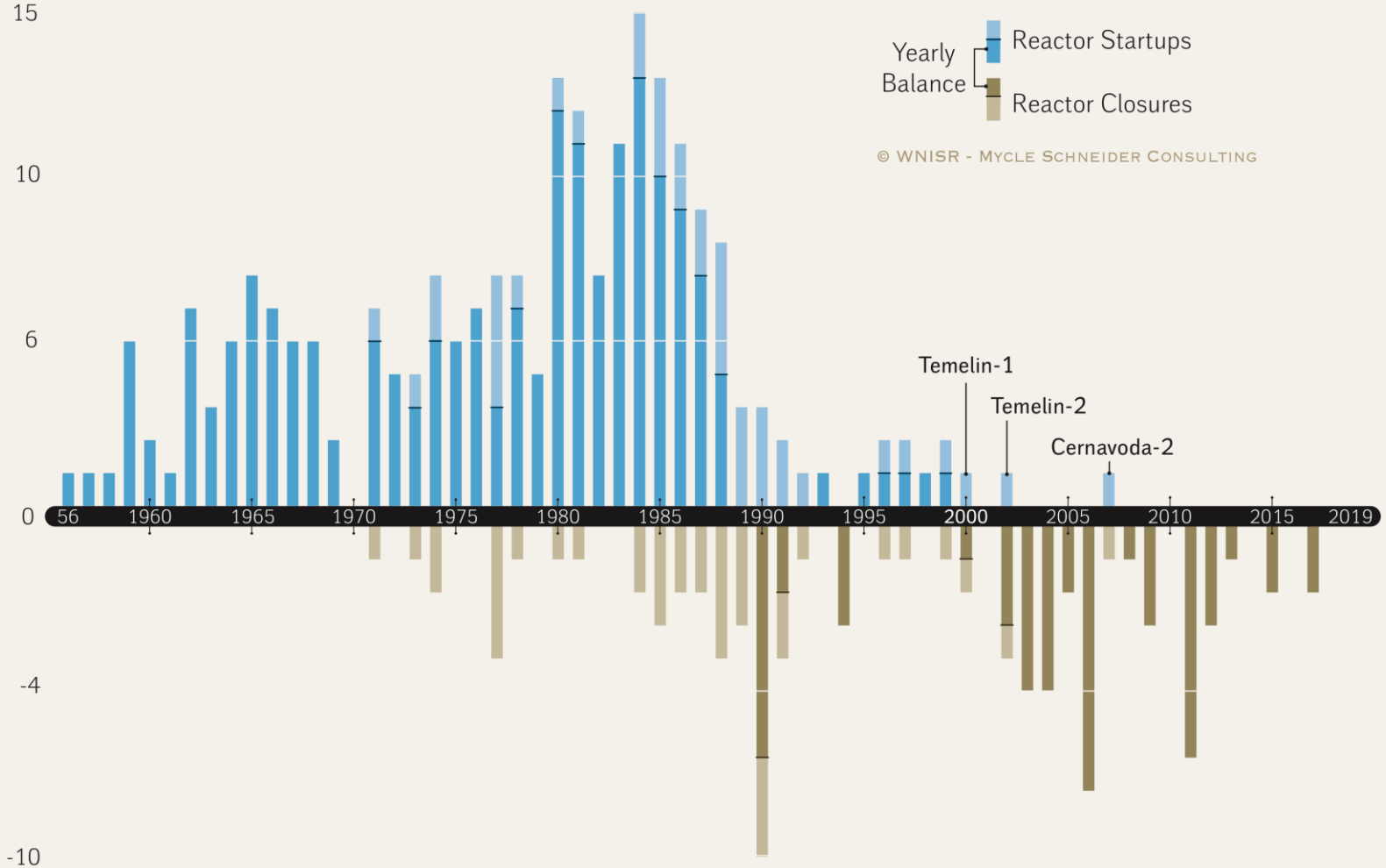


Sources: WNISR, with IAEA-PRIS, 2019

Reactor Startups and Closures in the EU28

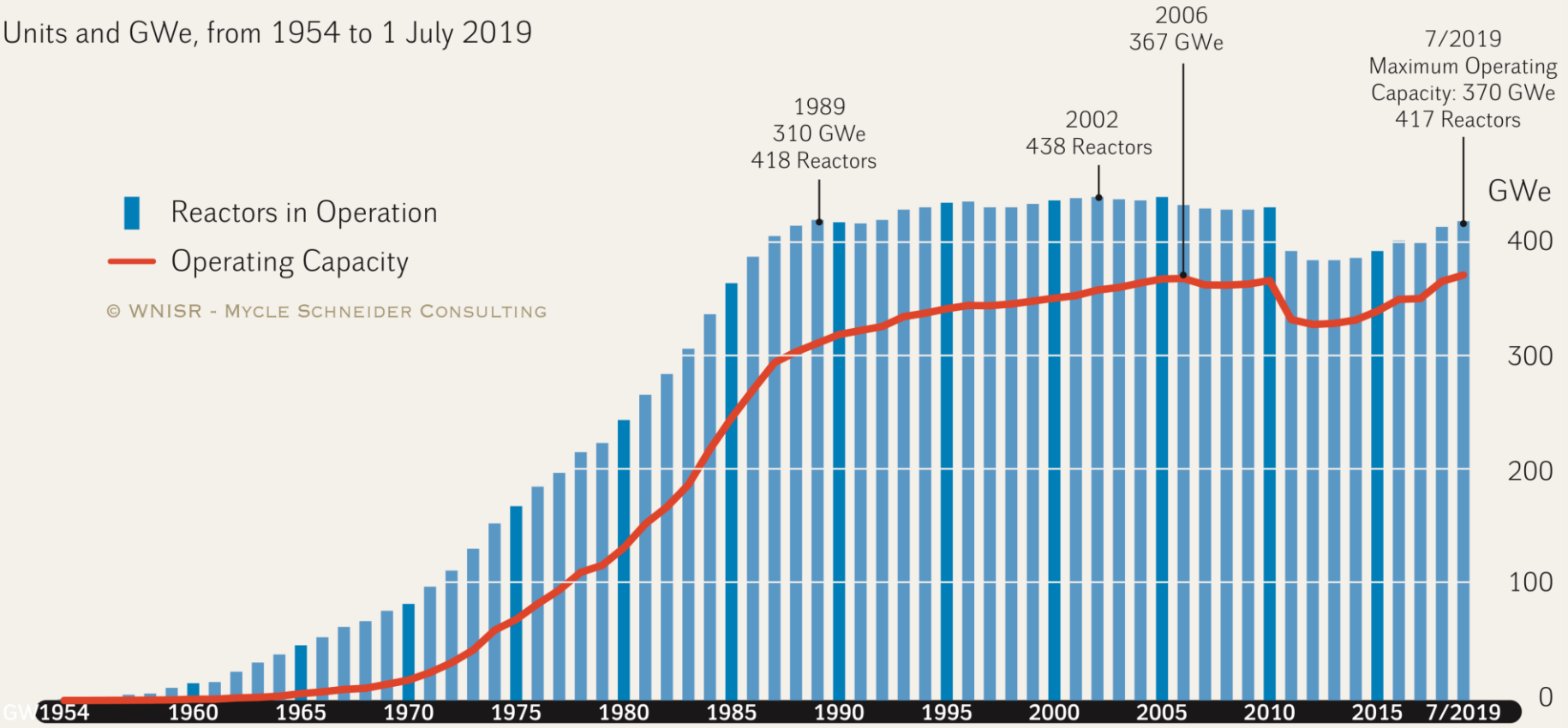
in Units, from 1956 to 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

Nuclear Reactors and Net Operating Capacity in the World

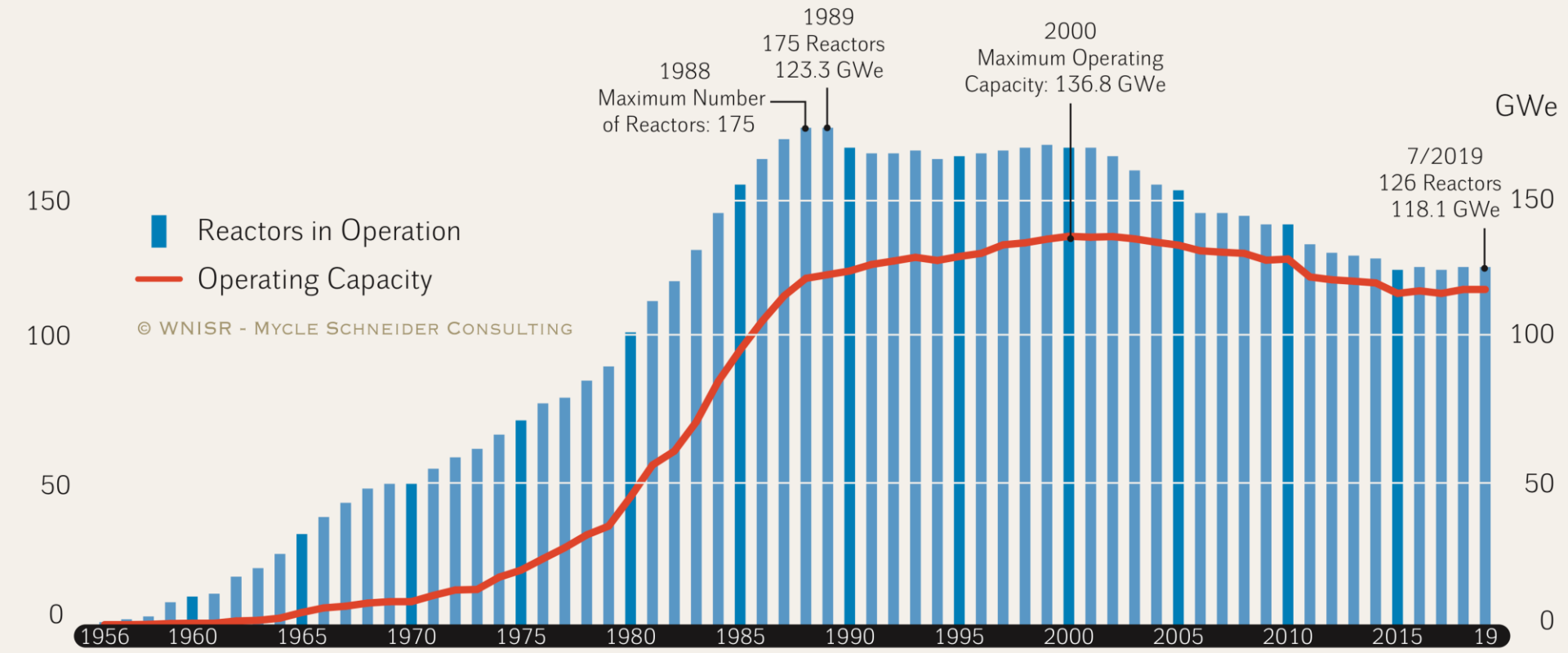
in Units and GWe, from 1954 to 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

Nuclear Reactors and Net Operating Capacity in the EU 28

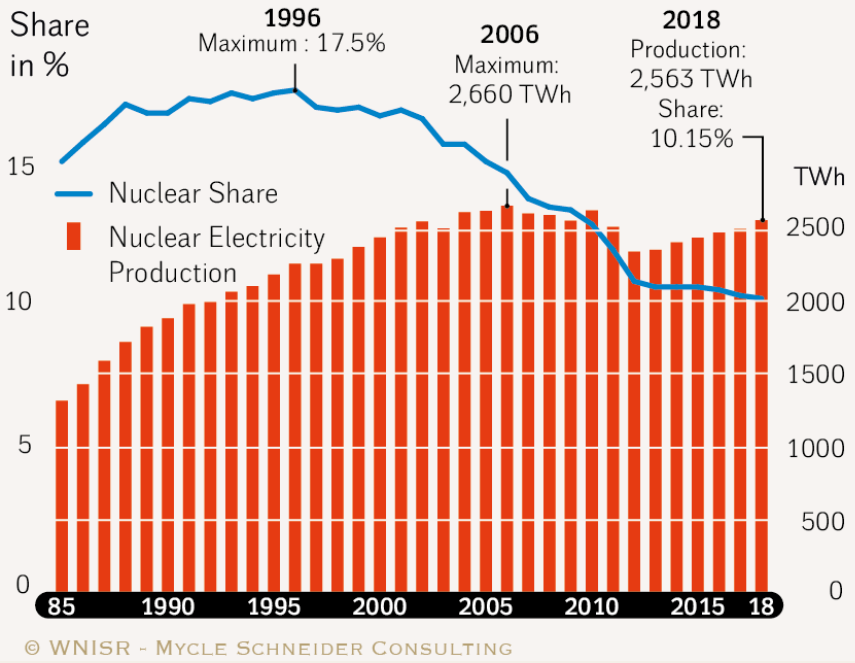
in Units and GWe, from 1956 to 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

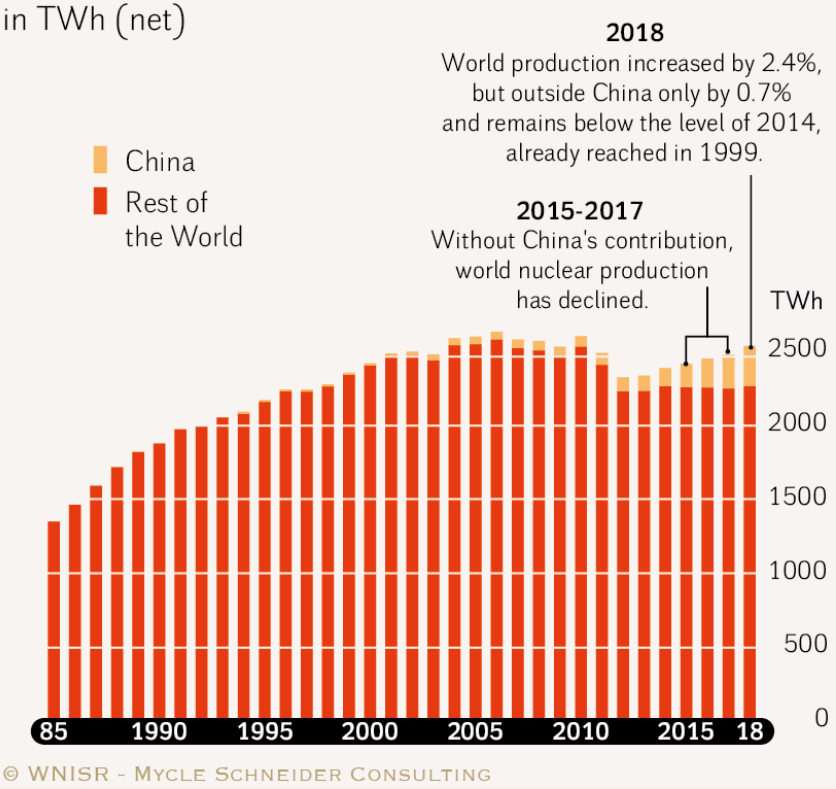
Nuclear Electricity Production 1985-2018 in the World...

in TWh (net) and Share in Electricity Generation (gross)



...and in China and the Rest of the World

in TWh (net)



Sources: IAEA-PRIS, BP, 2019

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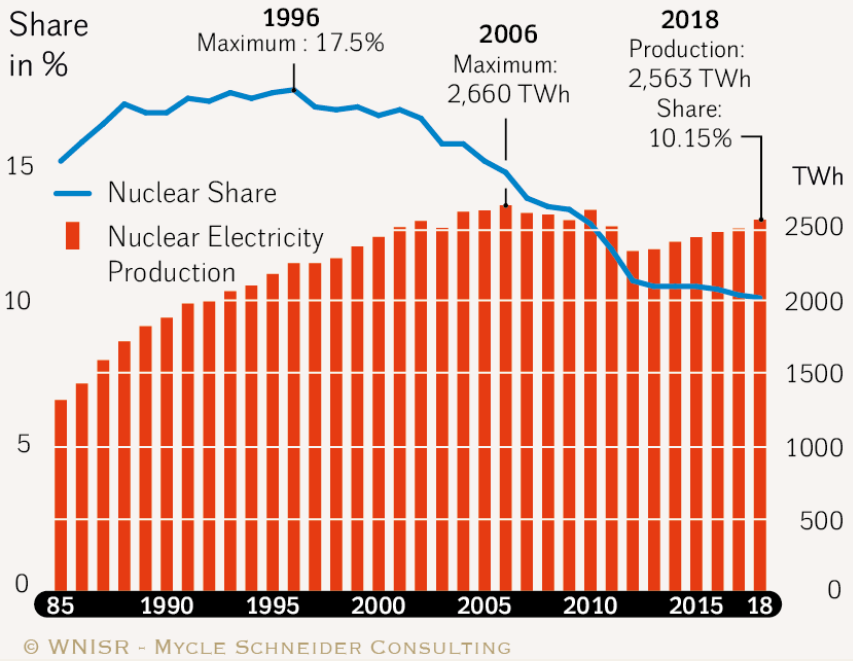

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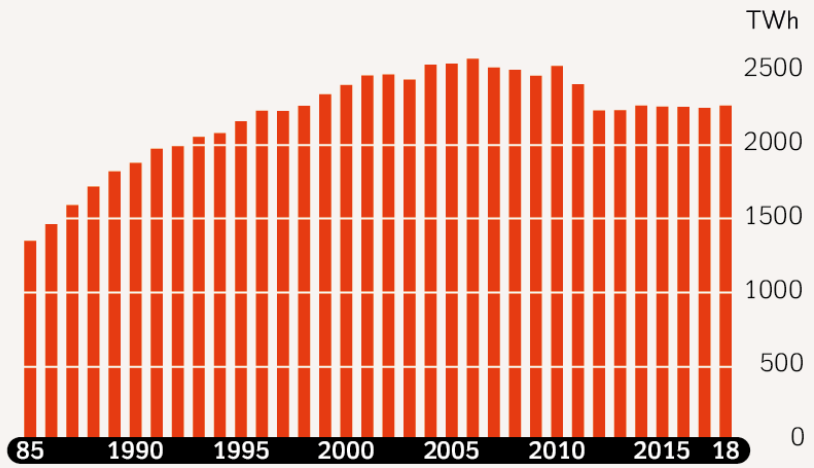
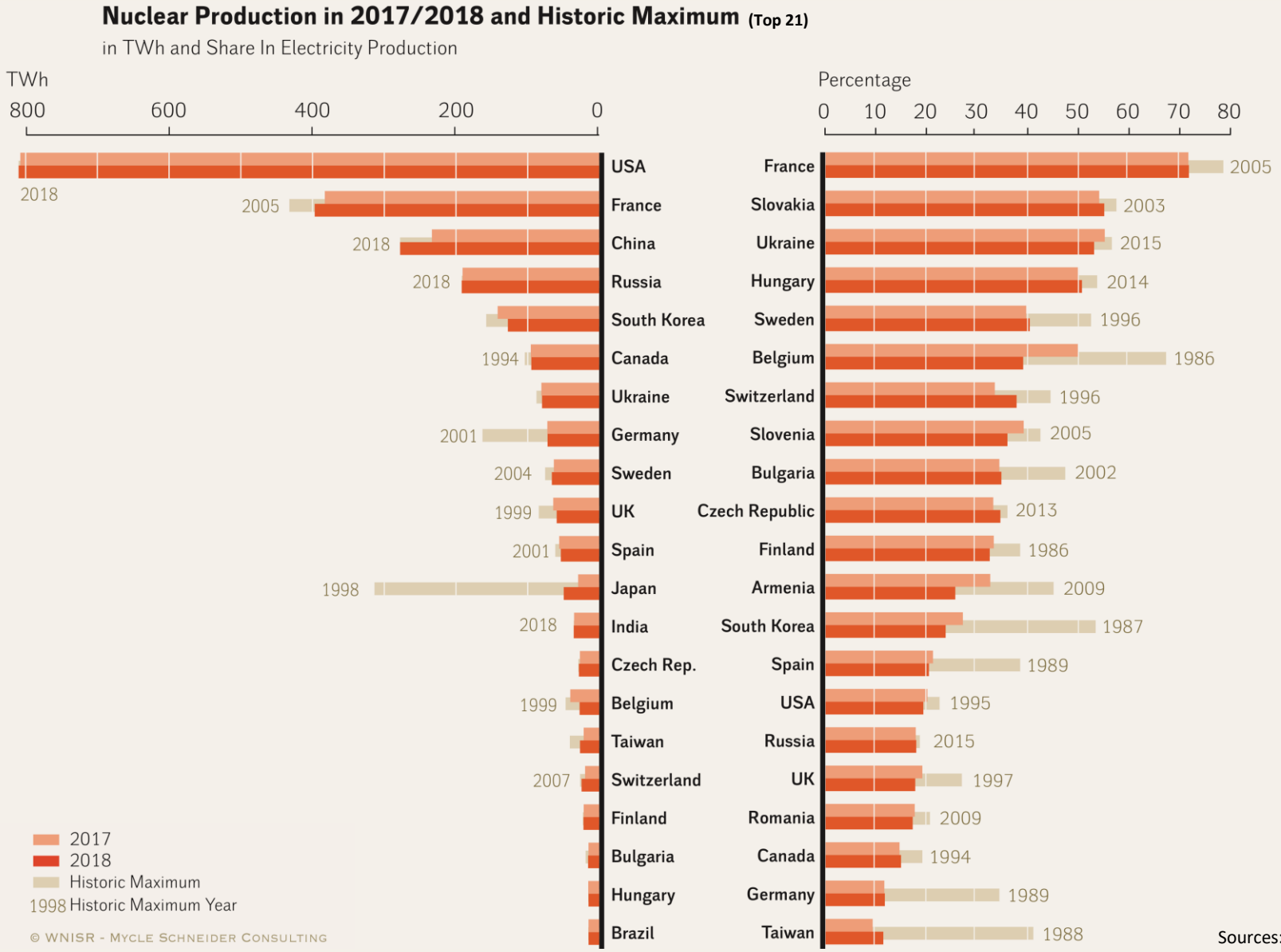
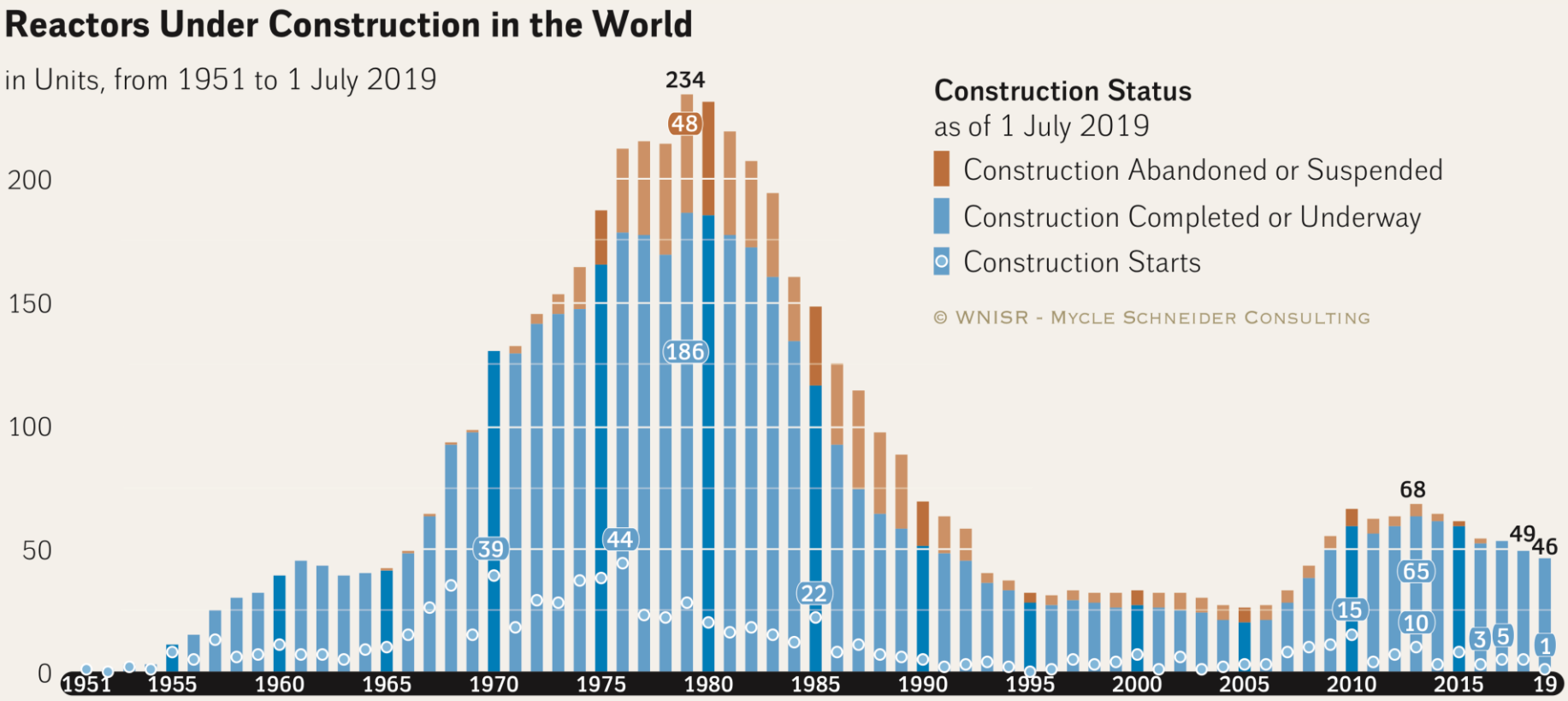


Sources: IAEA-PRIS, BP, 2019



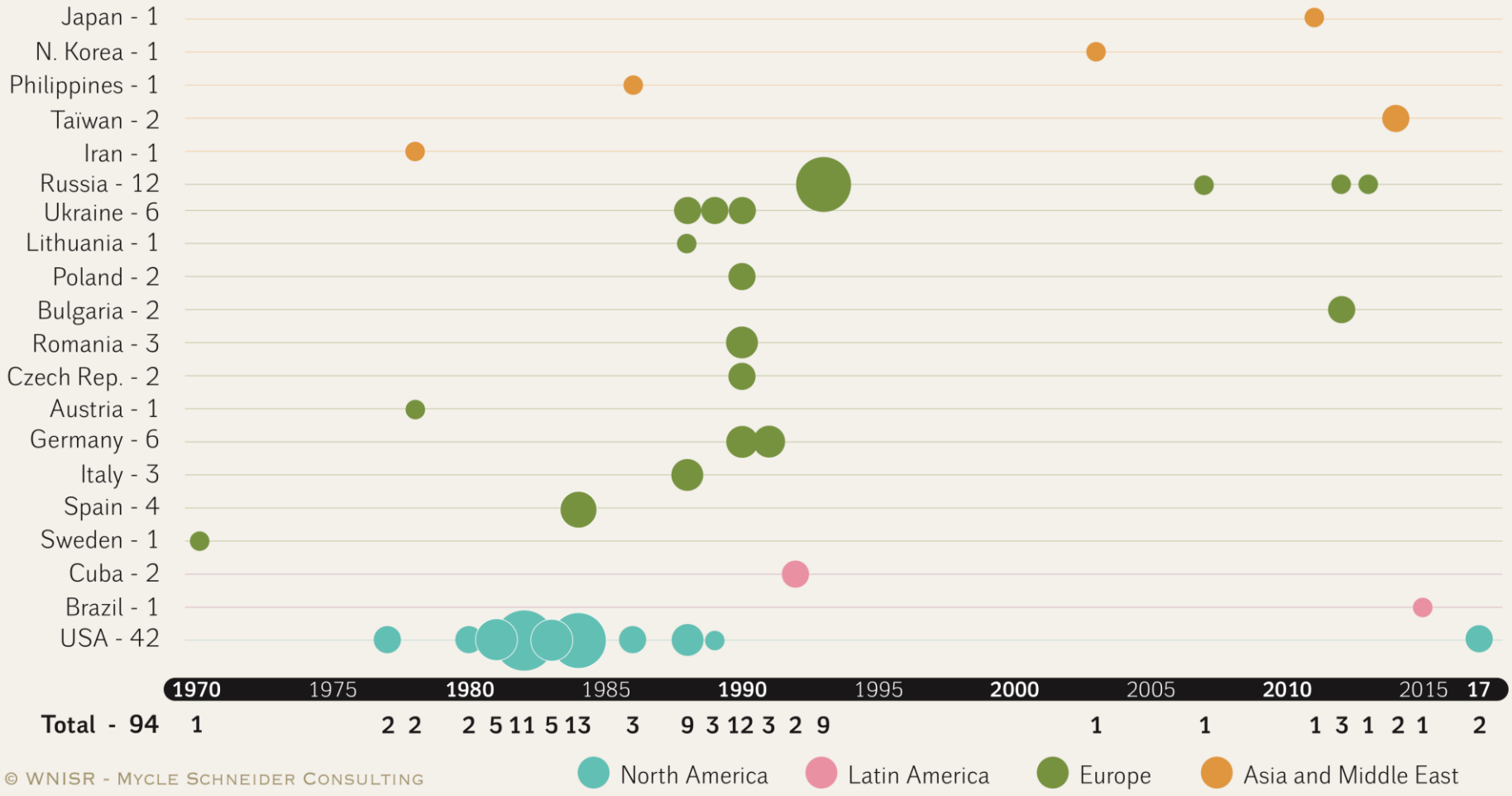
Sources: IAEA-PRIS, BP, 2019



Sources: WNISR, with IAEA-PRIS, 2019

Abandoned Reactor Constructions from 1970 to 1 July 2019

in Units by Cancellation Year and Country

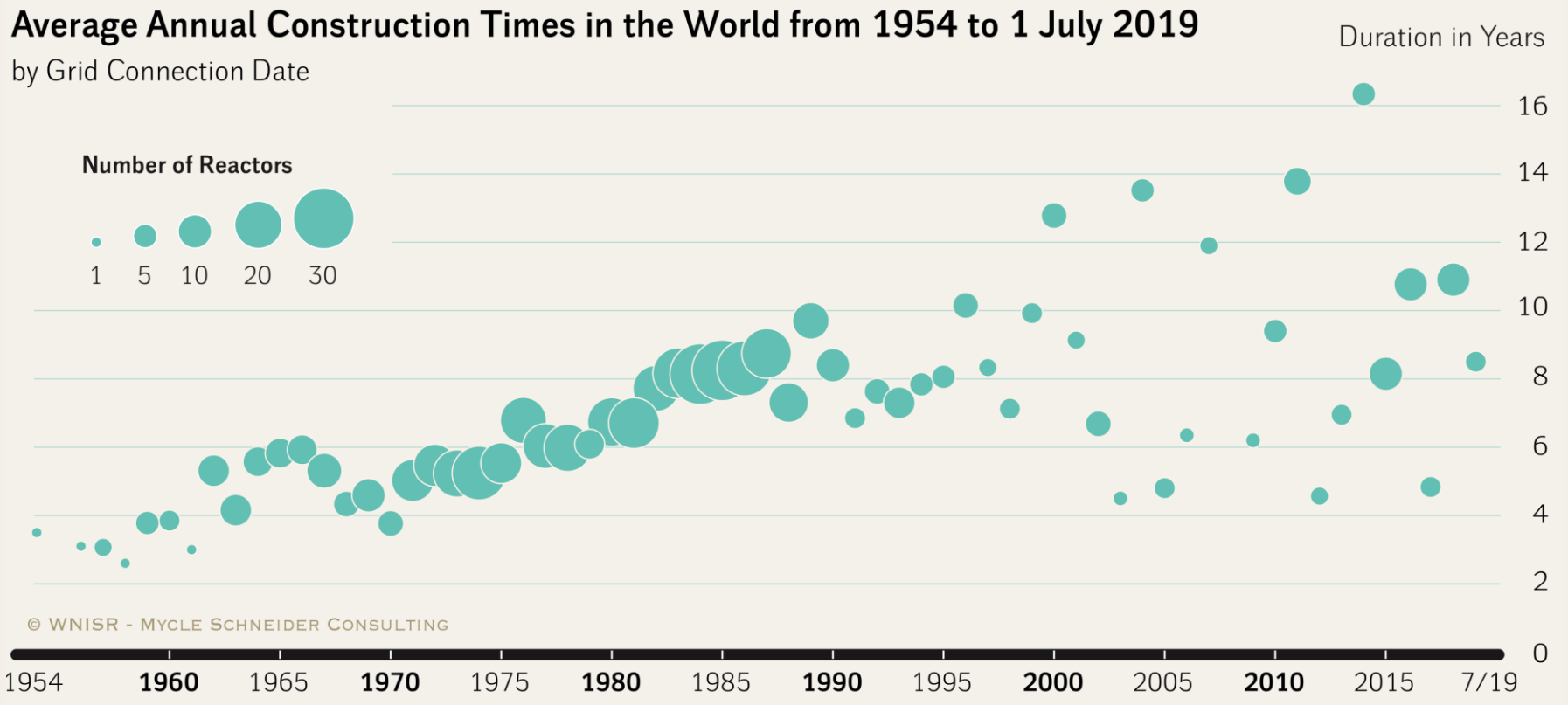


Sources: WNISR, with IAEA, and various sources, 2019

WNISR2019 GENERAL OVERVIEW — CONSTRUCTIONS

Country	Units	Capacity (MW net)	Construction Starts	Grid Connection	Units Behind Schedule
China	10	8 800	2012 - 2017	2020 - 2023	2-3
India	7	4 824	2004 - 2017	2019 - 2023	5
Russia	5	3 379	2007 - 2019	2019 - 2023	3
UAE	4	5 380	2012 - 2015	2020 - 2023	4
South Korea	4	5 360	2012 - 2018	2019 - 2024	4
Belarus	2	2 218	2013 - 2014	2019 - 2020	1-2
Bangladesh	2	2 160	2017 - 2018	2023 - 2024	0
Slovakia	2	880	1985	2020 - 2021	2
USA	2	2 234	2013	2021 - 2022	2
Pakistan	2	2 028	2015 - 2016	2020 - 2021	0
Japan	1	1 325	2007	?	1
Argentina	1	25	2014	2021	1
UK	1	1 630	2018	2025	0
Finland	1	1 600	2005	2020	1
France	1	1 600	2007	2022	1
Turkey	1	1 114	2018	2024	0
Total	**46**	**44 557**	**1985 - 2019**	**2019 - 2025**	**27-29**

Sources: Compiled by WNISR, 2019

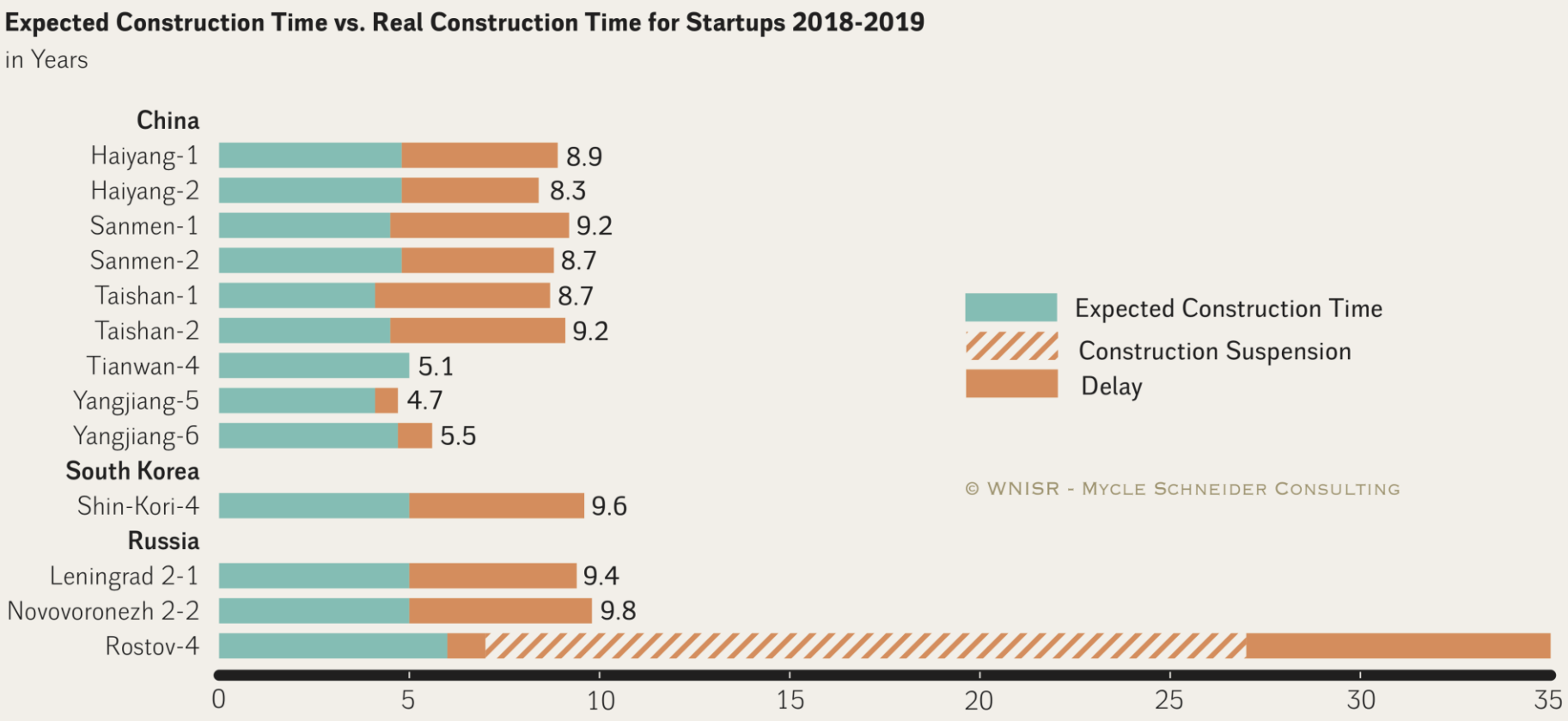


Sources: WNISR, with IAEA-PRIS, 2019

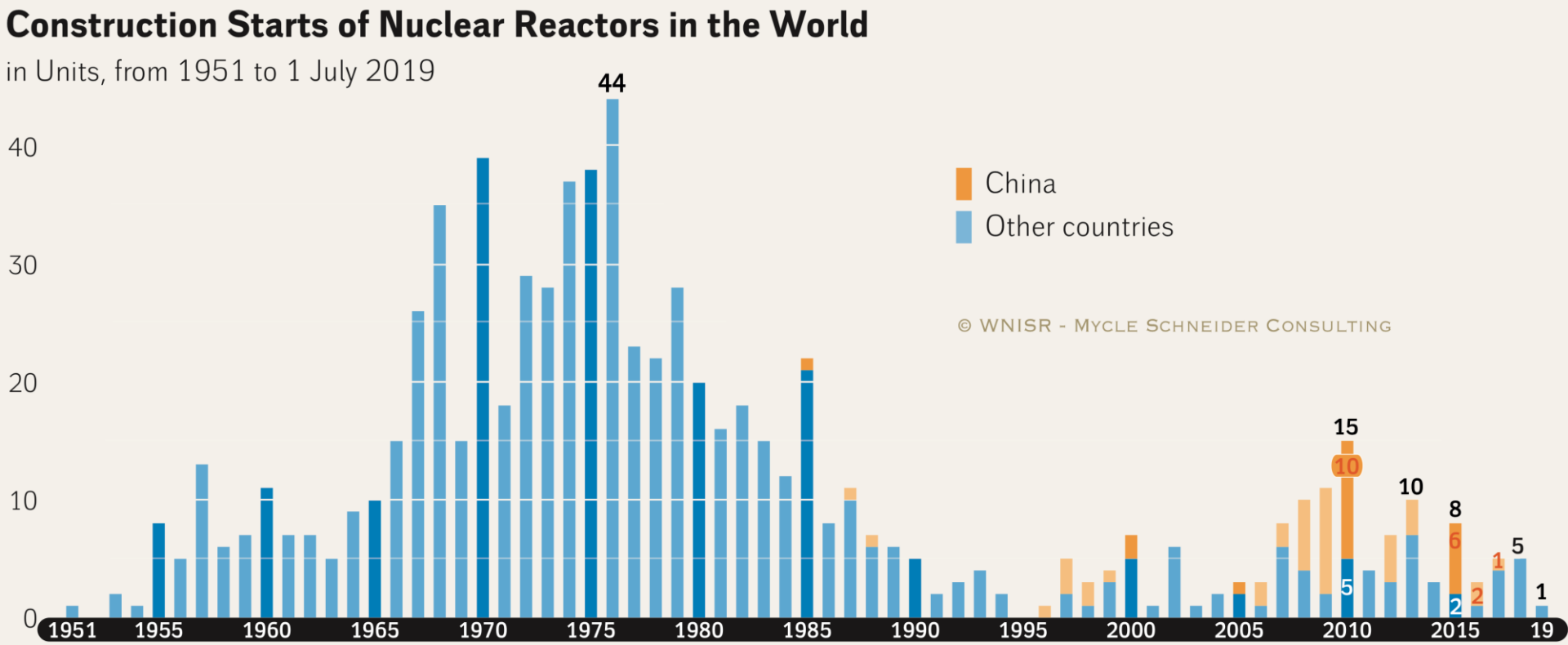
Construction Times of 63 Units Started-up 2009-7/2019				
Country	Units	Construction Time (in Years)		
		Mean Time	Minimum	Maximum
China	37	6.0	4.1	11.2
Russia	8	22.2	8.1	35.0
South Korea	6	6.0	4.1	9.6
India	5	9.8	7.2	14.2
Pakistan	3	5.4	5.2	5.6
Argentina	1	33.0	33.0	
Iran	1	36.3	36.3	
Japan	1	5.1	5.1	
USA	1	43.5	43.5	
World	63	9.8	4.1	43.5

Sources: Compiled by WNISR, 2019

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS

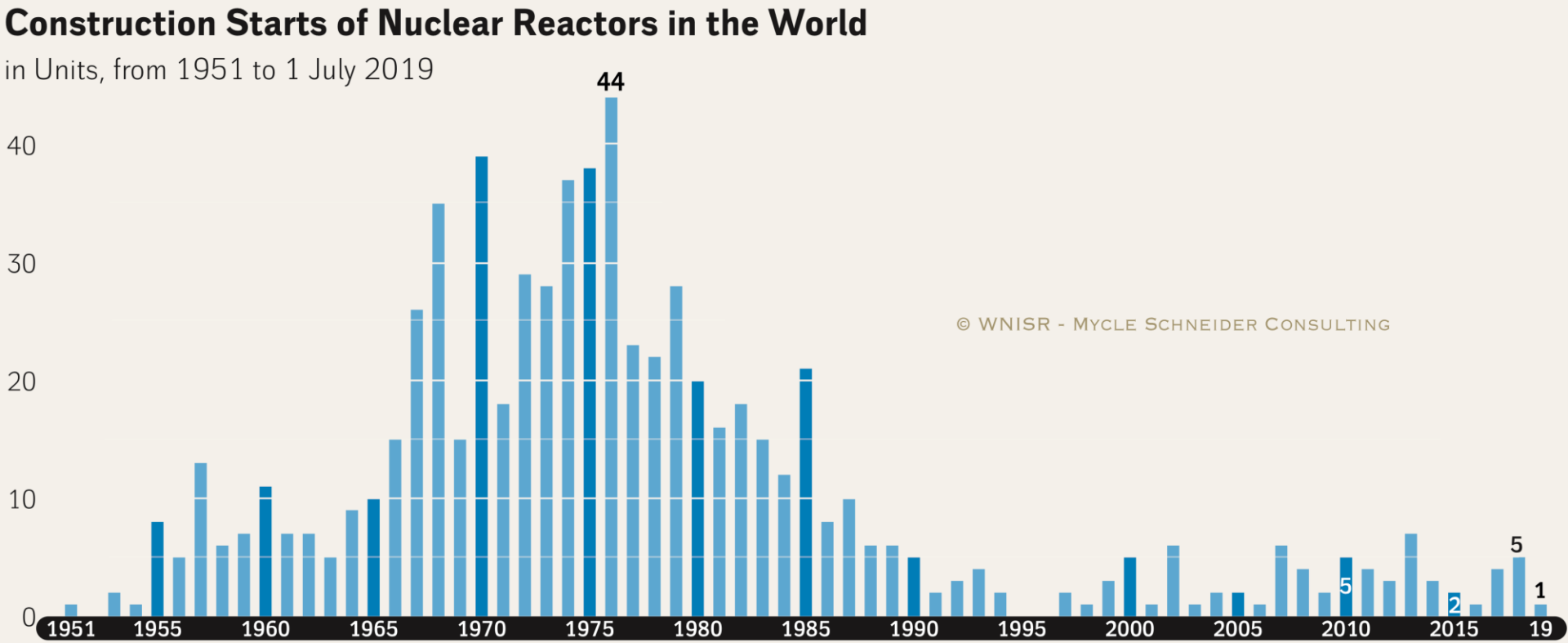


Sources: WNISR, with IAEA-PRIS, 2019

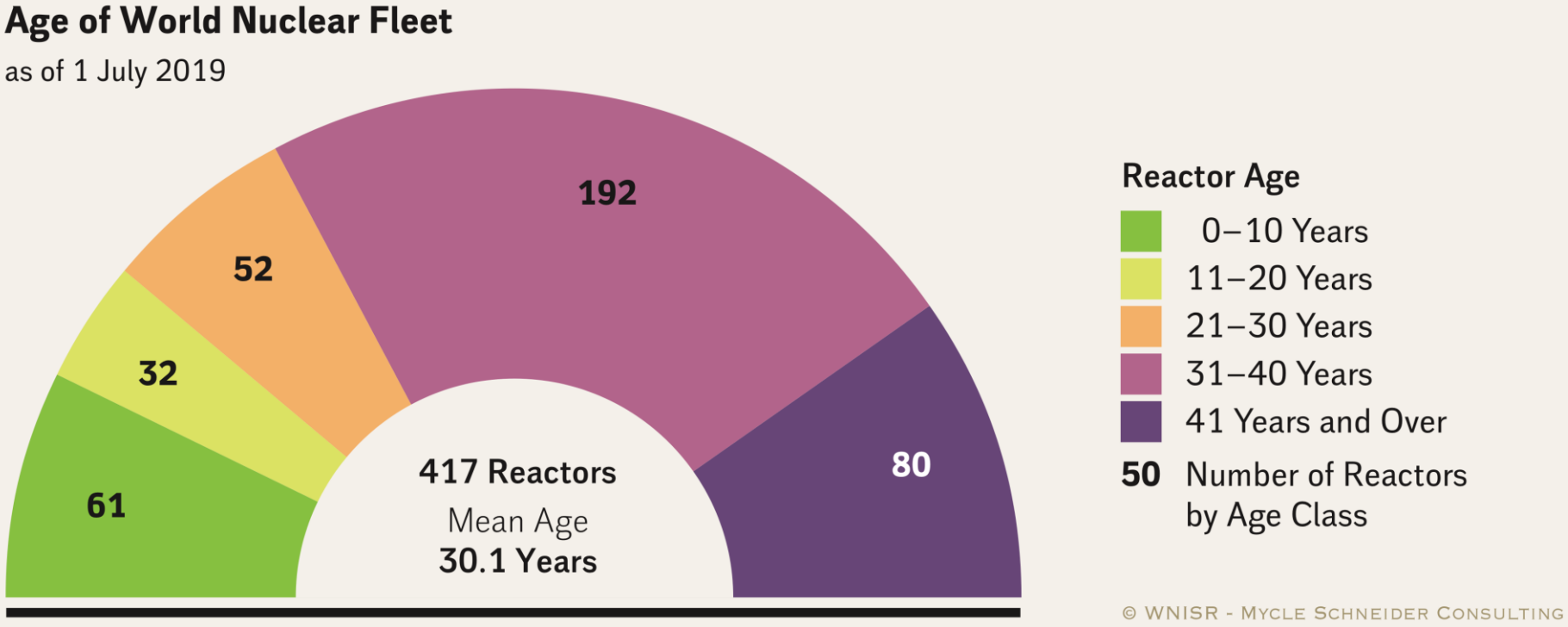


Sources: WNISR, with IAEA-PRIS, 2019

GLOBAL OVERVIEW – CONSTRUCTIONS STARTS WORLD…



Sources: WNISR, with IAEA-PRIS, 2019

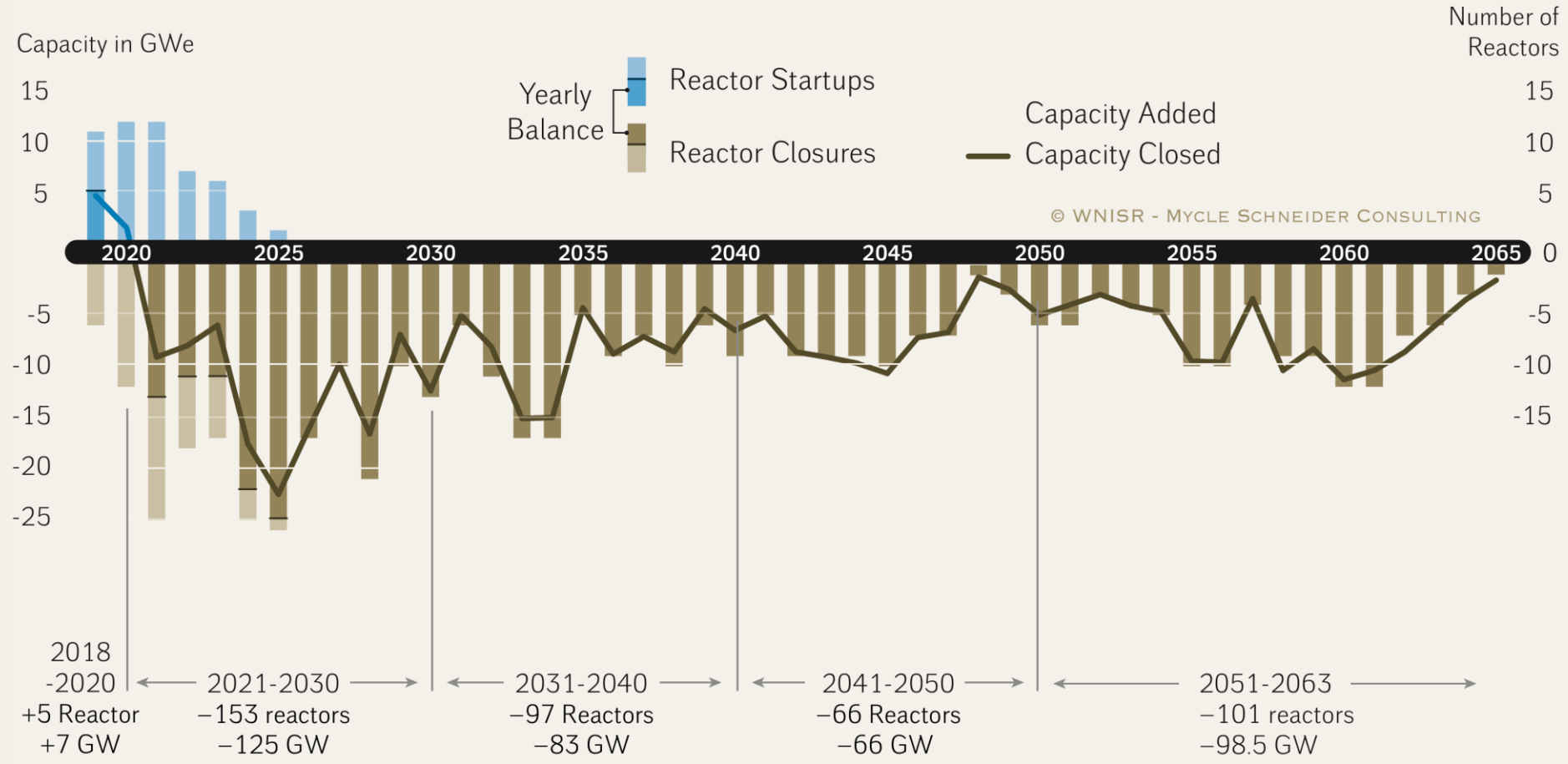


Sources: WNISR, with IAEA-PRIS, 2019

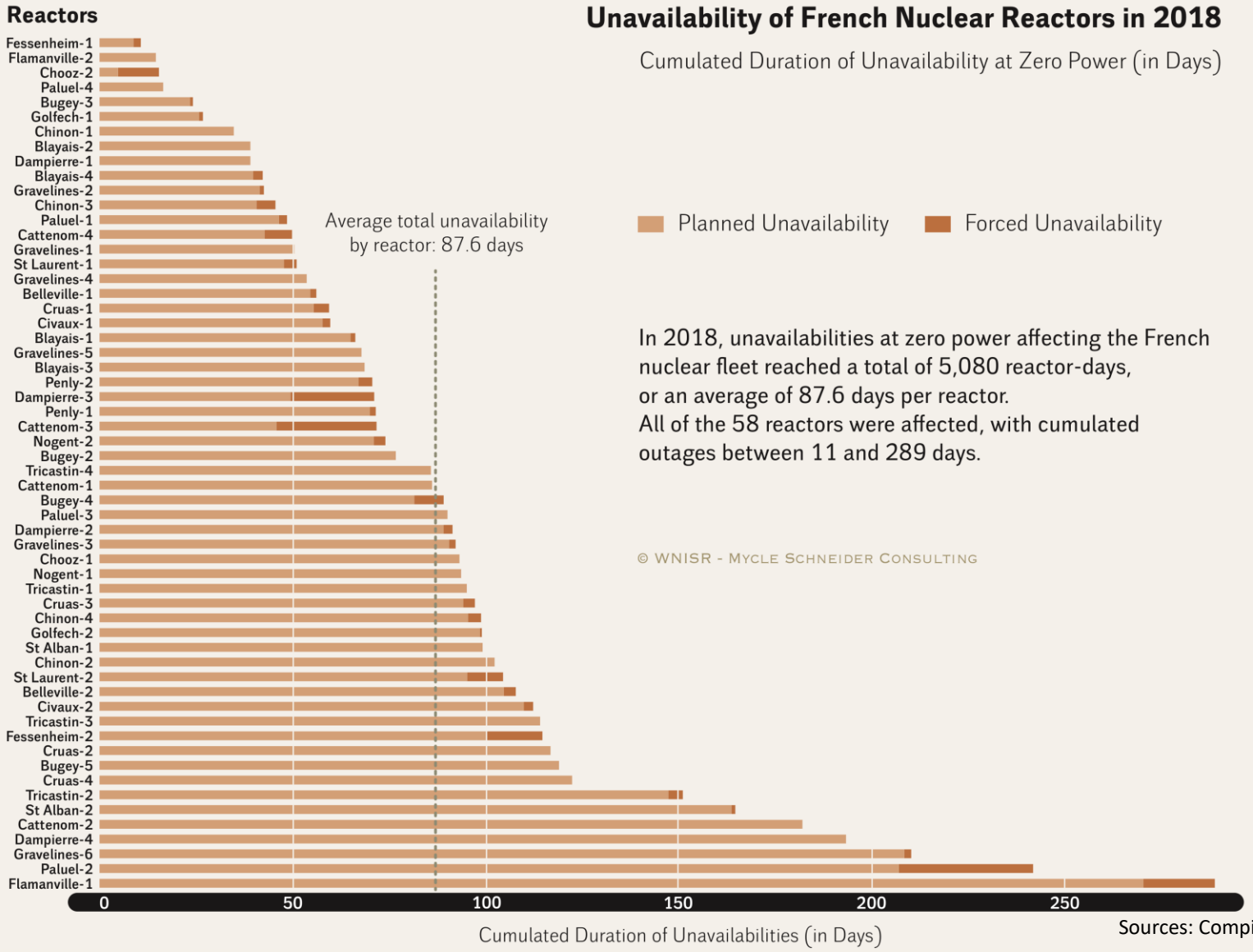
Projection 2019-2065 of Nuclear Reactor/Capacity in the World

General assumption of 40-year mean lifetime + Authorized Lifetime Extensions

Operating and Under Construction as of 1 July 2019, in GWe and Units



Sources: Various sources, compiled by WNISR, 2019



Unavailability of French Nuclear Reactors in 2018

Cumulated Duration of Unavailability at Zero Power (in Days)

Planned Unavailability Forced Unavailability

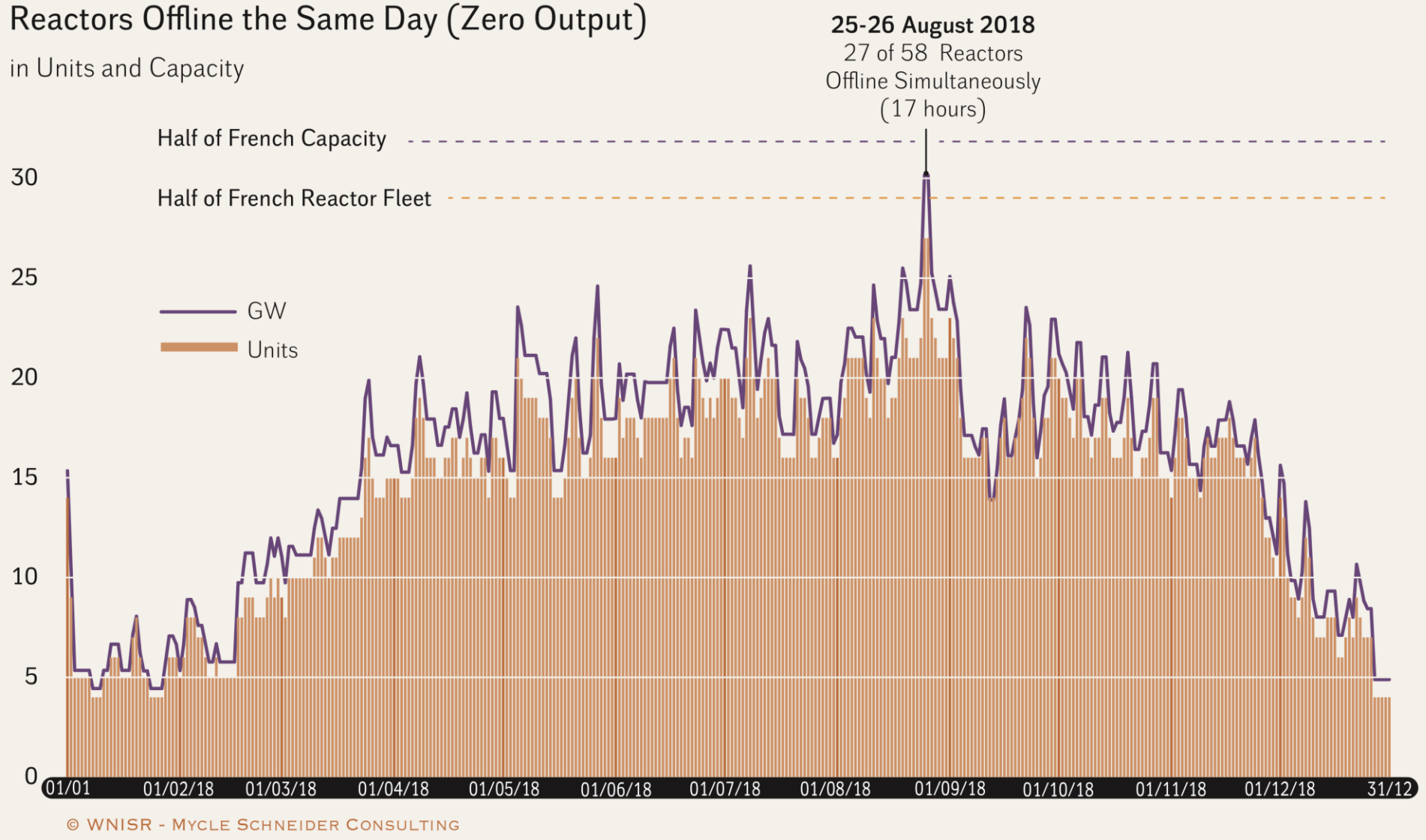
In 2018, unavailabilities at zero power affecting the French nuclear fleet reached a total of 5,080 reactor-days, or an average of 87.6 days per reactor.
All of the 58 reactors were affected, with cumulated outages between 11 and 289 days.

Sources: Compilation from RTE, 2019

Unavailability of French Nuclear Reactors in 2018

Reactors Offline the Same Day (Zero Output)

in Units and Capacity

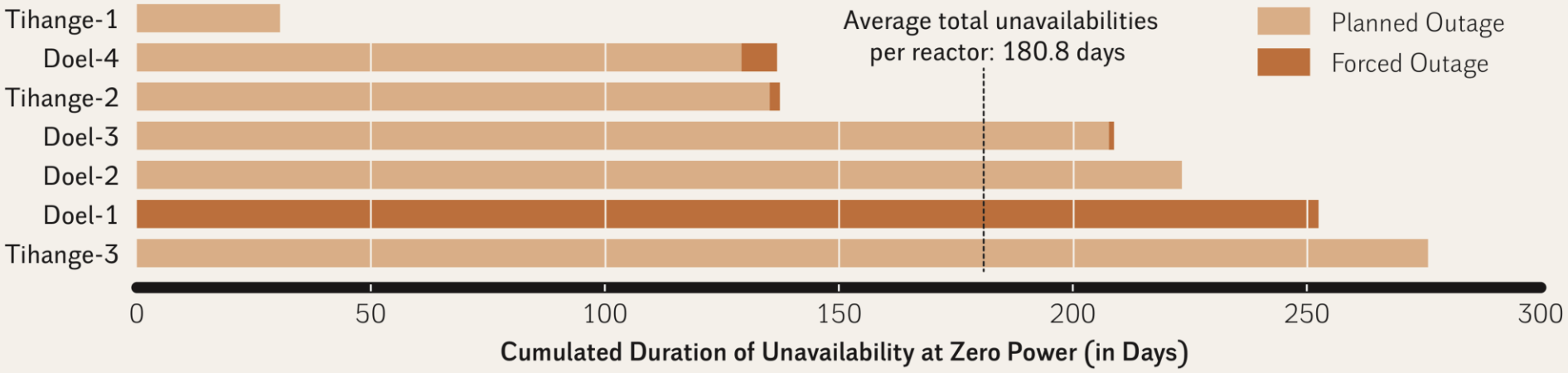


Sources: Compilation from RTE, 2019

Unavailability of Belgian Nuclear Reactors in 2018

Total Unavailabilities in Days per Reactor

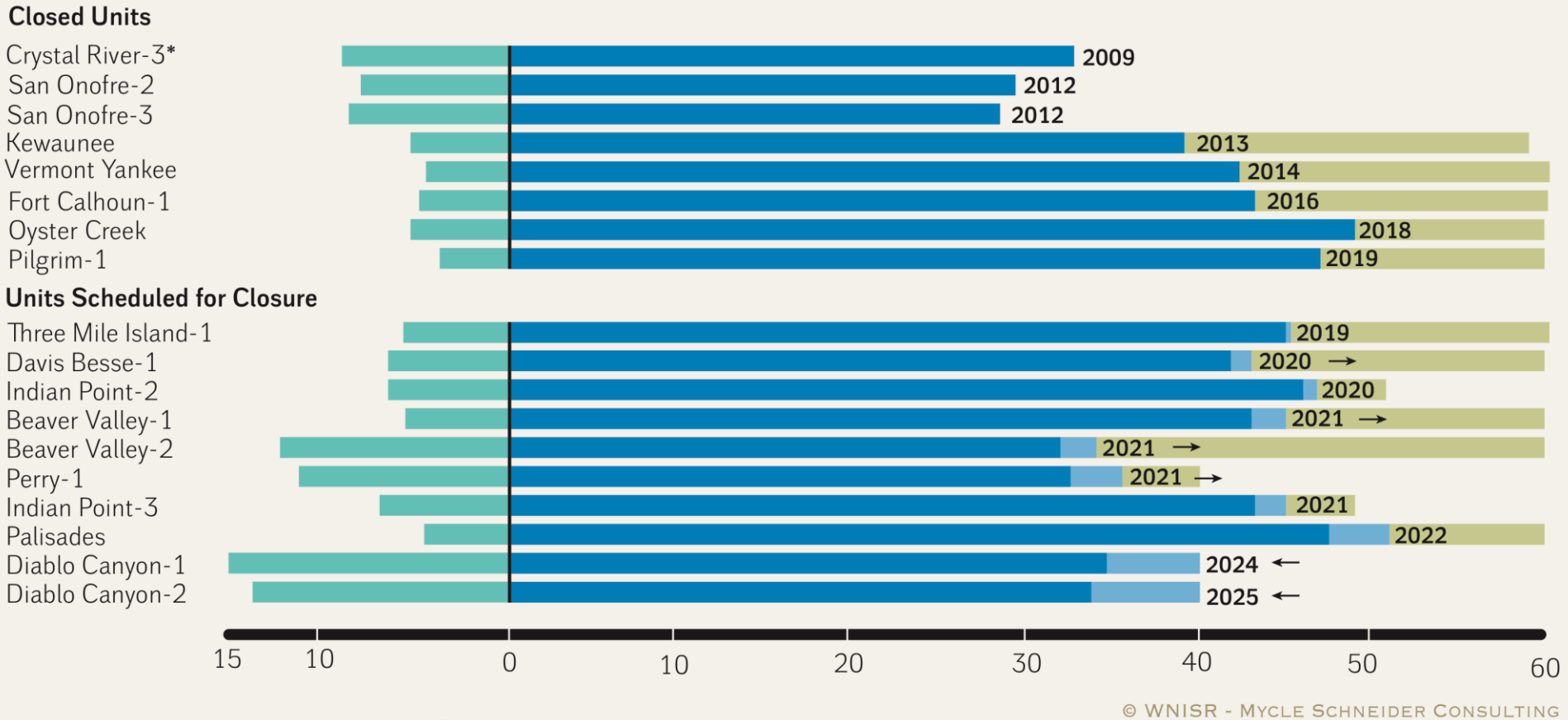
In 2018, unavailabilities at zero power affecting the Belgian nuclear fleet reached a total of 1,265 reactor-days, or an average of 180.8 days per reactor.
All of the 7 reactors were affected, with cumulated outages between 31 and 276 days.



Source: ENTSO-E and Engie Transparency Platforms, 2019

Timelines of 18 U.S. Reactors Subject to Early-Retirement 2009–2025

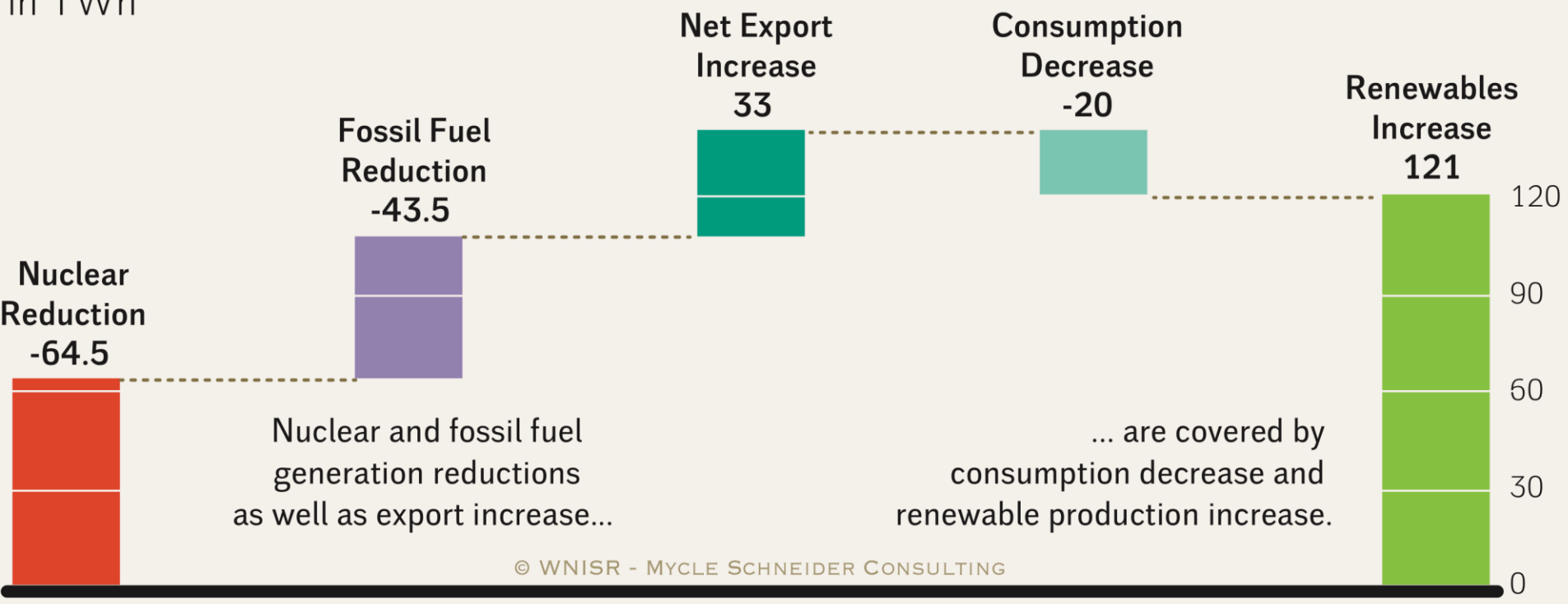
as of 1 July 2019



Sources: Various, compiled byWNISR, 2019

Main Evolution of the German Power System Between 2010 and 2018

in TWh



Sources WNISR, based on AGEB 2019

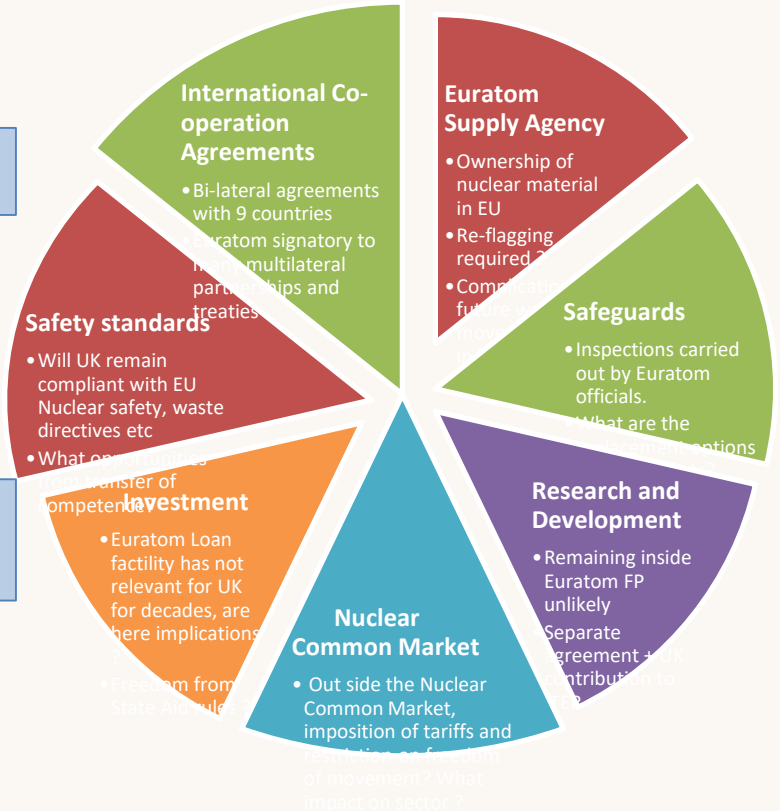
Why does Brexit lead to Brexatom

- **Legal***:* Article 106a of the Euratom Treaty
    - "Within the framework of this Treaty, the references to the Union, to the 'Treaty on European Union', to the 'Treaty on the Functioning of the European Union' or to the 'Treaties' in the provisions referred to in paragraph 1 and those in the protocols annexed both to those Treaties and to this Treaty shall be taken, respectively, as references to the European Atomic Energy Community and to this Treaty".
- **Regulatory**: Remaining in Euratom not compatible with 'taking back control'
- **Political**: Precedent for those Member states that may want to be part of the EU but not Euratom. Currently, Member states need to be members of both.

Brexatom Considerations

Outside Single Electricity Market?

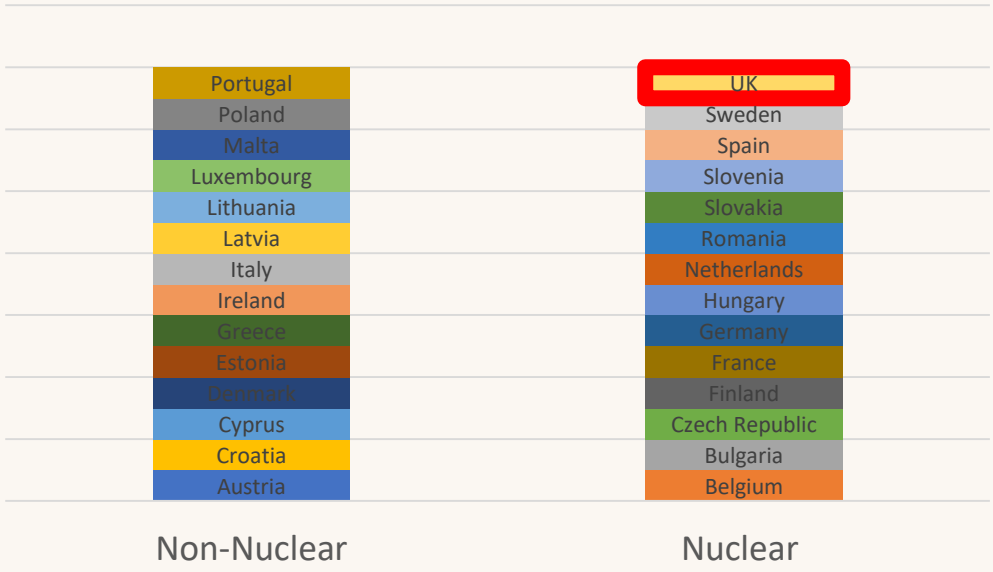
Outside Single Market and Customs Union ?



Impact on nuclear policies in EU

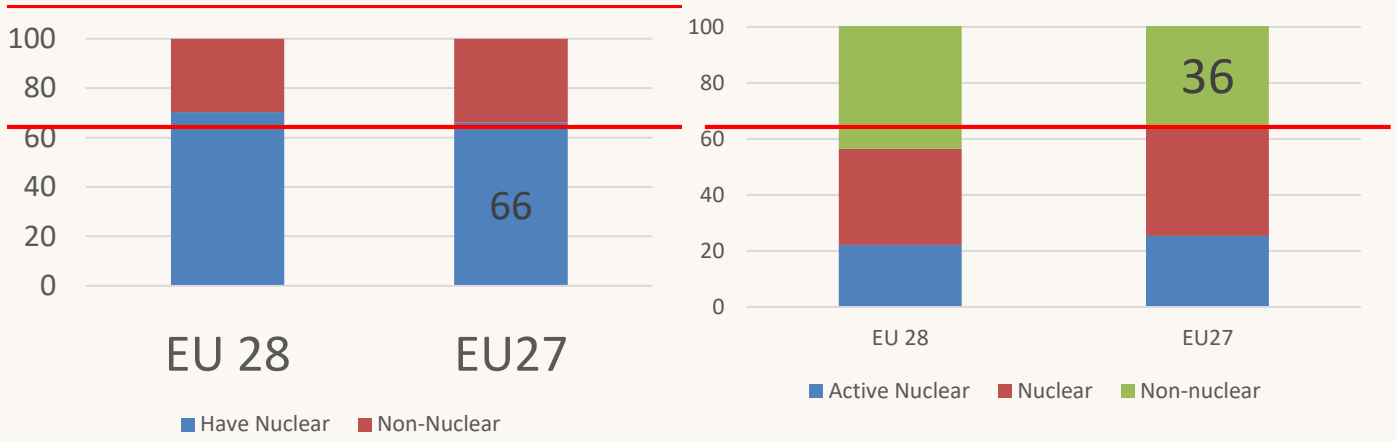
Impact on the EU

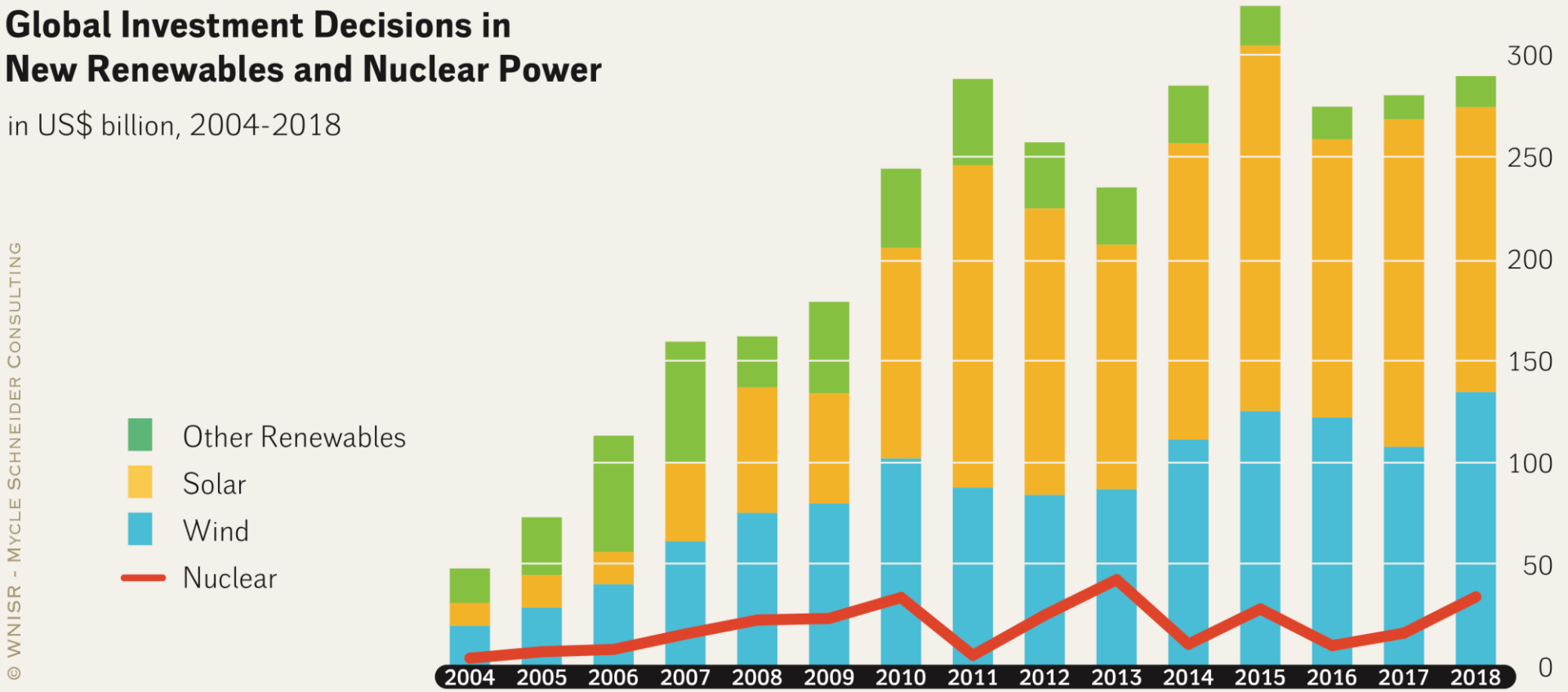
- Foratom: “if the UK leaves Euratom, the nuclear industry will lose a crucial advocate in the Council and especially at the Atomic Question Group” – June 2016.



European Council Voting

- Simple majority: - Requires the support of 15 countries
- Qualified majority – 55% of countries and 65% of population
- Unanimity

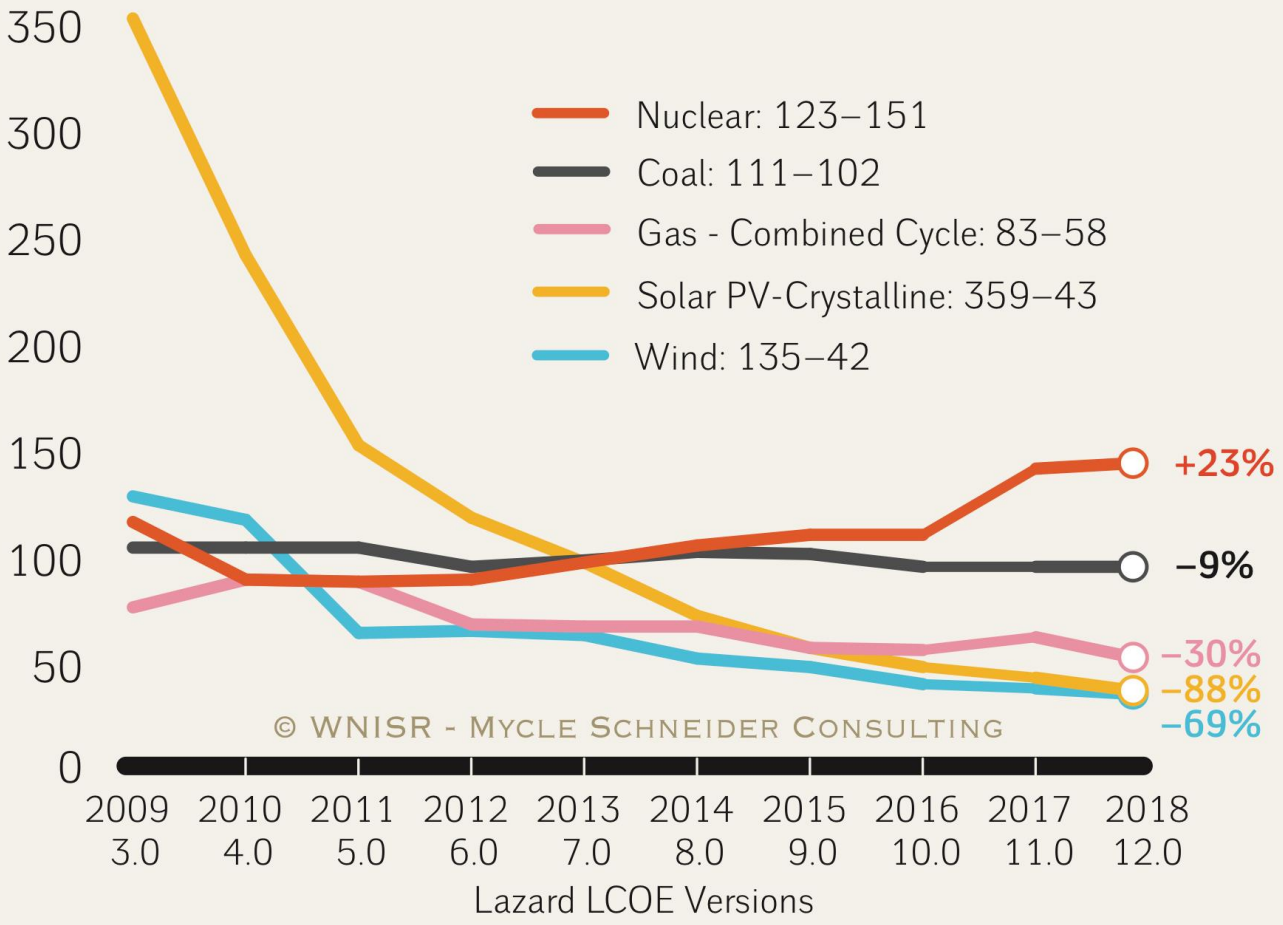




Sources: *FS-UNEP/BNEF 2019 and WNISR Original Research*

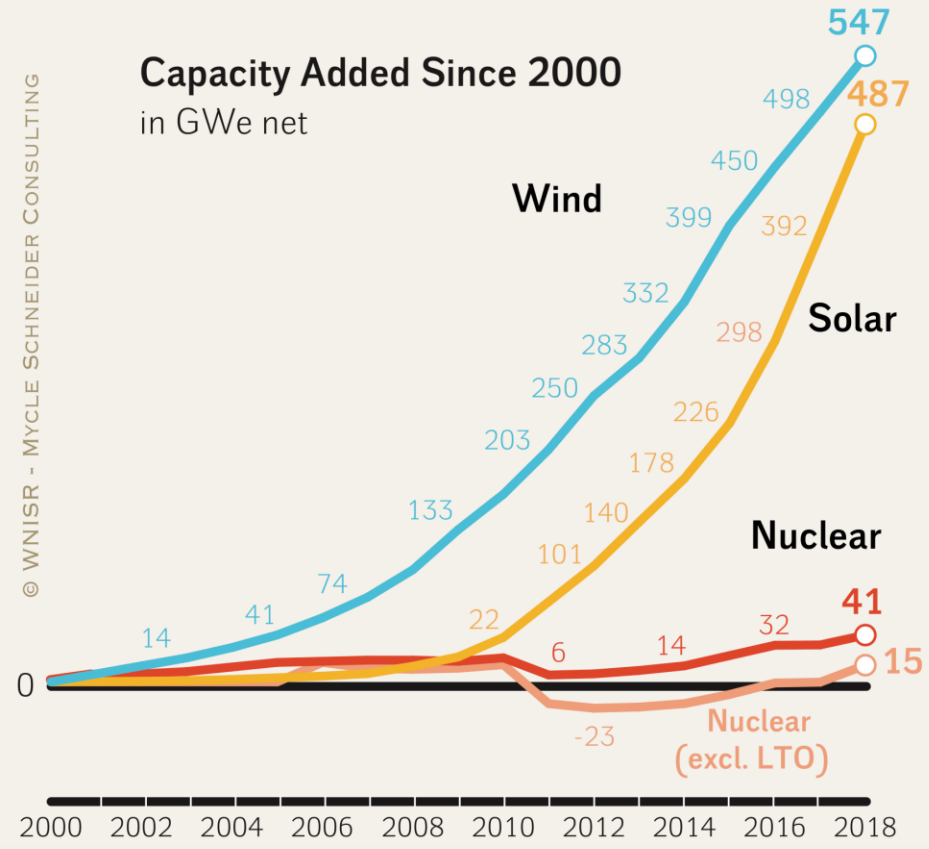
Selected Historical Mean Costs by Technology

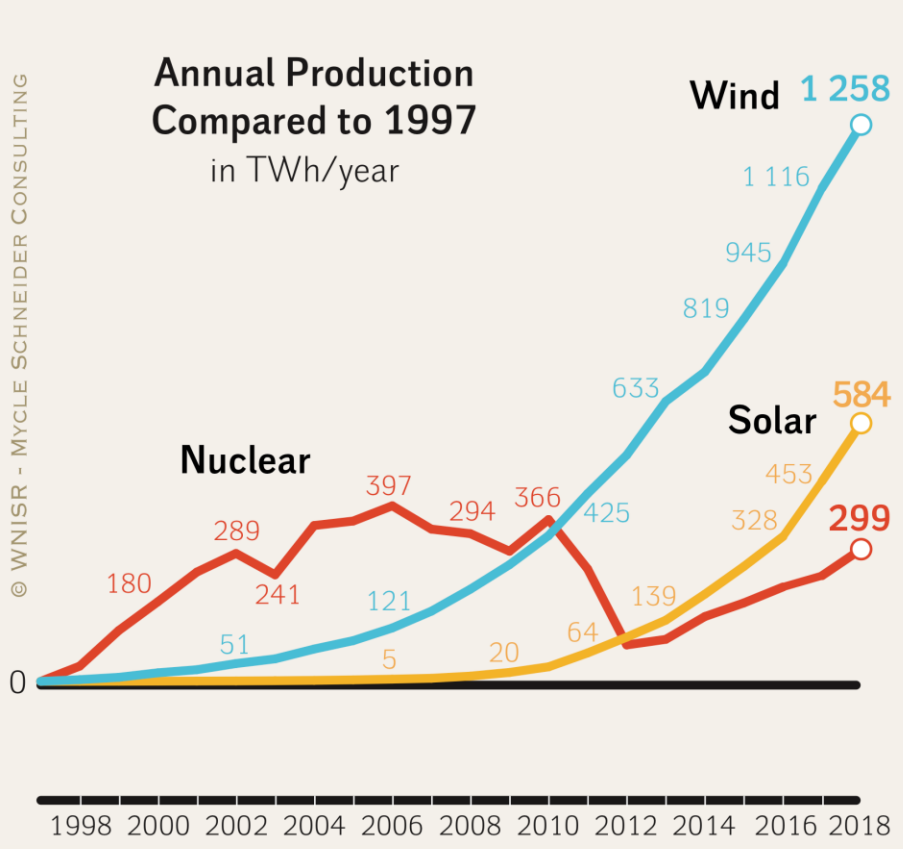
LCOE values in US$/MWh (1)



Sources: Lazard Estimates, 2018

Wind, Solar and Nuclear Developments: Installed Capacity and Electricity Production in the World

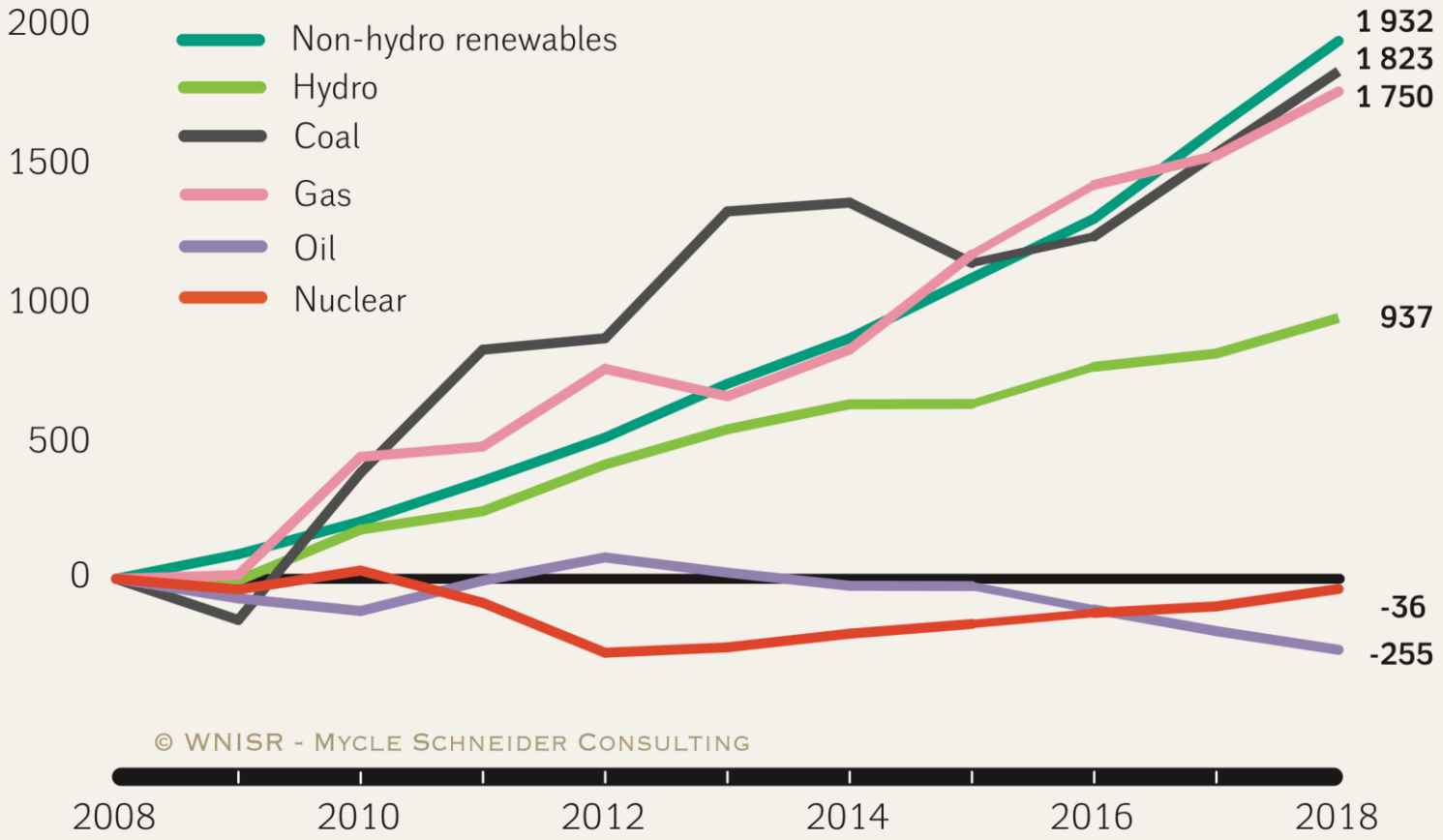




Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019

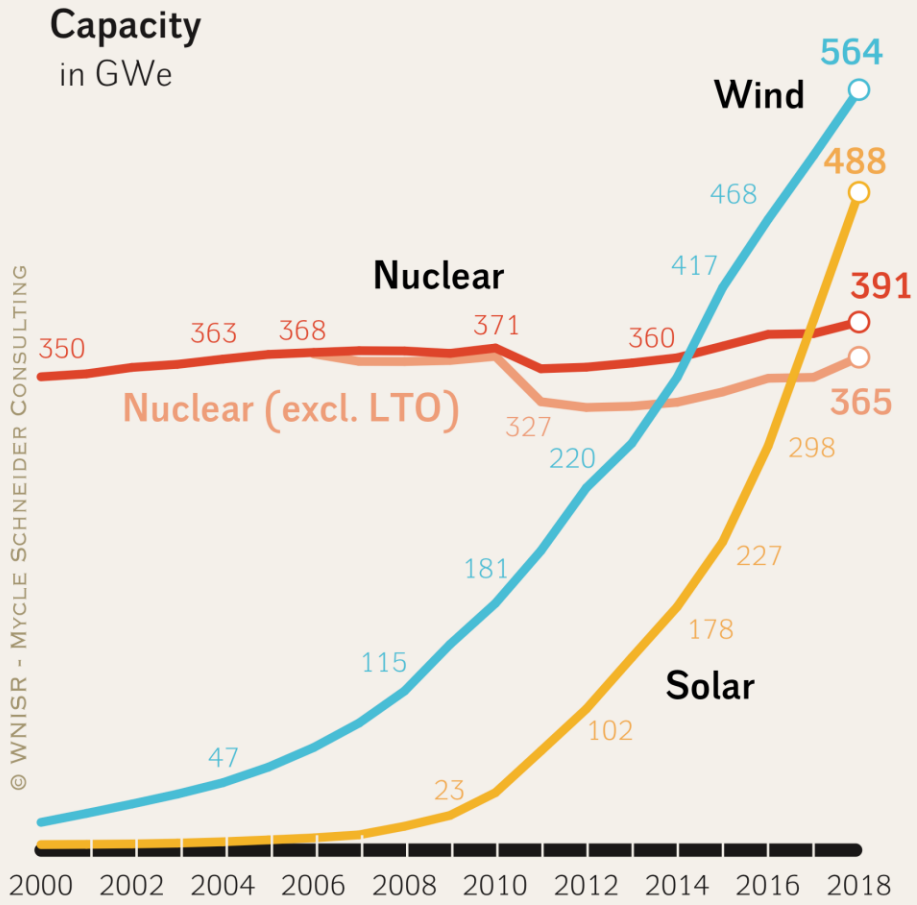
Power Generation in the World
Annual Production Compared to 2008

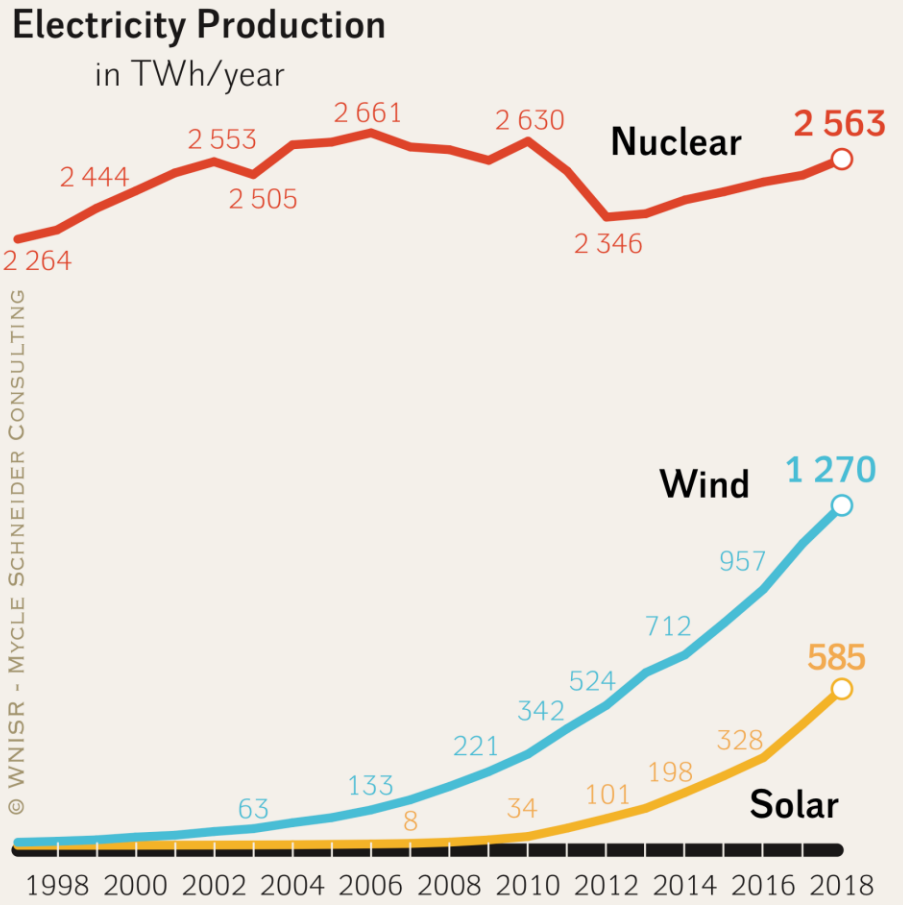
in added TWh by Source



Sources: BP Statistical Review 2019

Wind, Solar and Nuclear Installed Capacity and Electricity Production in the World

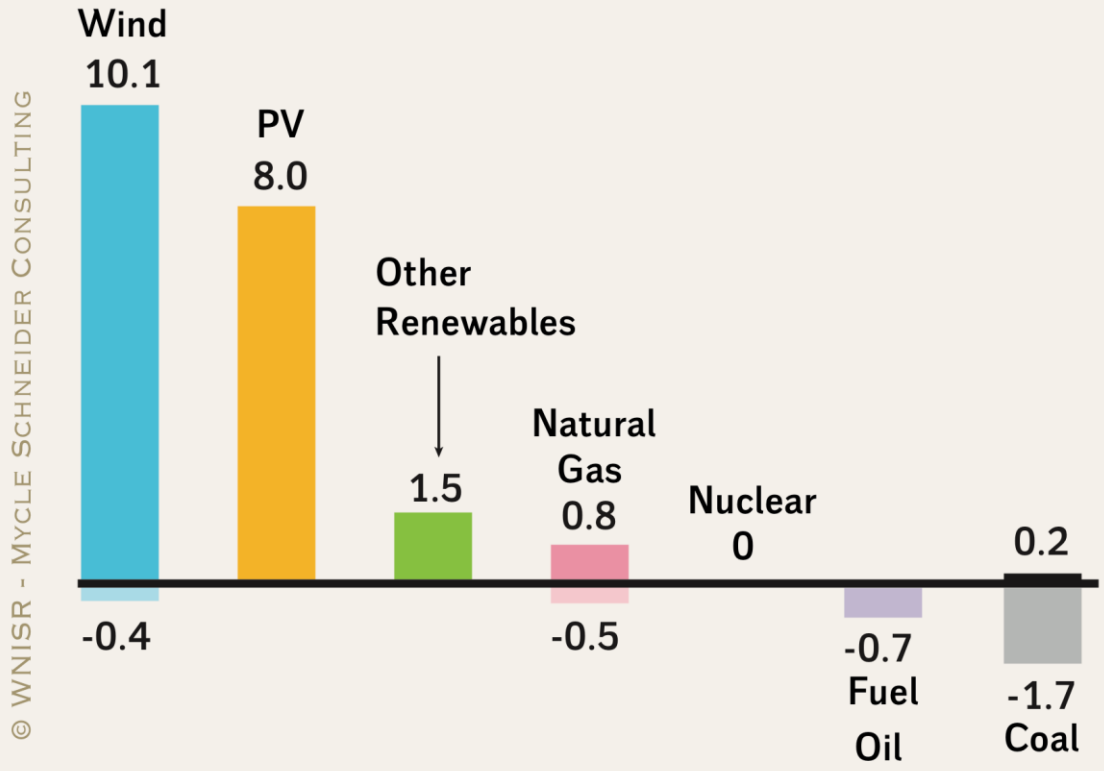




Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019

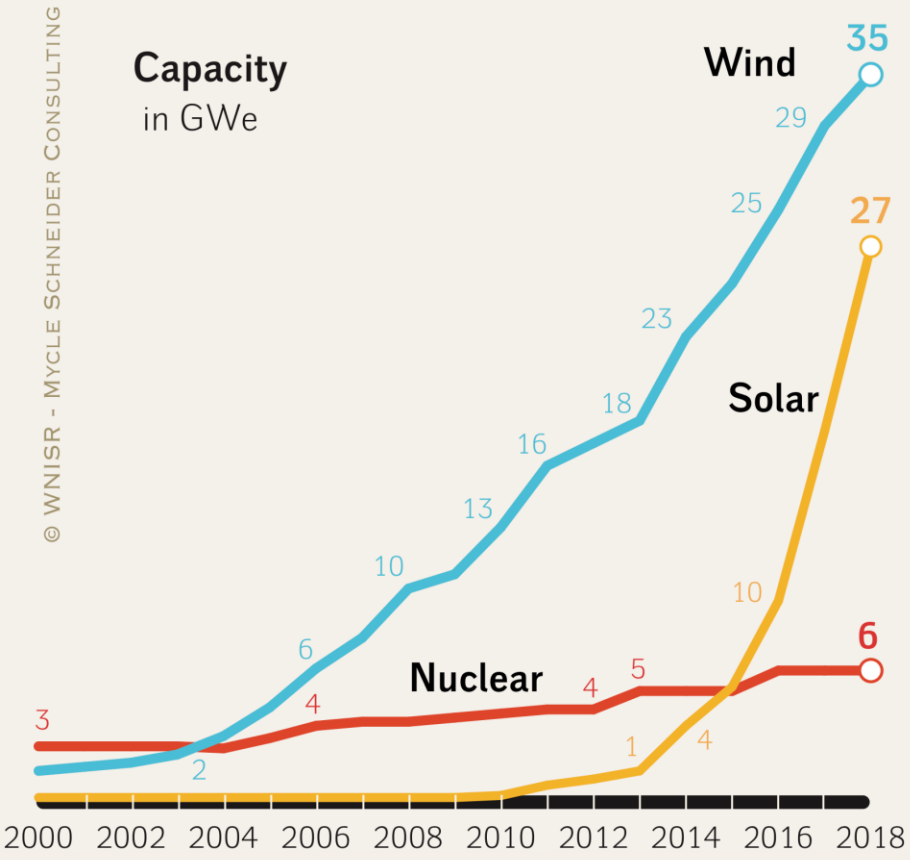
Startup and Closure of Electricity Generating Capacity in the EU in 2018

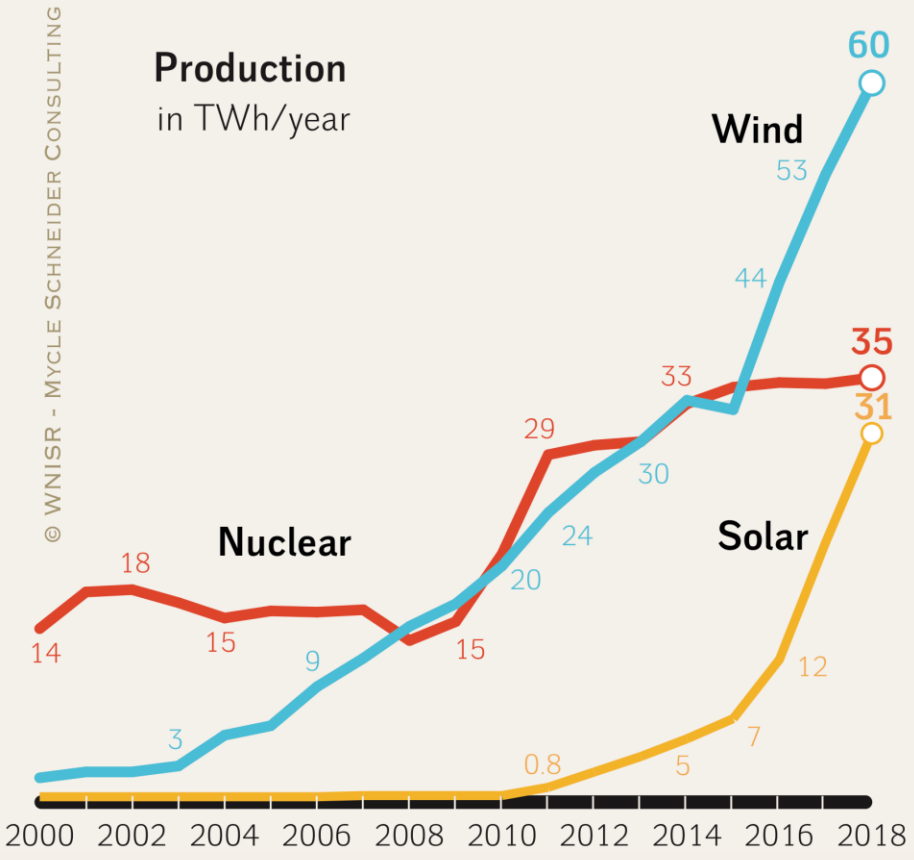
by Energy Source in GWe



Sources: WindEurope, WNISR, 2019

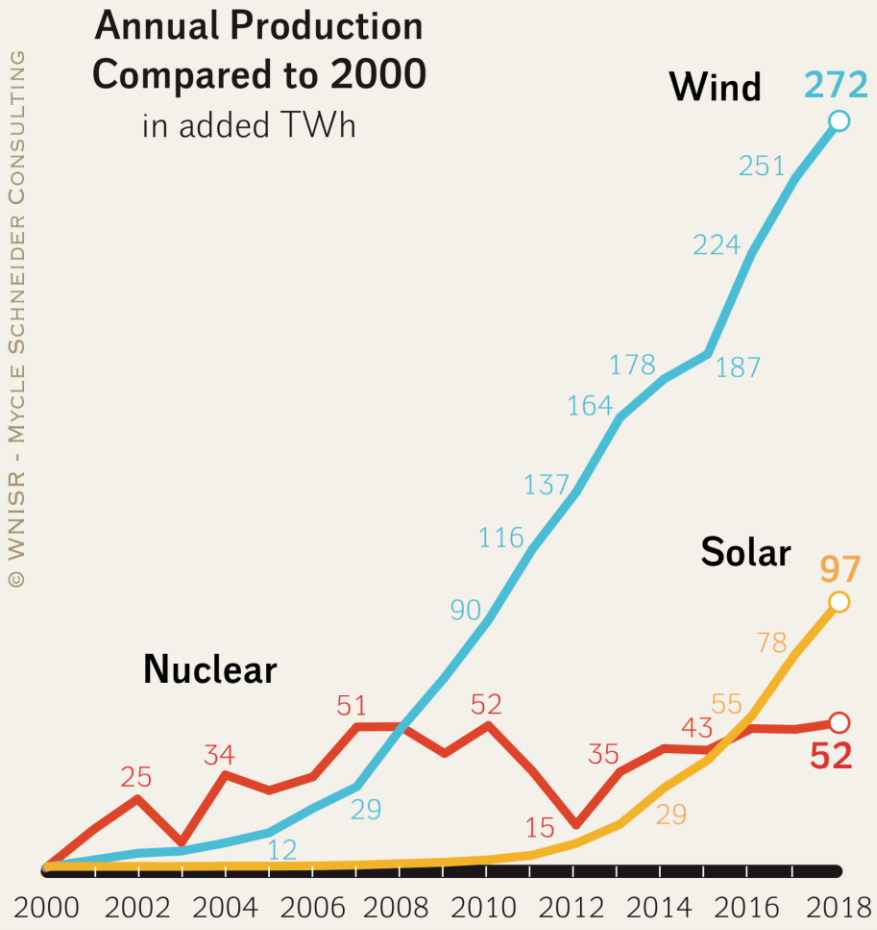
Installed Wind, Solar and Nuclear Capacity and Production in India 2000-2018



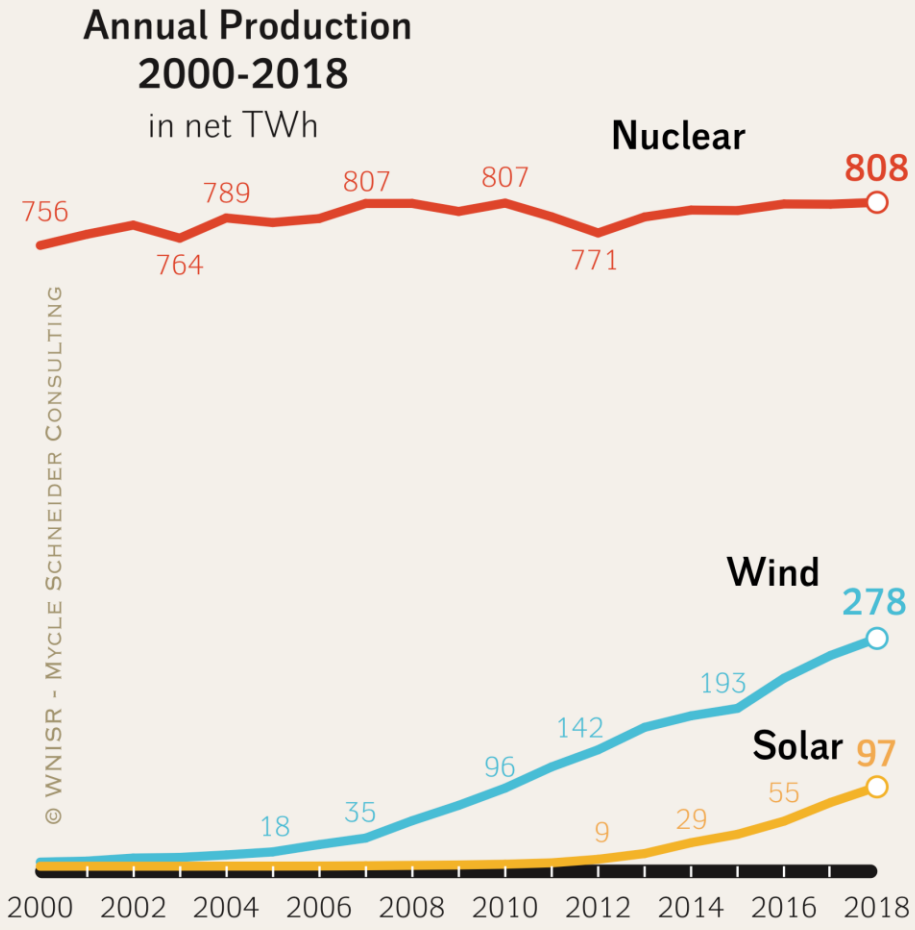


Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019

Wind, Solar and Nuclear Developments in the United States 2000-2018



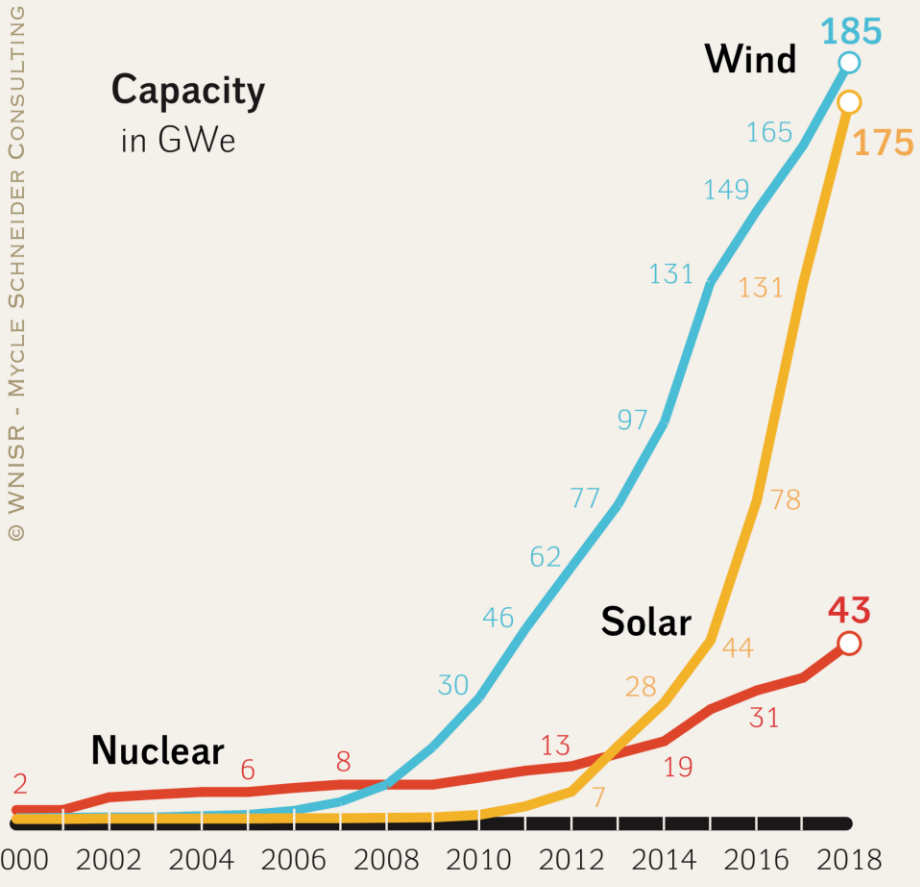
Sources: BP, 2019

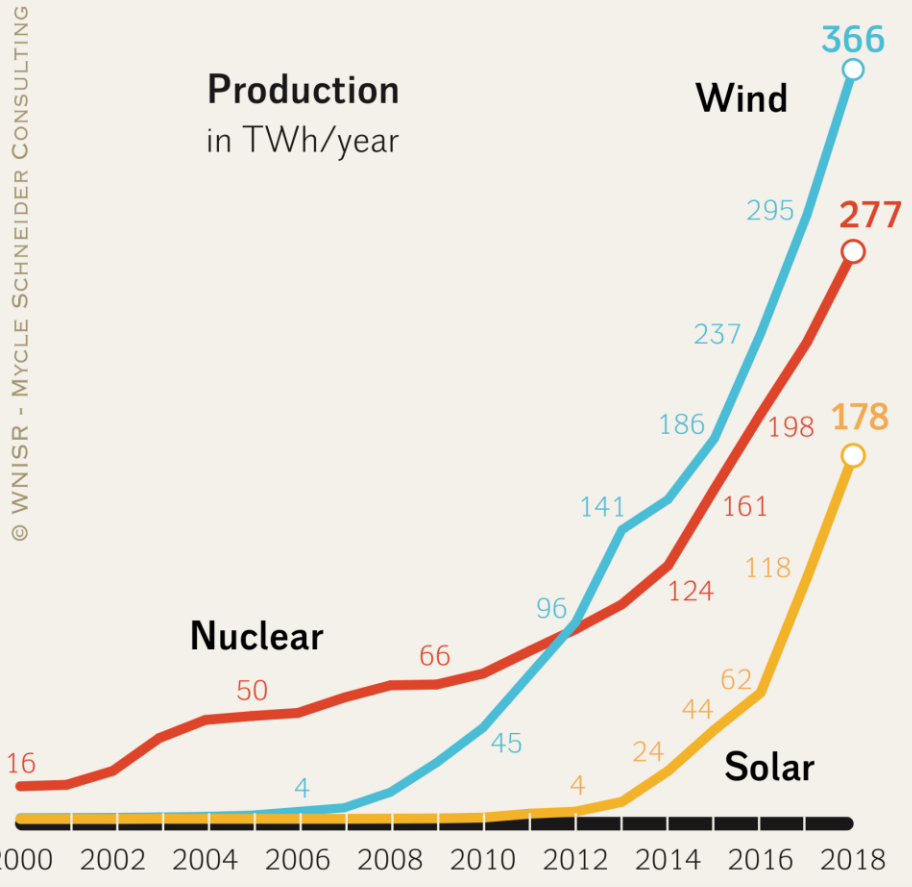


Sources: BP, 2019

Sources: BP, 2019

Installed Wind, Solar and Nuclear Capacity and Production in China 2000-2018





Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019

What do these developments mean for the fight against Climate Change?

• The generation of electricity is only about 20% of final energy but emits 38% of CO2 (2016). Therefore, decarbonizing the power sector is crucial.

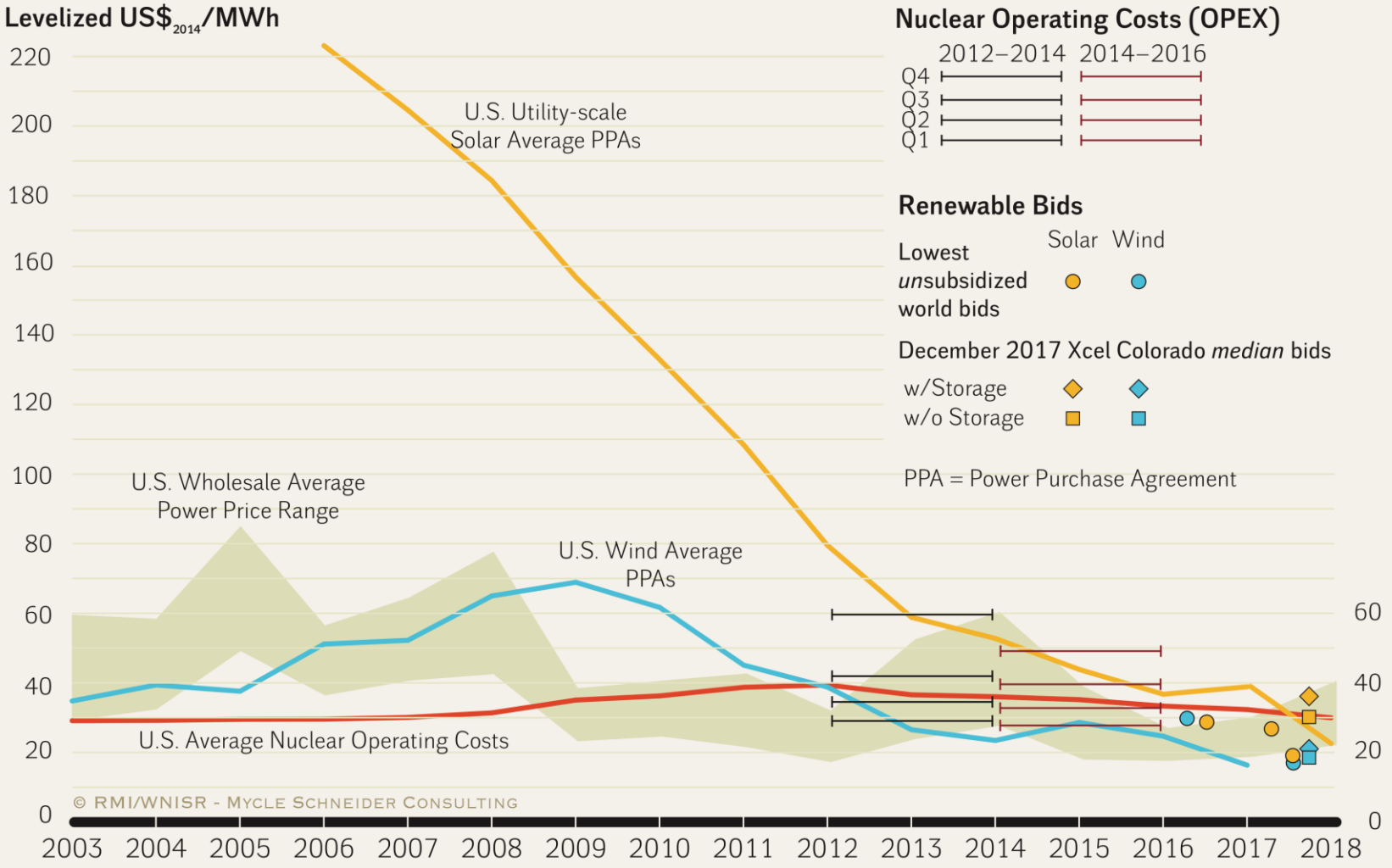
• The challenge: per invested dollar, euro or forint reducing greenhouse gas emissions **as much as possible as fast as possible**.

• Over the past decade, **new nuclear power** plants took 10 years to build while their average costs increased to levels exceeding any other electricity generating option.

• **Existing nuclear power plants** are increasing outpaced by unsubsidized new renewables.

Renewable Electricity vs. Nuclear Operating Costs U.S./World

in US$/MWh



WNISR2019 Conclusions

• For the first time the average age of world nuclear fleet exceeds 30 years.

In 2018,
• nuclear power added 9 GW to the world's power grids to reach a record 370 GW, while renewables added a record 165 GW (wind and solar cumulate >1,000 GW total);
• nuclear power generation increased by 2.4%, wind by 29%, solar by 13%;
• nuclear construction down to a trickle with 5 starts vs. 15 in 2010 (1 so far in 2019);
• 10 of 31 nuclear countries generate more power with renewables than with nuclear.

• Average construction times average 10 years over the past decade.
• The costs of new nuclear have *increased* by 23%, while solar costs *decreased* by 88% and wind by 69%.

• Fighting the climate emergency requires to invest into effective strategies combining *speed* and *competitive cost* to drastically reduce emissions. Nuclear power turns out not only the most expensive, but the slowest option to generate "low-carbon" electricity and to provide essential energy services.

Contact: mycle@worldnuclearreport.org www.WorldNuclearReport.org

About the Author

Photo: ©Nina Schneider

Mycle Schneider works as independent international consultant on energy and nuclear policy. He is the initiator and Convening Lead Author of the *World Nuclear Industry Status Reports* and Founding Board Member and Spokesperson of the International Energy Advisory Council (IEAC). He is a member of the International Panel on Fissile Materials (IPFM), based at Princeton University, USA. In 2010-2011, he acted as Lead Consultant for the Asia Clean Energy Policy Exchange, implemented by IRG, funded by USAID, with the focus of developing a policy framework to boost energy efficiency and renewable energies. Between 2004 and 2009 he has been in charge of the Environment and Energy Strategies Lecture of the International Master of Science for Project Management for Environ-mental and Energy Engineering at the *Ecole des Mines* in Nantes, France.

From 2000 to 2010 he was an occasional advisor to the German Environment Ministry. 1998-2003 he was an advisor to the French Environment Minister's Office and to the Belgian Minister for Energy and Sustainable Development.

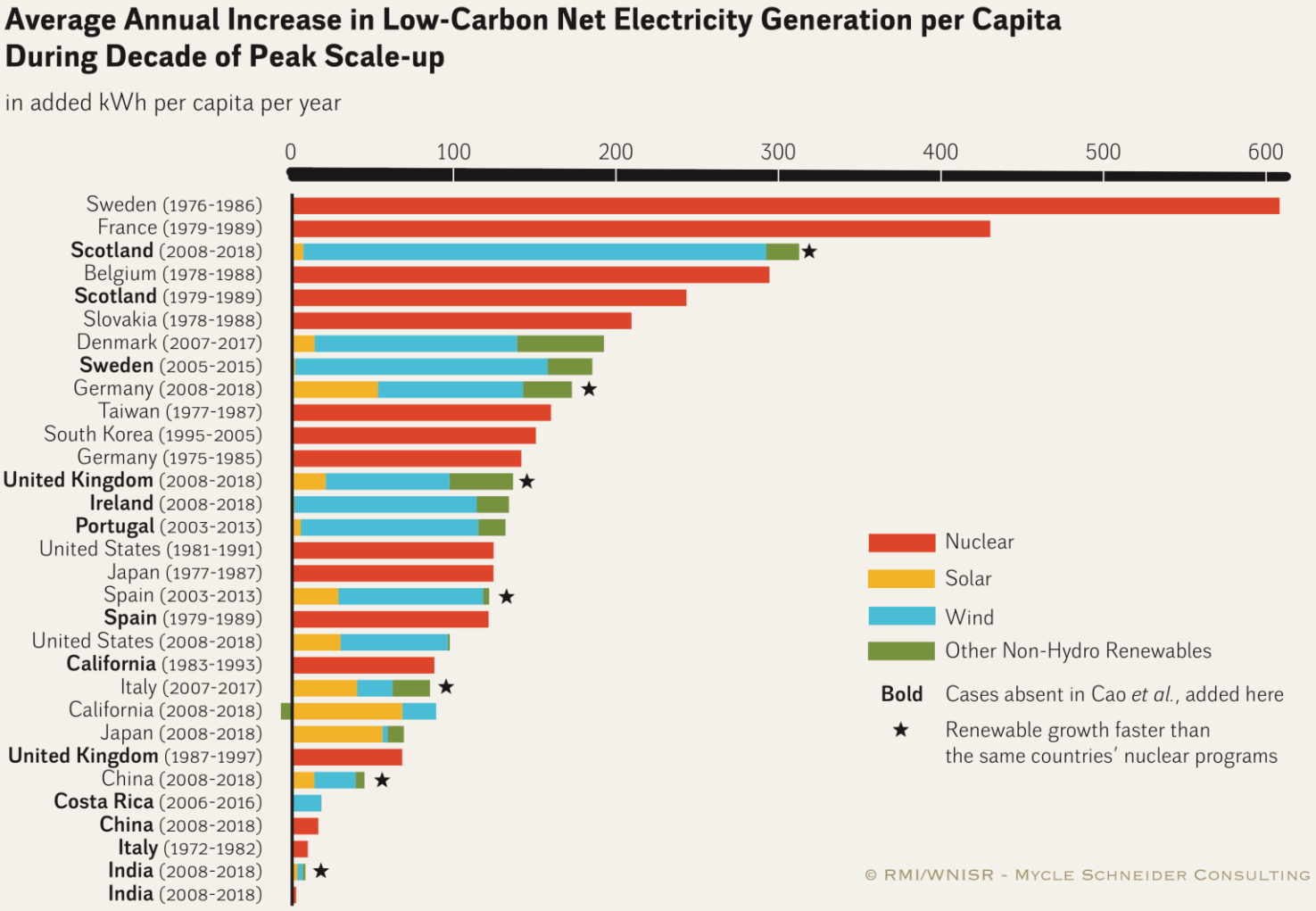
Mycle Schneider has given evidence or held briefings at national Parliaments in 15 countries and at the European Parliament. He has advised Members of the European Parliament from four different groups over the past 30 years. He has given lectures or had teaching appointments at over 20 universities and engineering schools in more than 10 countries.

Mycle Schneider has provided information and consulting services to a large variety of clients including international institutions and organizations, think tanks and NGOs.

In 1997 he was honoured with the *Right Livelihood Award* ("Alternative Nobel Prize").

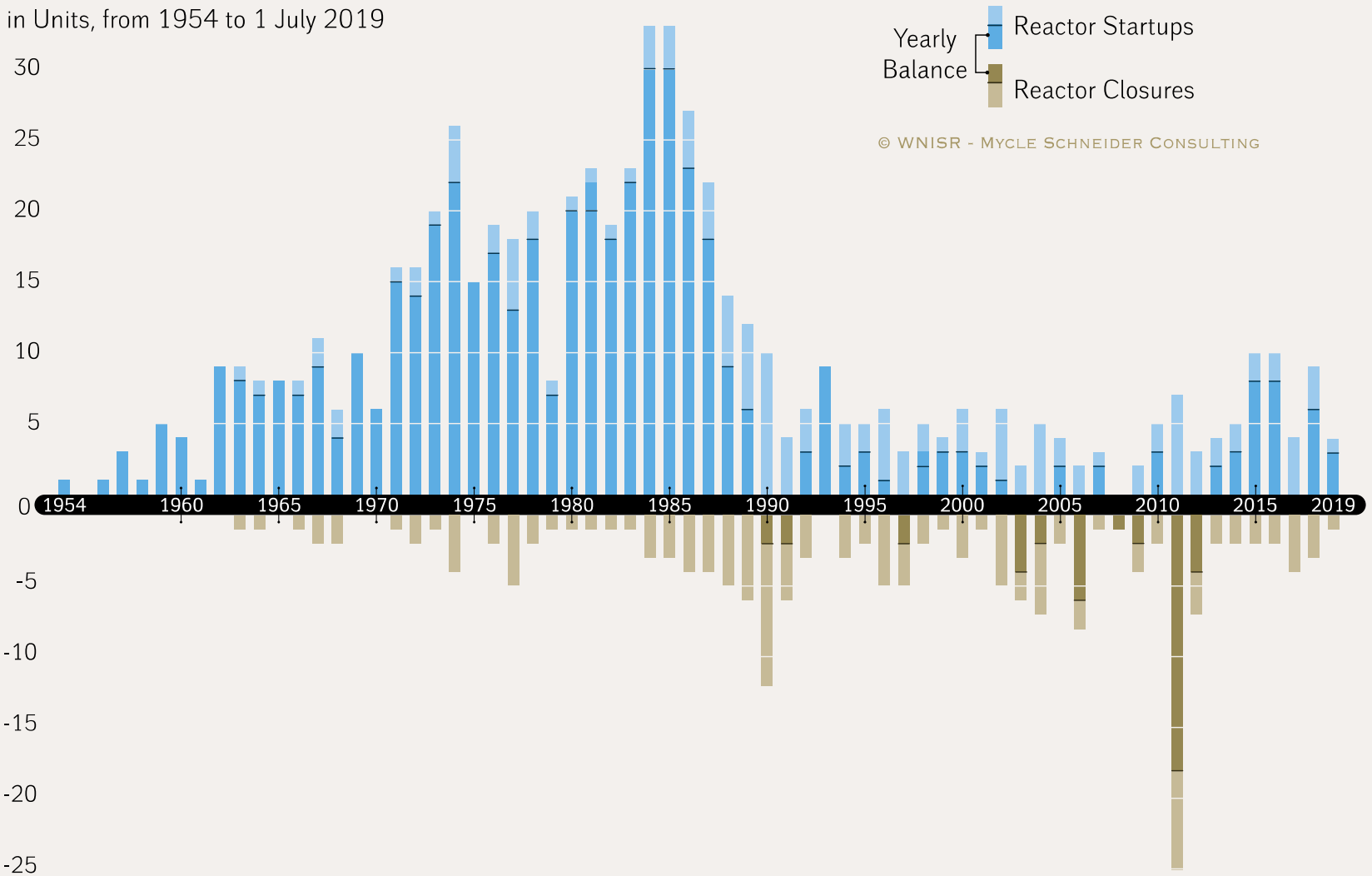
Mycle Schneider Consulting

NUCLEAR POWER VS. CLIMATE CHANGE



Reactor Startups and Closures in the World

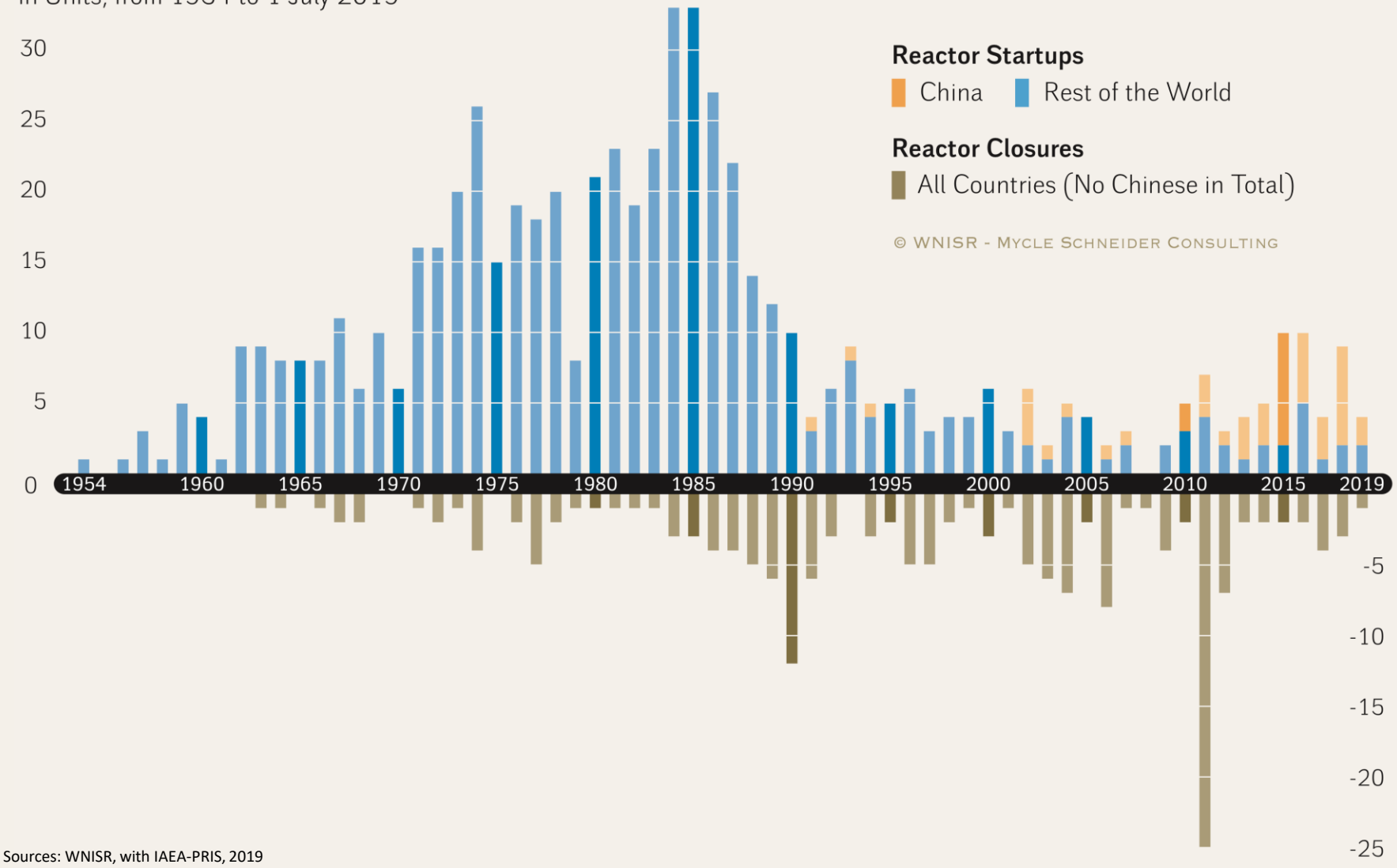
in Units, from 1954 to 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

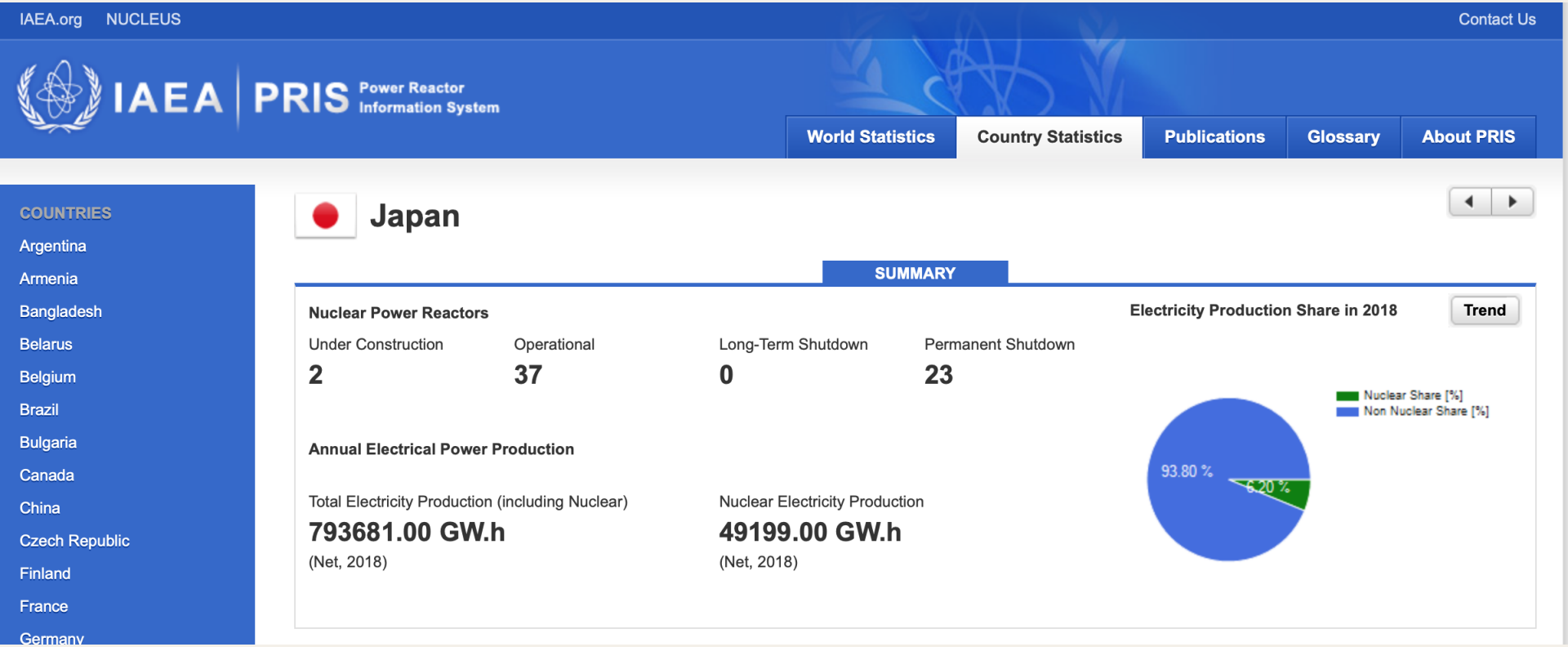
Reactor Startups and Closures in the World

in Units, from 1954 to 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

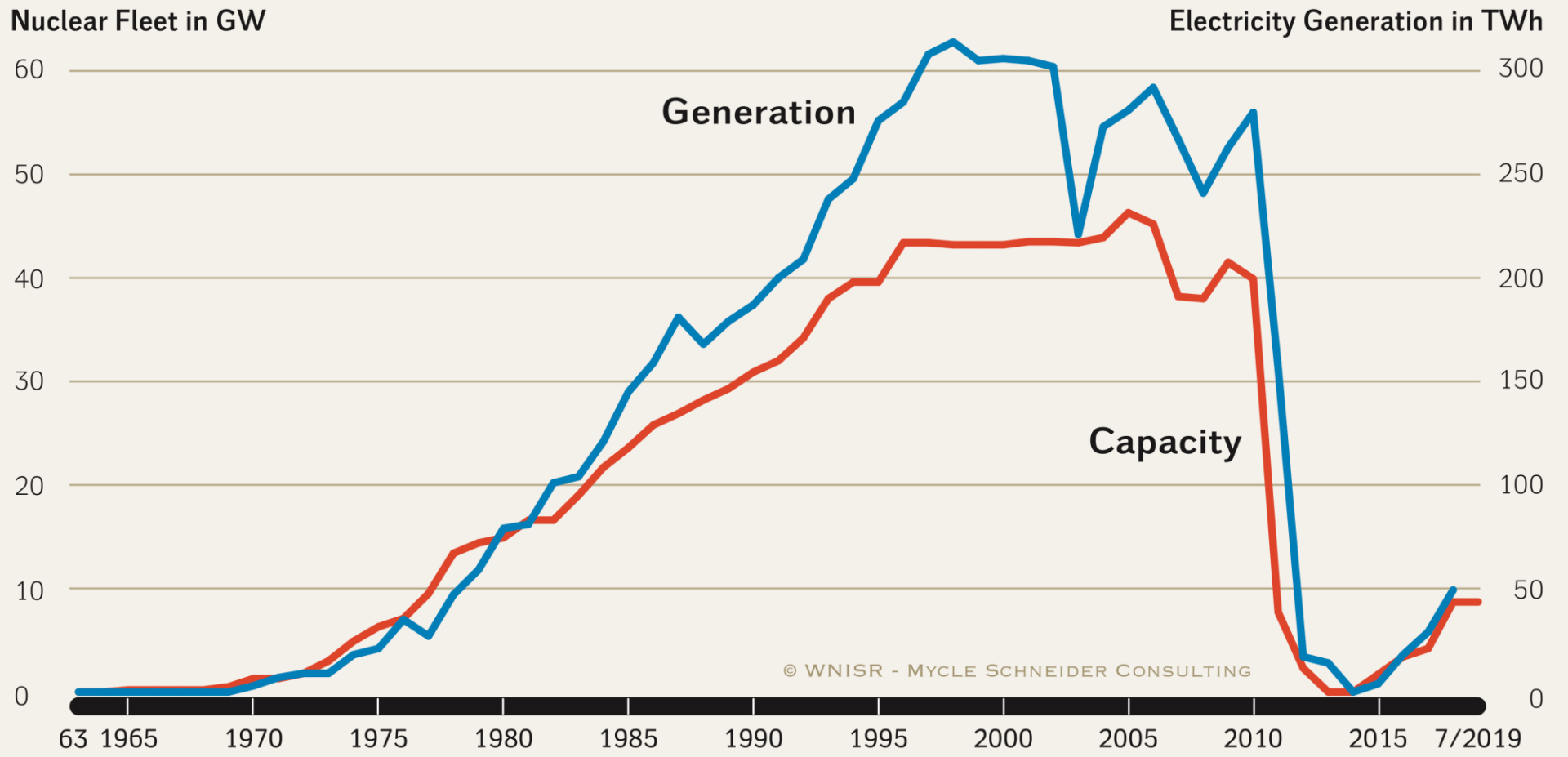
MISLEADING IAEA STATISTICS



Source: IAEA-PRIS, screenshot 2 October 2019

Rise and Fall of the Japanese Nuclear Program - 1963 to July 2019

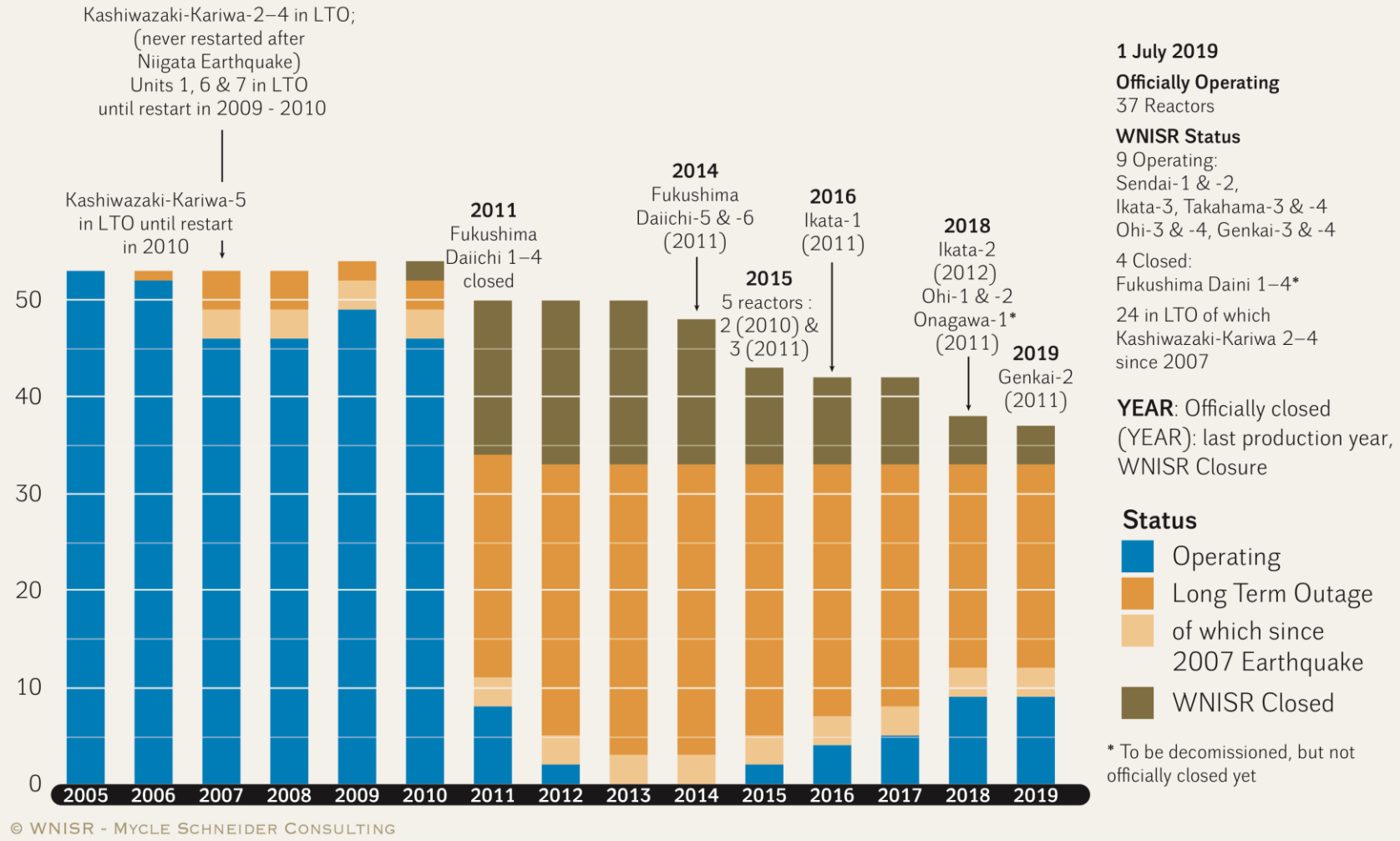
Fleet (in GW) and Electricity Generation (in TWh)



Sources: WNISR, with IAEA-PRIS, 2019

Status of Reactors Officially Operational in Japan vs WNISR Assessment

in Units, as of year end 2005-2018 and mid-2019



1 July 2019

Officially Operating
37 Reactors

WNISR Status
9 Operating:
Sendai-1 & -2,
Ikata-3, Takahama-3 & -4
Ohi-3 & -4, Genkai-3 & -4

4 Closed:
Fukushima Daini 1–4*

24 in LTO of which
Kashiwazaki-Kariwa 2–4
since 2007

YEAR: Officially closed
(YEAR): last production year,
WNISR Closure

Status

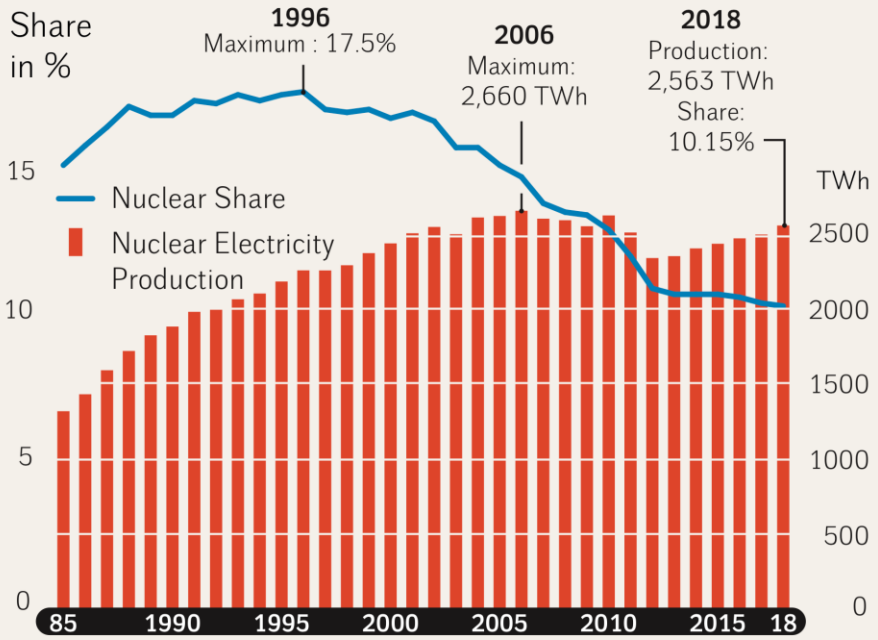
- Operating
- Long Term Outage
- of which since 2007 Earthquake
- WNISR Closed

* To be decomissioned, but not officially closed yet

Sources: WNISR, with IAEA-PRIS, 2019

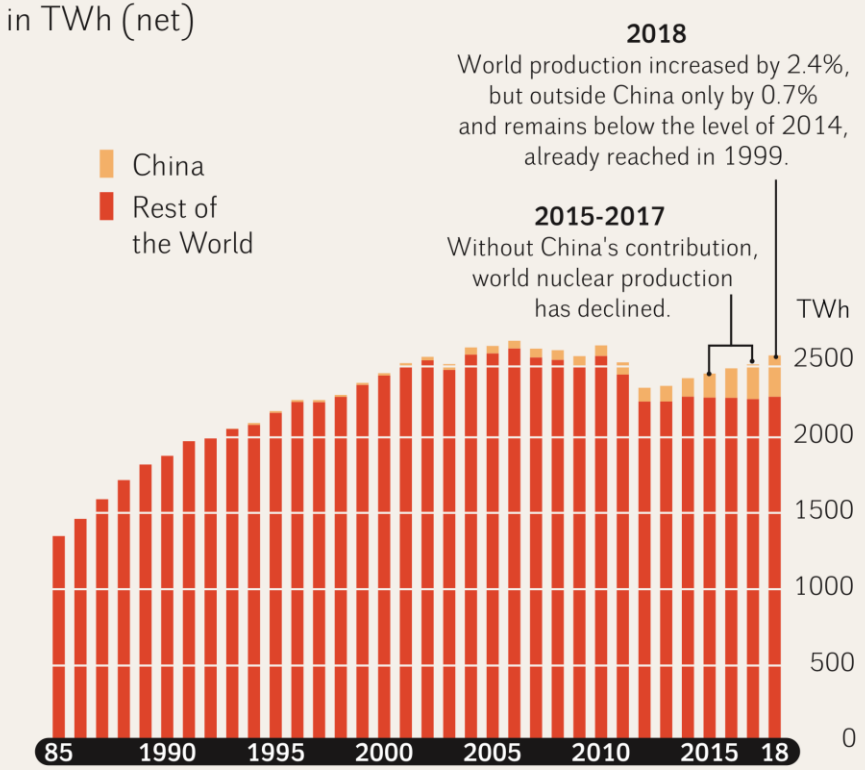
Nuclear Electricity Production 1985-2018 in the World...

in TWh (net) and Share in Electricity Generation (gross)

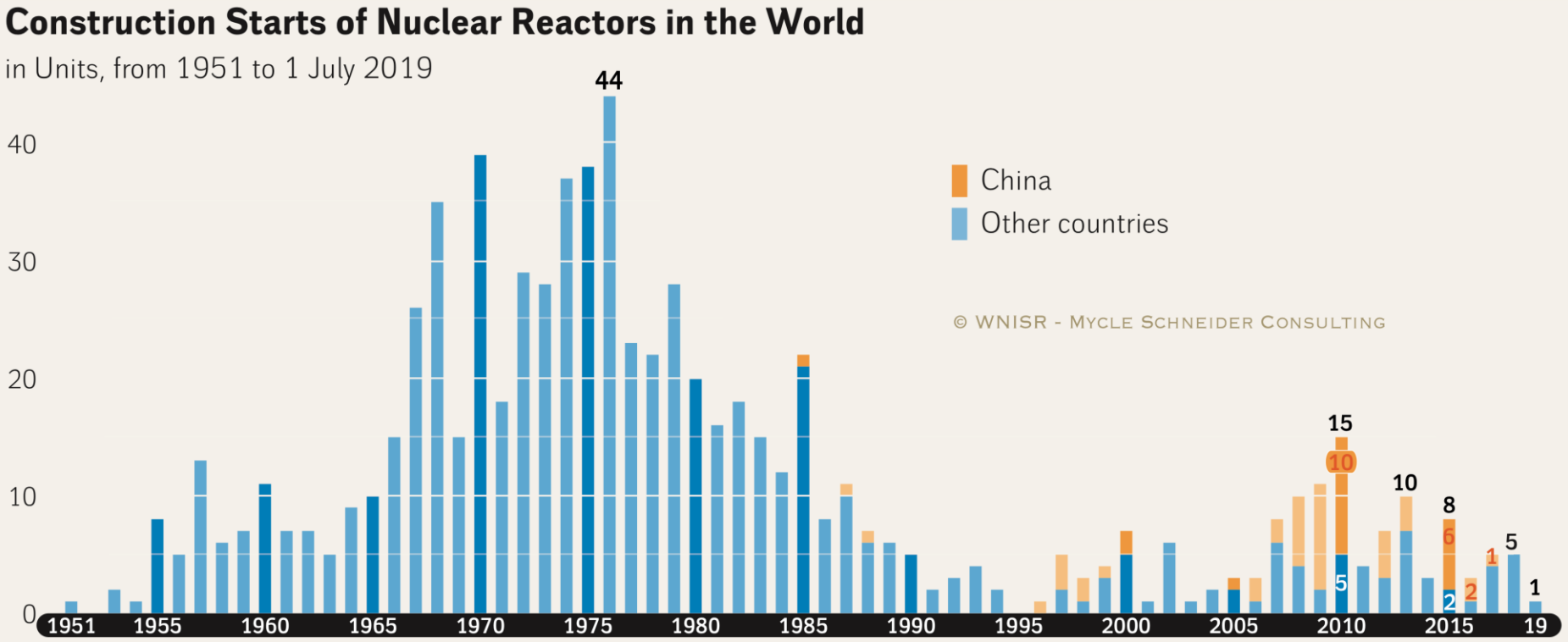


...and in China and the Rest of the World

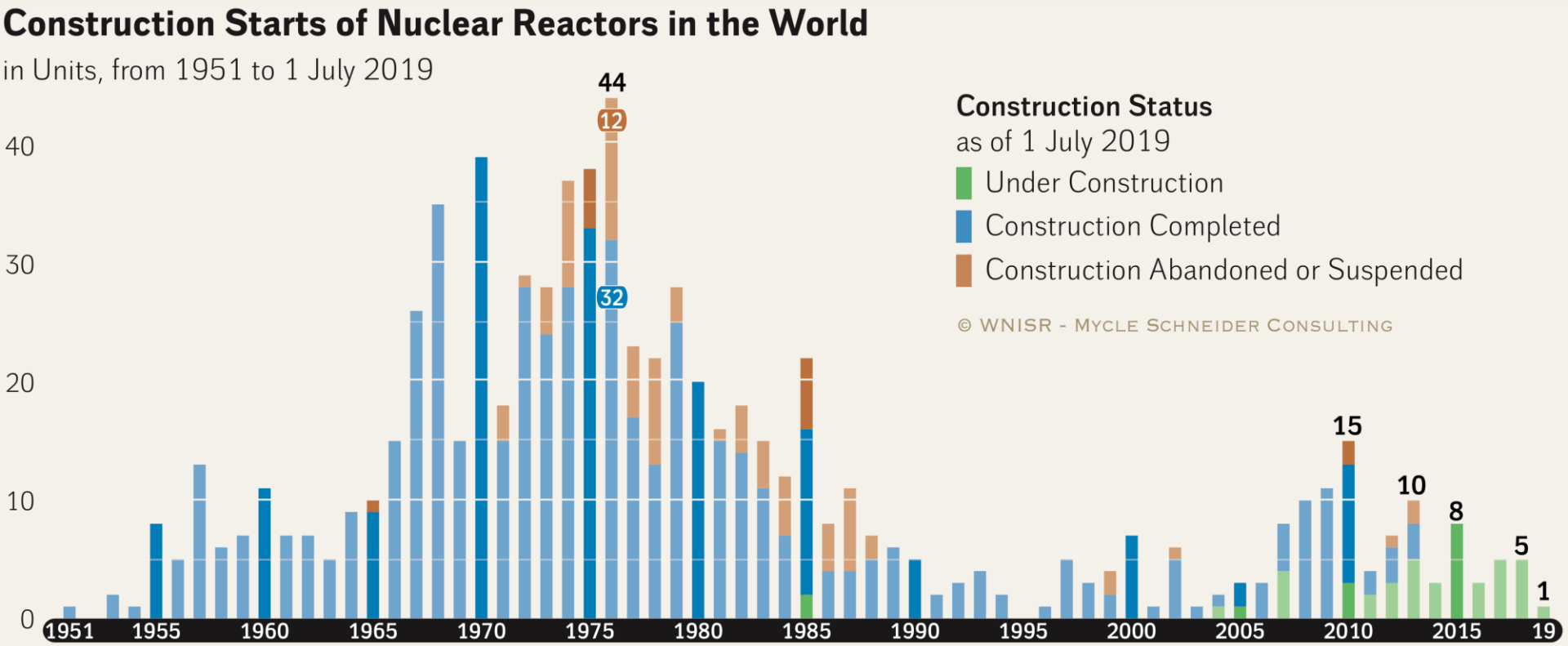
in TWh (net)



Sources: IAEA-PRIS, BP, 2019



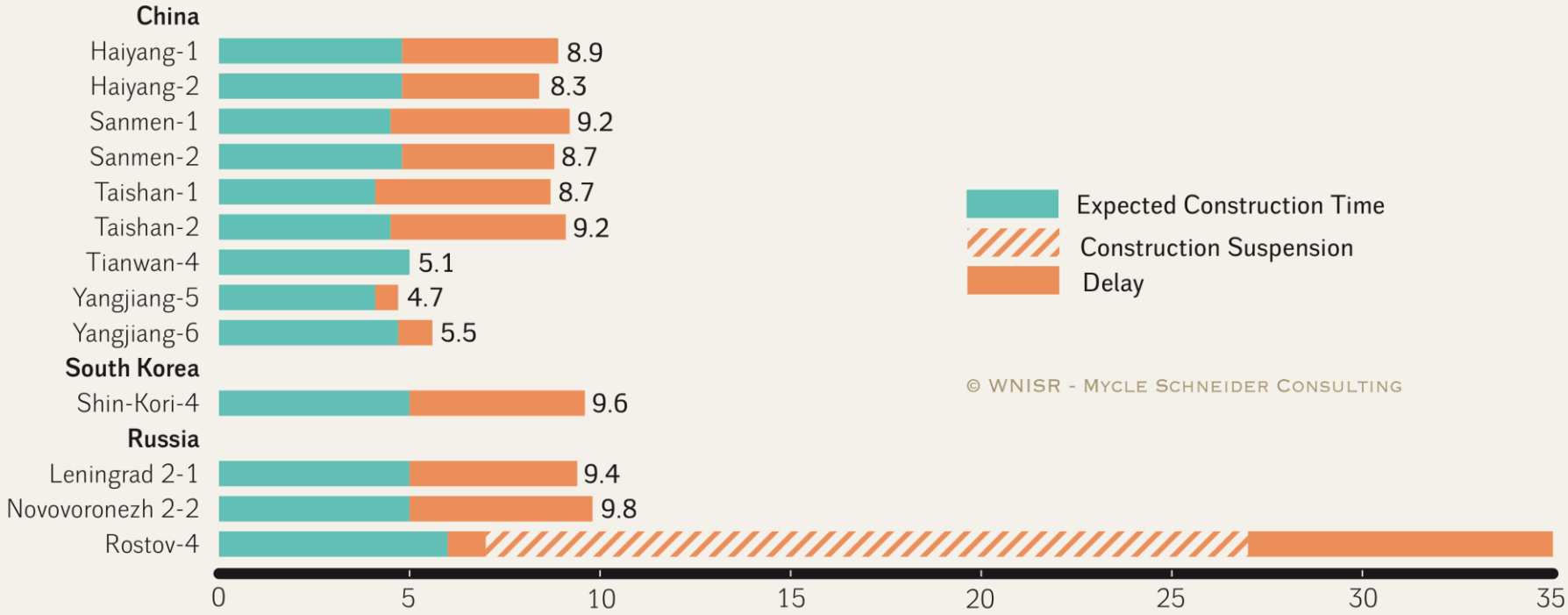
Sources: WNISR, with IAEA-PRIS, 2019



Sources: WNISR, with IAEA-PRIS, 2019

Expected Construction Time vs. Real Construction Time for Startups 2018-2019

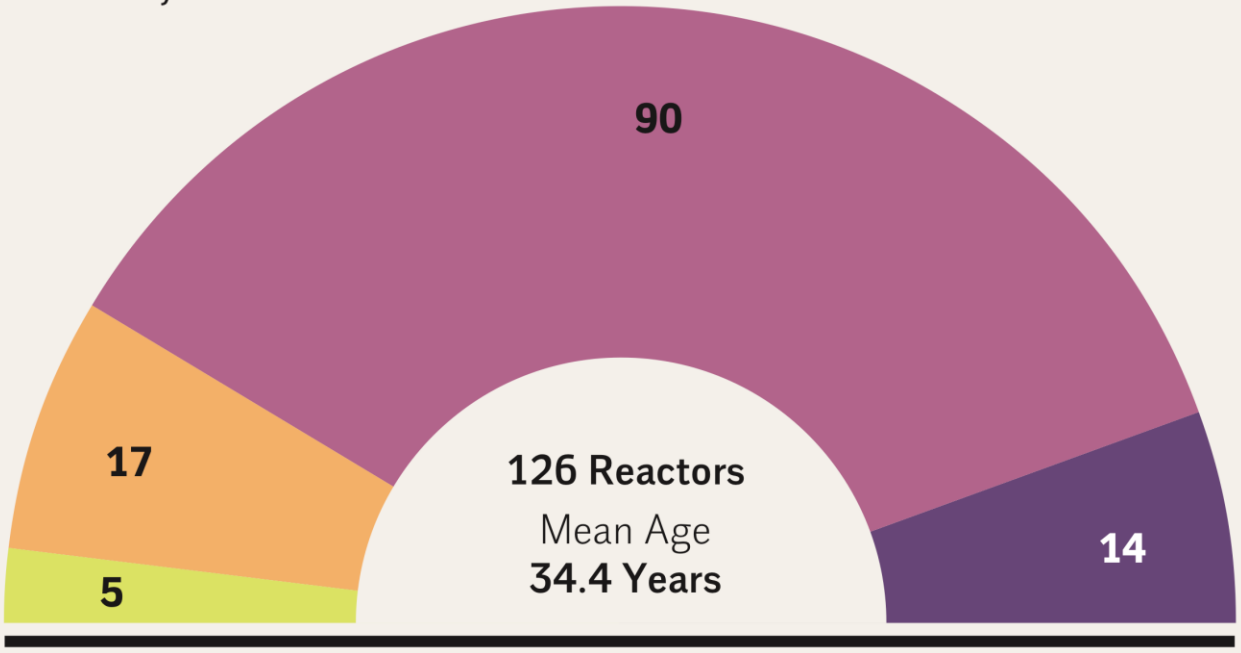
in Years



Sources: WNISR, with IAEA-PRIS, 2019

Age of EU Nuclear Fleet

as of 1 July 2019



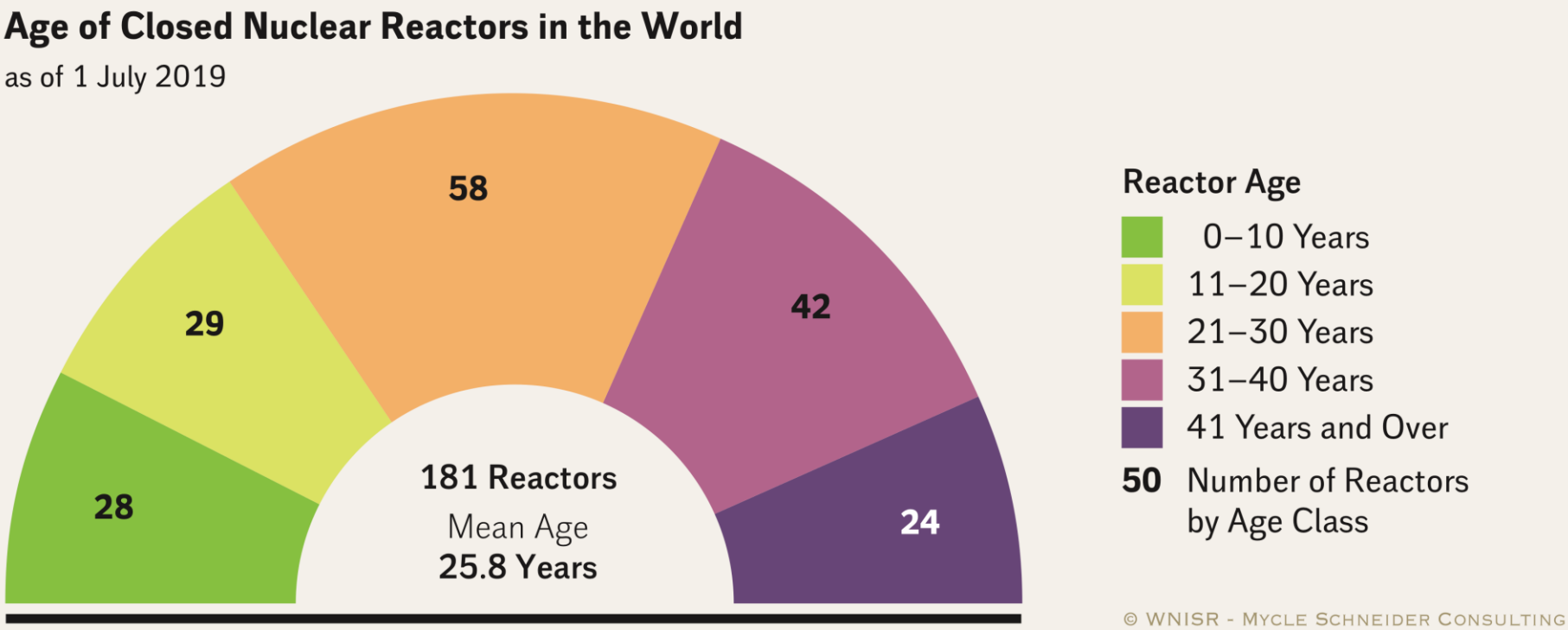
Reactor Age

- 11–20 Years
- 21–30 Years
- 31–40 Years
- 41 Years and Over

50 Number of Reactors by Age Class

Sources: WNISR, with IAEA-PRIS, 2019

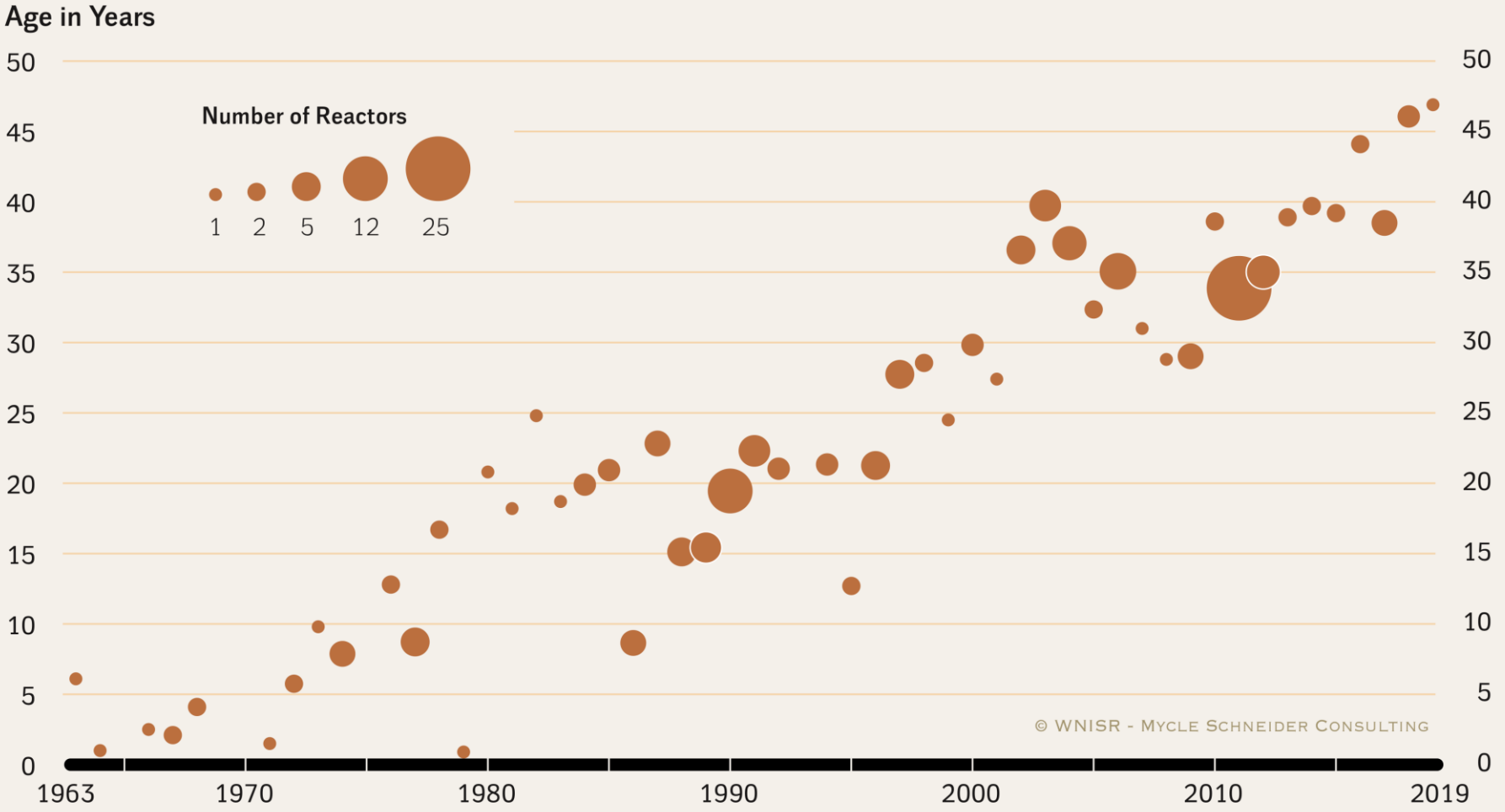
WORLD FLEET – CLOSED REACTORS AGE



Sources: WNISR, with IAEA-PRIS, 2019

Evolution of Nuclear Reactors' Average Closure Age 1963 – 1 July 2019

by Closure Year

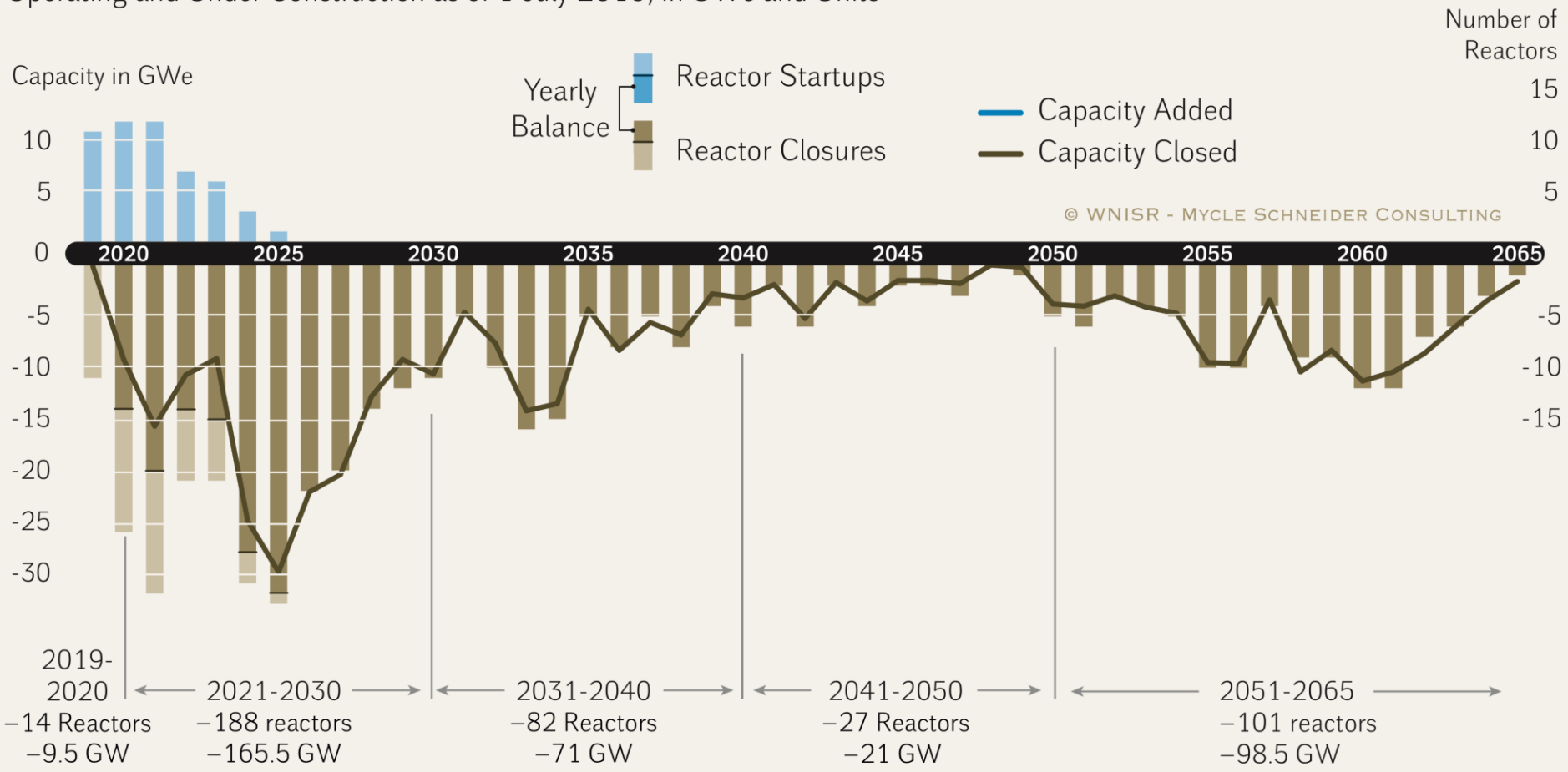


Sources: WNISR, with IAEA-PRIS, 2019

Projection 2019-2065 of Nuclear Reactor/Capacity in the World

General assumption of 40-year mean lifetime

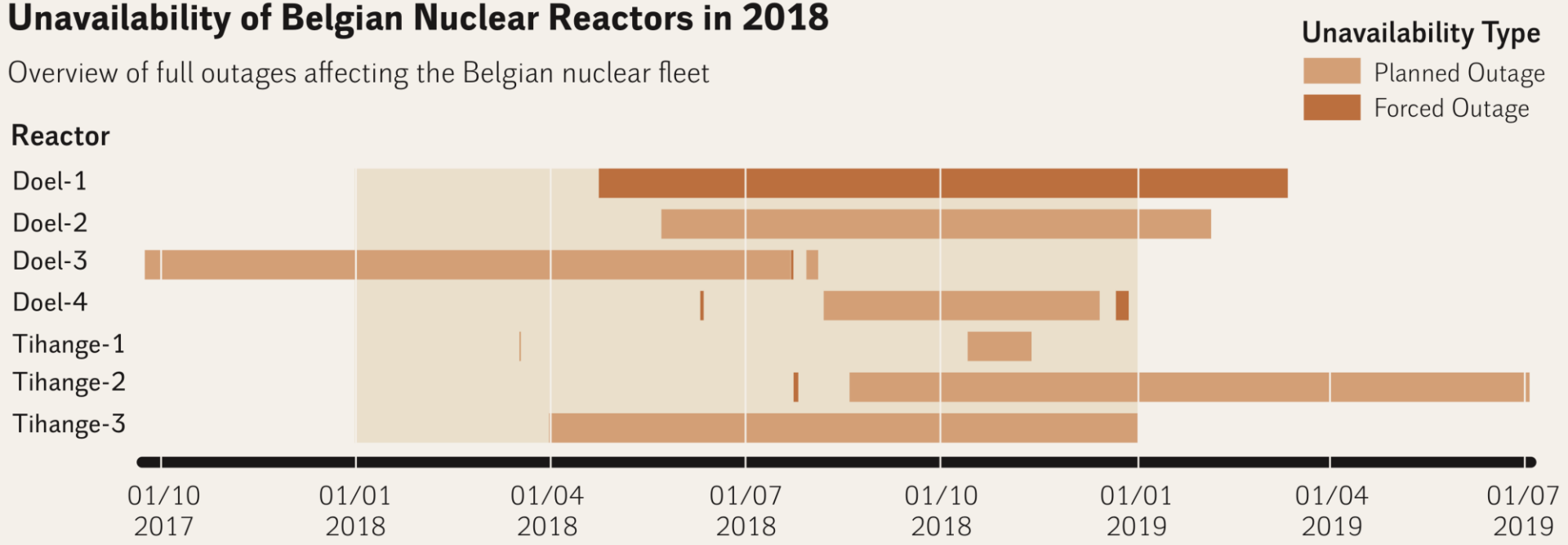
Operating and Under Construction as of 1 July 2019, in GWe and Units



Sources: Various sources, compiled by WNISR, 2019

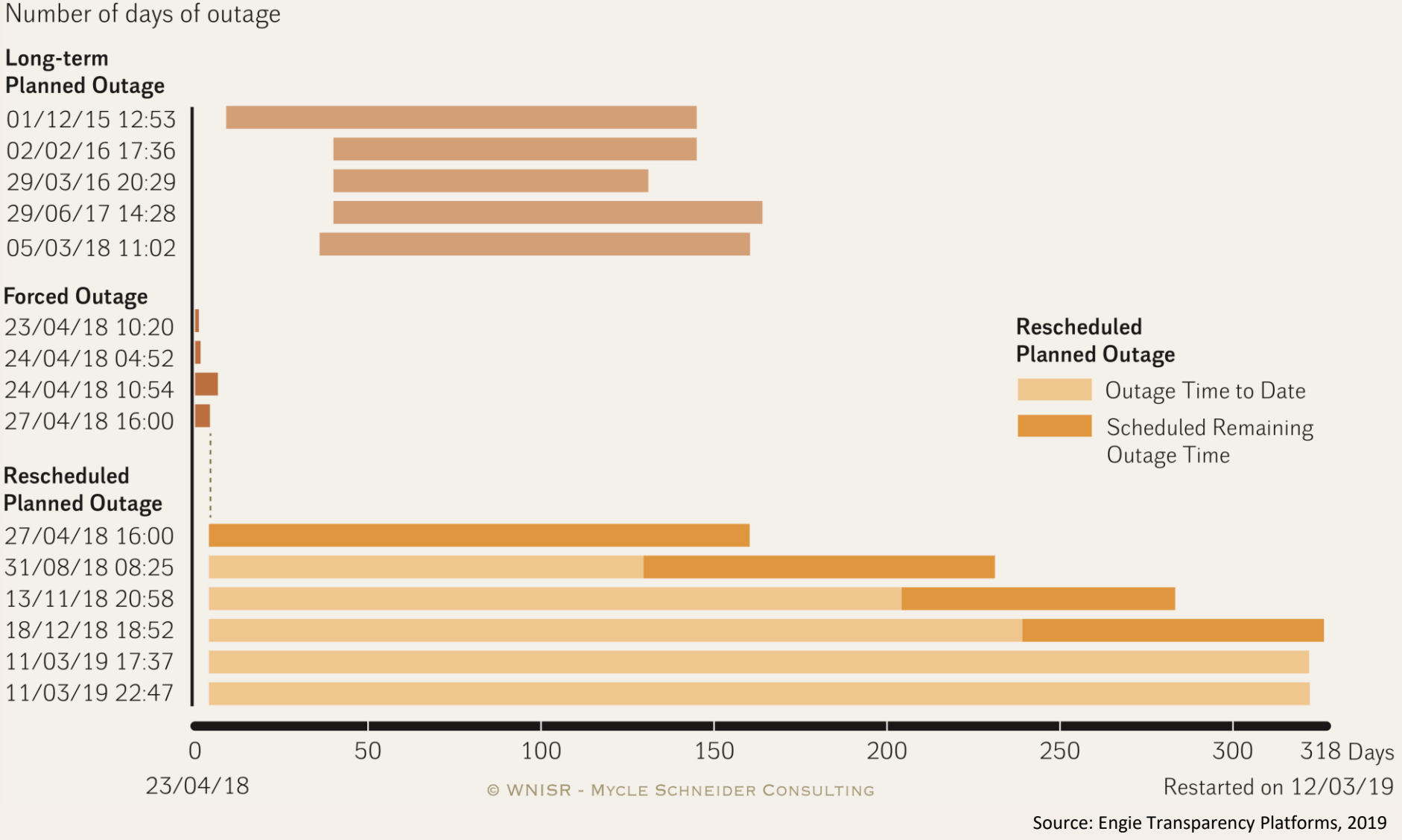
Unavailability of Belgian Nuclear Reactors in 2018

Overview of full outages affecting the Belgian nuclear fleet



Source: ENTSO-E and Engie Transparency Platforms, 2019

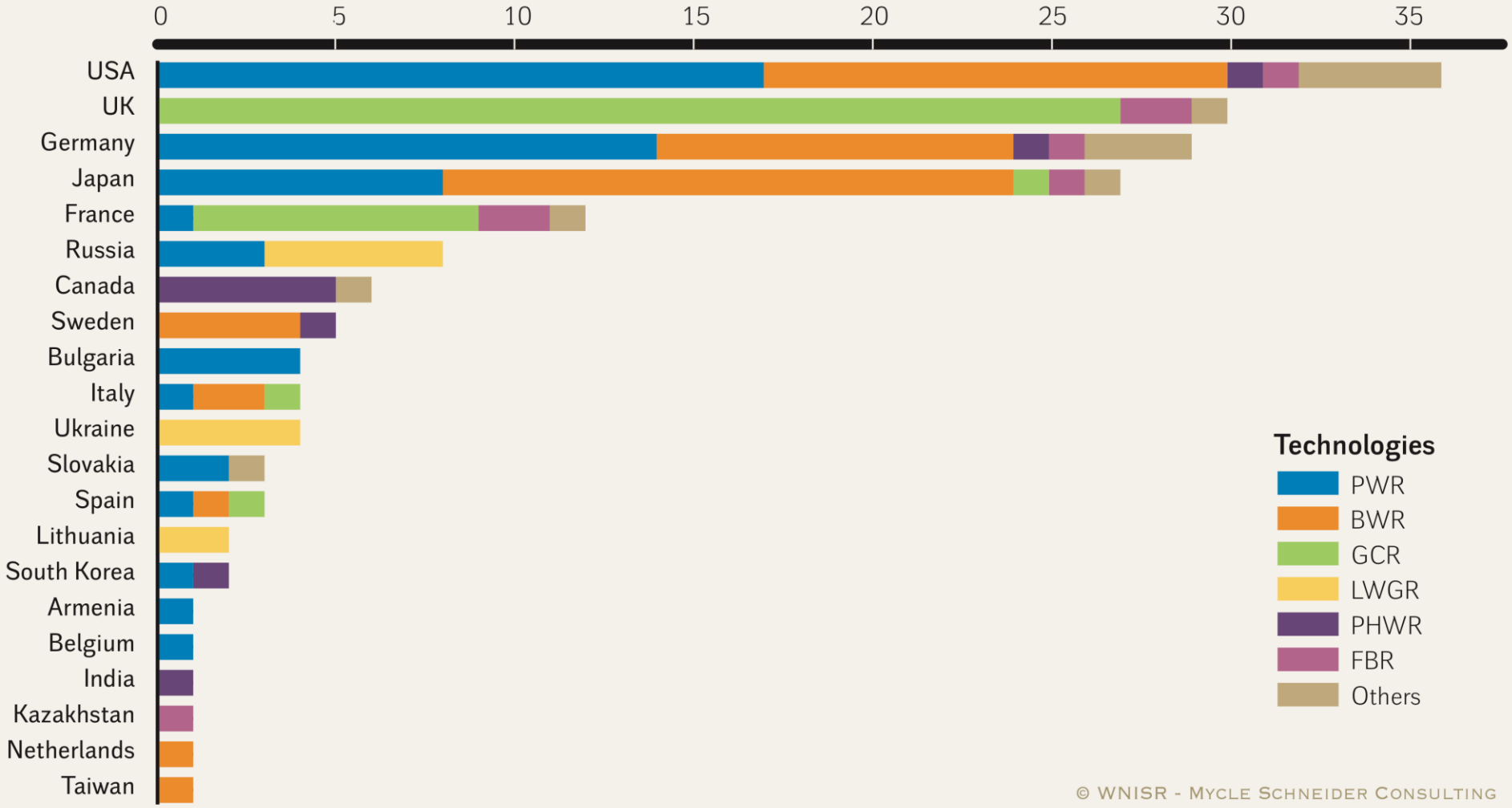
Doel-1: Overhaul Outage Takes Over "Forced" Outage



Source: Engie Transparency Platforms, 2019

Closed Reactors Worldwide by Country and Reactor Technology

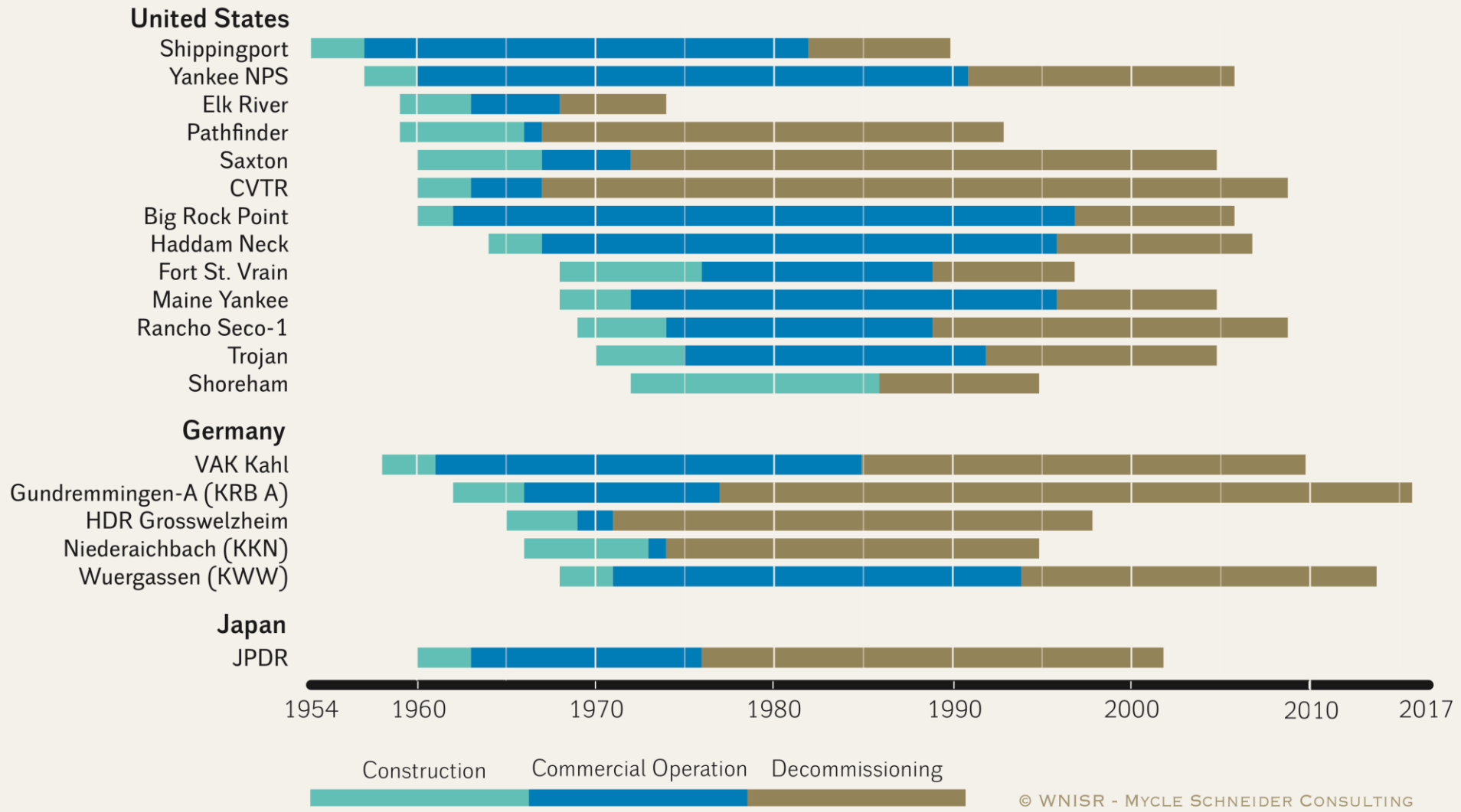
in Units, as of 1 July 2019



Sources: WNISR, with IAEA-PRIS, 2019

Overview of Completed Reactor Decommissioning Projects, 1953-2017

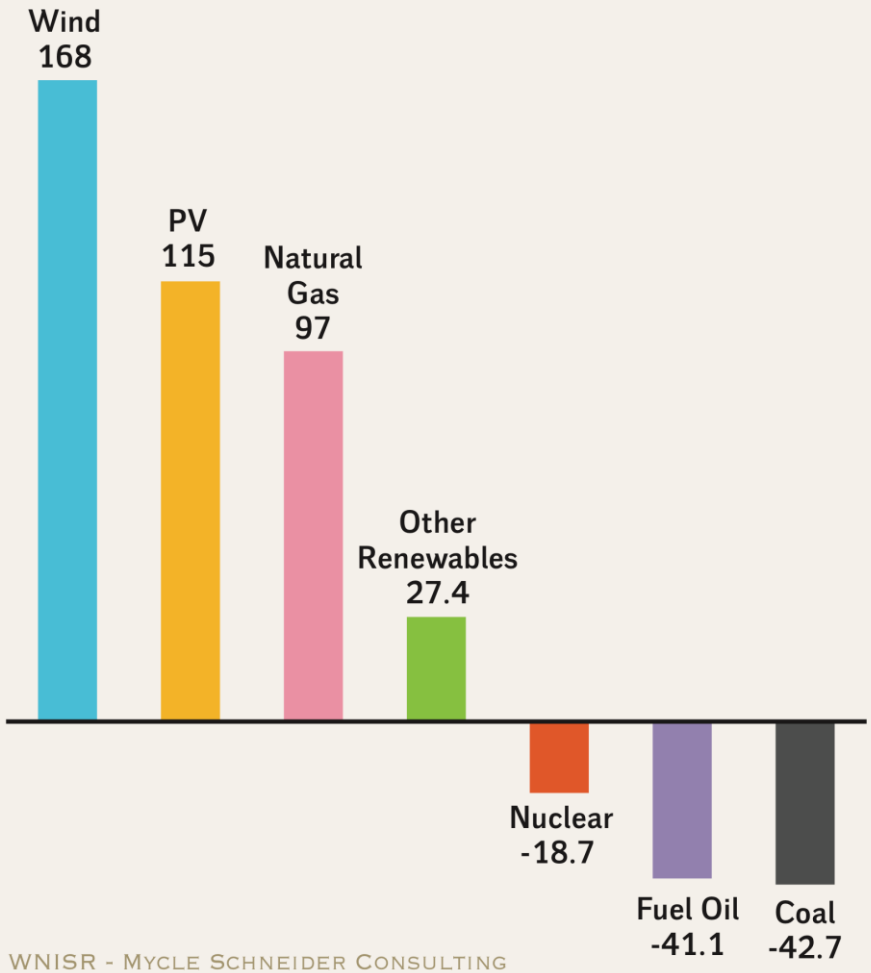
in the U.S., Germany and Japan



Sources: WNISR, with IAEA-PRIS, 2019

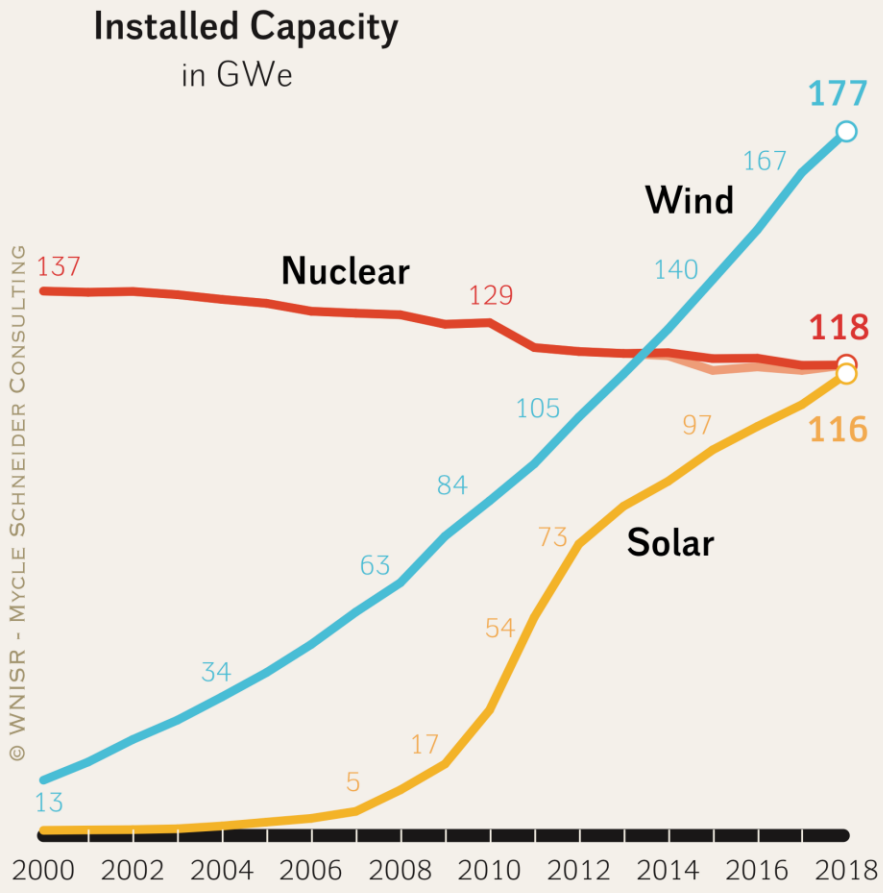
Changes in Installed Capacity in the EU 2000-2018

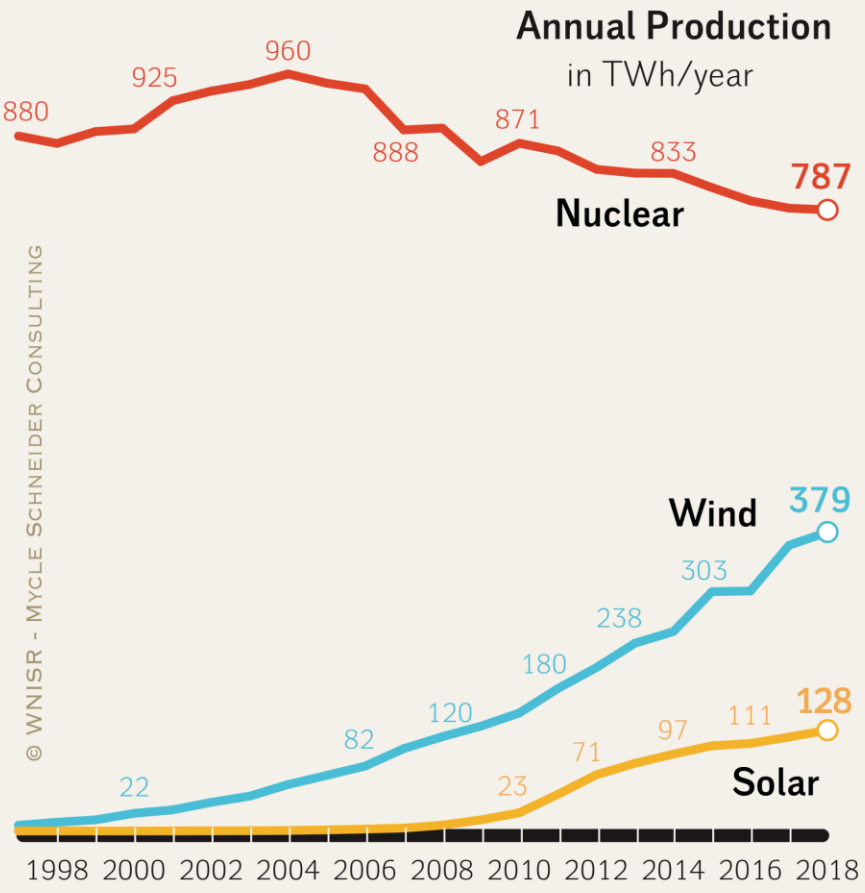
by Energy Source in GWe



Sources: WindEurope, WNISR, 2019

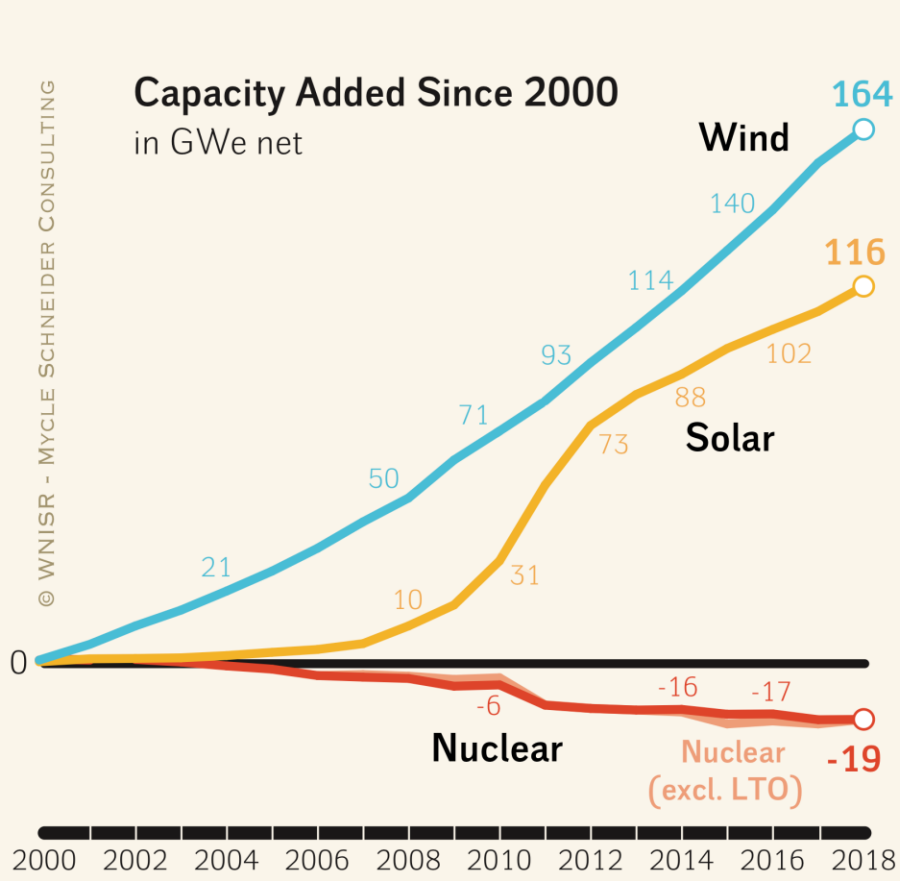
Wind, Solar and Nuclear Installed Capacity and Electricity Production in the EU

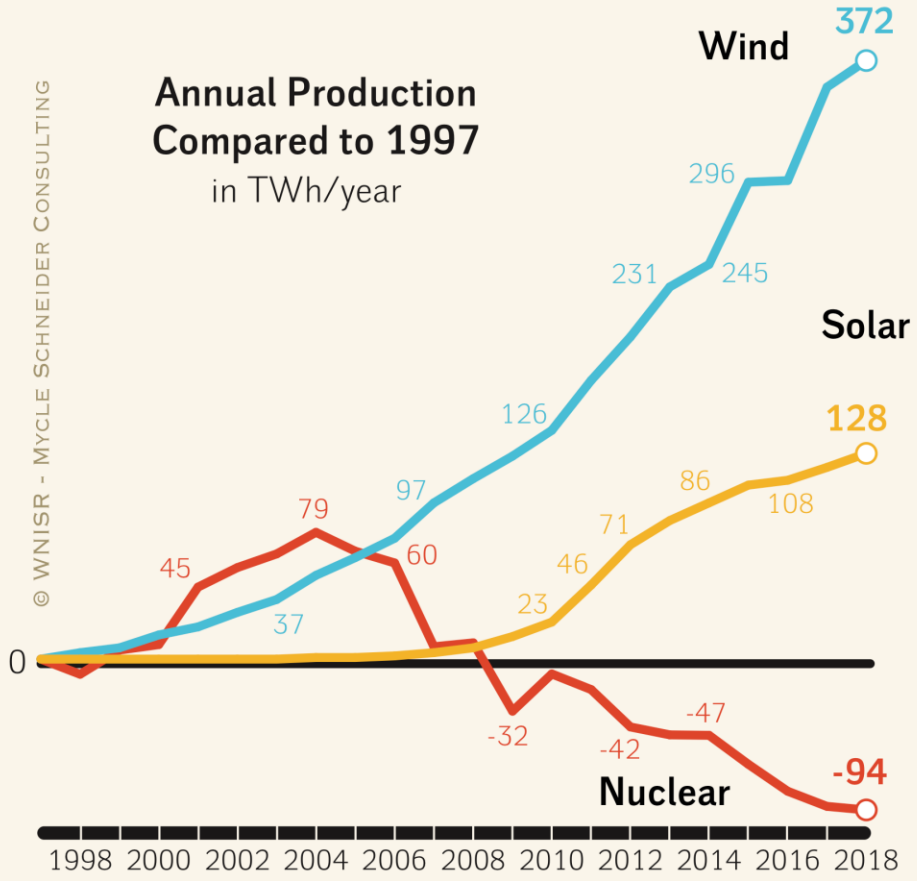




Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019

Wind, Solar and Nuclear Developments: Installed Capacity and Electricity Production in the EU





Sources: WNISR, IAEA-PRIS, BP Statistical Review 2019