

Internationale Trends der Atomindustrie: Wahrnehmung versus Realität

Auf der Basis des *World Nuclear Industry Status Report 2021 - Plus Updates zum Jahresende!*

www.WorldNuclearReport.org

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The World Nuclear Industry Status Report 2021

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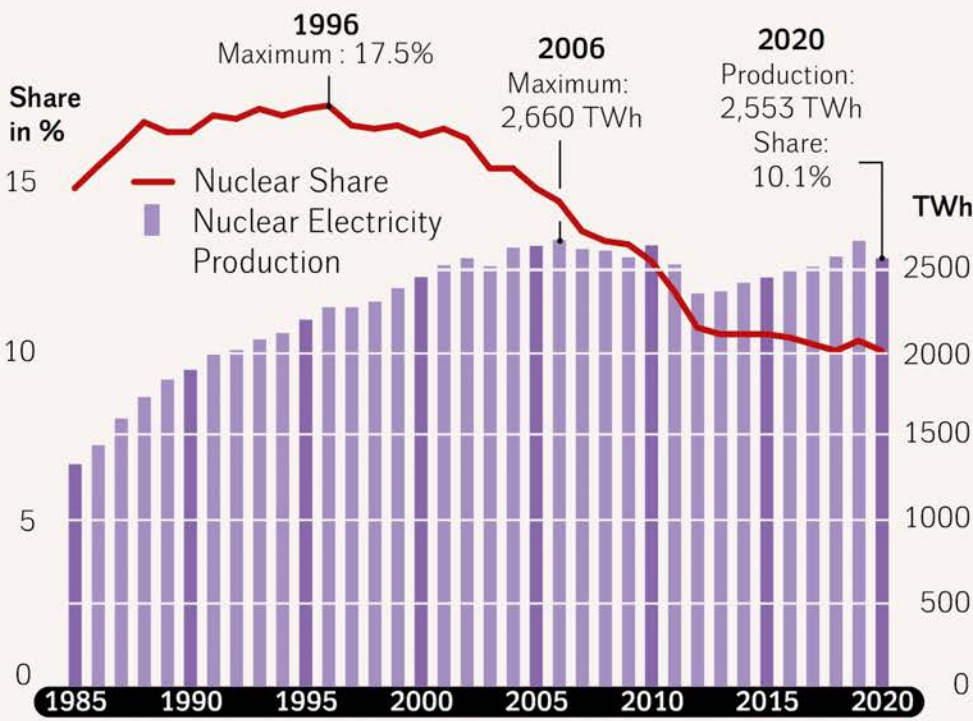
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Visual Artist, Painter, Rodgau, Germany
Cover-page Design, Painting and Layout

**Nuclear Electricity Production 1985–2020
in the World...**

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

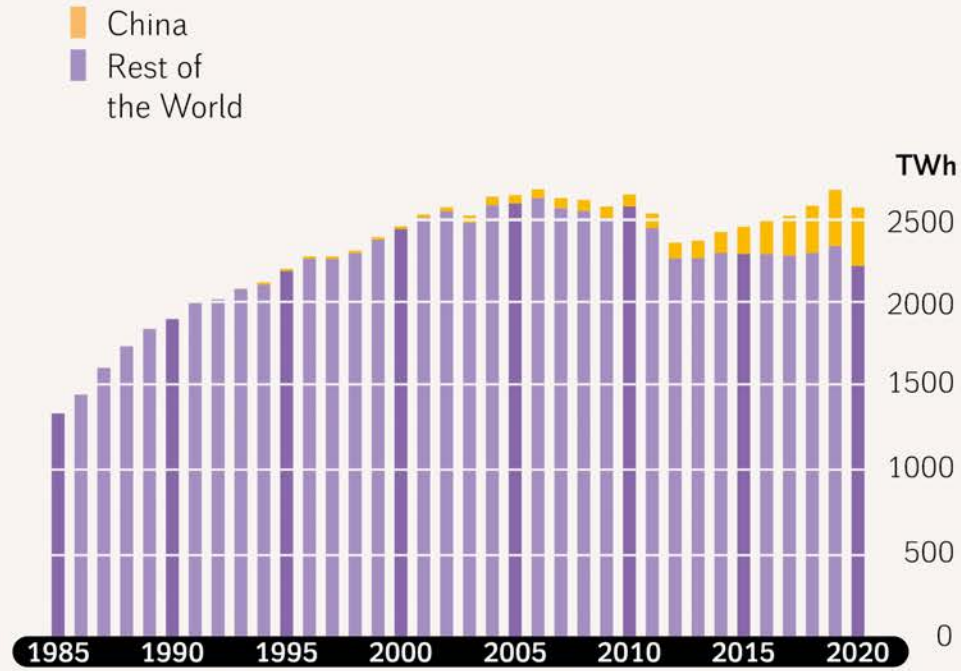


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**...and in China
and the Rest of the World**

in TWh (net)

2020
For the first time since 2012,
world nuclear production decreased,
by around 3.9%.

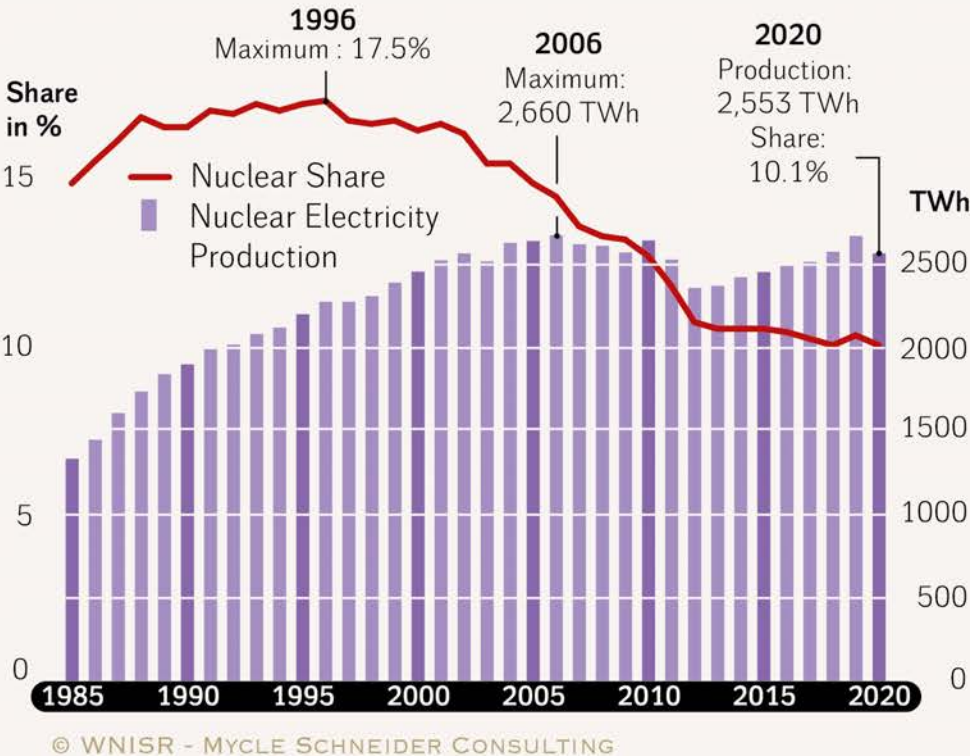


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Sources: WNISR, with BP, IAEA-PRIS, 2021

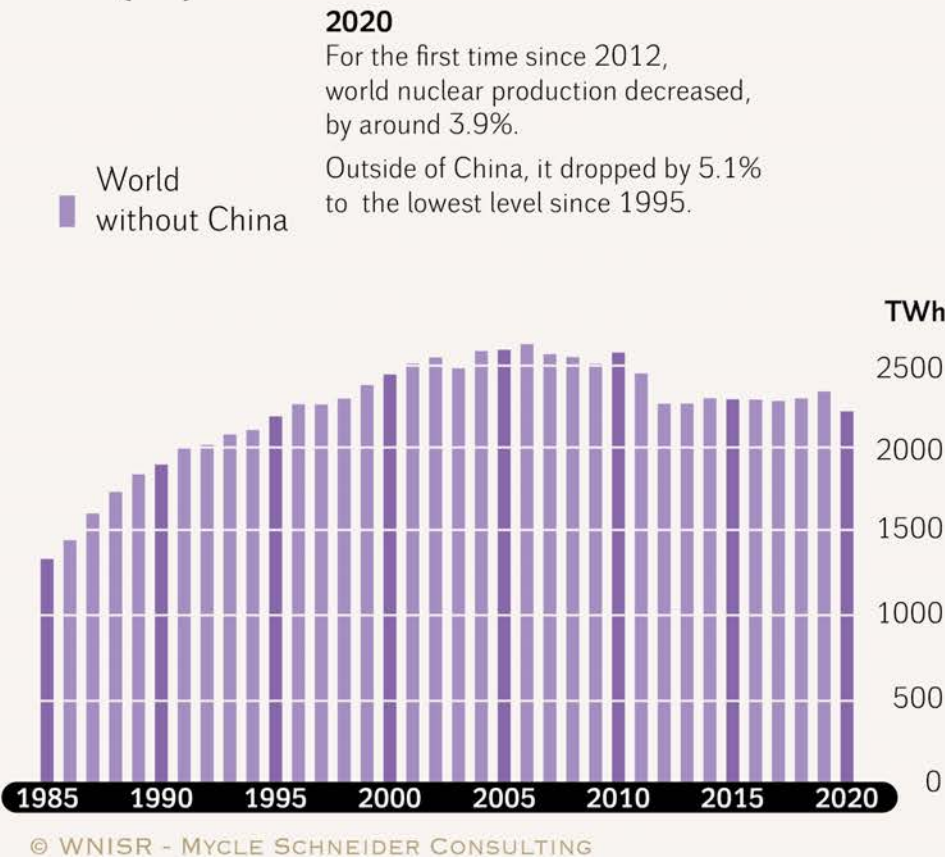
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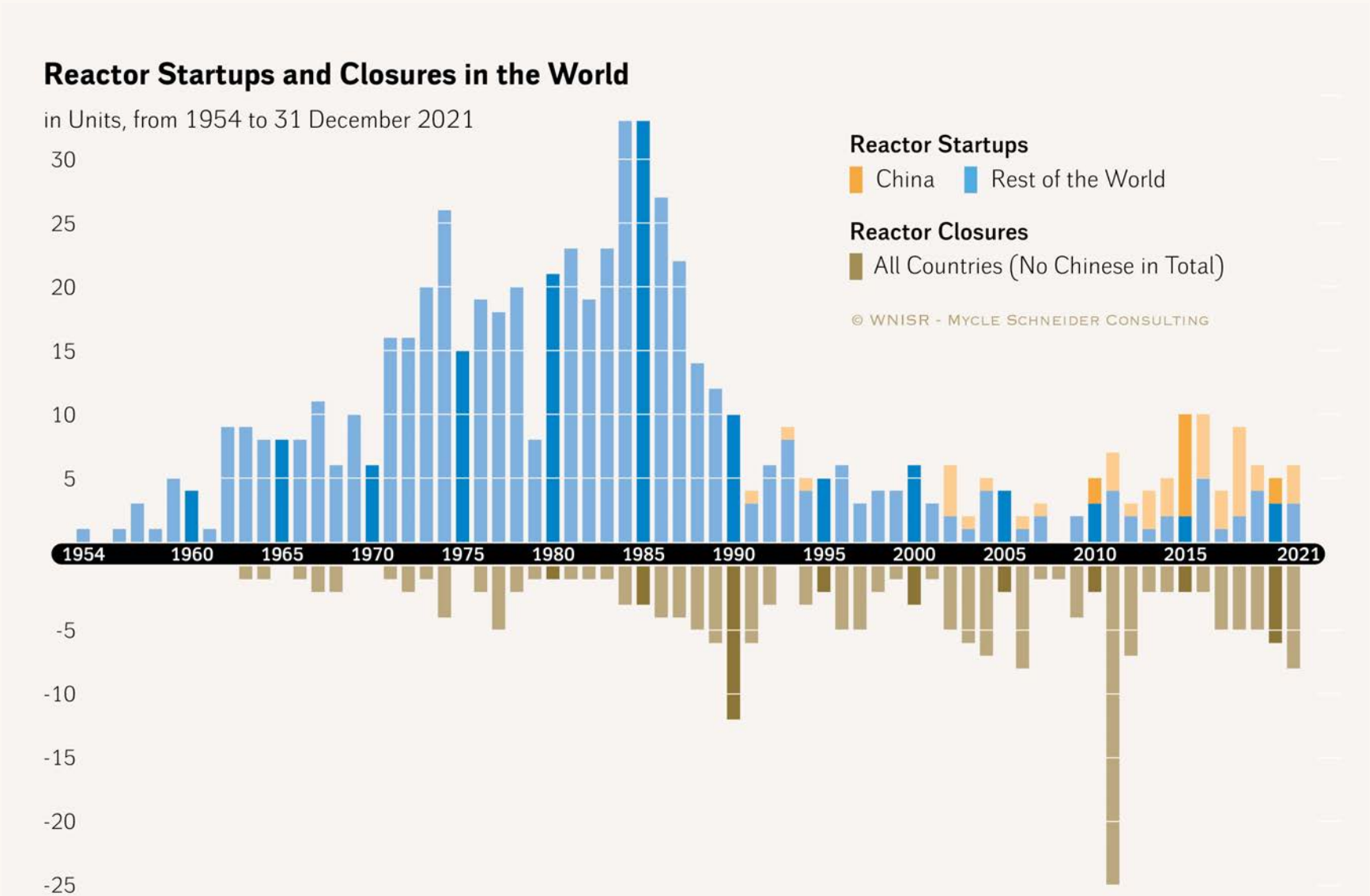


...and in China and the Rest of the World

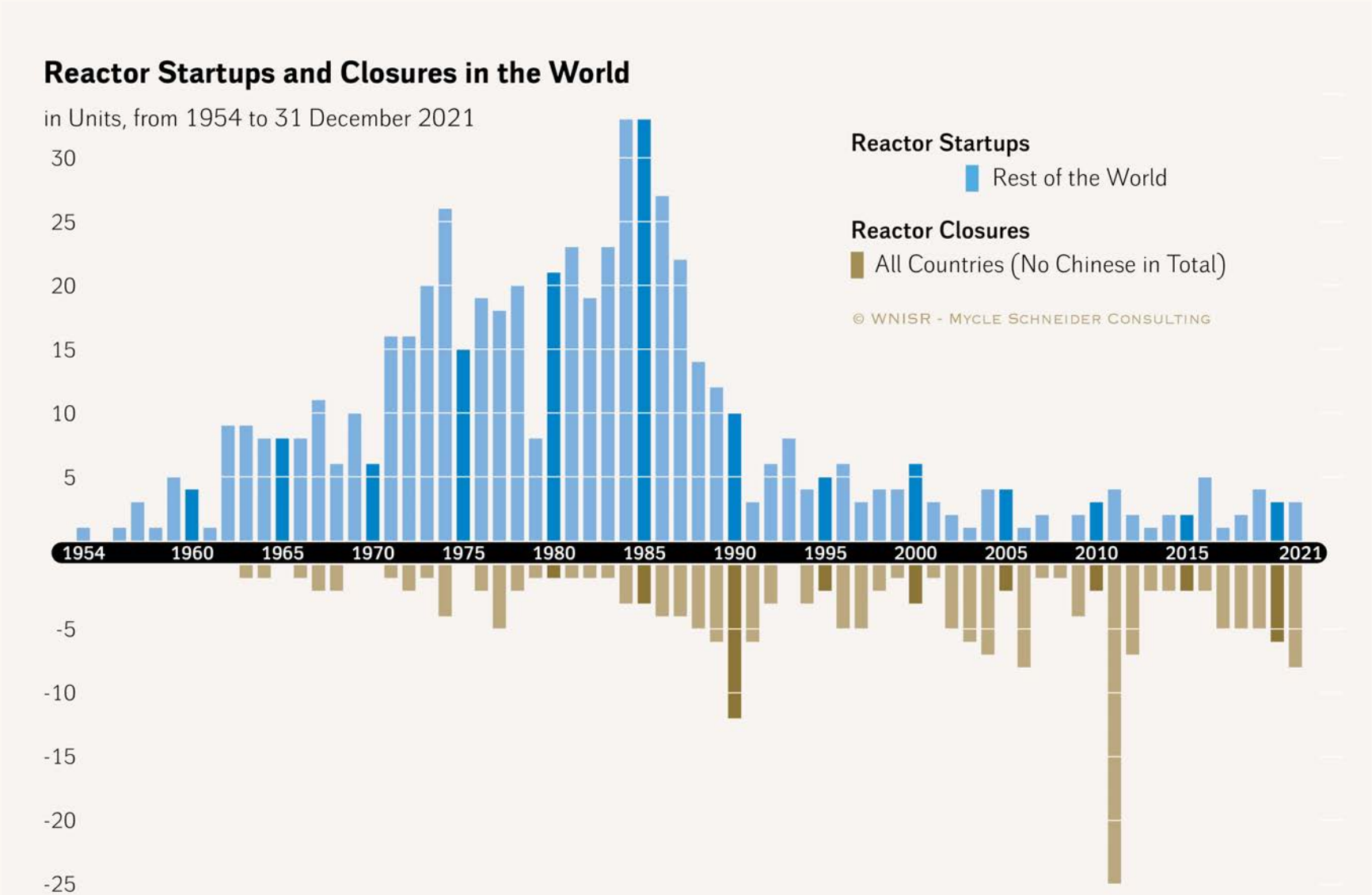
in TWh (net)



Sources: WNISR, with BP, IAEA-PRIS, 2021



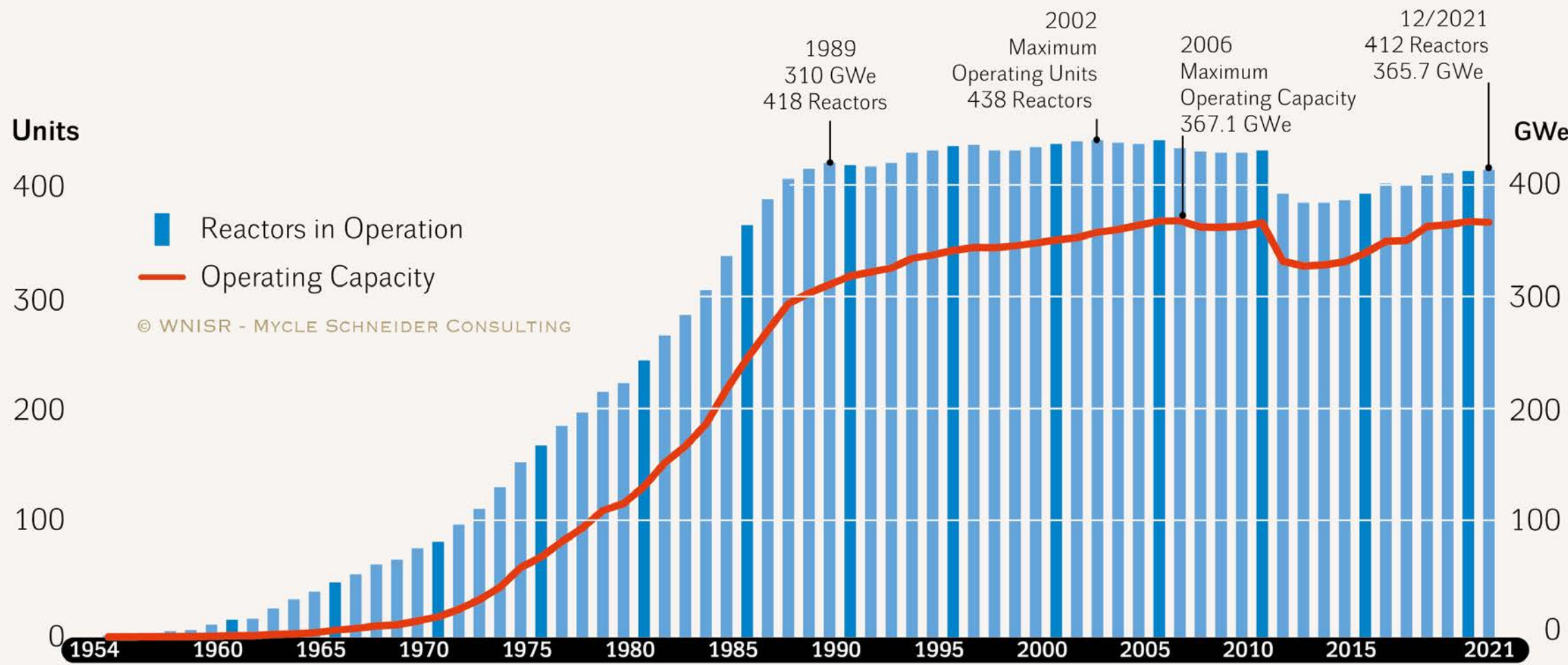
Sources: WNISR, with IAEA-PRIS, 2022



Sources: WNISR, with IAEA-PRIS, 2022

Nuclear Reactors and Net Operating Capacity in the World

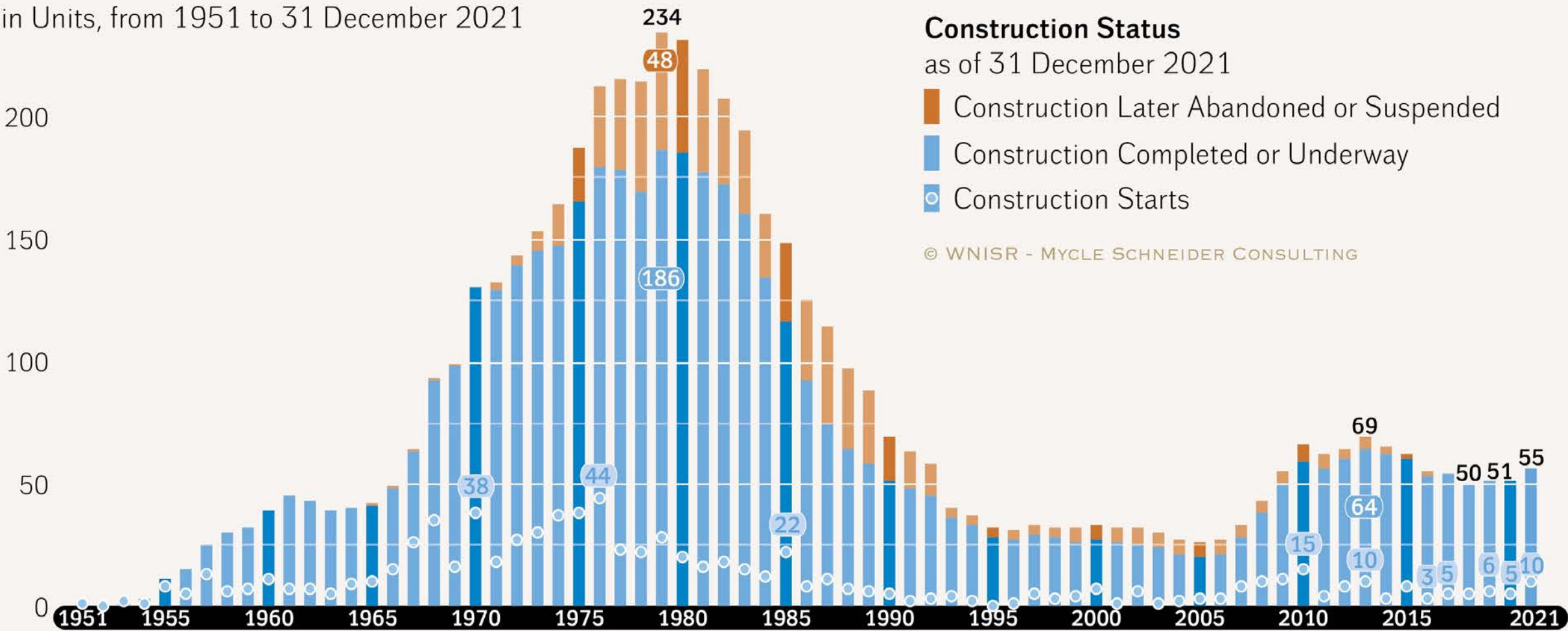
in Units and GWe, from 1954 to 31 December 2021



Sources: WNISR, with IAEA-PRIS, 2022

Reactors Under Construction in the World

in Units, from 1951 to 31 December 2021



Sources: WNISR, with IAEA-PRIS, 2022

Nuclear Reactors “Under Construction” (as of 31 December 2021)

Country	Units	Capacity (MW net)	Construction Start	Grid Connection	Units Behind Schedule
China	20	19 204	2012 – 2021	2022 – 2027	4
India	8	6 194	2004 – 2021	2022 – 2026	6
South Korea	4	5 360	2012 – 2018	2022 – 2025	4
Russia	3	2 650	2018 – 2021	2022 – 2026	0
Turkey	3	3 342	2018 – 2021	2024 – 2026	1
Bangladesh	2	2 160	2017 – 2018	2023 – 2024	0
Slovakia	2	880	1985	2022 – 2023	2
UAE	2	2 690	2014 – 2015	2022 – 2023	2
UK	2	3 260	2018 – 2019	2026 – 2027	2
USA	2	2 234	2013	2022 – 2023	2
Argentina	1	25	2014	2024	1
Belarus	1	1 110	2014	2022	1
Finland	1	1 600	2005	2022	1
France	1	1 600	2007	2023	1
Iran	1	1 196	1976	2024	1
Japan	1	1 325	2007	2025	1
Pakistan	1	1 014	2016	2022	1
Total	55	55 844	1976 - 2021	2022 – 2027	30

Sources: WNISR, with IAEA-PRIS, 2022

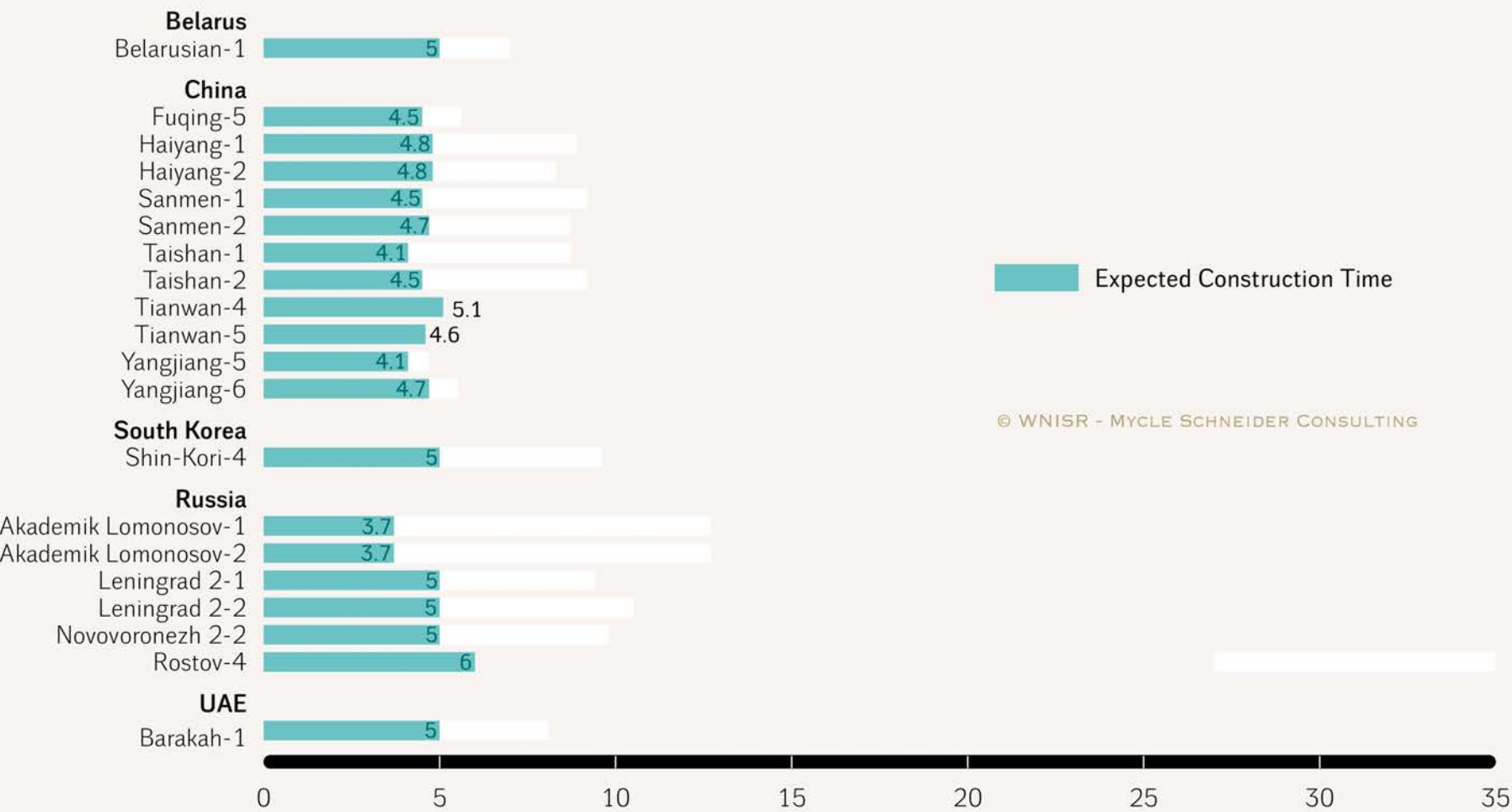
Duration from Construction Start to Grid Connection

Construction Times of 63 Units Started-up 2011–2020				
Country	Units	Construction Time (in Years)		
		Mean Time	Minimum	Maximum
China	37	6.1	4.1	11.2
Russia	10	18.7	8.1	35.1
South Korea	5	6.4	4.2	9.6
India	3	11.5	8.7	14.2
Pakistan	3	5.4	5.2	5.6
Argentina	1	33.0	33.0	
Belarus	1	7.0	7.0	
Iran	1	36.3	36.3	
UAE	1	8.1	8.1	
USA	1	42.8	42.8	
World	63	9.9	4.1	42.8

Sources: WNISR, with IAEA-PRIS, 2021

Expected vs. Real Duration from Construction Start to Grid Connection for Startups 2018–2020

in Years

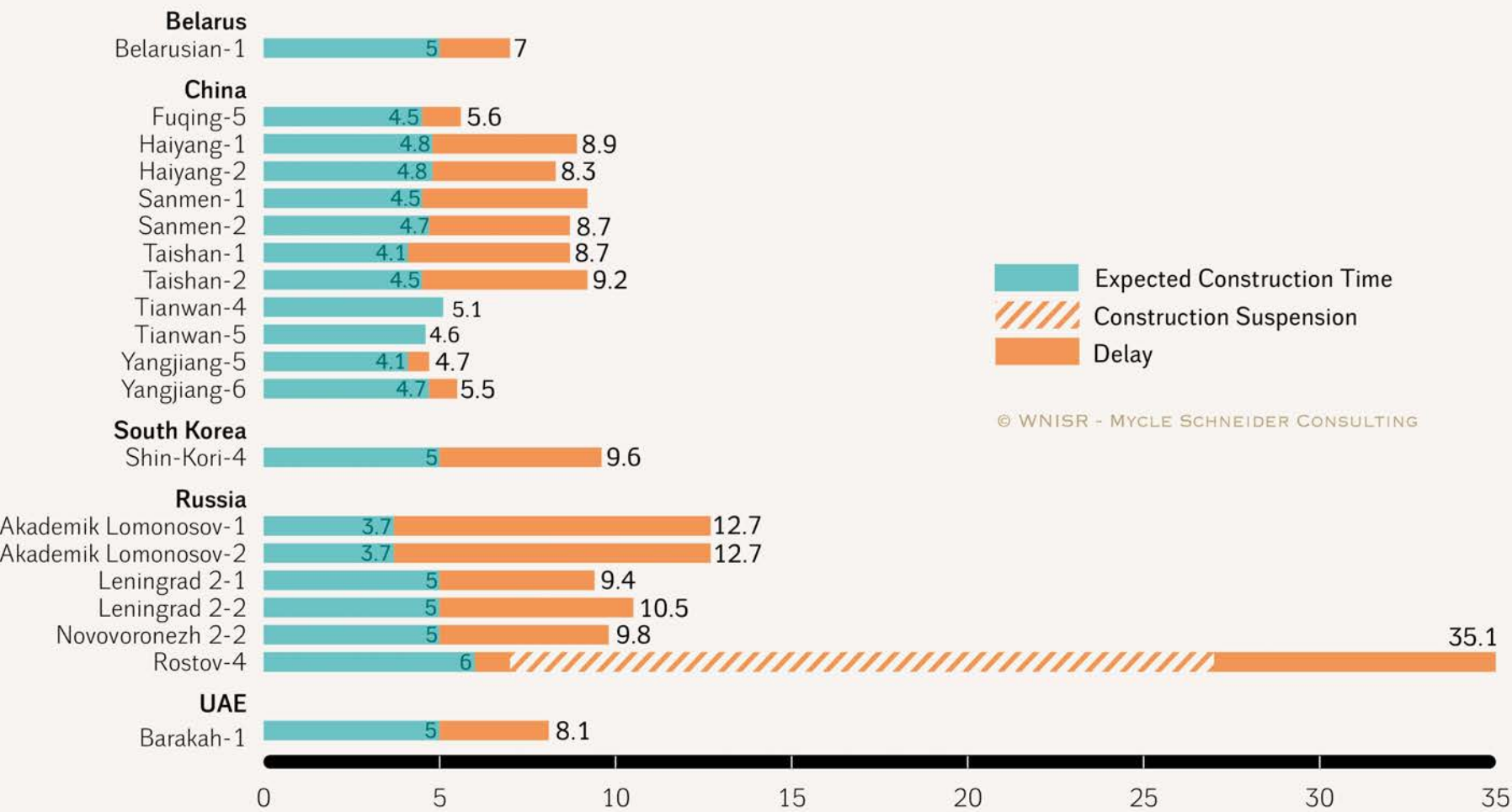


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Sources: WNISR, with IAEA-PRIS, 2021

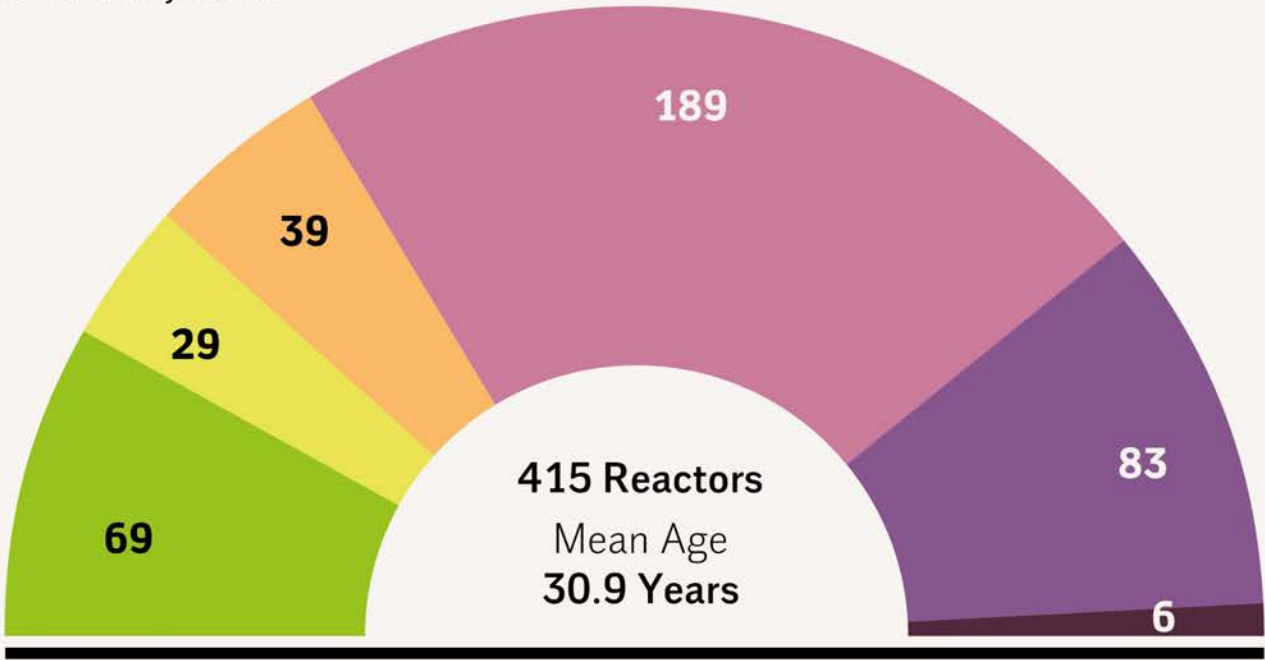
Expected vs. Real Duration from Construction Start to Grid Connection for Startups 2018–2020

in Years



Sources: WNISR, with IAEA-PRIS, 2021

Age of World Nuclear Fleet
as of 1 July 2021



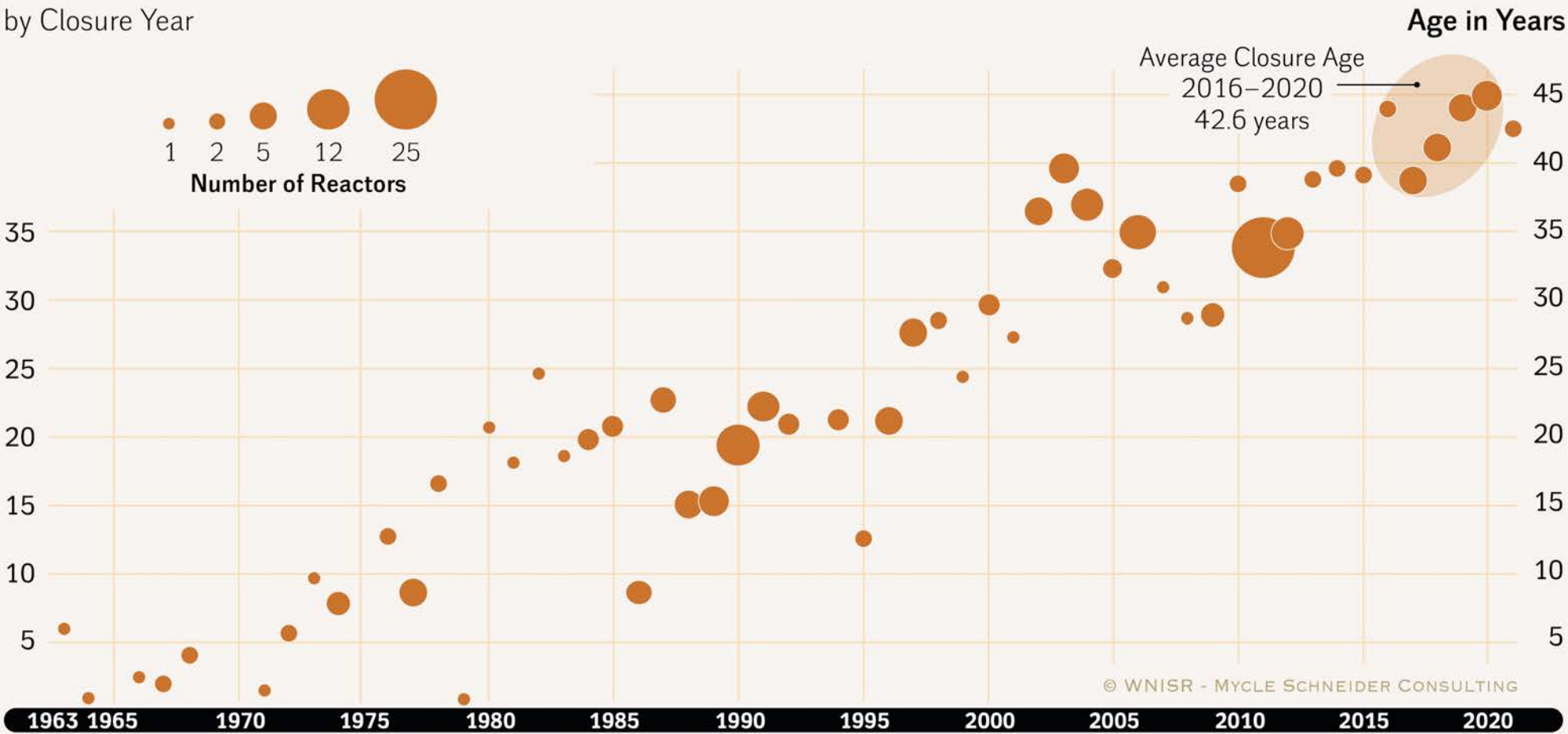
- Reactor Age**
- 0–10 Years
 - 11–20 Years
 - 21–30 Years
 - 31–40 Years
 - 41–50 Years
 - 51 Years and Over
- 50** Number of Reactors by Age Class

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Sources: WNISR, with IAEA-PRIS, 2021

Evolution of Nuclear Reactors' Average Closure Age 1963 – 1 July 2021

by Closure Year

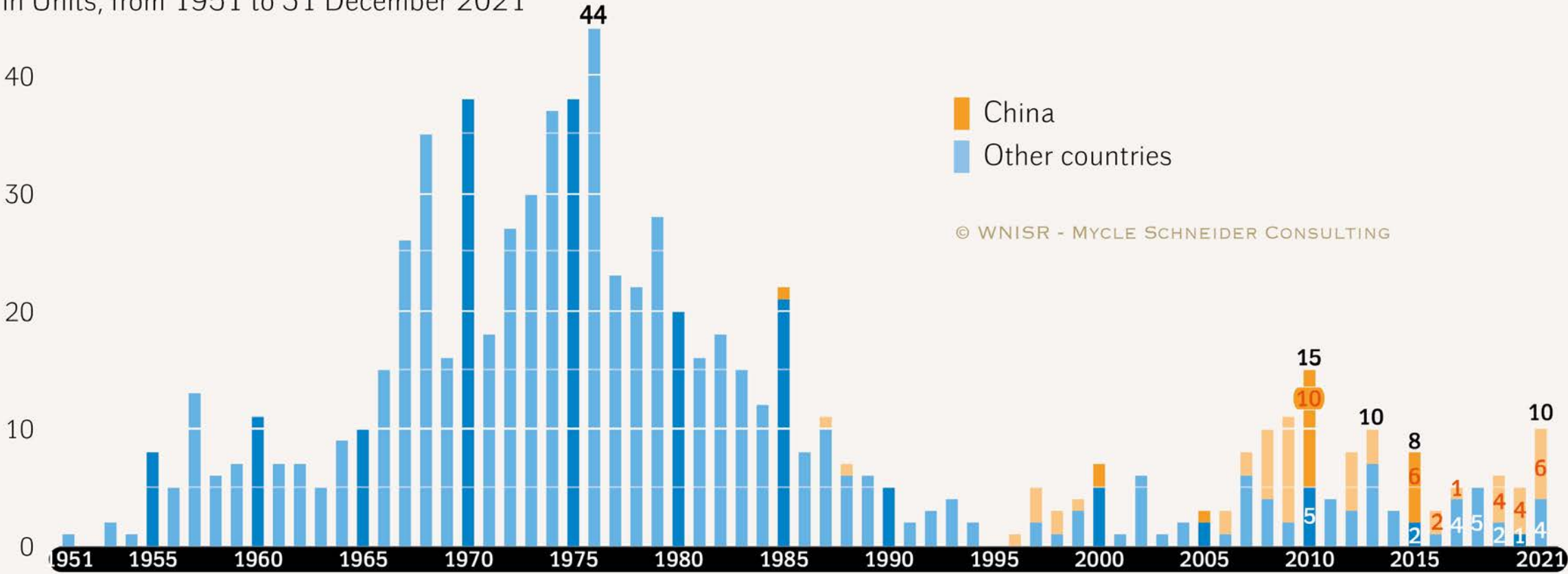


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Sources: WNISR, with IAEA-PRIS, 2021

Construction Starts of Nuclear Reactors in the World

in Units, from 1951 to 31 December 2021

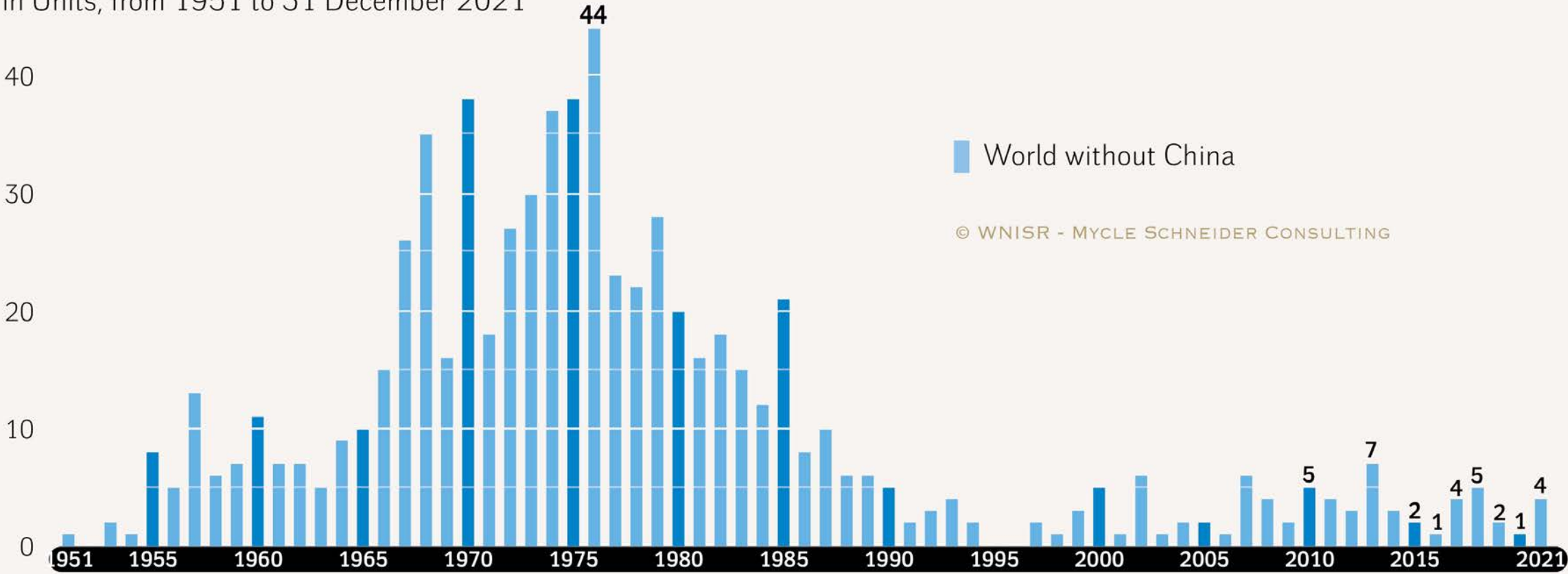


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Sources: WNISR, with IAEA-PRIS, 2022

Construction Starts of Nuclear Reactors in the World

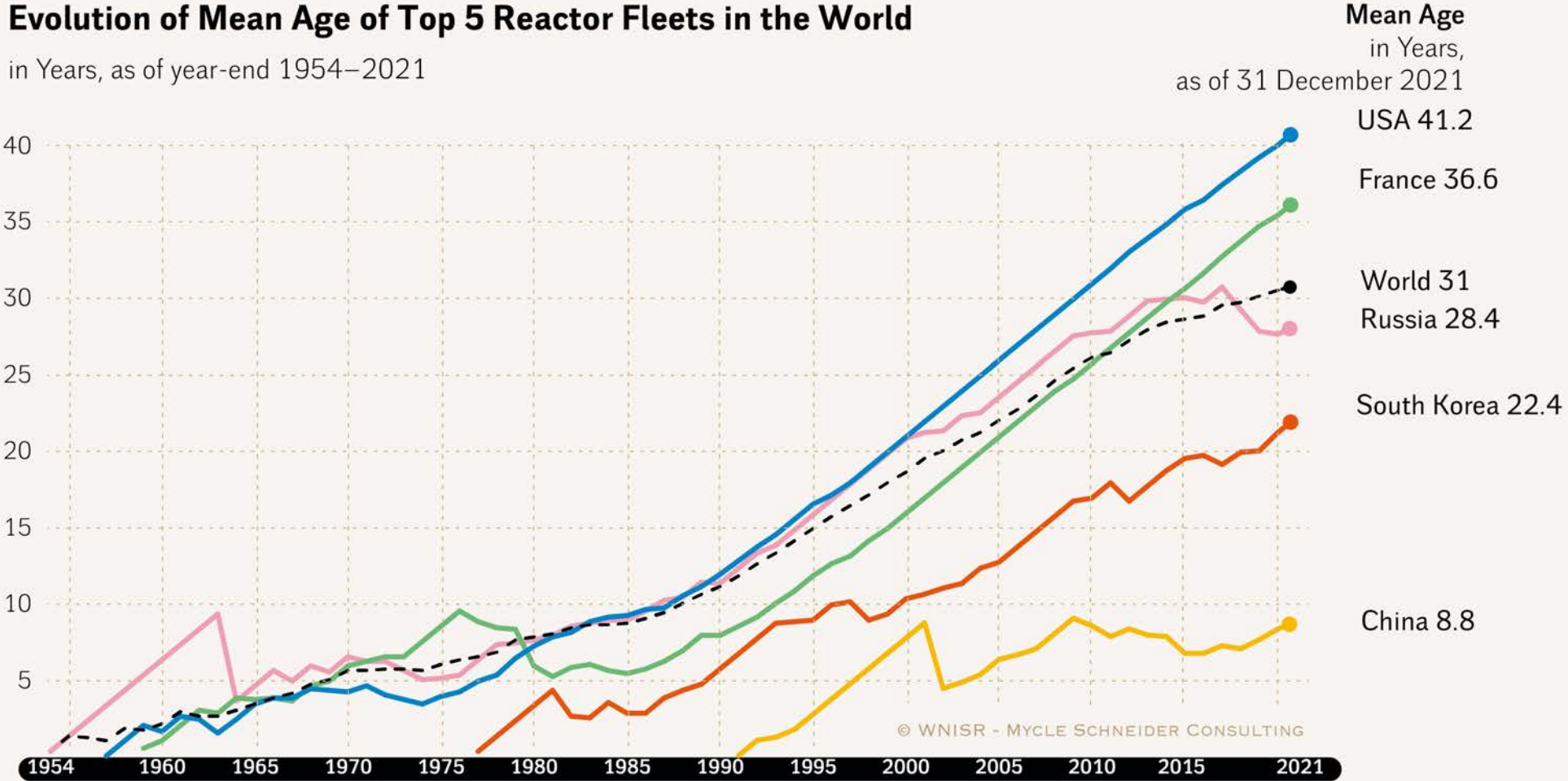
in Units, from 1951 to 31 December 2021



Sources: WNISR, with IAEA-PRIS, 2022

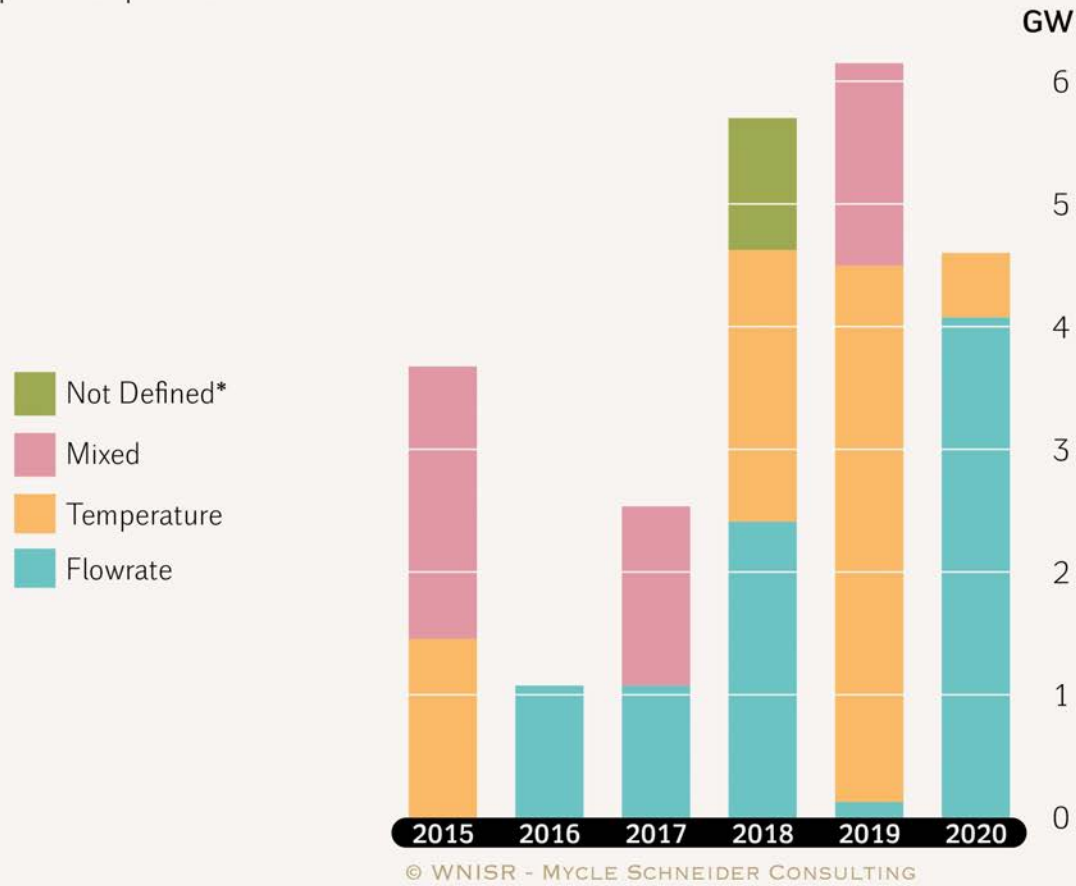
Evolution of Mean Age of Top 5 Reactor Fleets in the World

in Years, as of year-end 1954–2021



Climate Related Unavailabilities of French Nuclear Power Plants 2015–2020 Maximum Simultaneous Unavailable Capacity

in GW per Year per Cause



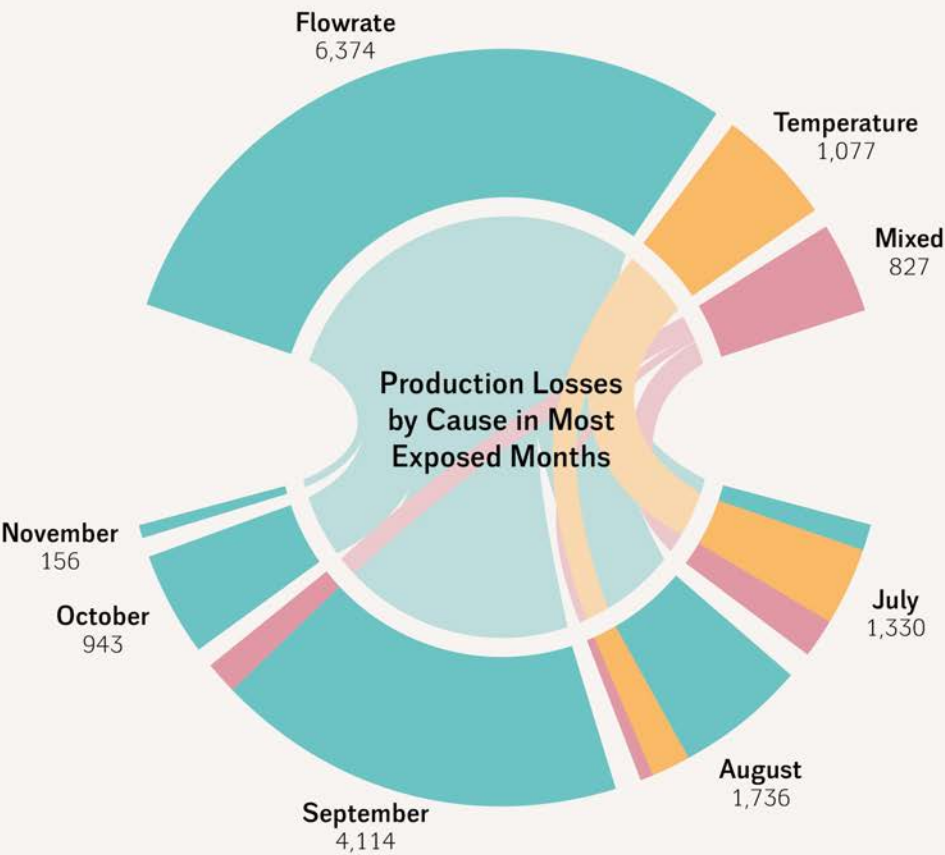
Sources: RTE and Callendar, 2021

Weather-related disruptions of nuclear power production in France since 2015:

- ▶ **357 outages** identified
- ▶ At least a few dozen disruptions a year
- ▶ Up to **2,300 reactor-hours** lost in a year
- ▶ Up to **6.2 GW** unavailable

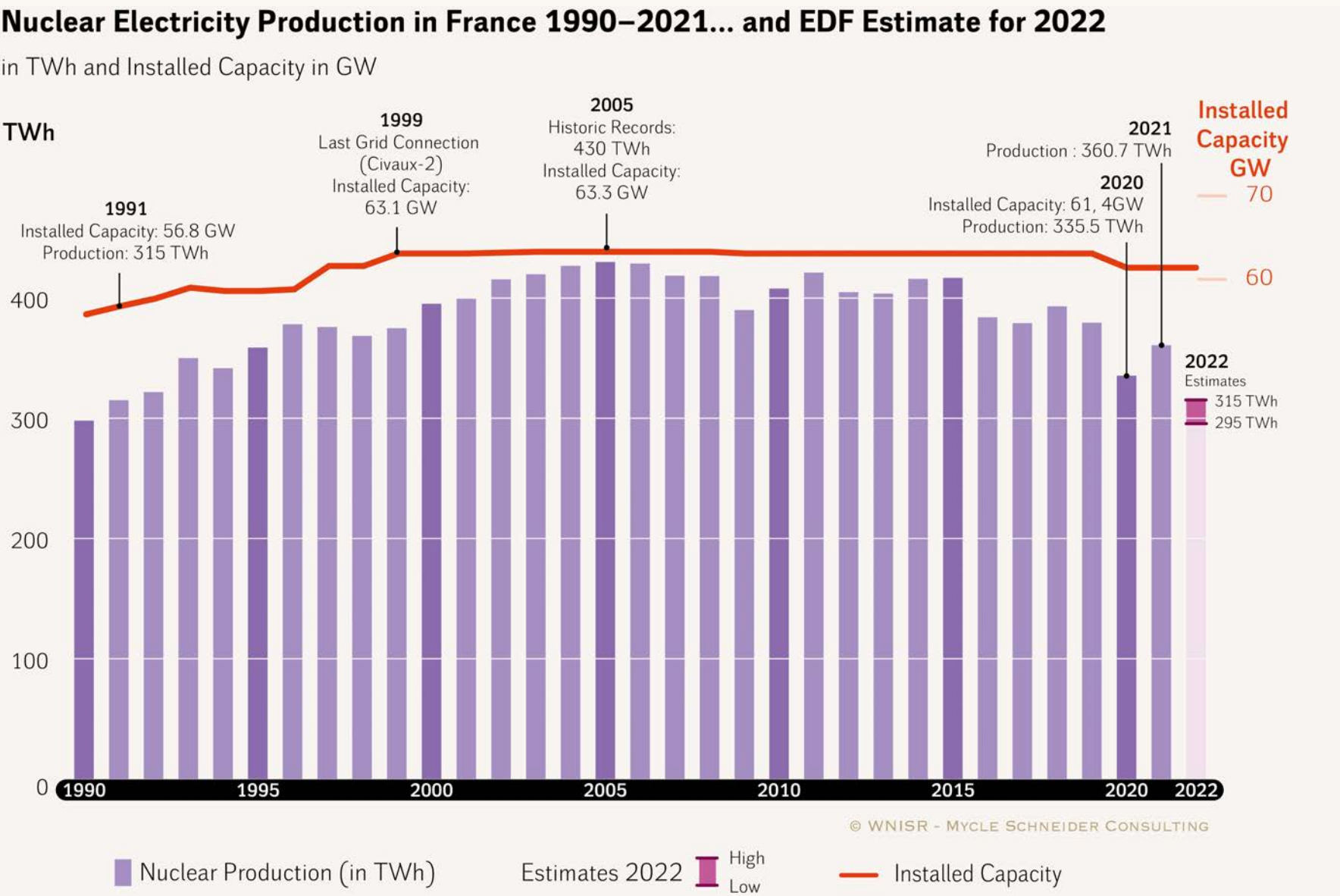
Climate Related Unavailabilities of French Nuclear Power Plants 2015–2020

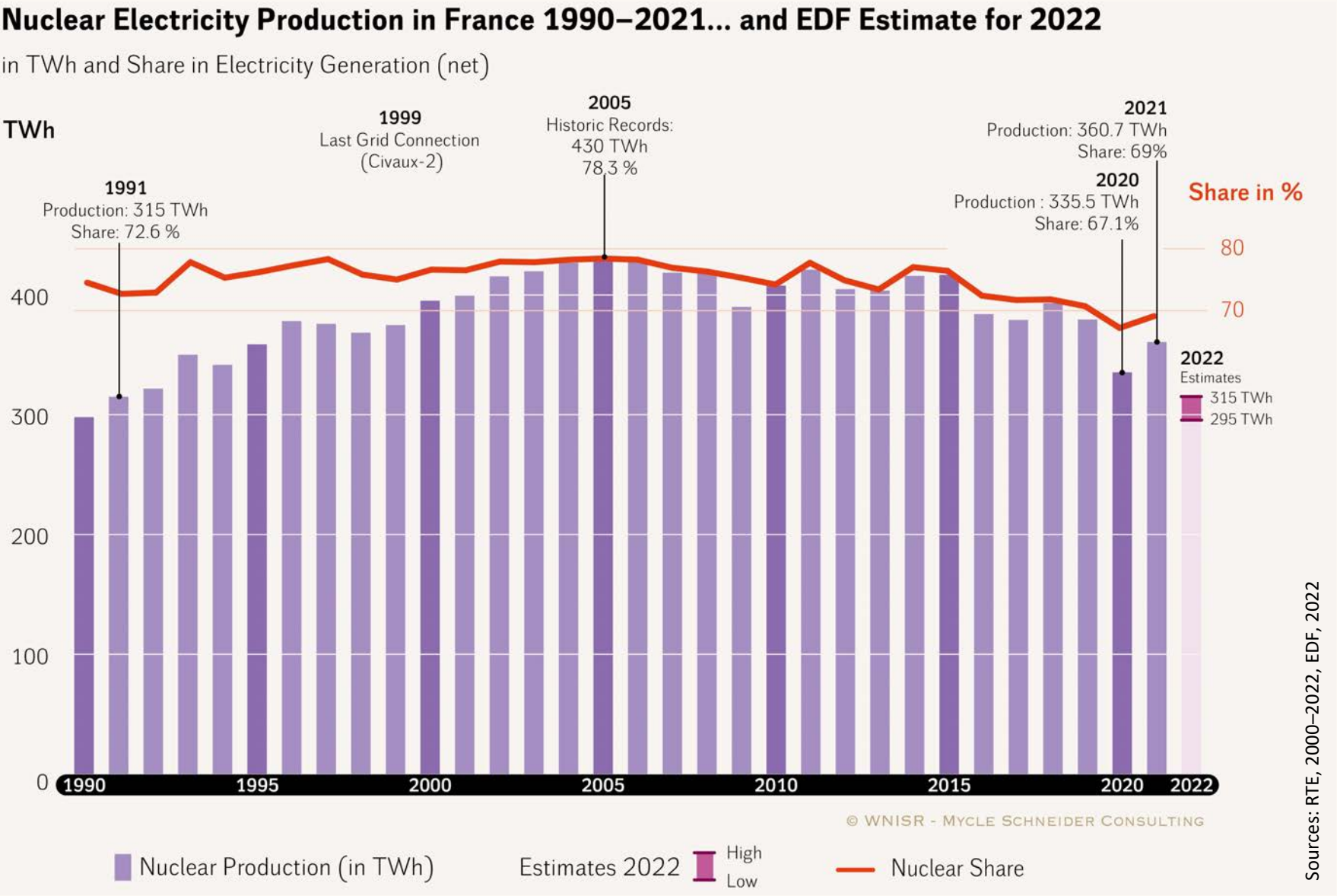
in GWh by Most Probable Cause and Month

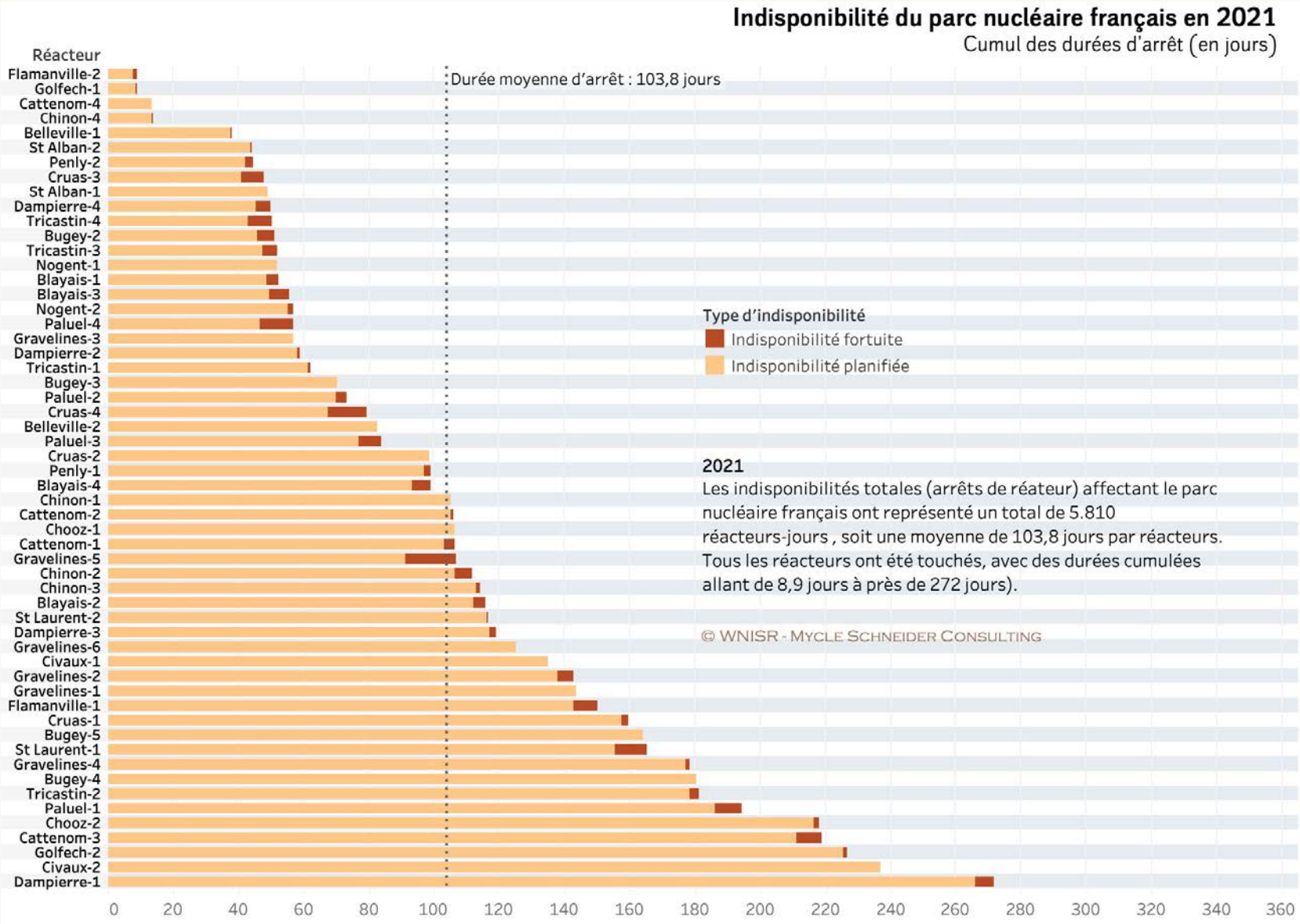


Sources: REMIT, compiled by Callendar 2021

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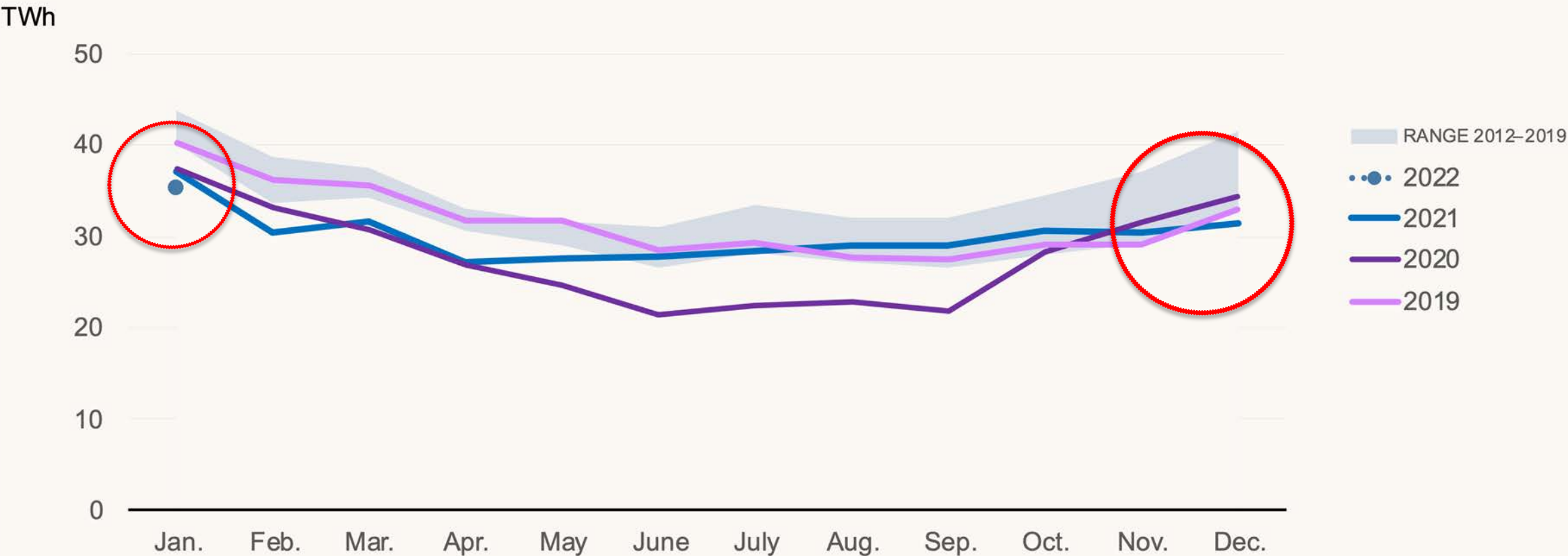




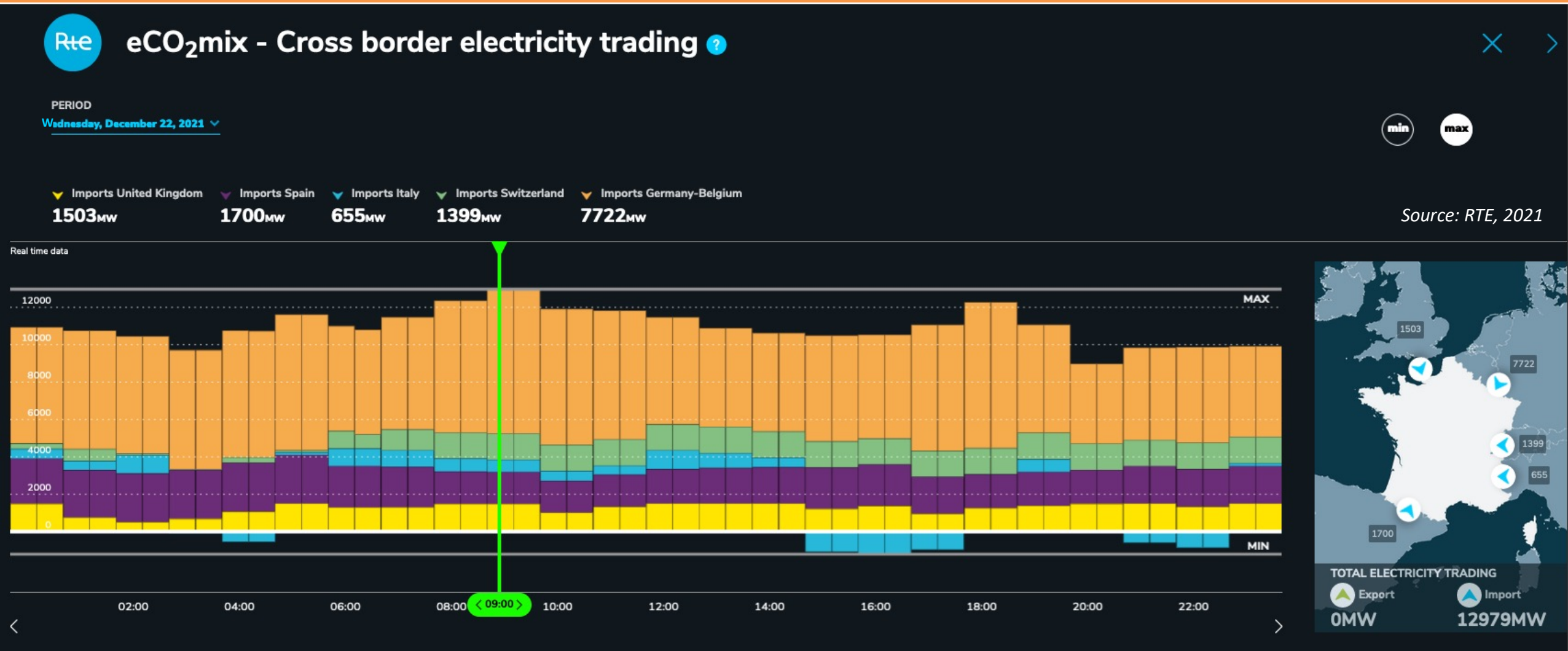
Sources: RTE and EDF, 2022

Monthly Nuclear Production in France

in TWh, 2012–2022

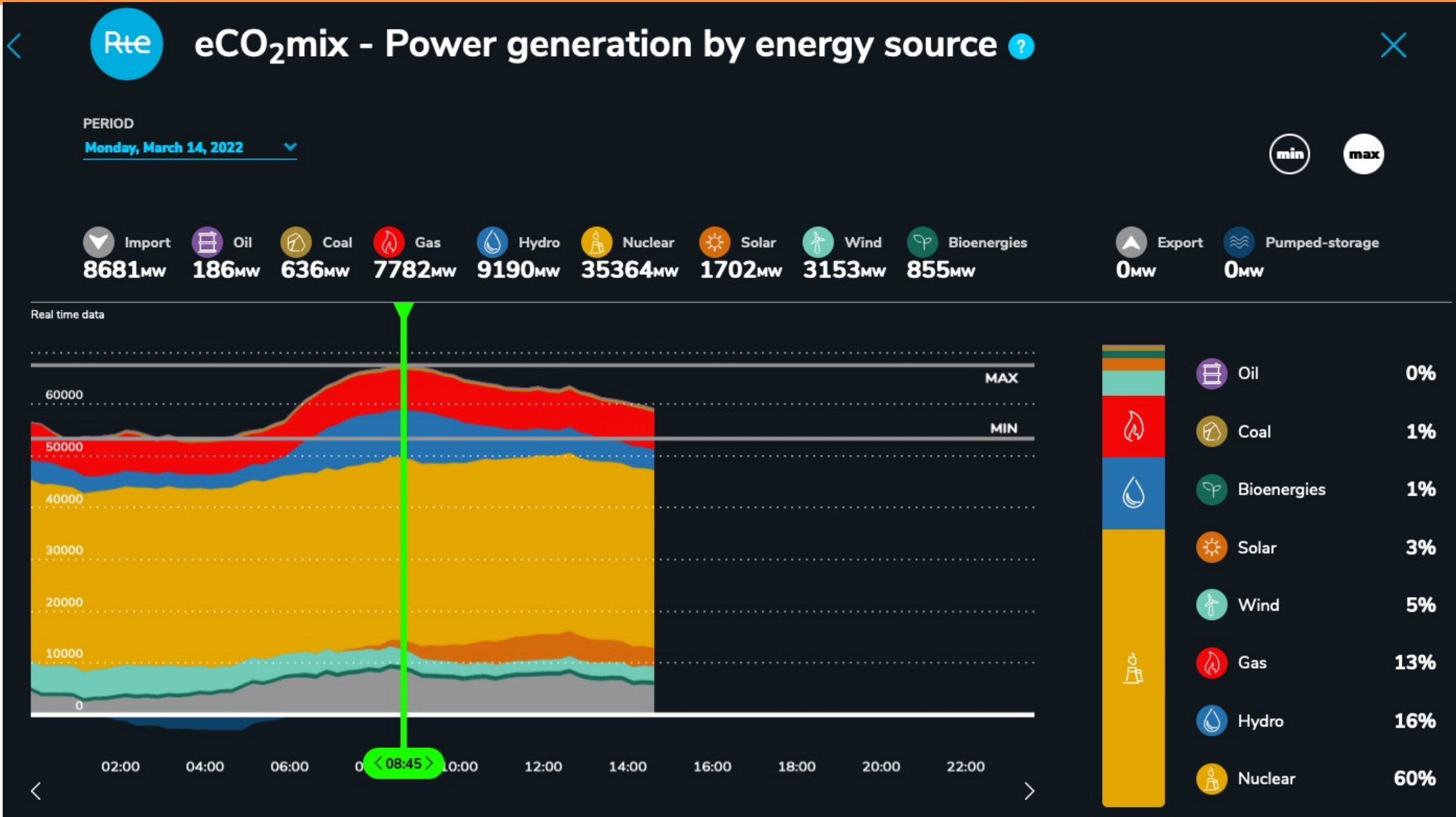


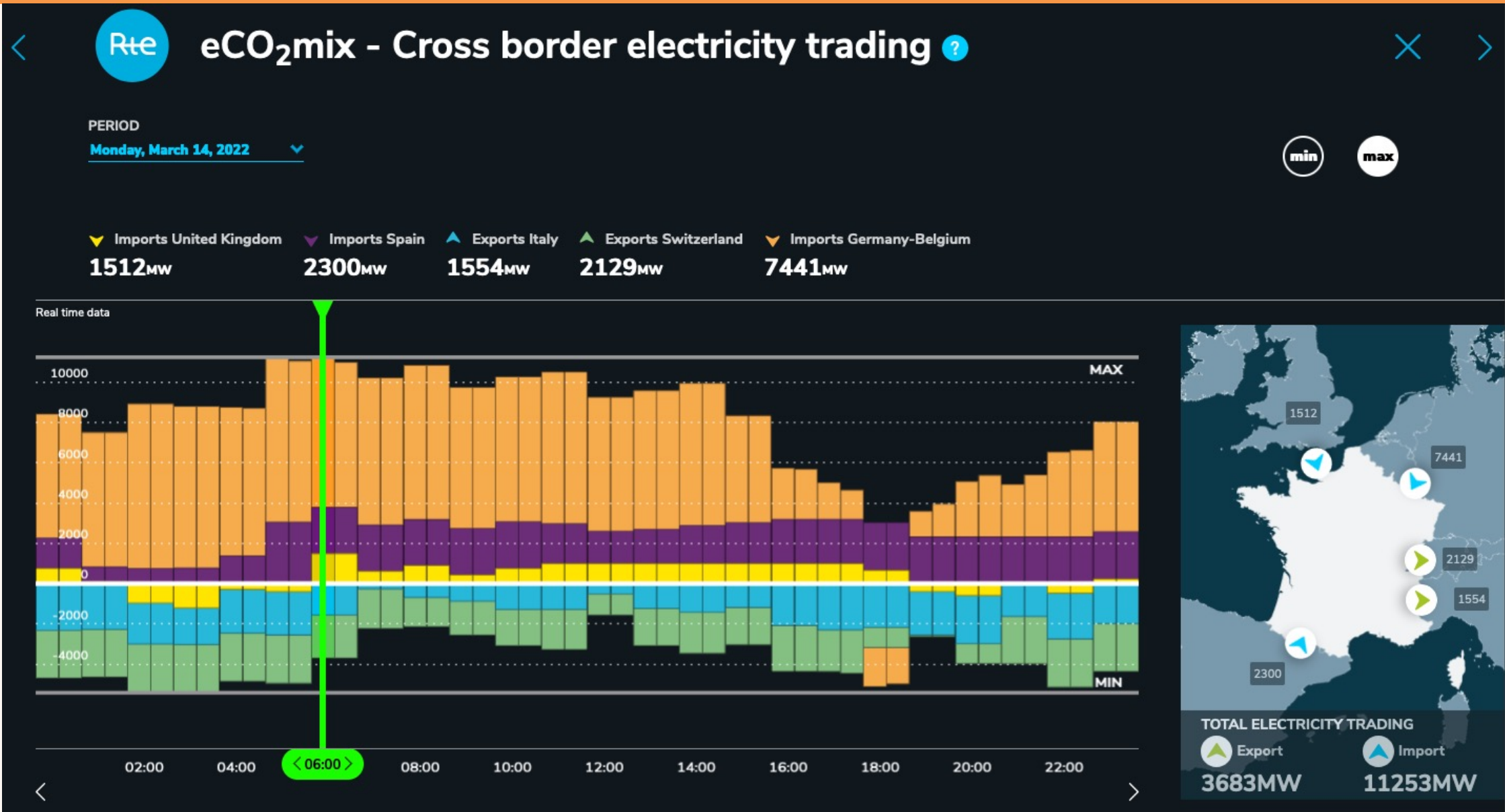
Source : RTE, EDF, 2021-22



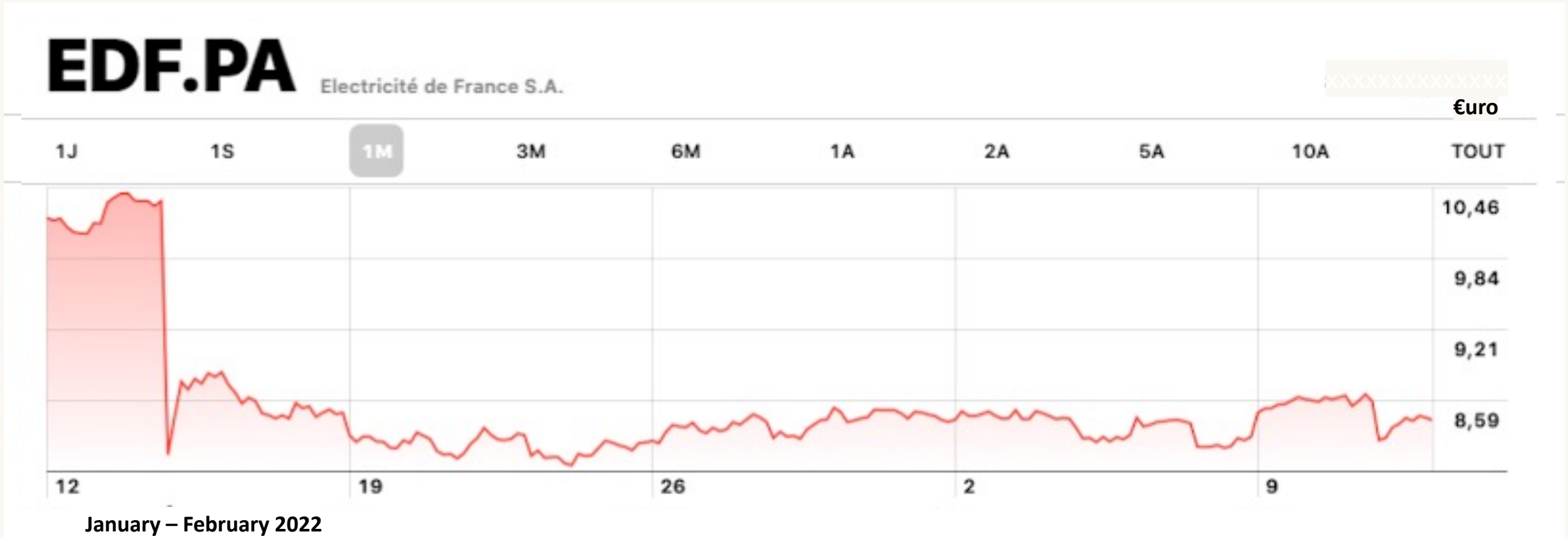
**French Power Trade
22 December 2021**

- Net import most of the day
- Min. >9 GW net
- Max. 13 GW net from all neighbouring countries
- >60% from Germany / Belgium





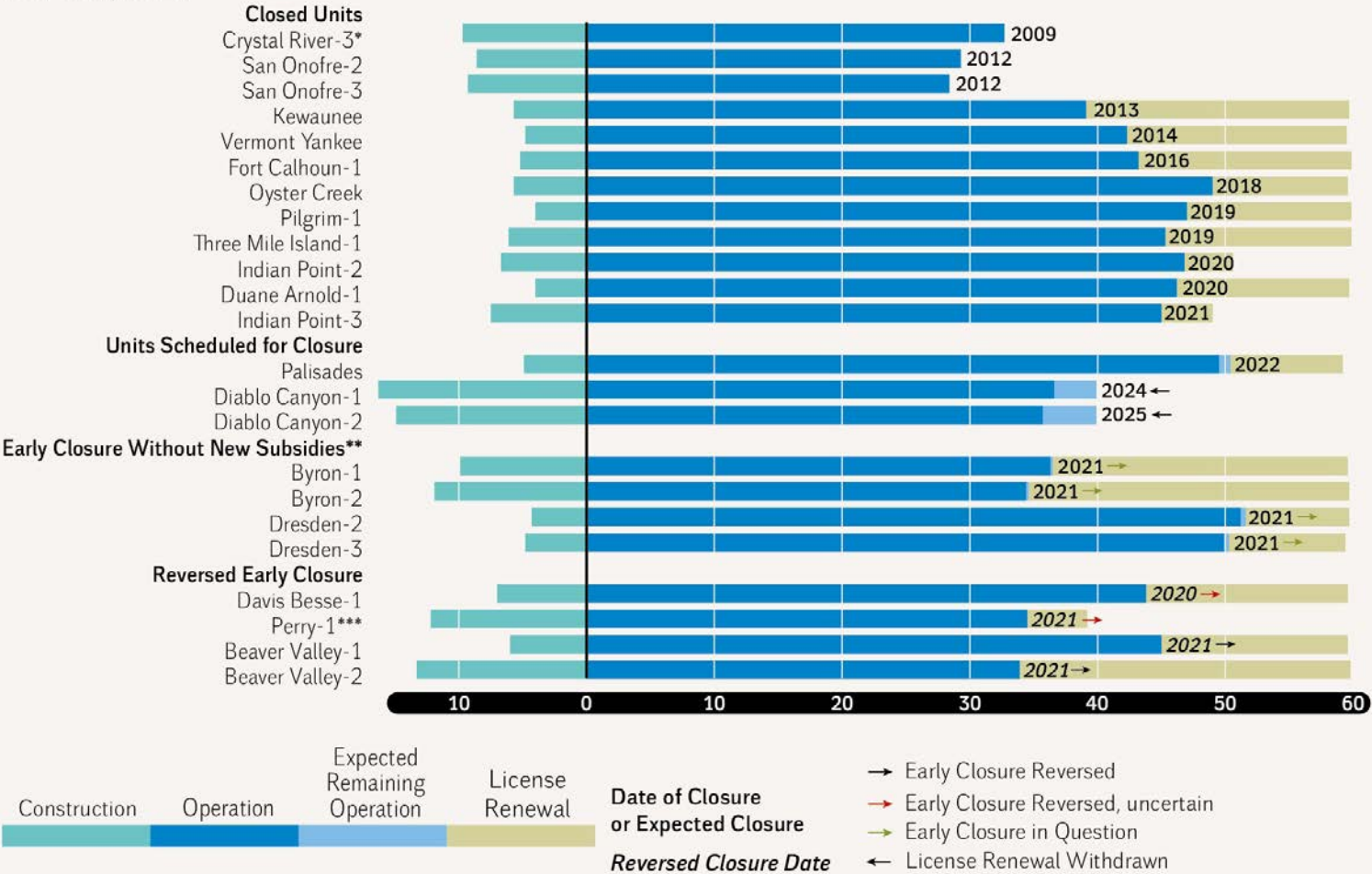
Friday, 14 January 2022: EDF shares plunge by 23% at stock market opening



Source: Yahoo Finance, 13 February 2022

Timelines of 23 U.S. Reactors Subject to Early-Retirement 2009–2025

as of 1 July 2021



Sources: Various,, compiled by WNISR, 2021

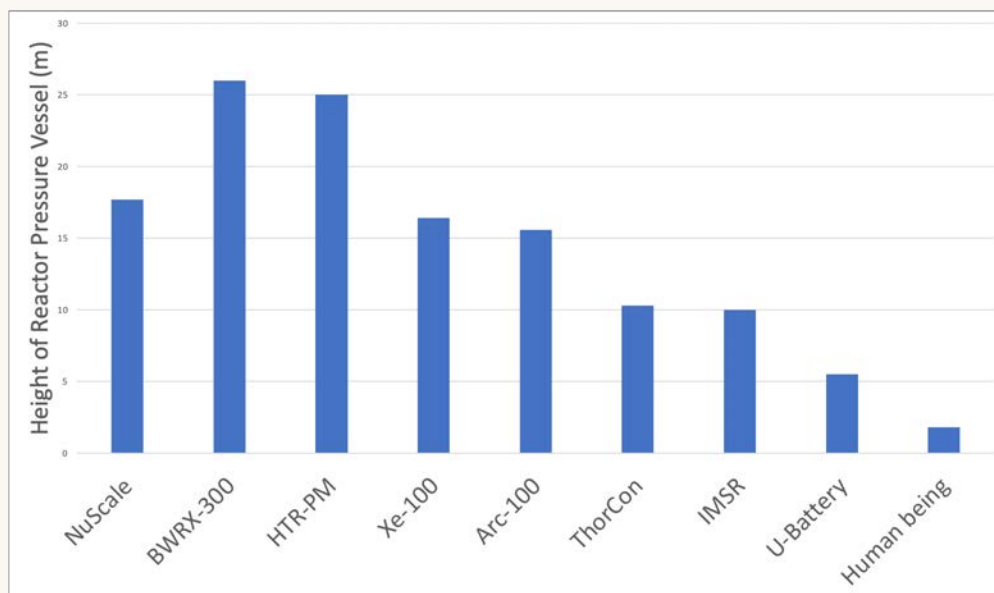
- Lots of media coverage
- Some public funding
- Favourable regulation



France

- 2000-2010 (?): Areva promoted NP300
- 2011: DCNS company promoted Flexblue
- 2012 onwards: EDF-led consortium with CEA, Naval Group, and TechnicAtome, France develops NuWard design (formal announcement in 2019)
 - Eur50 million from French government
 - Eur1 billion promise from Macron

Size	Capacity
Small	< 300 MWe
Medium	300 to 700 MWe



Source : ARTE TV, <https://www.arte.tv/fr/videos/107547-000-A/nucleaire-mini-reacteur-pour-maxi-controverse/>

- Assembled from factory-fabricated modules
- Each module represents portion of finished plant
- Current large nuclear plants require substantial amount of field work

- **Argentina**

Carem-25 construction start 2014; November 2020 report: “physical completion of Carem 25 is at 70%”; completion “within 3 years”?

- **China**

HTR-PM construction start 2012; projected to generate electricity in 2017; grid connection in December 2021 (4+ years late)

- **Russia**

KLT-40S construction start 2007; projected to start operations in October 2010; commissioned in May 2020; load factors in 2020 just 29 and 16 percent (remote location)

Case Study NuScale

2008 projection: electricity generation by 2015-16; current: 2029-30?

2020: Advisory Committee on Reactor Safeguards identification of problems with steam generator and boron dilution

Increasing costs in UAMPS project: from \$3 billion for 600 MWe (gross) in 2014 to \$5.32 billion for 462 MWe (gross) in 2021; per unit cost of \$11,515/kW = 80 percent more than AP 1000 reactors at Vogtle when construction started (whose costs have more than doubled since then)

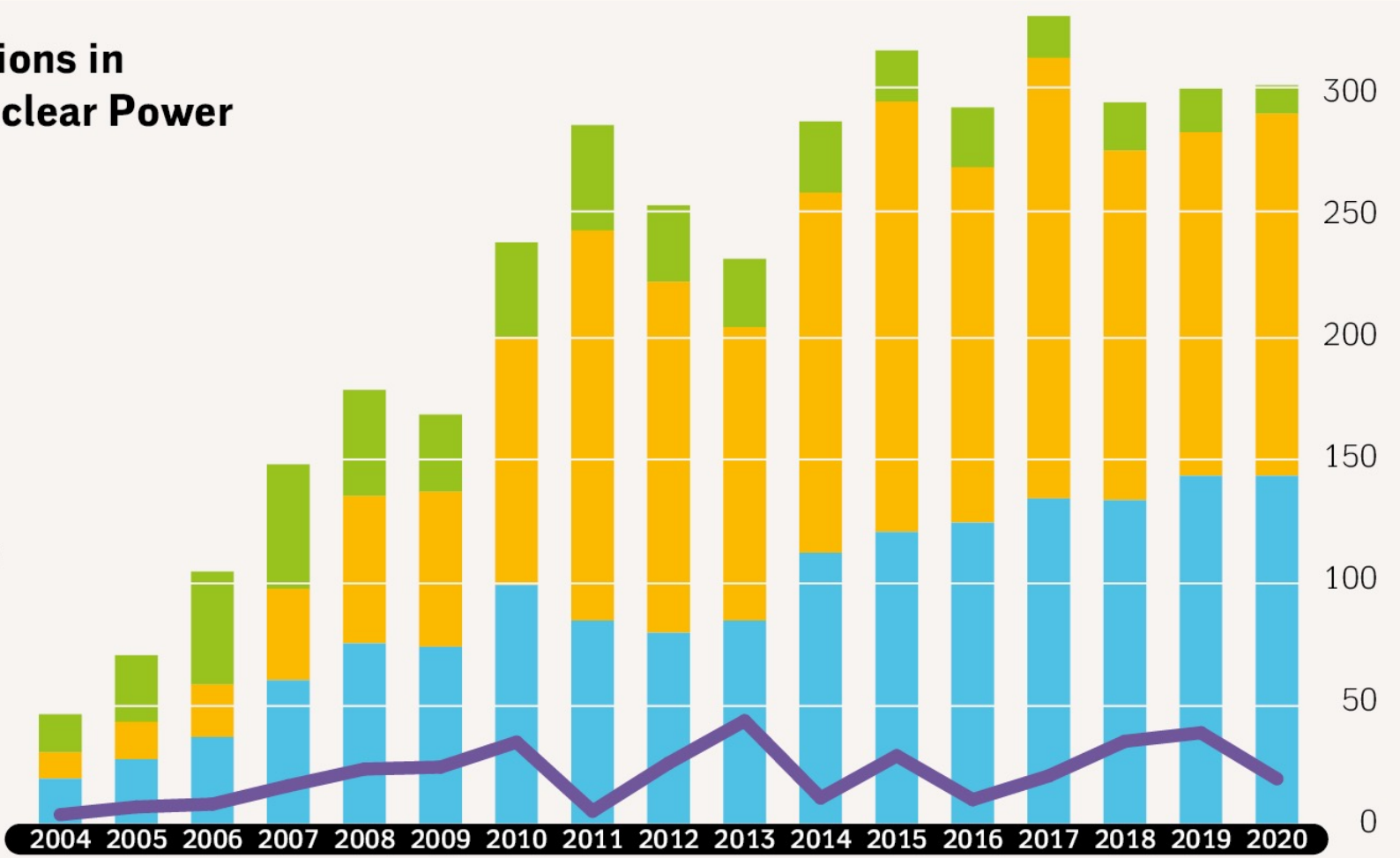
- **Loss of economies of scale**
 - Nuclear power is already costly
- **More spent fuel/proliferation potential**
 - Accentuates problems

Global Investment Decisions in New Renewables and Nuclear Power

in US\$ billion, 2004-2020

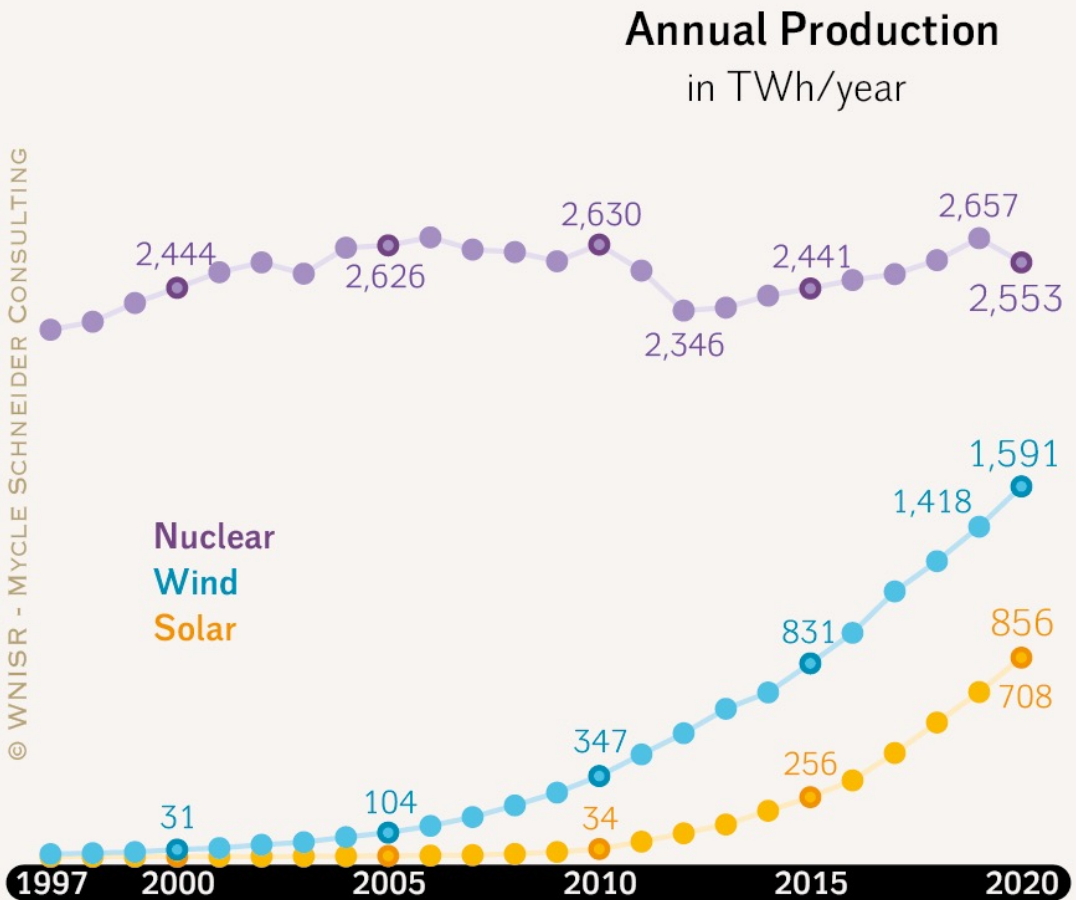
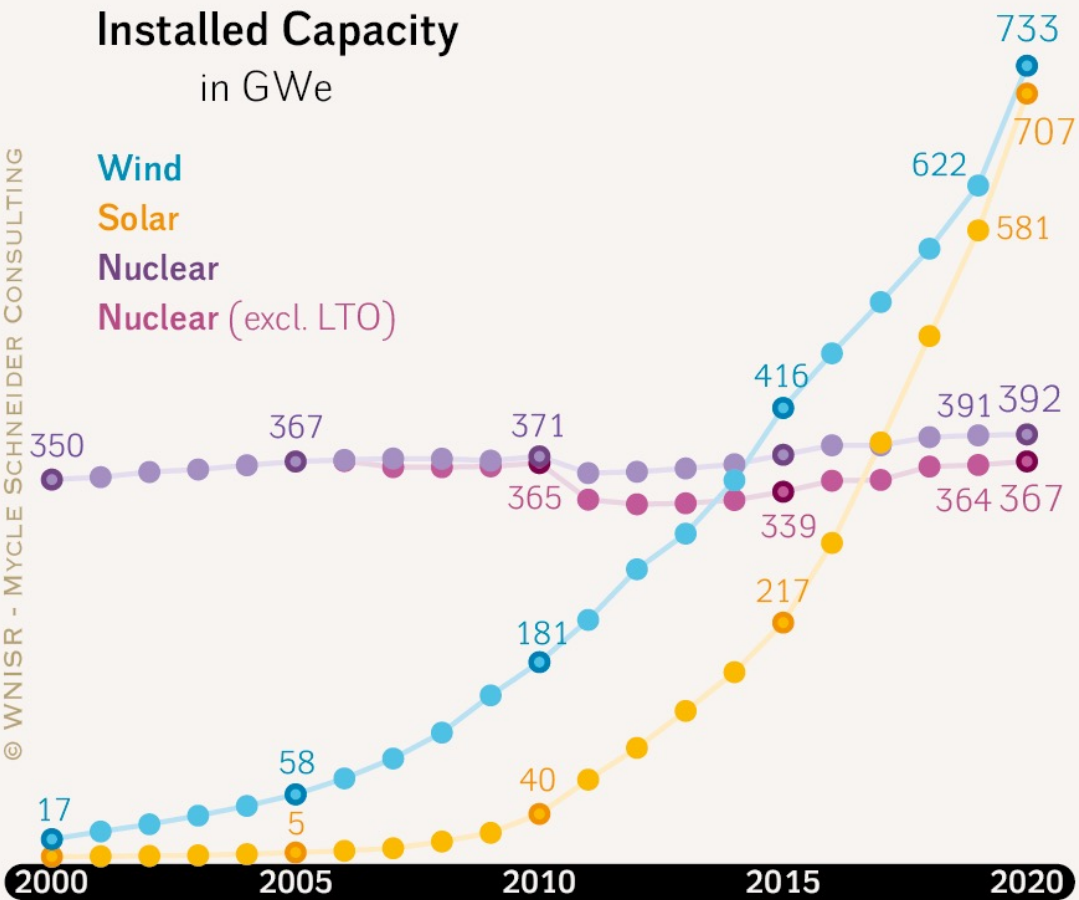
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- Other Renewables
- Solar
- Wind
- Nuclear*



Sources: FS-UNEP/BNEF 2018, 2020, REN21 2019, BNEF 2021 and WNISR Original Research, 2021

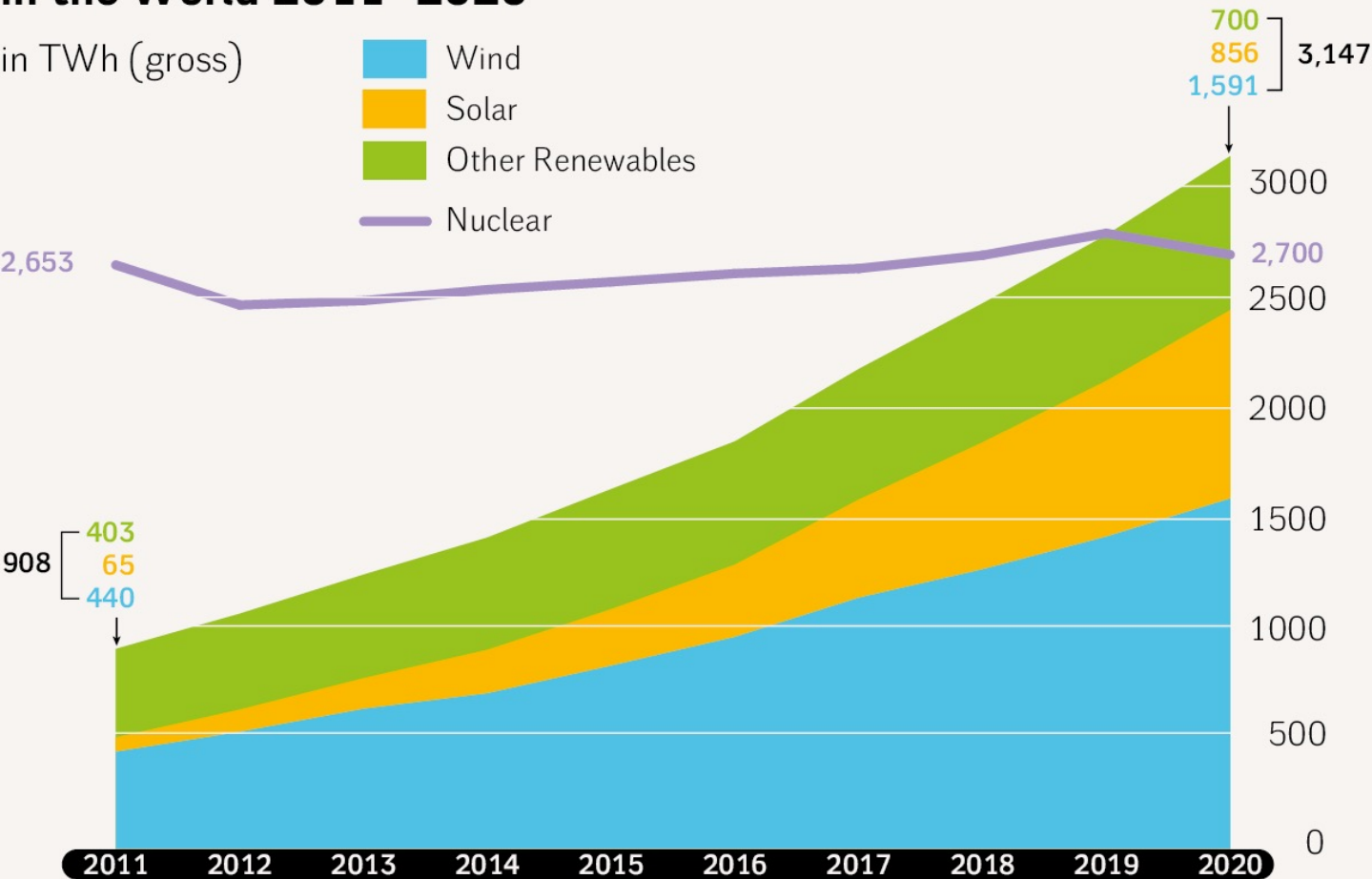
Wind, Solar and Nuclear Capacity and Electricity Production in the World



Sources: WNISR with IAEA-PRIS, IRENA, BP Statistical Review, 2021

Nuclear vs. Non-Hydro Renewable Electricity Production in the World 2011–2020

in TWh (gross)

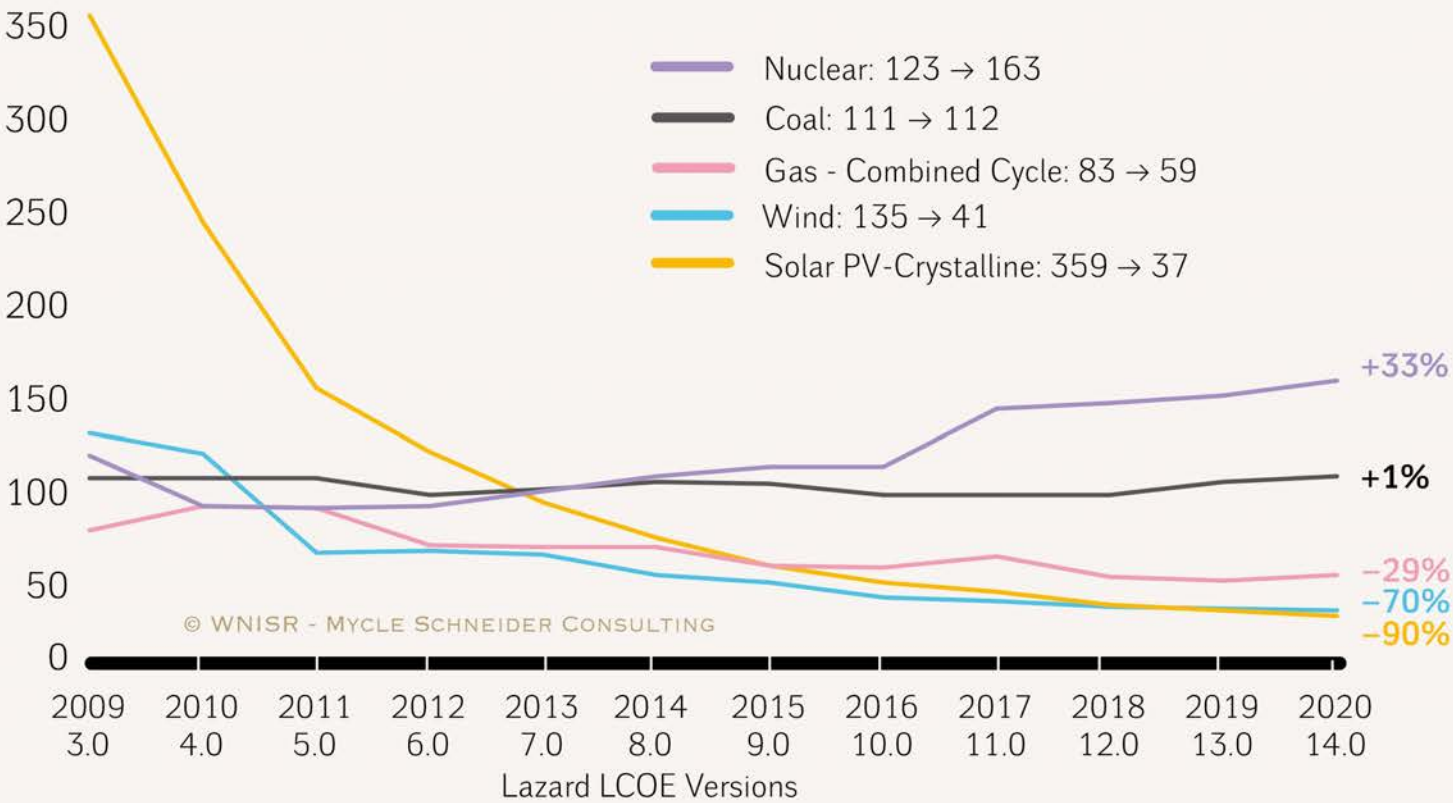


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Sources: BP Statistical Review, 2021

Selected Historical Mean Costs by Technology

LCOE values in US\$/MWh *

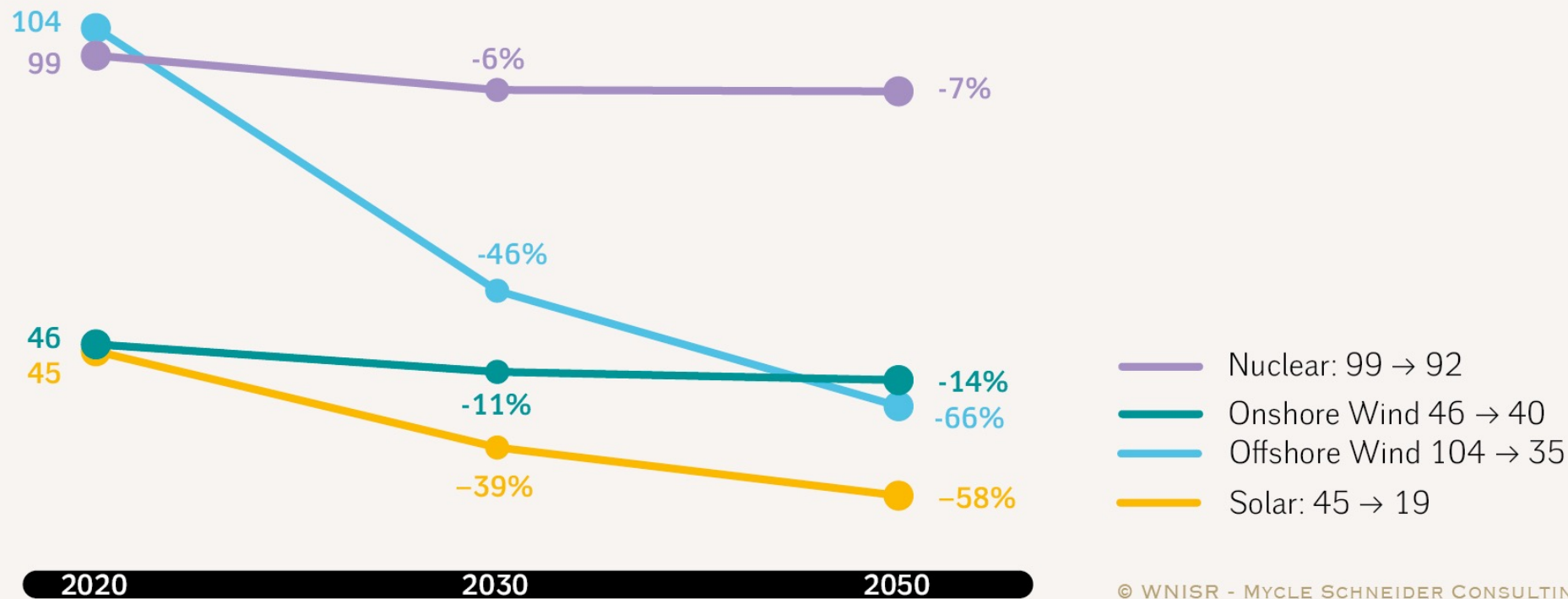


* Reflects total decrease in mean LCOE since Lazard's LCOE VERSION 3.0 in 2009.

Source: Lazard Estimates, 2020

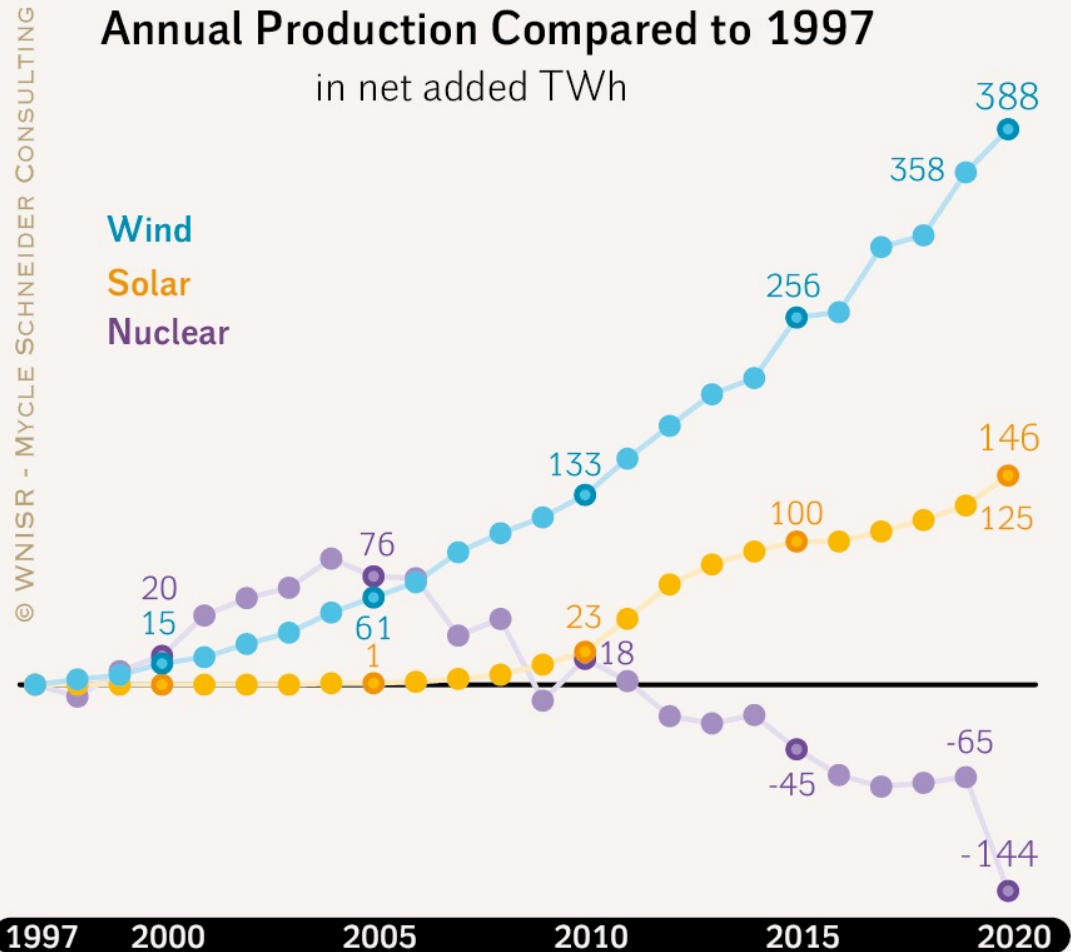
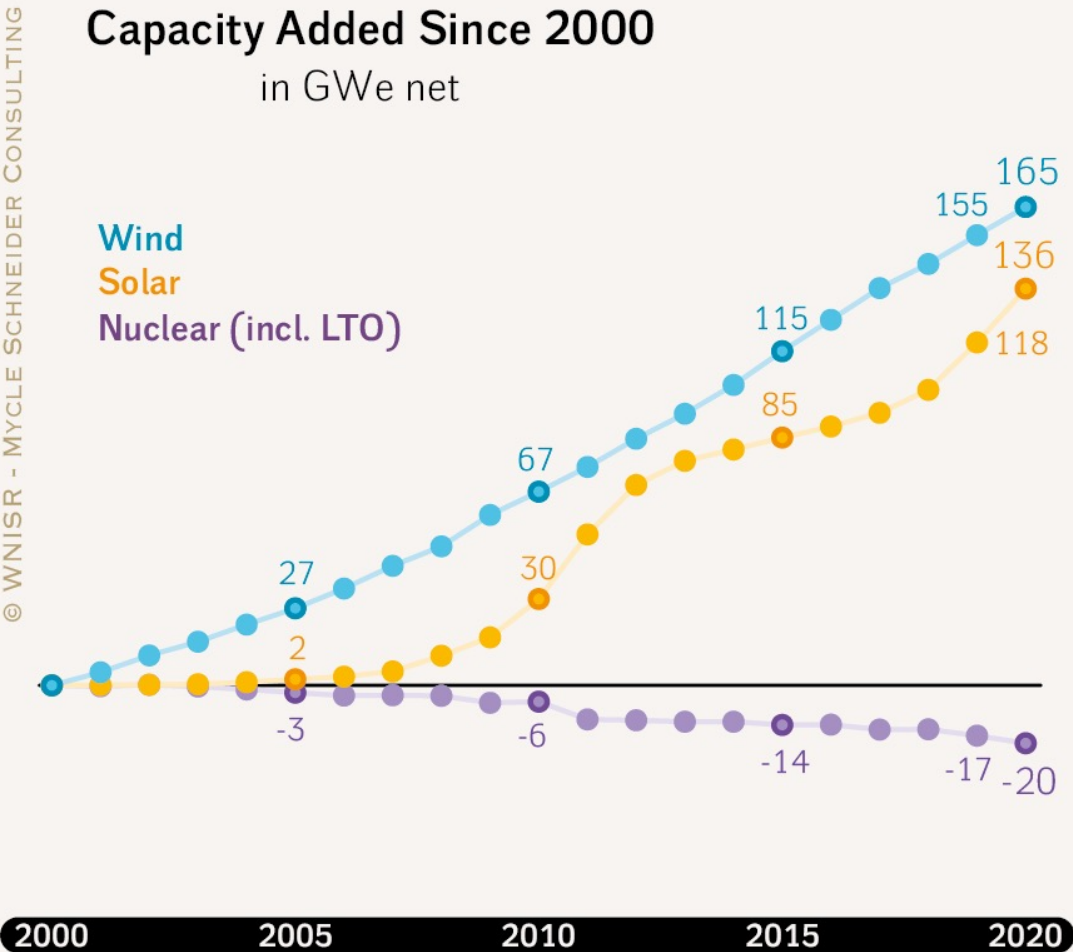
2050 Forecasted Average Cost of Electricity from Nuclear and Renewables

in US\$/MWh

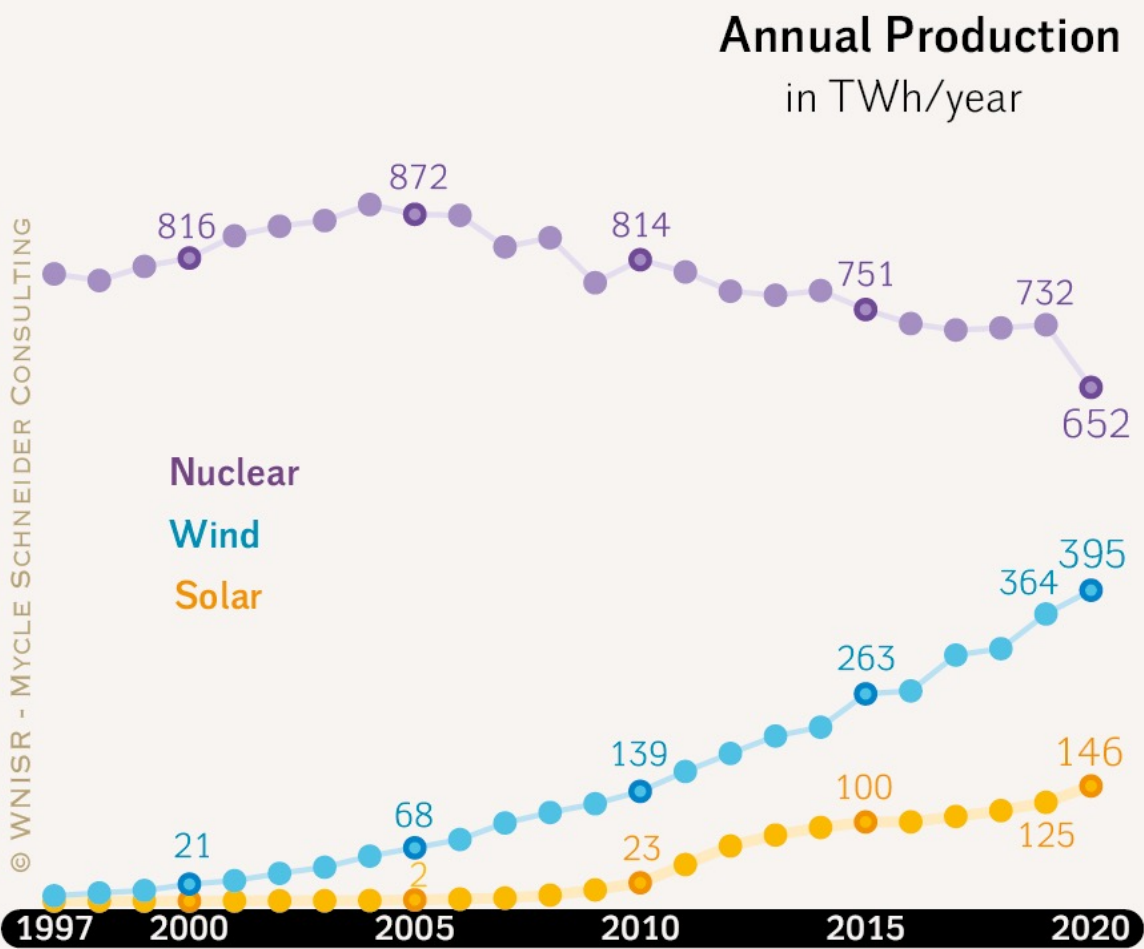
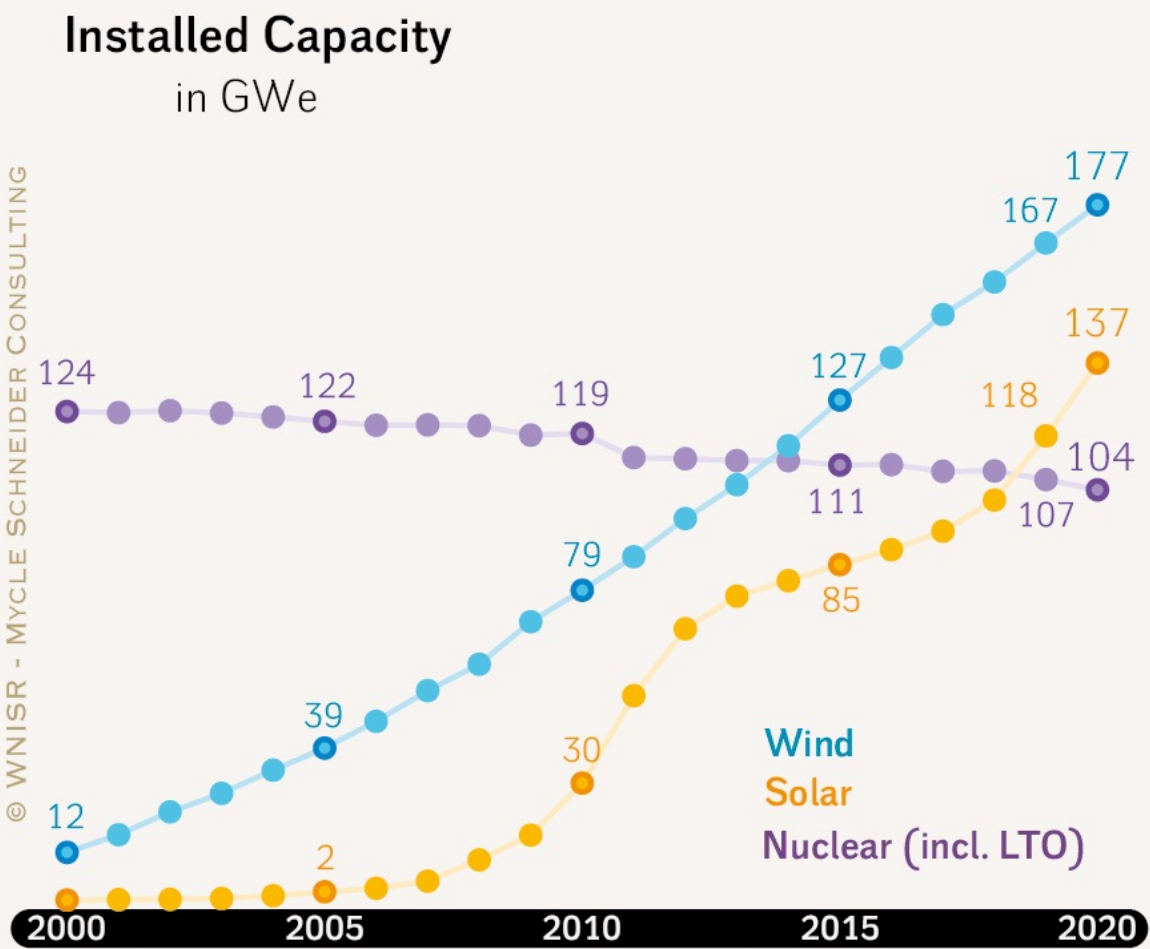


Source: IEA, 2021

Wind, Solar and Nuclear Developments: Installed Capacity and Electricity Production in the EU27



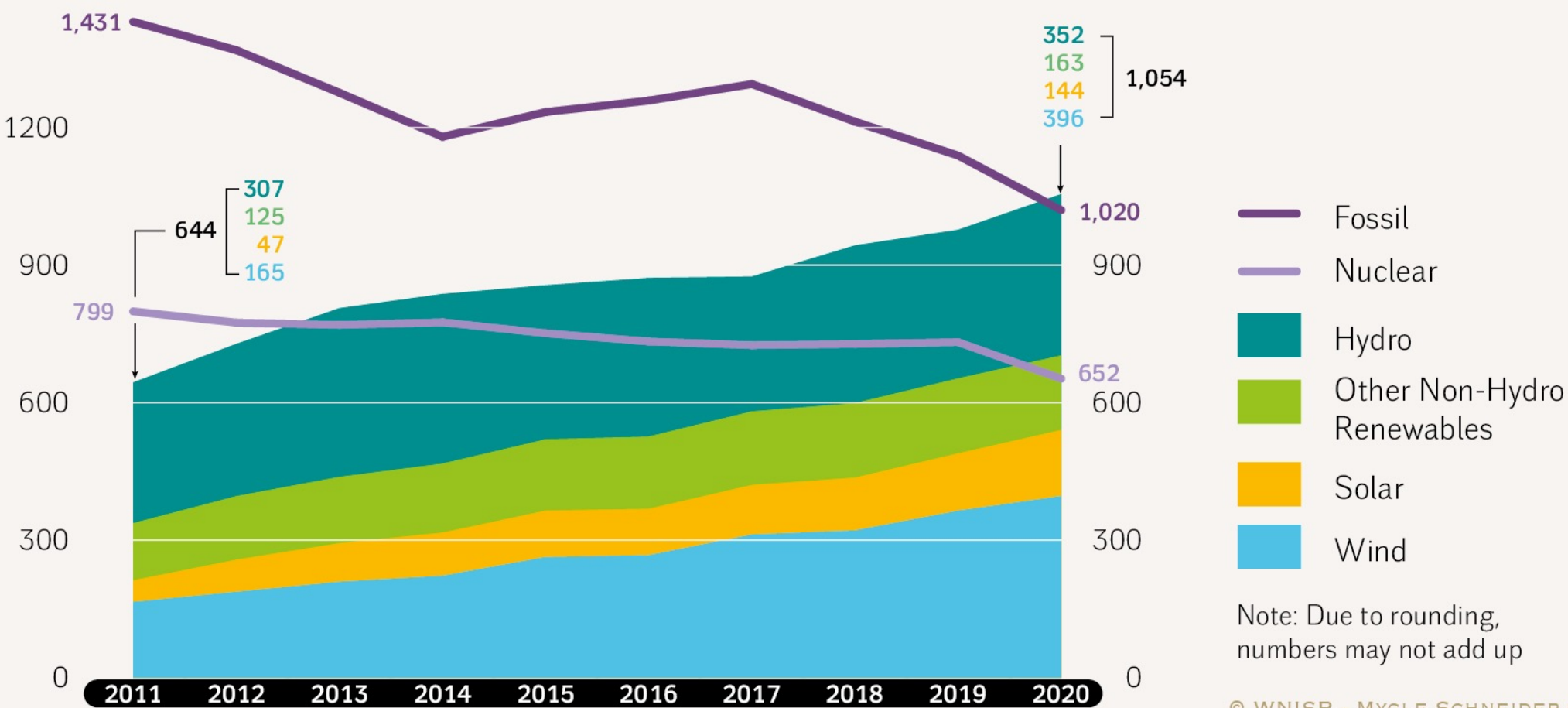
Wind, Solar and Nuclear Capacity and Electricity Production in the EU27



Sources: WNISR with IAEA-PRIS, IRENA, BP Statistical Review, 2021

Electricity Production in the EU27 2011–2020

in TWh/year

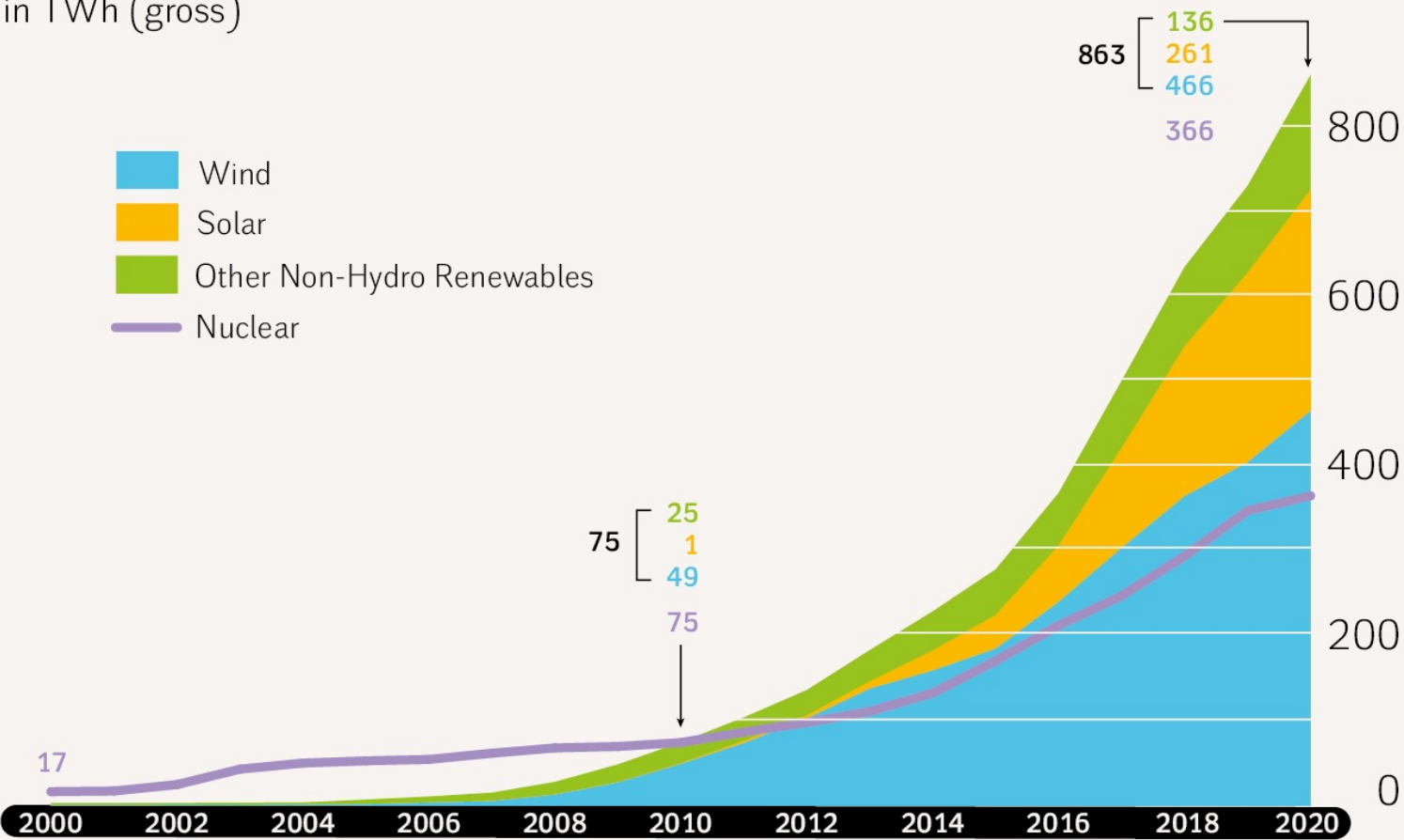


Note: Due to rounding, numbers may not add up

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Nuclear vs. Non-Hydro Renewable Electricity Production in China 2000–2020

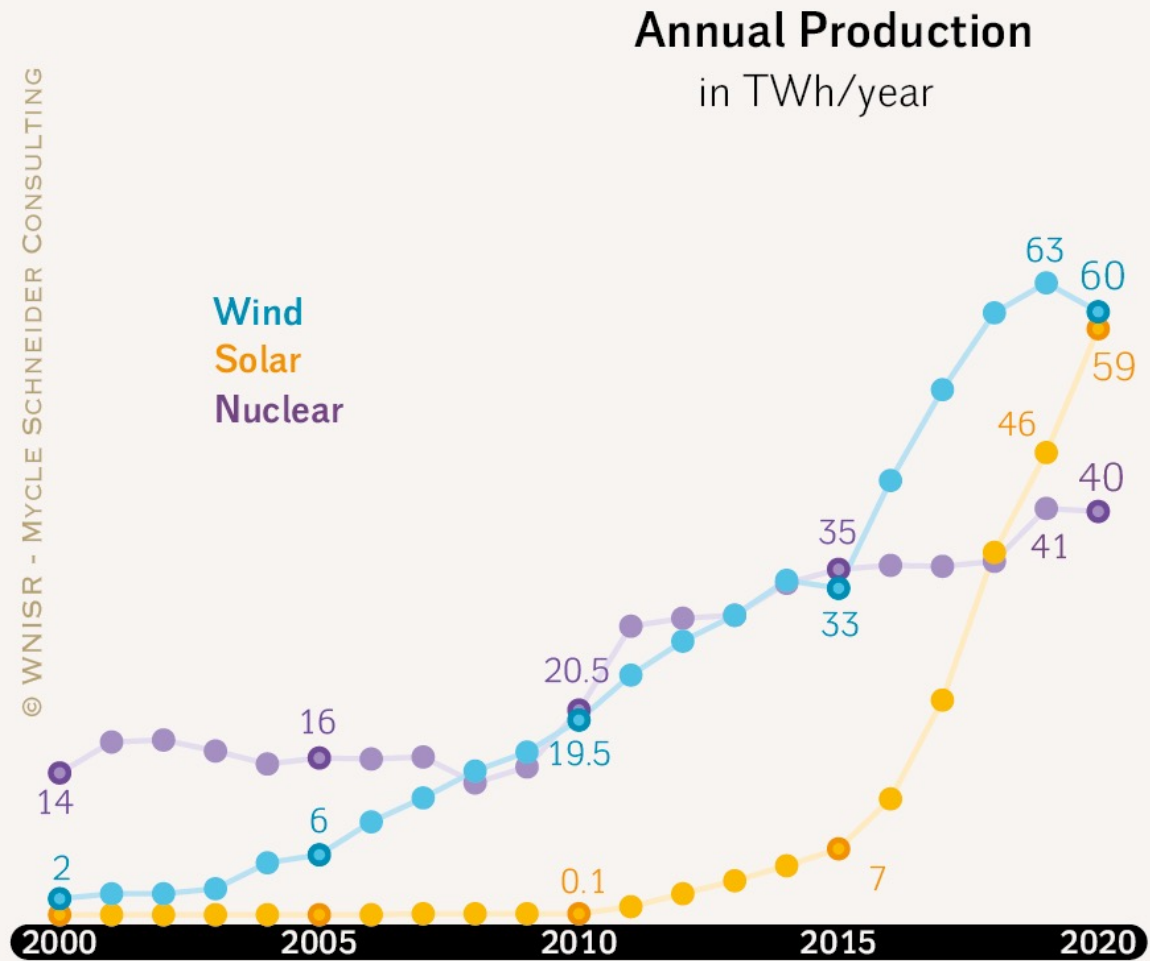
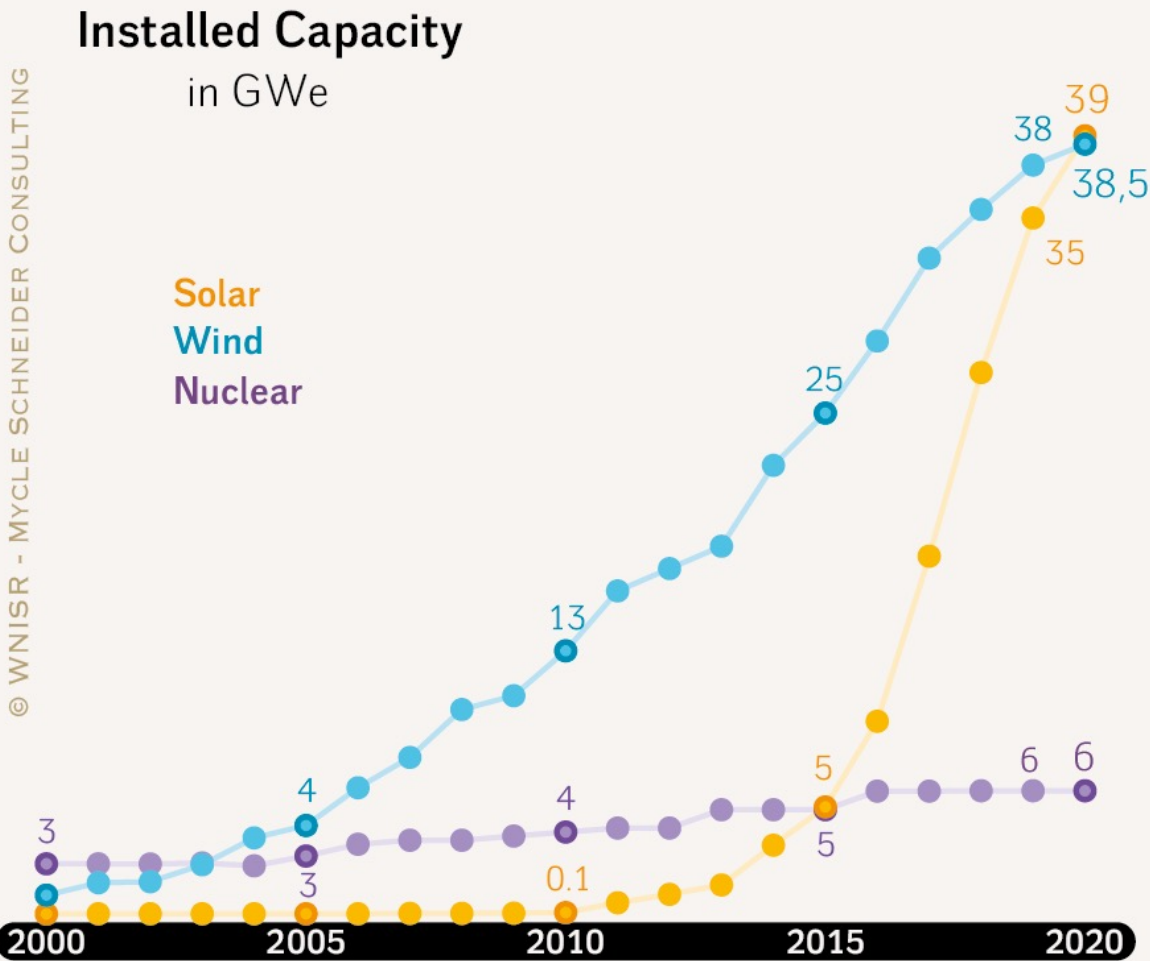
in TWh (gross)



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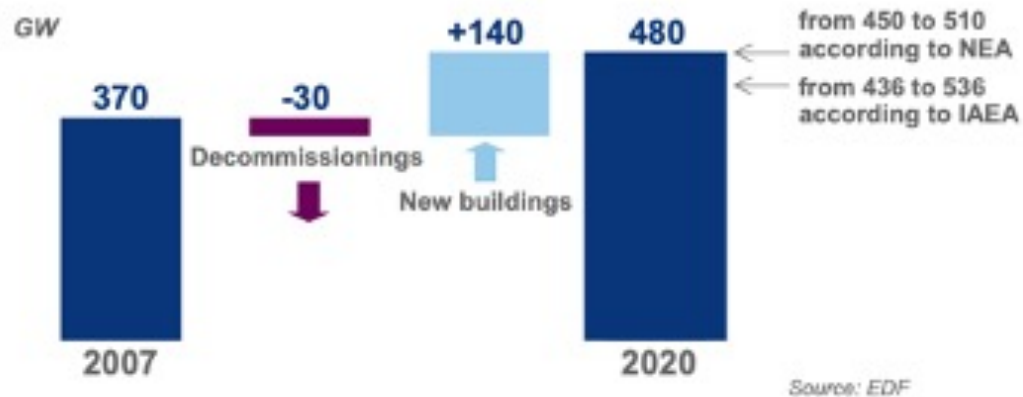
Sources: BP Statistical Review, 2021

Wind, Solar and Nuclear Capacity and Electricity Production in India 2000–2020



Sources: WNISR with IAEA-PRIS, IRENA, BP Statistical Review, 2021

Prospects for the New Nuclear revival: 140 GW to be built by 2020



140 new GW by 2020



- Replacements needed for the decommissioned facilities, in Europe and the United States
- Response to growing demand for electricity, mainly in Asia and Russia



WNISR2008

in the *Bulletin of the Atomic Scientists*

« After thorough analysis it seems surprisingly evident that contrary to the public's perception and the industry's efforts, nuclear power will continue its long-term decline rather than move toward a flourishing future revival. »

Reality 2020

367 GW operating

- 2020 kam es weltweit zu einem beispiellosem Absinken der Atomstromproduktion (mit Ausnahme der post-311 Jahre 2011–12). Der Fall Frankreich illustriert die Schwierigkeiten mit alternden Reaktoren: der Atomanteil im Strommix schrumpfte auf das tiefste Niveau in 35 Jahren.
- Erneuerbare (ohne Wasserkraft)—vor allem Wind, Sonne und Biomasse—haben die Atomkraftproduktion weltweit eingeholt. Wasserkraft alleine produziert seit drei Jahrzehnten mehr als Atomkraftwerke.
- Zum ersten Mal haben Erneuerbare (ohne Wasserkraft) in der EU mehr Strom erzeugt als Atomkraftwerke, und Erneuerbare einschl. Wasserkraft auch mehr als alle fossilen Energien zusammen.
- Der Nettozuwachs an atomarer Kapazität—Betriebsaufnahmen minus Schliessungen—sank auf 0.4 GW in 2020 und wurde negativ in 2021 (vgl. mit +290 GW für Erneuerbare). Mit 10 AKWs gingen mehr AKWs ausser Betrieb als in jedem anderen Jahr seit 311. Atomkraft ist irrelevant am Neubaumarkt der Stromkapazitäten.
- Small Modular Reactors (SMRs) erzeugen großes Medieninteresse, aber wenig begrenzte öffentliche Gelder und bleiben bisher und mindestens für weitere 10–15 Jahre kommerziell inexistent. Pilotprojekte in Argentinien, China, und Russland haben sehr enttäuscht.
- Atomkraft hat sich als sehr sensibel für die COVID-19 Pandemie erwiesen. Eine erste Analyse zeigt auch ihre geringe Resilienz gegen die geläufigsten Effekte des Klimawandels (wird in Zukunft wahrscheinlich weiter sinken) und gegen die Einwirkungen eines Krieges.



Photo: @Nina Schneider

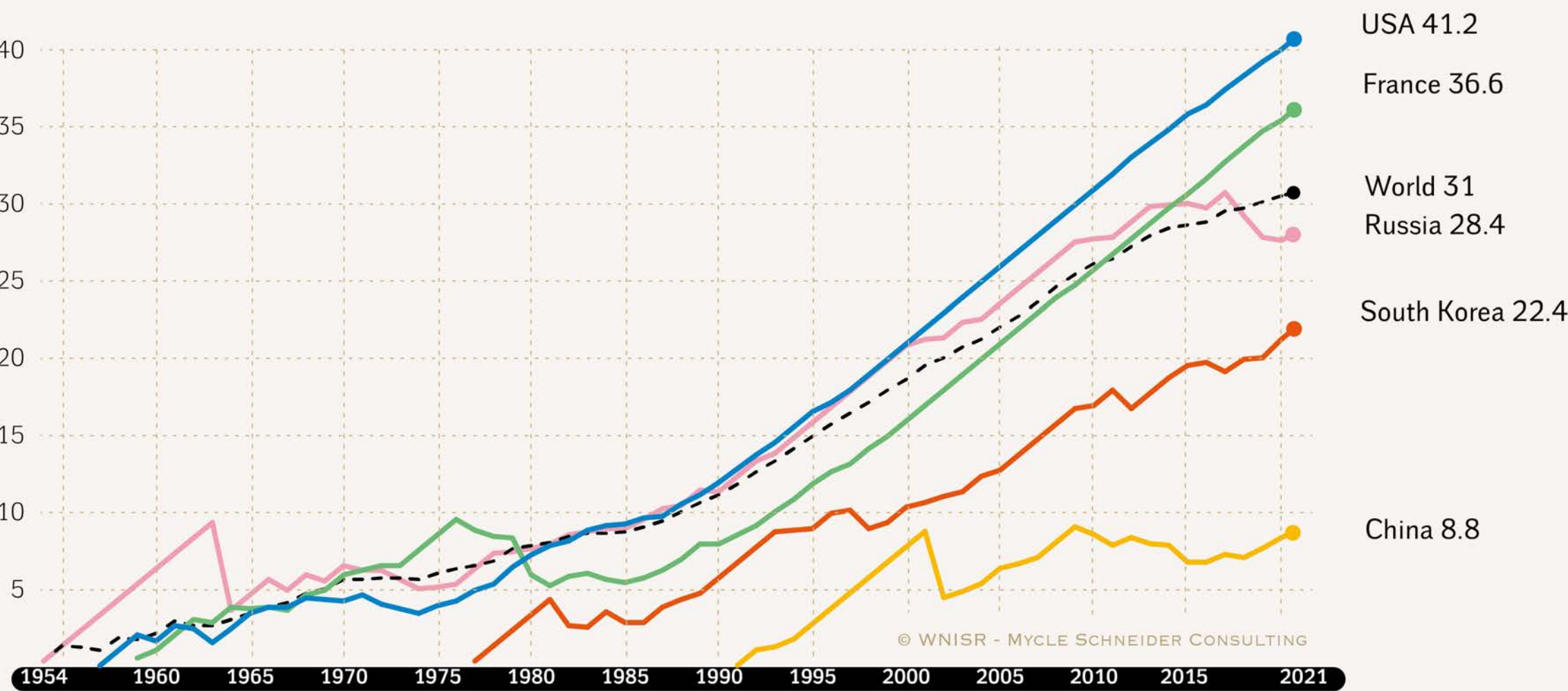
Mycle Schneider works as independent international consultant on energy and nuclear policy. He is the initiator, Coordinator and Publisher of the [World Nuclear Industry Status Reports](http://www.WorldNuclearReport.org). He is a Founding Board Member and the Spokesperson for the International Energy Advisory Council ([IEAC](http://www.IEAC.org)). He is a Founding Member of the International Nuclear Risk Assessment Group (INRAG) and a member of the International Nuclear Security Forum ([INSF](http://www.INSF.org)), based at the Stimson Center, USA. He is a member of the International Panel on Fissile Materials (IPFM), based at Princeton University, USA.

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 Environmental 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 16 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 10 countries.

Evolution of Mean Age of Top 5 Reactor Fleets in the World

in Years, as of year-end 1954–2021



Sources: WNISR, with IAEA-PRIS, 2022