Status und Trends der Atomkraft in der Welt

10 Jahre nach dem Beginn der Fukushima Katastrophe

The World Nuclear Industry Status Report 2020+ (WNISR2020+)

www.WorldNuclearReport.org

Mycle Schneider

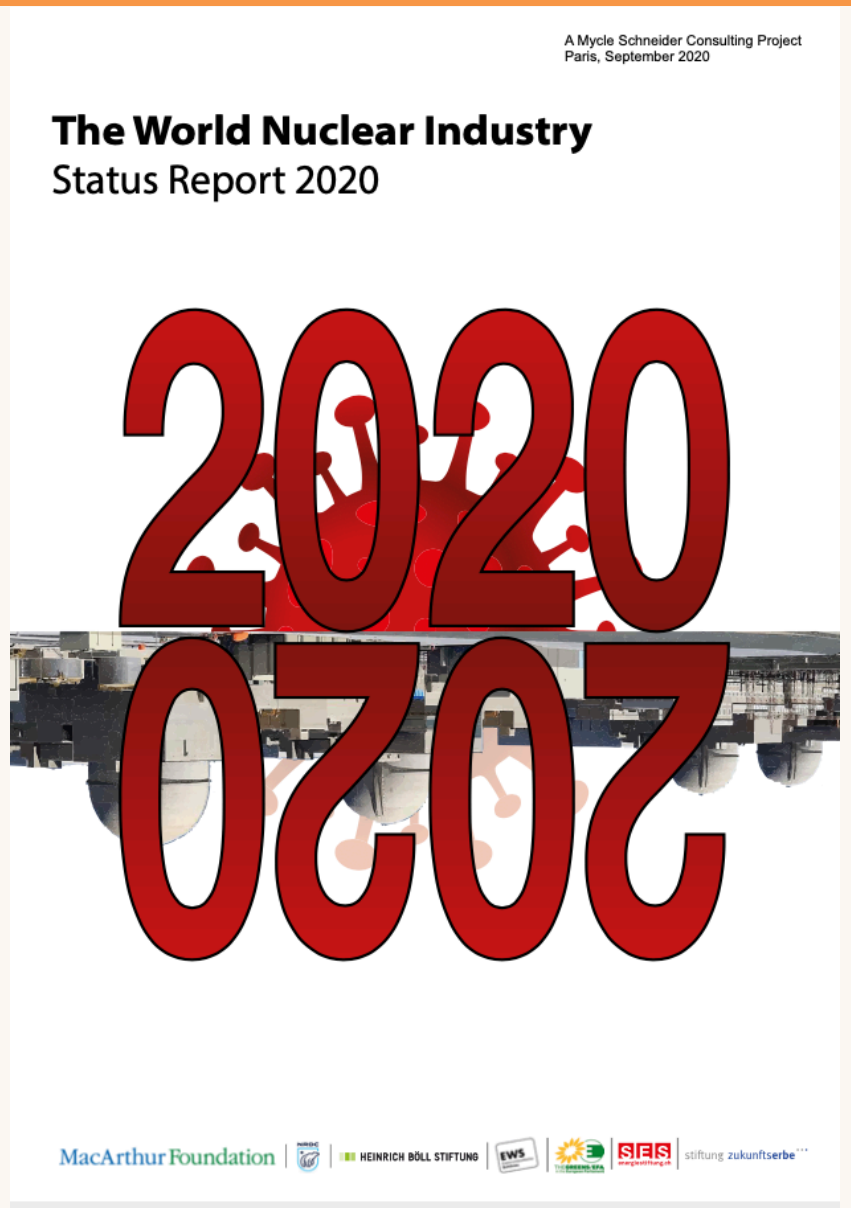
Internationaler Berater für Energie- und Atompolitik

Koordinator und Herausgeber des WNISR, Paris

Video-Konferenz – ausgestrahlt

1. März 2021

THE WNISR TEAM



By

Mycle Schneider
Independent Consultant, Paris, France
Project Coordinator and Lead Author

Antony Froggatt
Independent Consultant, London, U.K.
Lead Author

With

Julie Hazemann
Director of EnerWebWatch, Paris, France
Documentary Research, Modelling and Datavisualization

Ben Wealer
Research Associate, Workgroup for Economic and Infrastructure Policy, Berlin University of Technology (TU Berlin), Germany
Contributing Author

Ali Ahmad
Research Fellow, Project on Managing the Atom and International Security Program (ISP), Harvard Kennedy School, U.S.
Contributing Author

Agnès Stienne
Artist, Graphic Designer, Cartographer, Le Mans, France
Graphic Design & Layout

Tadahiro Katsuta
Professor, School of Law, Meiji University, Tokyo, Japan
Contributing Author

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

M.V. Ramana
Simons Chair in Disarmament, Global and Human Security with the Liu Institute for Global Issues at the University of British Columbia, Vancouver, Canada
Contributing Author

Foreword by

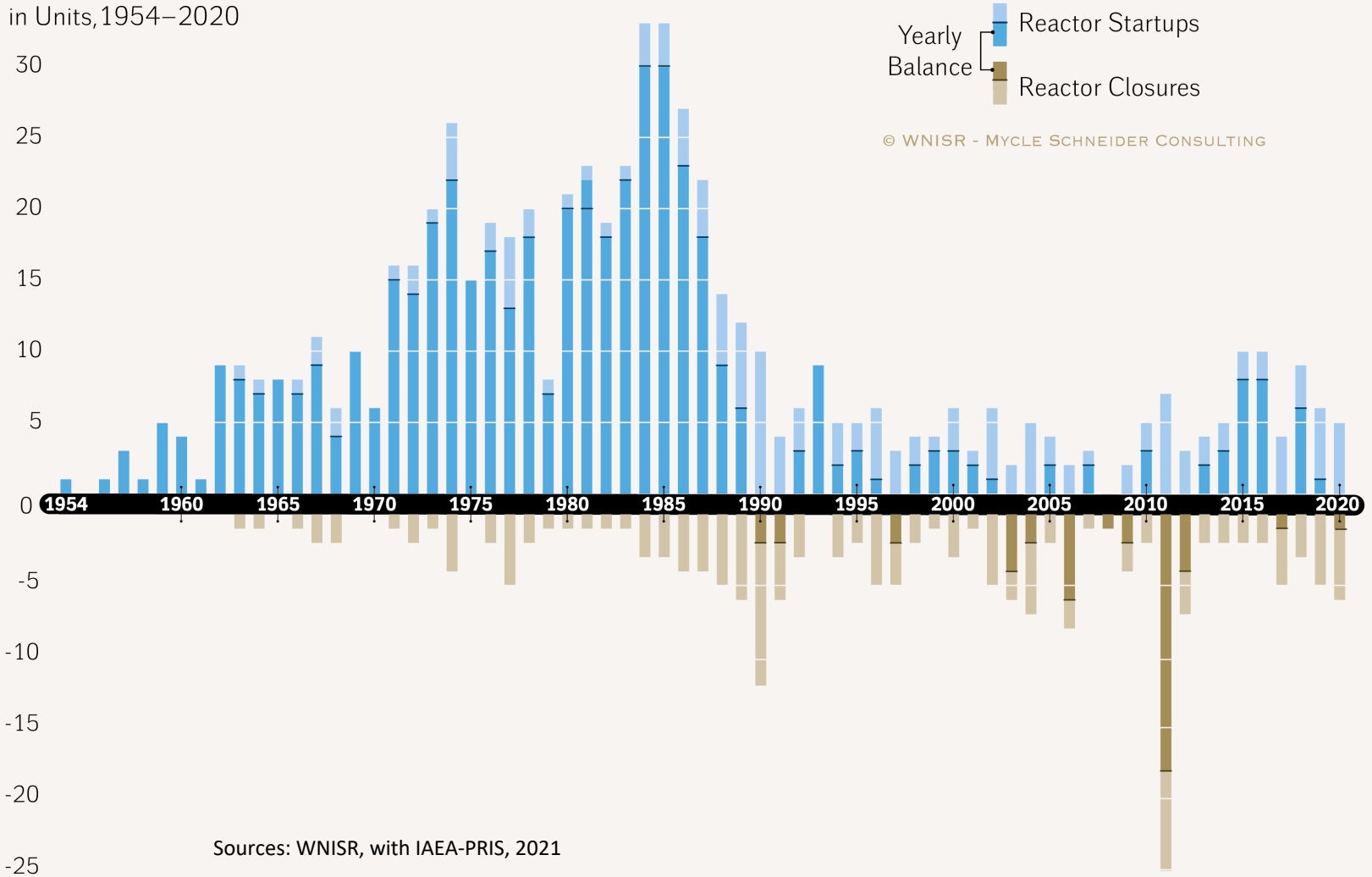
Jungmin Kang
Former Chair, Nuclear Safety & Security Commission, South Korea

Frank von Hippel
Professor Emeritus, Princeton University, U.S.

GLOBAL OVERVIEW – STARTUPS AND CLOSURES

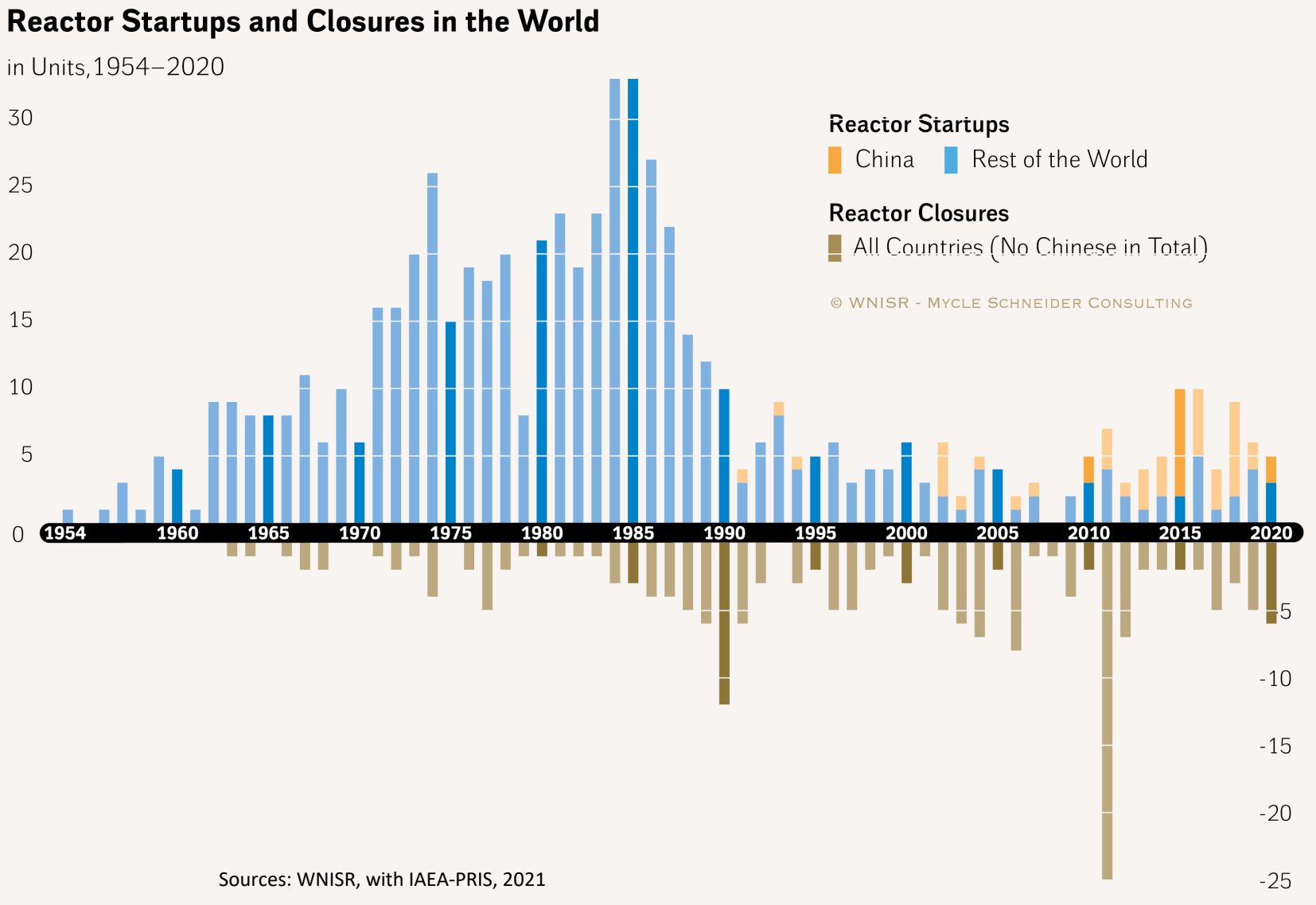
Reactor Startups and Closures in the World

in Units, 1954–2020



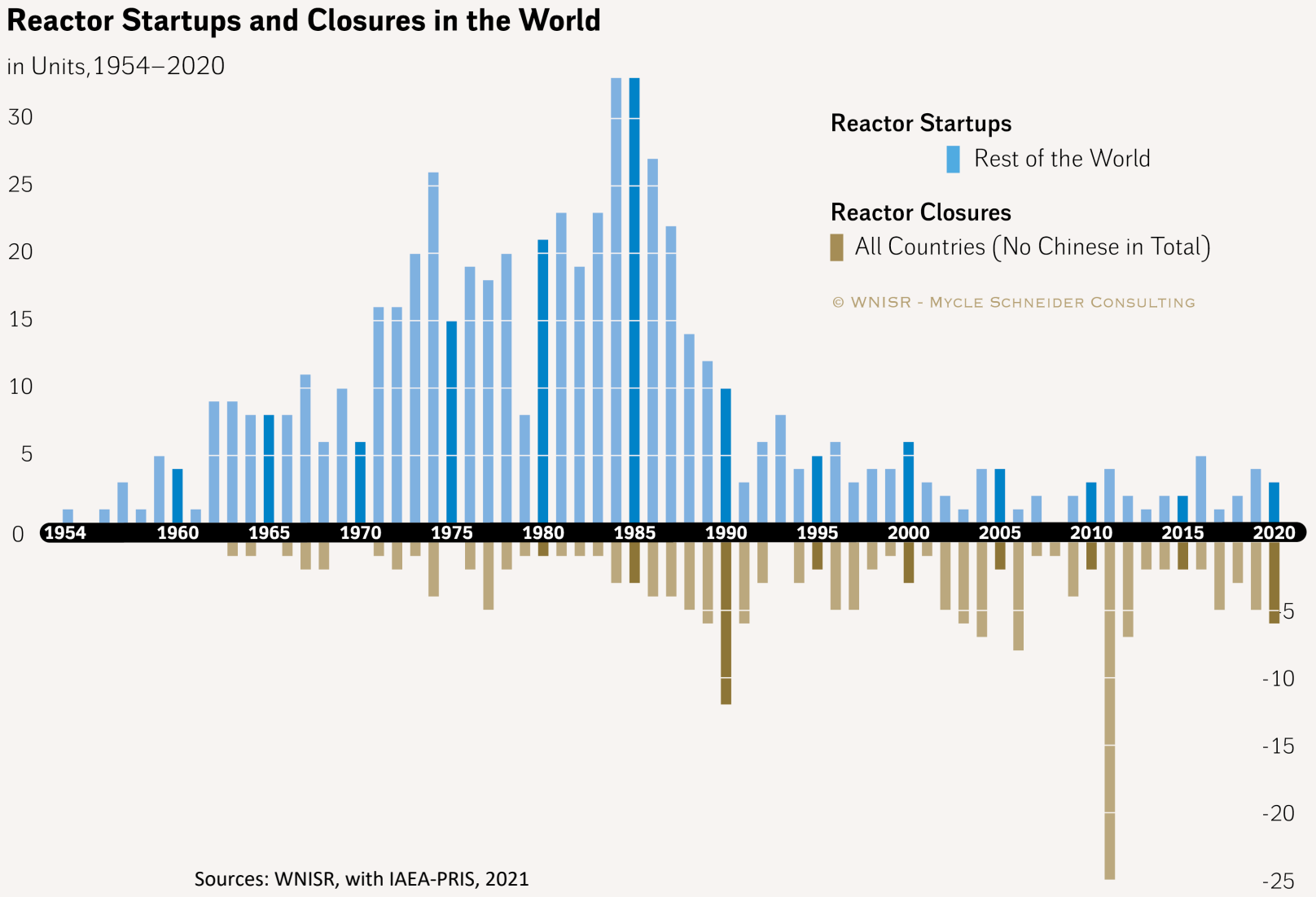
Sources: WNISR, with IAEA-PRIS, 2021

GLOBAL OVERVIEW – STARTUPS AND CLOSURES



Sources: WNISR, with IAEA-PRIS, 2021

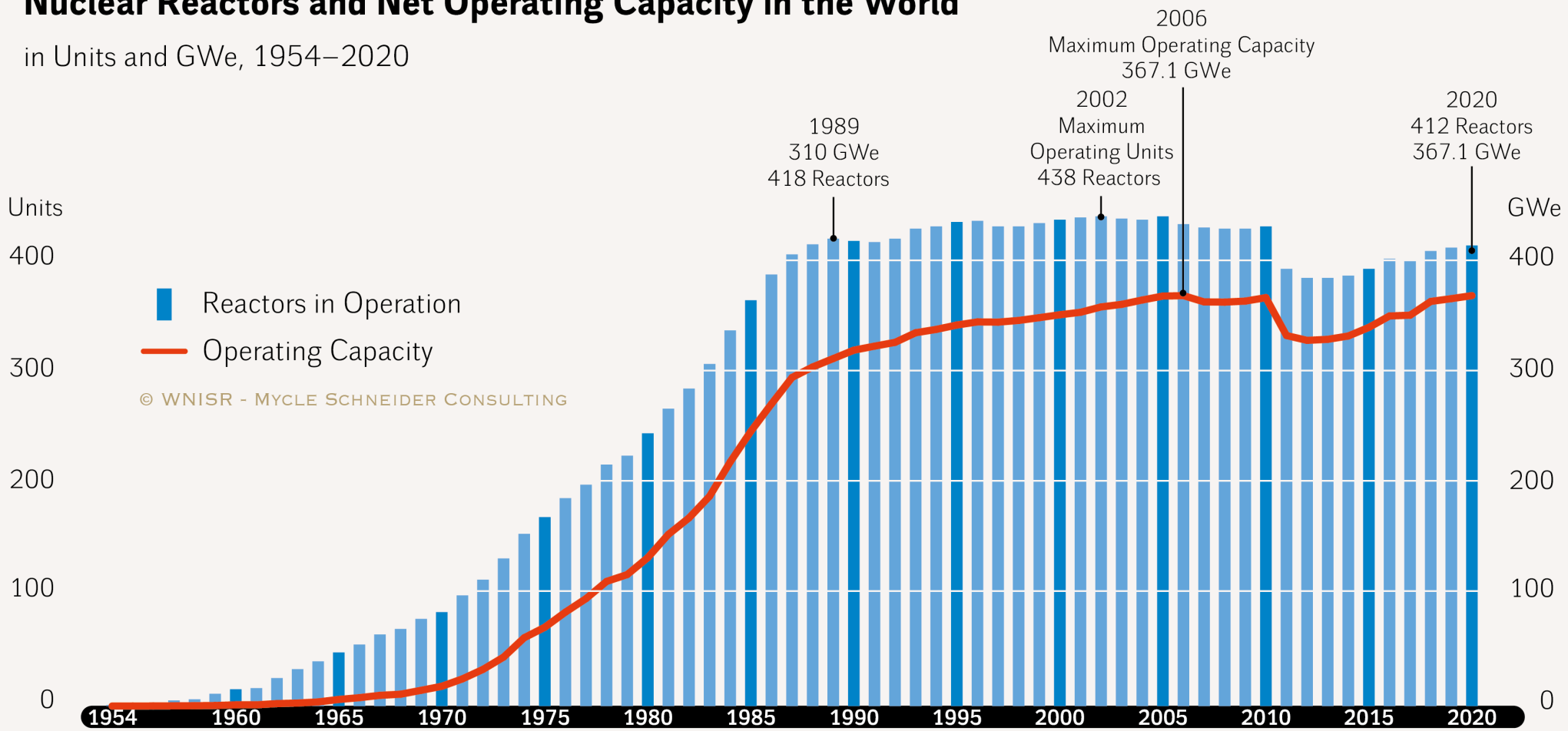
GLOBAL OVERVIEW – STARTUPS AND CLOSURES



Sources: WNISR, with IAEA-PRIS, 2021

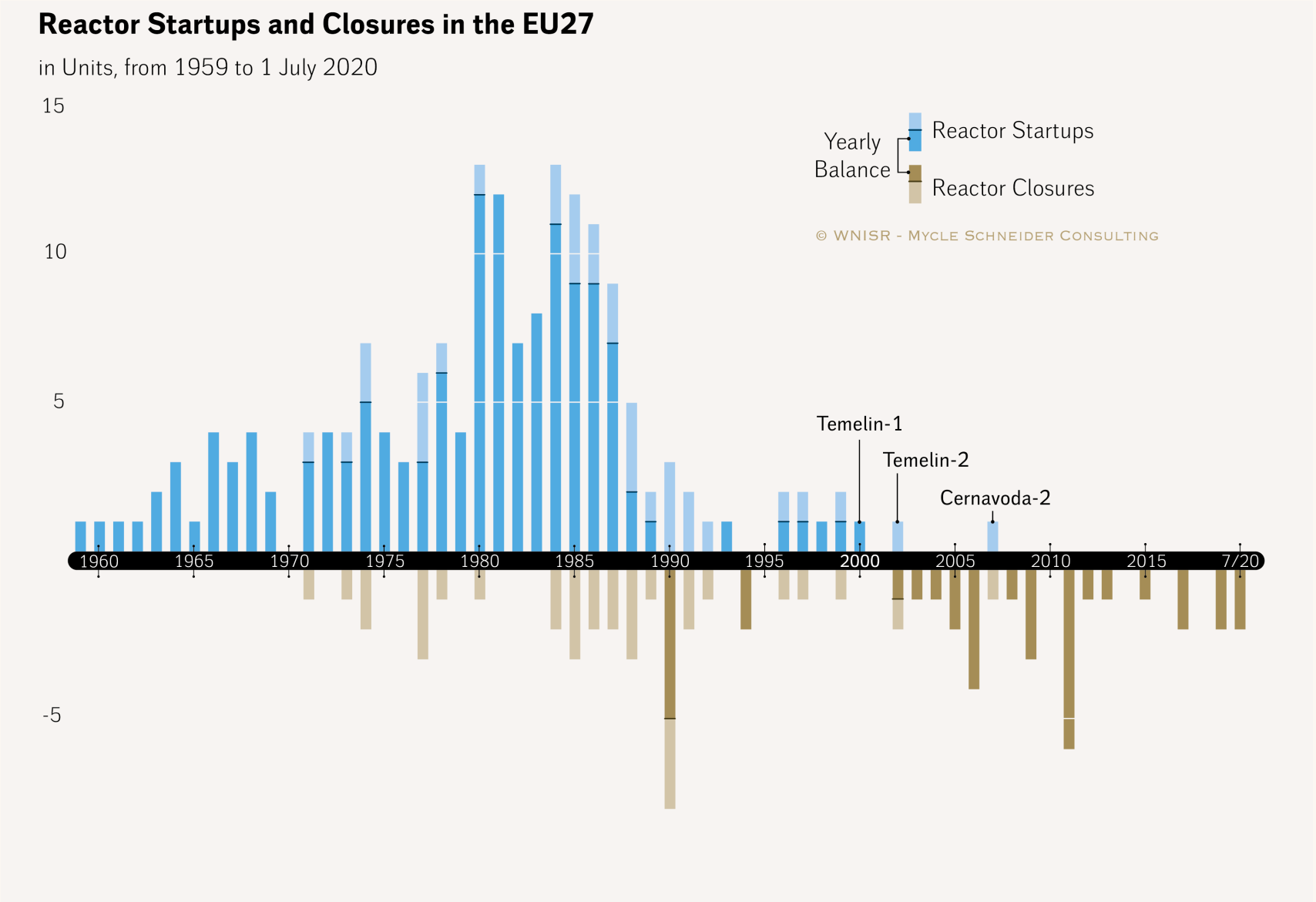
Nuclear Reactors and Net Operating Capacity in the World

in Units and GWe, 1954–2020



Sources: WNISR, with IAEA-PRIS, 2021

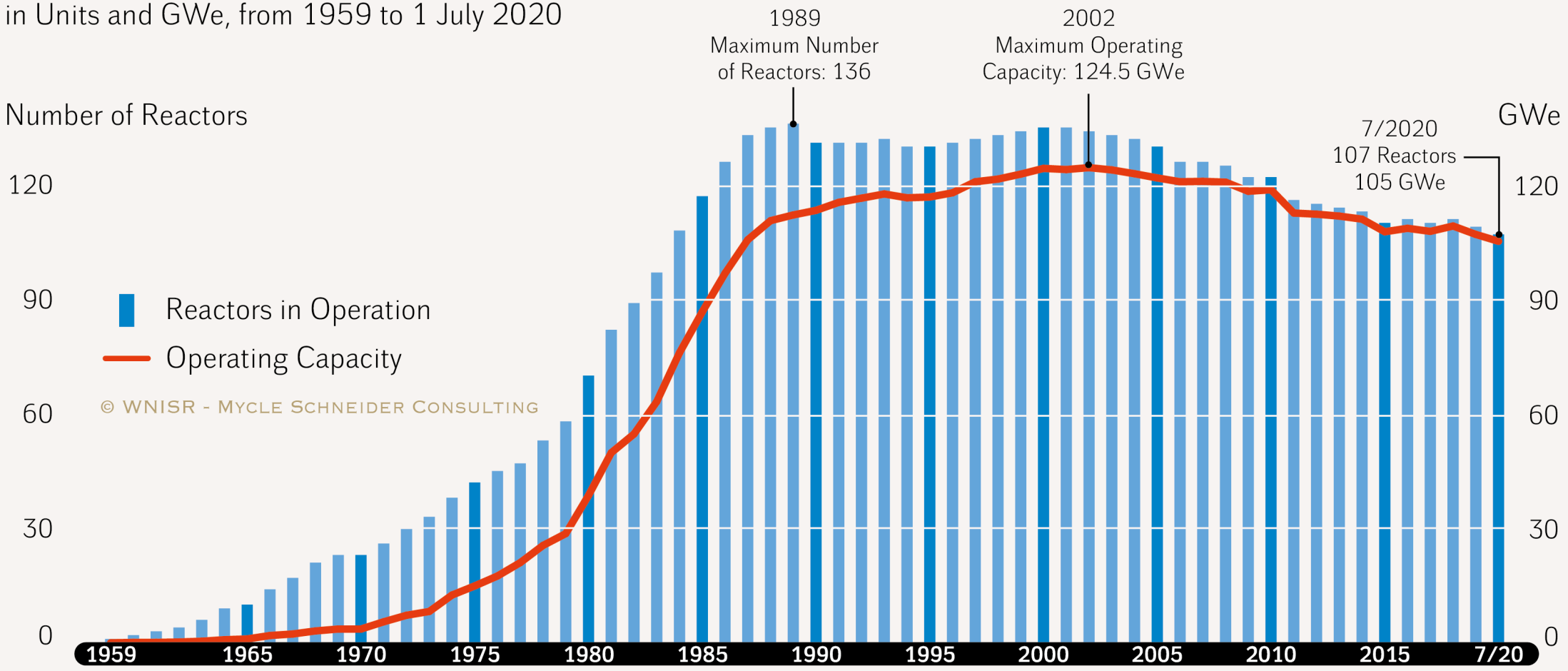
EUROPEAN UNION (EU27)



Sources: WNISR, with IAEA-PRIS, 2020

Nuclear Reactors and Net Operating Capacity in the EU 27

in Units and GWe, from 1959 to 1 July 2020

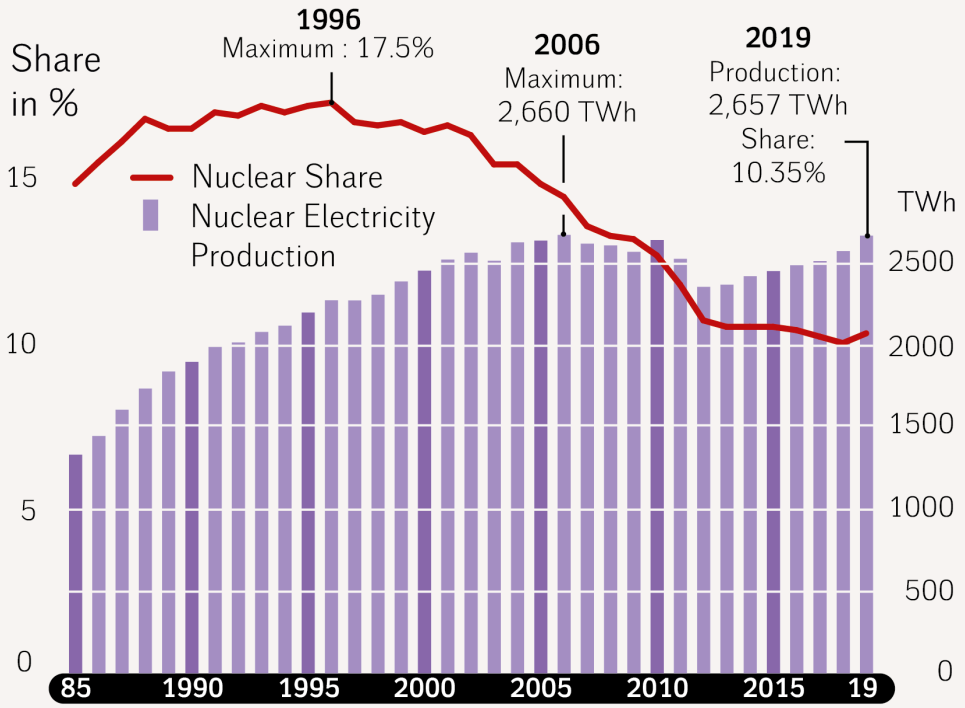


Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – ROLE OF NUCLEAR POWER

Nuclear Electricity Production 1985–2019 in the World...

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



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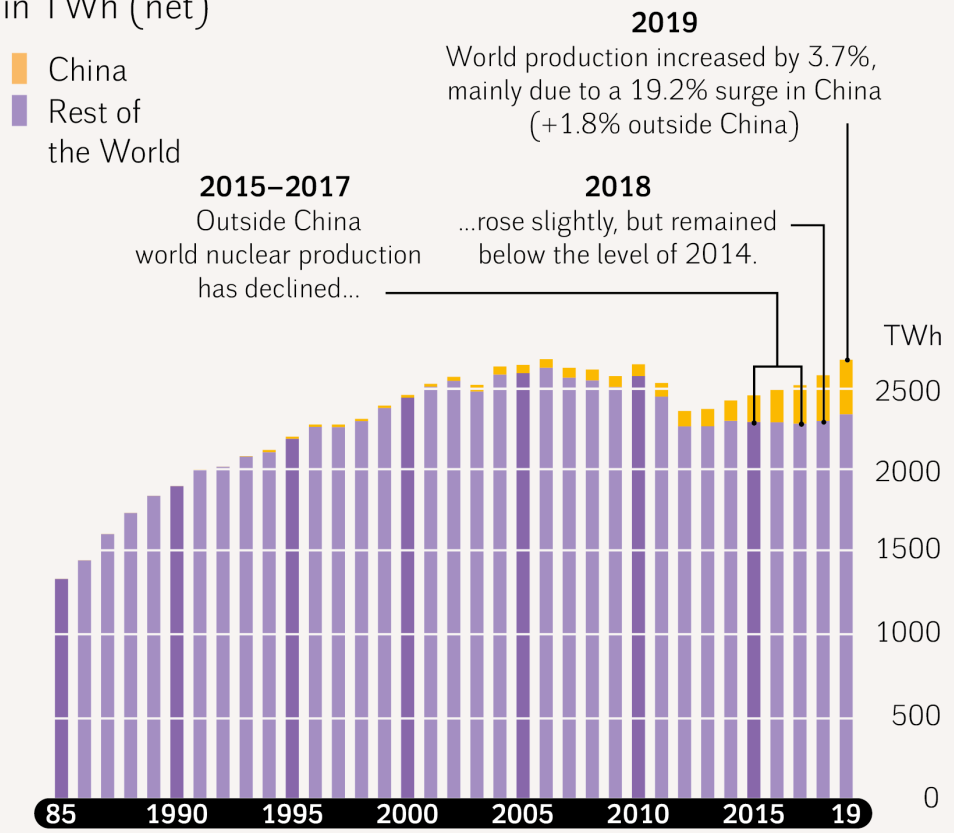
...and in China and the Rest of the World

in TWh (net)



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Sources: IAEA-PRIS, BP, 2020

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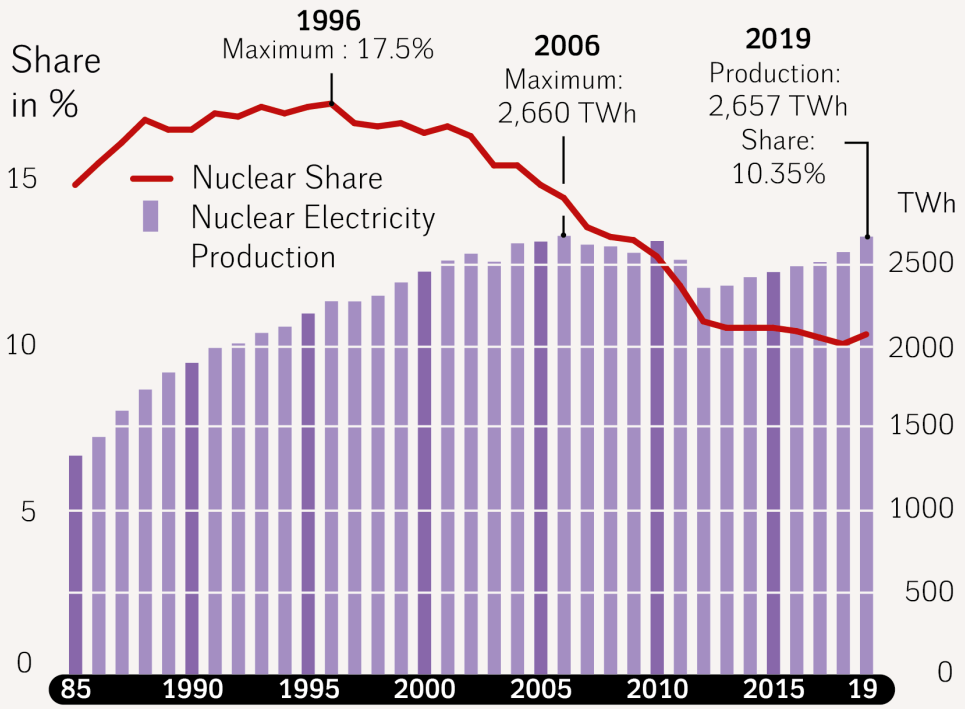

...and in China and the Rest of the World

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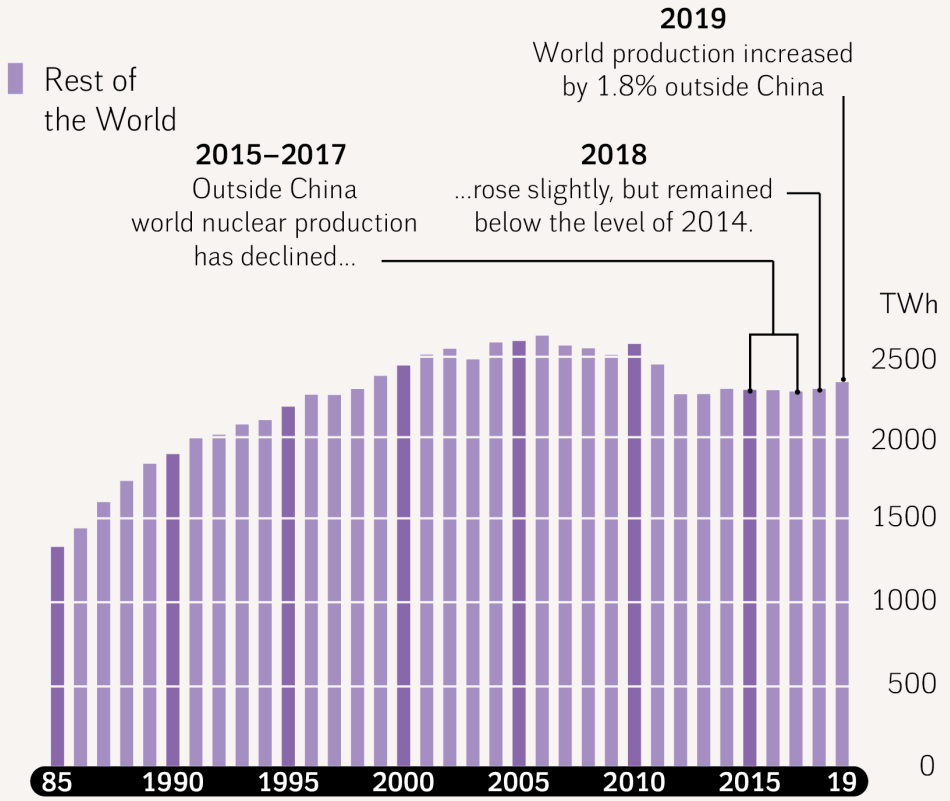
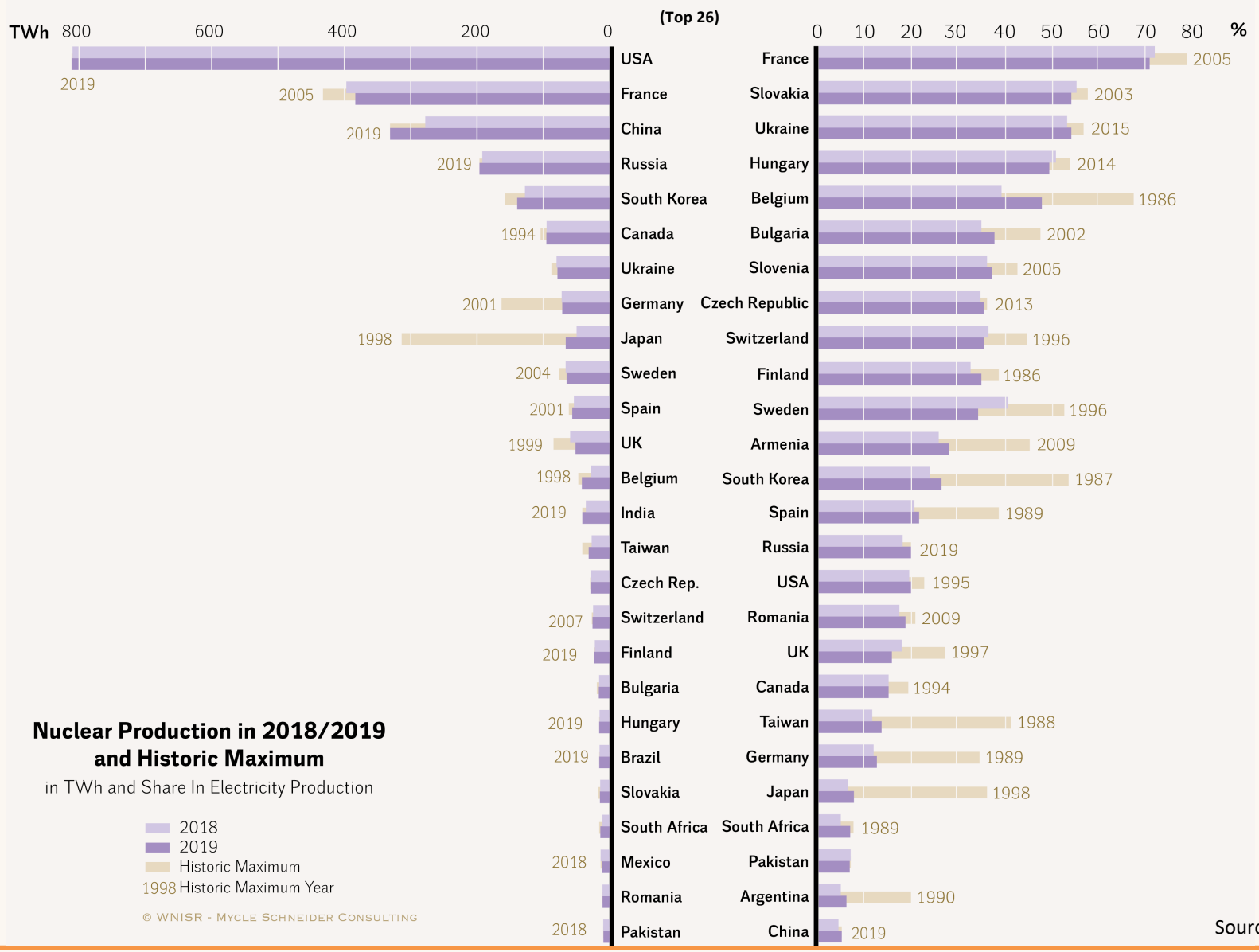
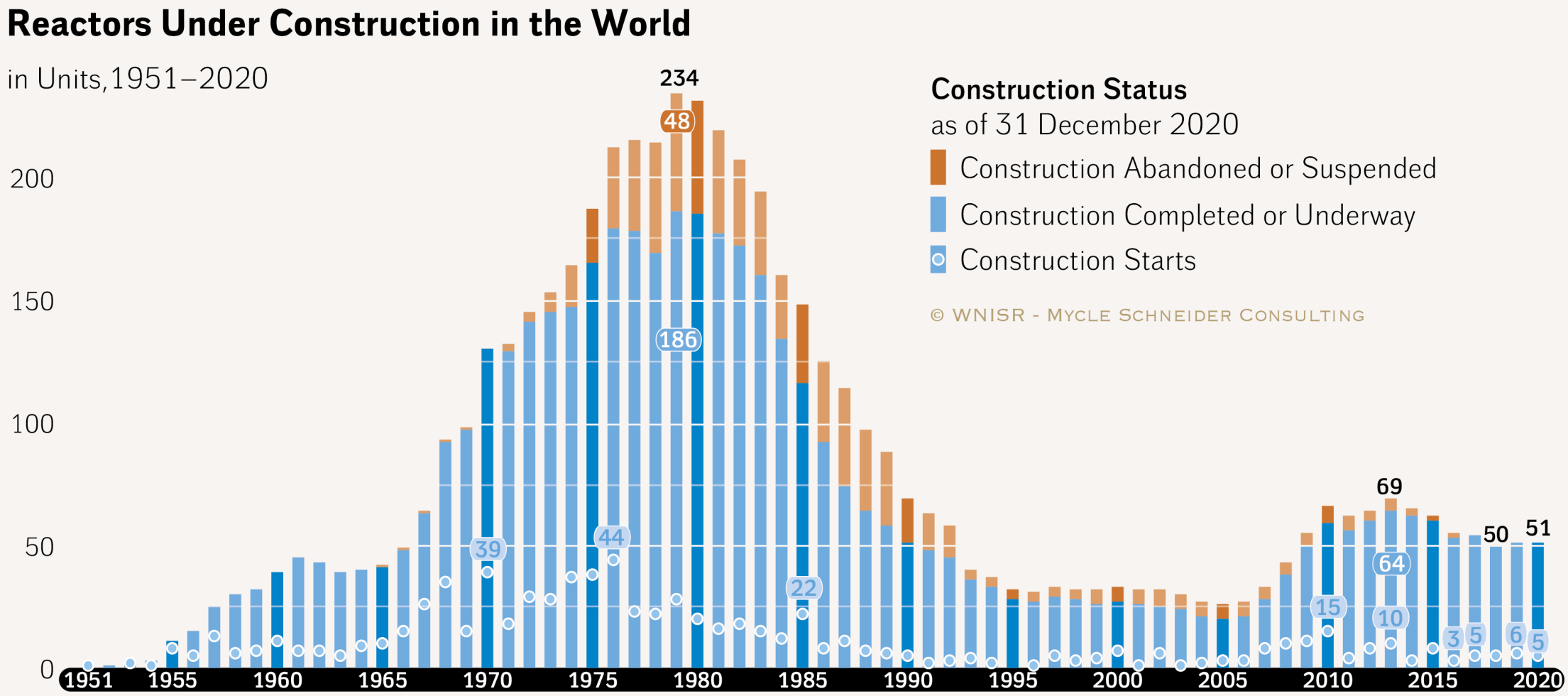


Sources: IAEA-PRIS, BP, 2020

GLOBAL OVERVIEW – ROLE OF NUCLEAR POWER



Sources: IAEA-PRIS, National Sources, 2020



Sources: WNISR, with IAEA-PRIS, 2021

Nuclear Reactors "Under Construction" (as of 31 December 2020)

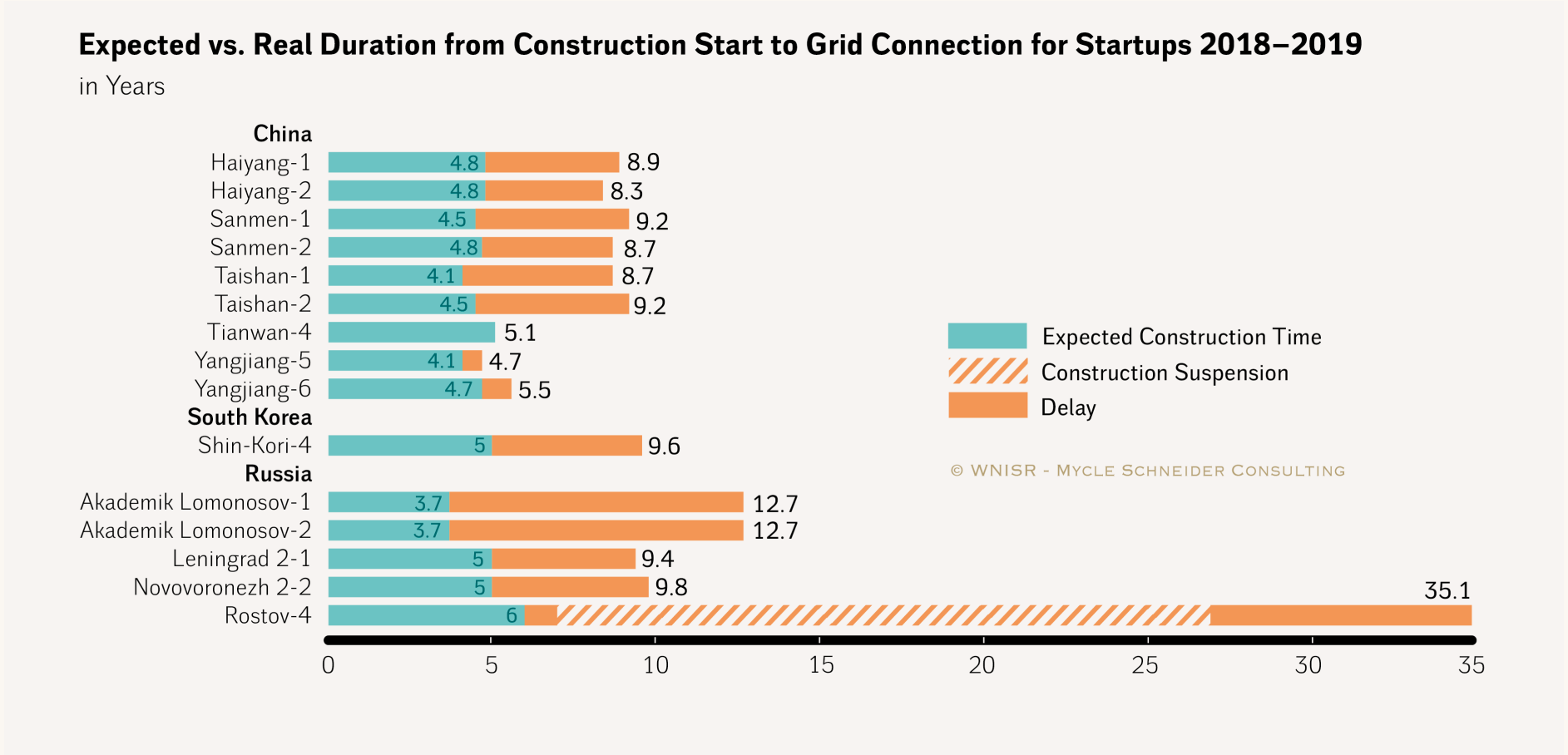
	Units	Capacity (MW net)	Construction Starts	Grid Connection	Units Behind Schedule
China	17	15 684	2012 - 2020	2021 – 2026	5
India	7	4 824	2004 - 2017	2021 - 2023	5–6
South Korea	4	5 360	2012 - 2018	2021 - 2024	4
UAE	3	4 035	2013 - 2015	2021 - 2023	3
USA	2	2 234	2013 - 2013	2021 - 2022	2
Turkey	2	2 228	2018 - 2020	2024 - 2025	1
Bangladesh	2	2 160	2017 - 2018	2023 - 2024	
UK	2	3 260	2018 - 2019	2025 - 2026	
Slovakia	2	880	1985 - 1985	2021 - 2023	2
Russia	2	2 230	2018 - 2019	2022 - 2023	
Pakistan	2	2 028	2015 - 2016	2021	1
Belarus	1	1 110	2014	2021	1
France	1	1 600	2007	2022	1
Argentina	1	25	2014	2021	1
Finland	1	1 600	2005	2021	1
Iran	1	1 196	1976	2024	1
Japan	1	1 325	2007	?	1
Total	**51**	**51 779**	**1976–2020**	**2021– 2026**	**29–30**

Sources: WNISR, with IAEA-PRIS, 2021

Duration from Construction Start to Grid Connection of 63 Units Started-up 2011–2020				
Country	Units	Duration 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	43.5	43.5	
World	**63**	**9.9**	**4.1**	**43.5**

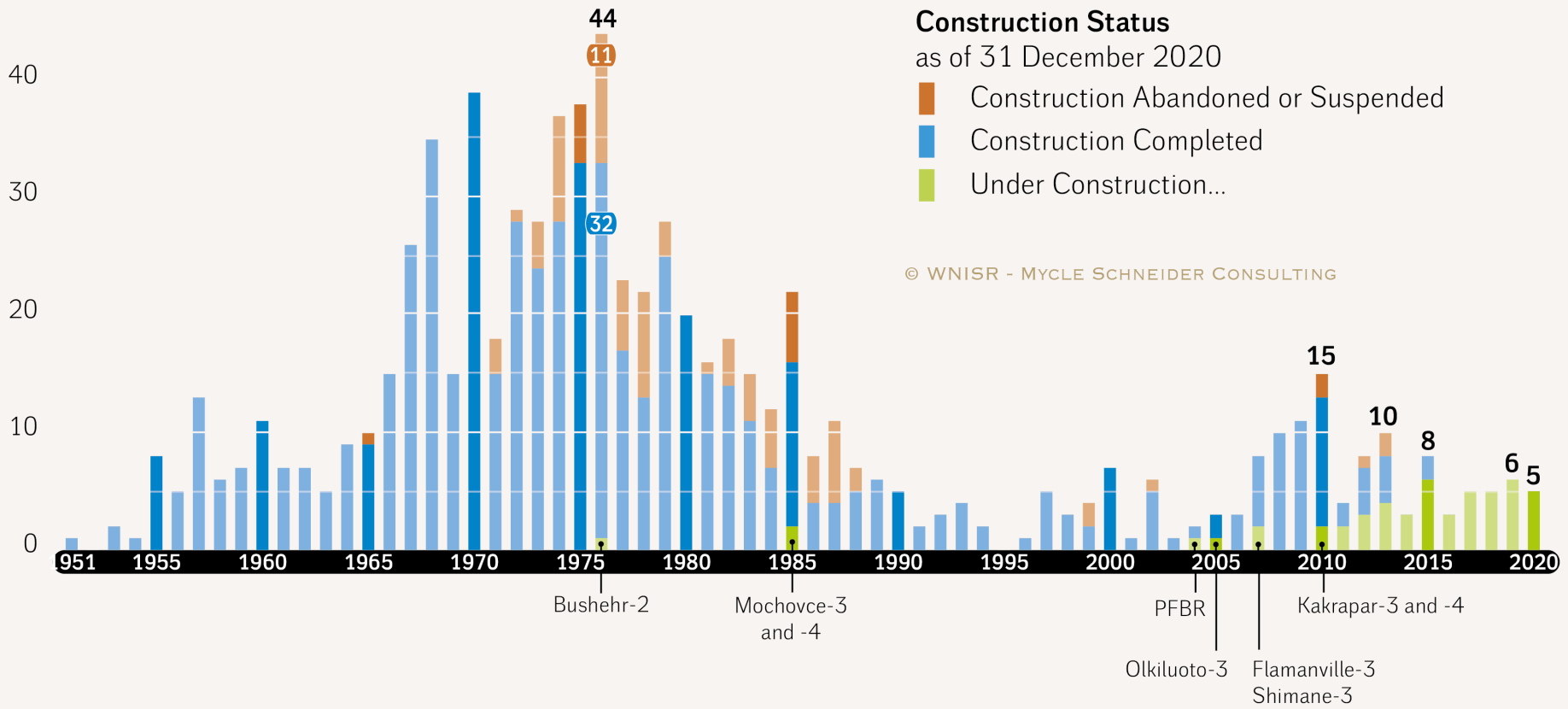
Sources: WNISR, with IAEA-PRIS, 2021

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS

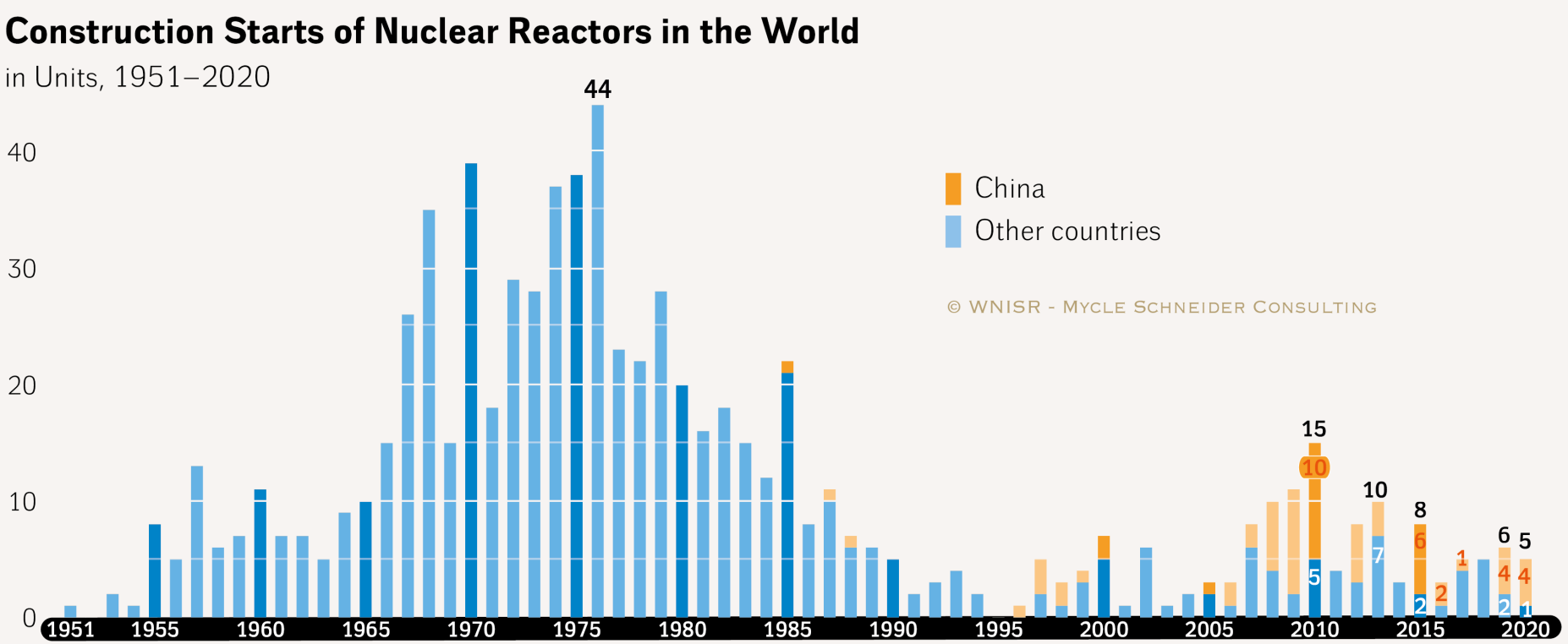


Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – CONSTRUCTIONS

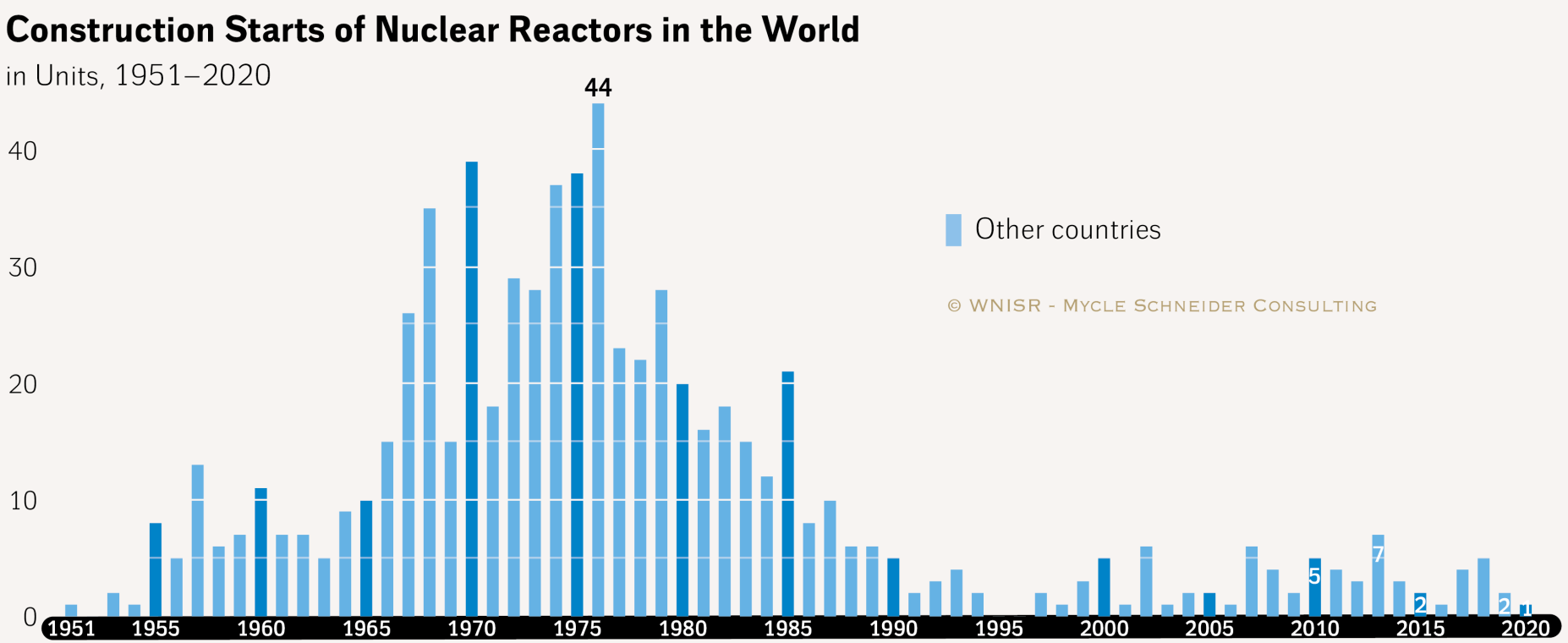


GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS



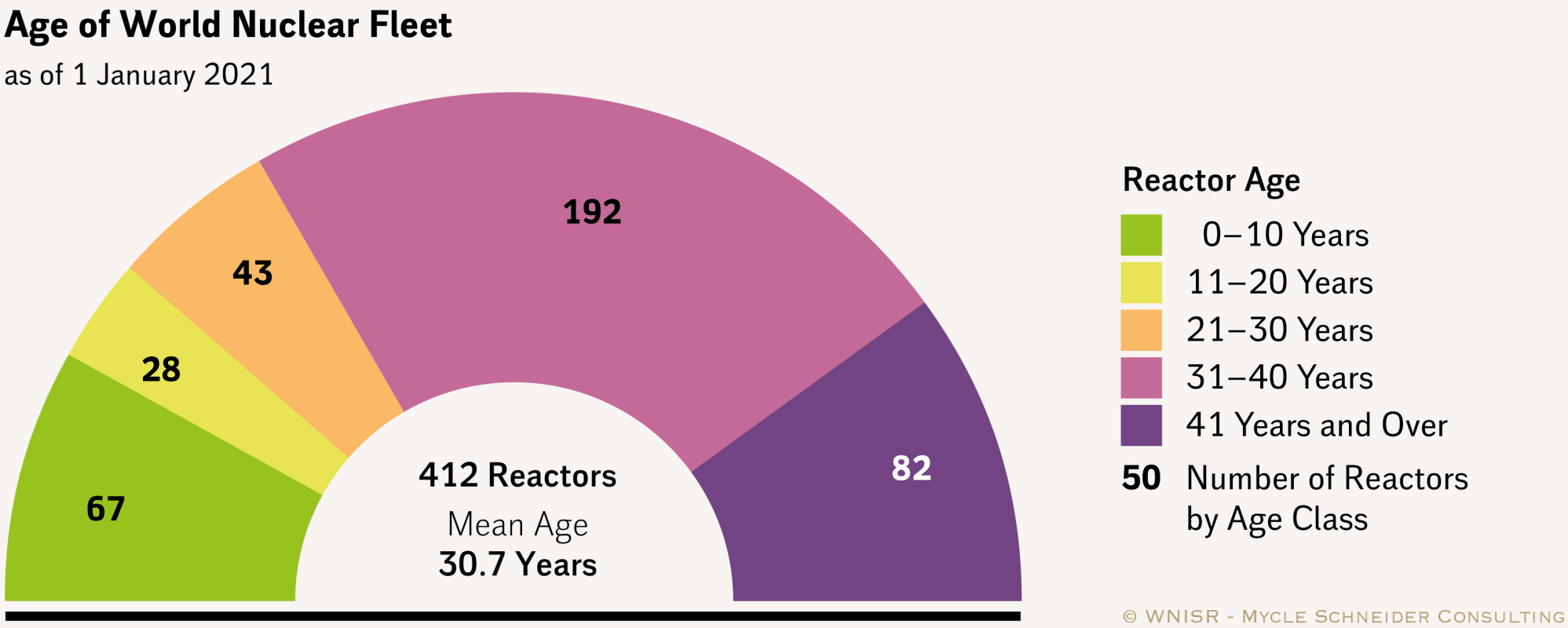
Sources: WNISR, with IAEA-PRIS, 2021

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS



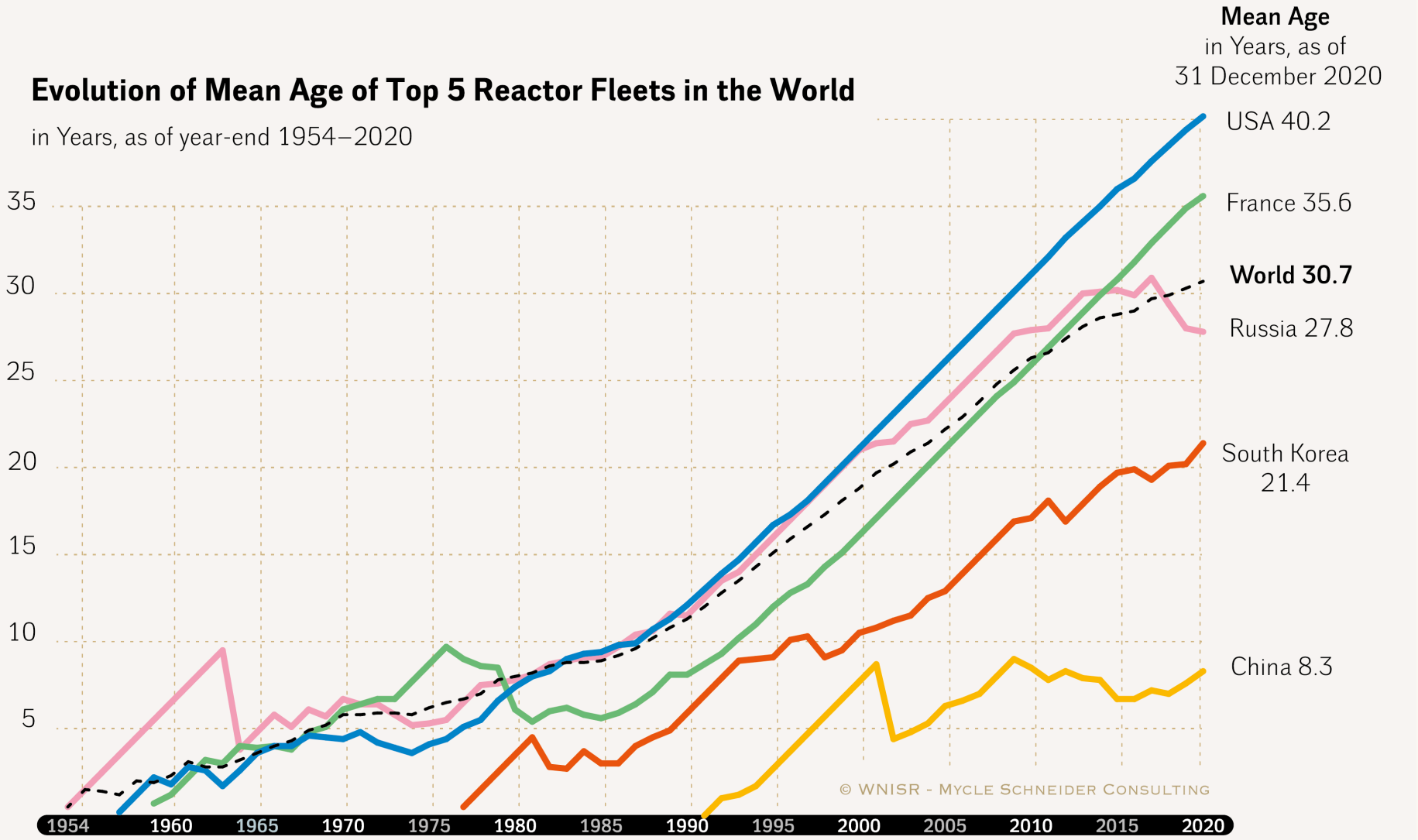
Sources: WNISR, with IAEA-PRIS, 2021

WORLD FLEET - OPERATING AGE



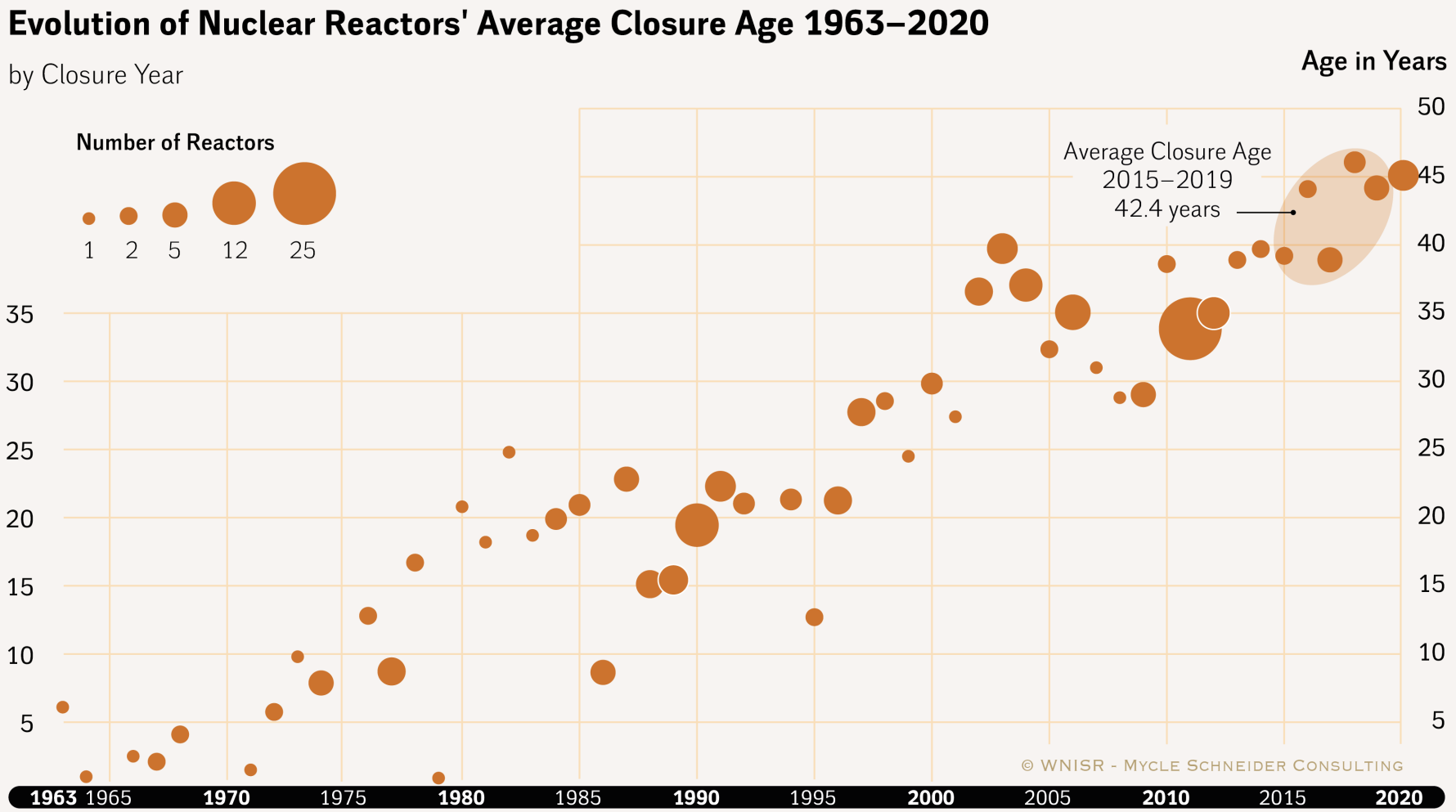
Sources: WNISR, with IAEA-PRIS, 2021

WORLD FLEETS - OPERATING AGE



Sources: WNISR, with IAEA-PRIS, 2021

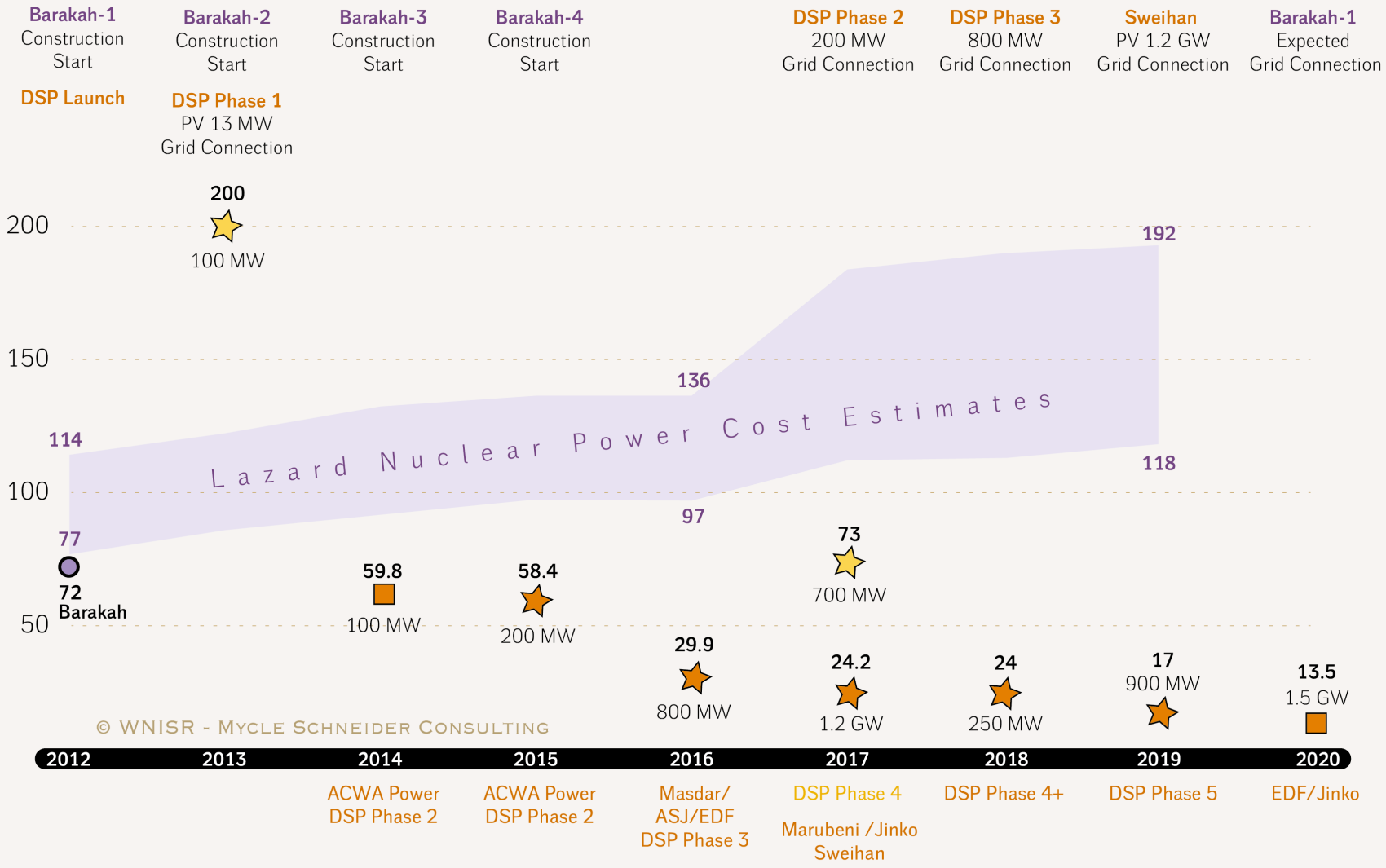
WORLD FLEET – CLOSED REACTORS AGE

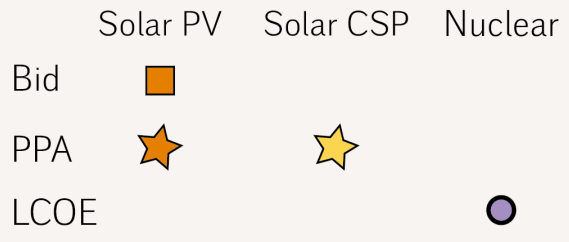


Sources: WNISR, with IAEA-PRIS, 2021

Evolution of Solar vs. Nuclear Power Cost Estimates in the UAE 2012-2020

in US$/MWh





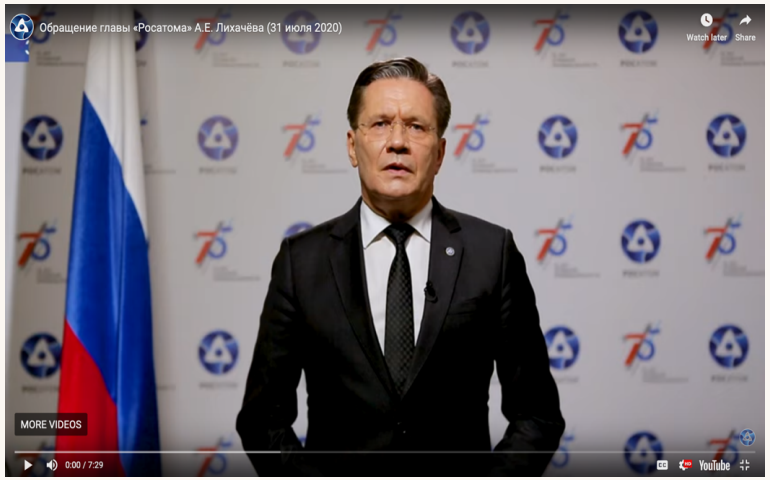
CSP = Concentrating Solar Plant
DSP = Dubai Solar Park
LCOE = Levelized Cost of Energy
PPA = Power Purchasing Agreement
PV = Photovoltaics

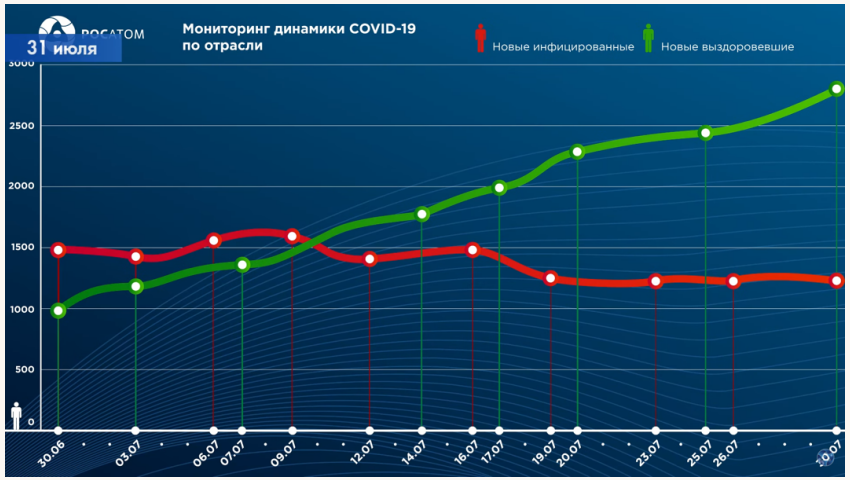
Sources: Various sources, compiled by WNISR, 2020

- **Das erste Mal in der Geschichte: Atomindustrie von globaler Pandemie betroffen**.
- **Kernaspekte von Sicherheit und Sicherung in Frage gestellt.**
  - Regelmässige Tests (Notwarte, Notstromversorgung, Kühlsysteme…).
  - Vier-Augen Prinzip.
  - Spezifische Personalkategorien (Leitwarte, Sicherung...).
  - Notfallmanagement (Brand, toxische Gase...).

FOCUS: NUCLEAR POWER IN THE AGE OF COVID-19 – INFECTIONS

- Fehlende nationale Statistiken, keine internationale Vergleichsbasis.
- Rosatom (Holding): 4.500 Fälle, darunter 1.200 aktiv Ende Juli 2020.

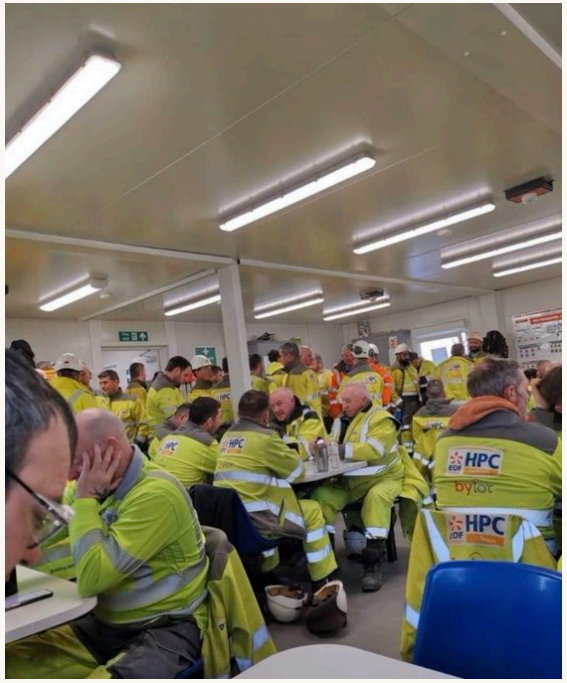




- EDF (franz. Betreiber): ca. 600 Fälle über Zeitraum von 12 Wochen (Stand Mitte Juni 2020).
- ASN (franz. Aufsicht): keine Fälle / IRSN (franz. TSO) 9 positiv / 13 getestet (von 1.800 Angestellten).
- Schwedische Aufsicht: “einige Fälle”.
- GB, Sellafield: Selbstquarantäne von ca. 1.000 Angestellten → Abschaltung WAA
- GB, Hinkley Point B: mindestens ein Toter, keine anderen Information veröffentlicht.
- USA, AKW: mehrere Dutzend Fälle an mehreren Standorten; 3 Reaktorfahrer positiv in Millstone; 200–300 Fälle während Ausstand Fermi-2; >800 Fälle auf der Baustelle Vogtle, Georgia.

FOCUS: NUCLEAR POWER IN THE AGE OF COVID-19 – MEASURES

- **Drastische Personalreduzierung** in Atomanlage, z.B. 2/3 (15.000 von 22.500) des EDF-Personals auf Telearbeit → Probleme bei der Aufsicht von Unterauftragnehmern.
- Genehming durch Aufsichtsbehörden für **stark verlängerte Arbeitszeiten**: z.B. in den USA, bis zu 16 Arbeitsstunden in 24 Stunden, bis zu 86 Arbeitsstunden in einer Zeitspanne von 7 Tagen.
- Physischer Abstand und andere sanitäre Massnahmen extrem variabel, z.B. Angestellte in mindestens 3 französischen AKW legten aus **Protest gegen unzulängliche Schutzmassnahmen** die Arbeit nieder.



Fotos: Cafeteria in Hinkley Point C, vor und nach der Implementierung von sozialen Abstandsmassnahmen (Fotos von Ende März 2020).

Zitat eines Arbeiters in der Lokalpresse: « Sie tun, was sie können, aber sobald sich jemand bewegt, hat man gezwungener Massen weniger als 2 m Abstand von jemand anderem. »

- Aussetzung aller **« force-on-force » Übungen** in den USA, und zahlreicher anderer Übungen und Trainingseinheiten in mehreren Ländern.
- Verzögerungen, Änderungen und Verschiebungen um **mehrere Monate** der Ausstände für Wartung und Brennelementwechsel; Eliminierung von « nicht essentiellen Aktivitäten ».
- Verzögerungen beim **AKW-Bau** in mindestens 12 der 17 Länder, die gegenwärtig bauen.
- Aussetzung fast aller **physischen Inspectionen** vor Ort der Aufsichtsbehörden in zahlreichen Ländern (z.B. Kanada, Finnland, Frankreich, USA); « pragmatischer » Umgang der Behörden mit Anträgen auf Ausnahmegenehmigungen der Betreiber.

Auswirkungen auf Sicherheit und Sicherung

• Es gibt keine Belege für die Behauptung, alle Pandemiemassnahmen hätten keinen Einfluss auf die Einhaltung der gebotenen Sicherheitsstandards.

• Vertrauen in derartige Aussagen schwer nachzuvollziehen angesichts:

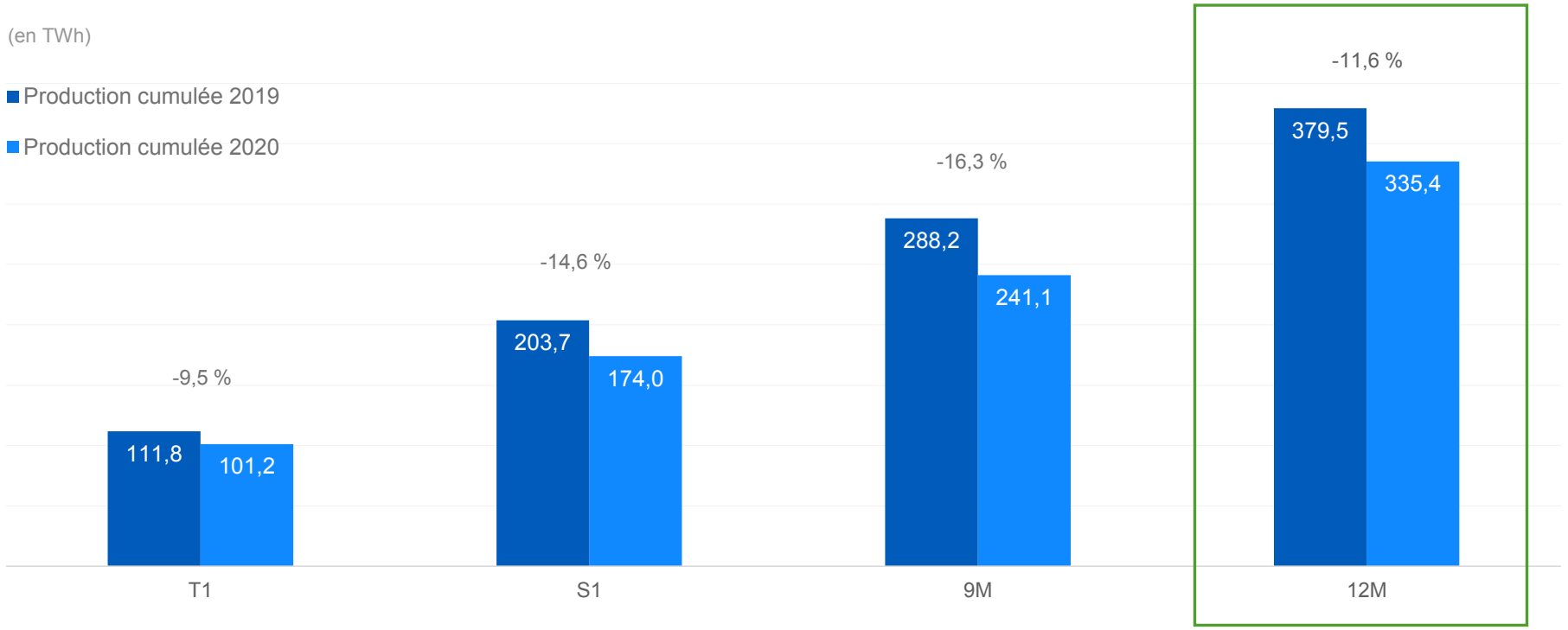
- eindeutig verschlechterten Arbeitsbedingungen;
- monatelang ausgesetzten Wartungsarbeiten;
- Fehlen der nach Regelwerk vorgesehenen physischen Kontrollen der Betreiber;
- mangelnde Aufsicht der Behörden, die angesichts der langen Liste von Fälschungen, Korruption und anderen betrügerischen Aktivitäten im Sektor, unabdingbar für die Garantie der Einhaltung der Sicherheits- und Sicherungsstandards sind.

• Selbst im Falle der Verlangsamung der Pandemie wird die signifikante Verbesserung der Situation viel Zeit kosten. Die Wiederherstellung einer Normalität—abgesehen vom Aufholen—wird mittelfristig sehr schwer werden und könnte Jahre dauern.

• Die finanziellen/wirtschaftlichen Auswirkungen auf viele Betreiber ist gewaltig: Preisverfall, Kostenexplosion, Verbrauchssenkung. Einsparmassnahmen werden Druck erhöhen.

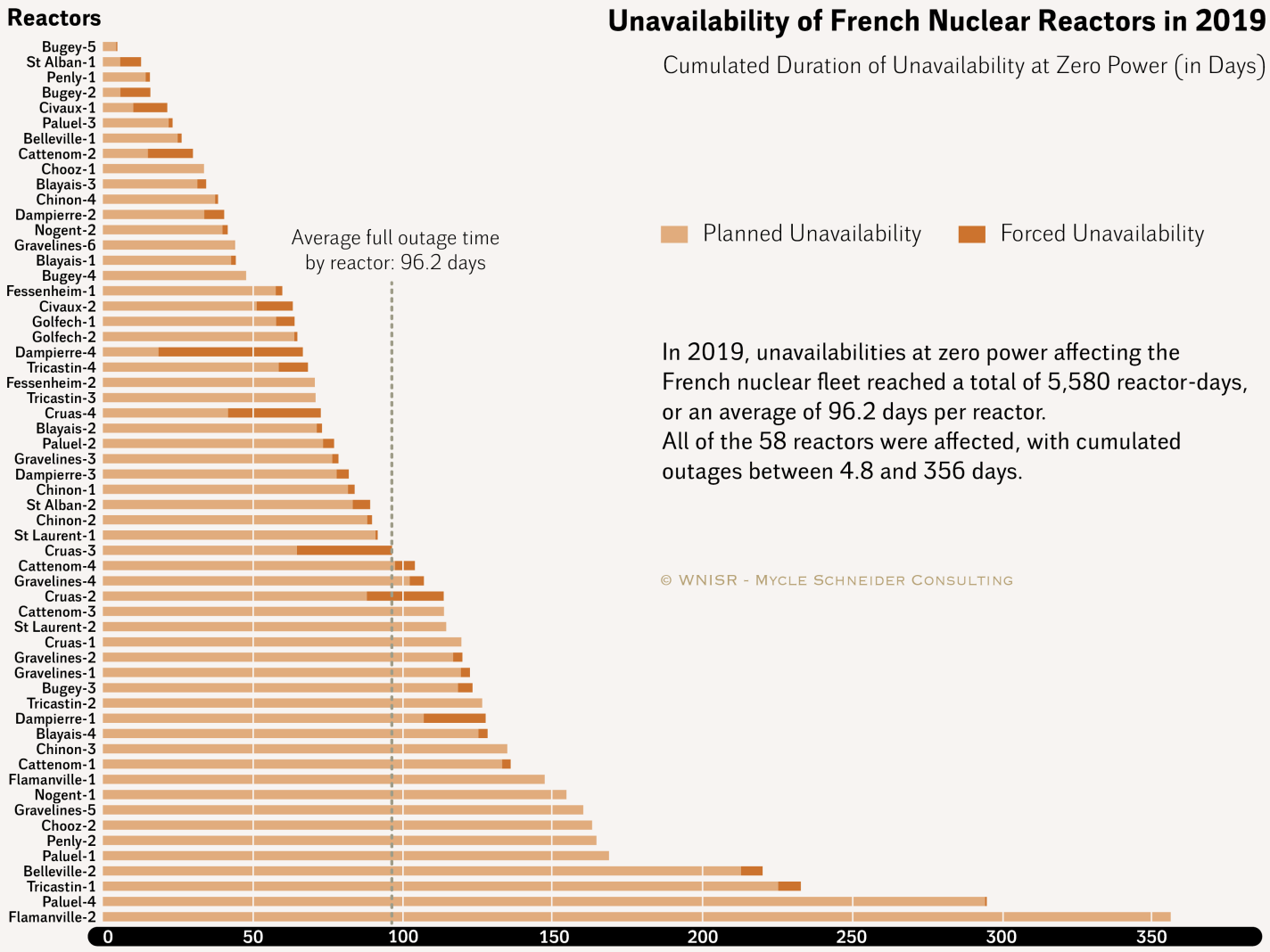
Résultats d'EDF en France : 42,3 milliards de dette nette

PRODUCTION NUCLÉAIRE FRANCE

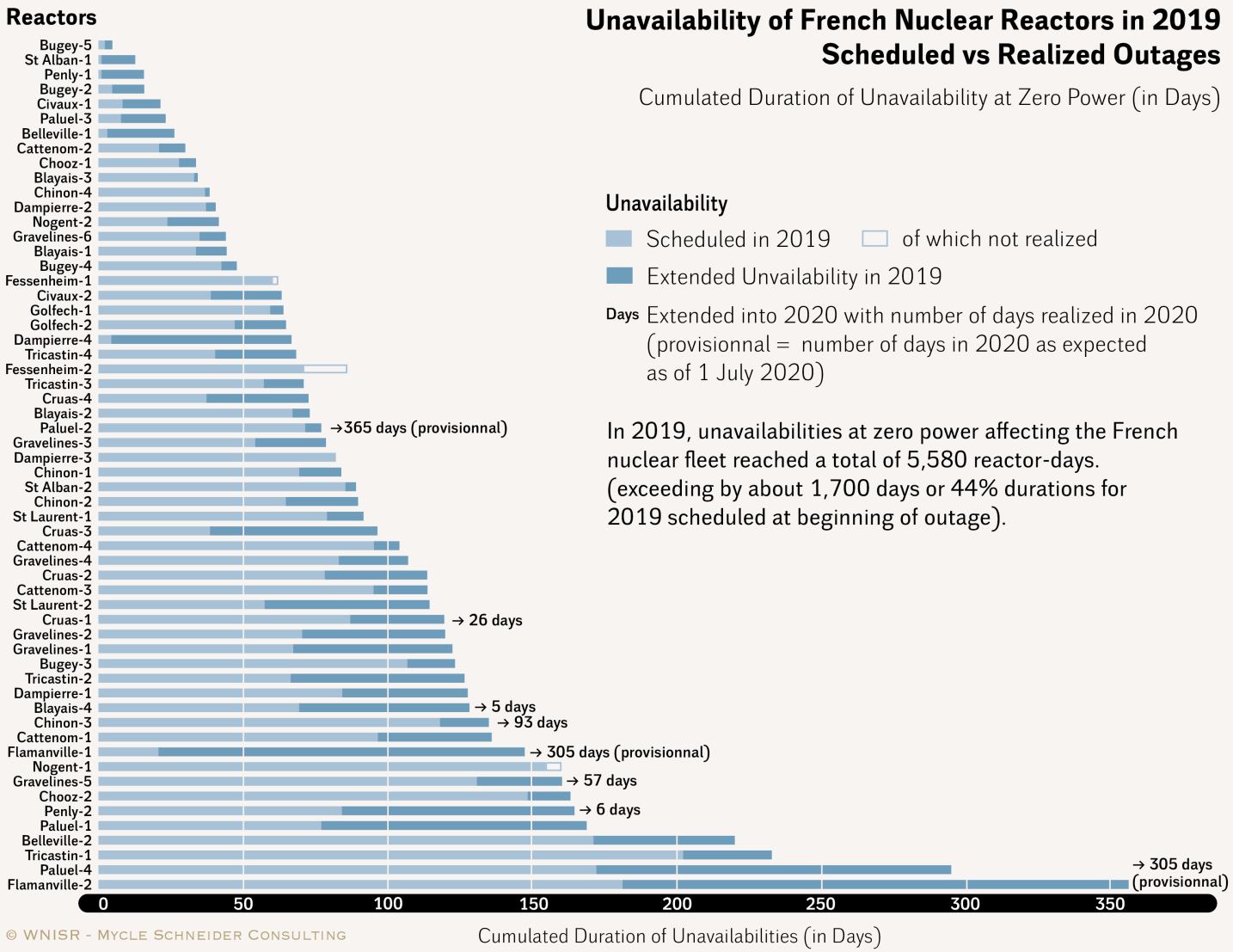


➢ **Production nucléaire en baisse de -44 TWh dont ~ -33 TWh (1) liés à la crise sanitaire Covid-19**

(1) Chiffres estimés



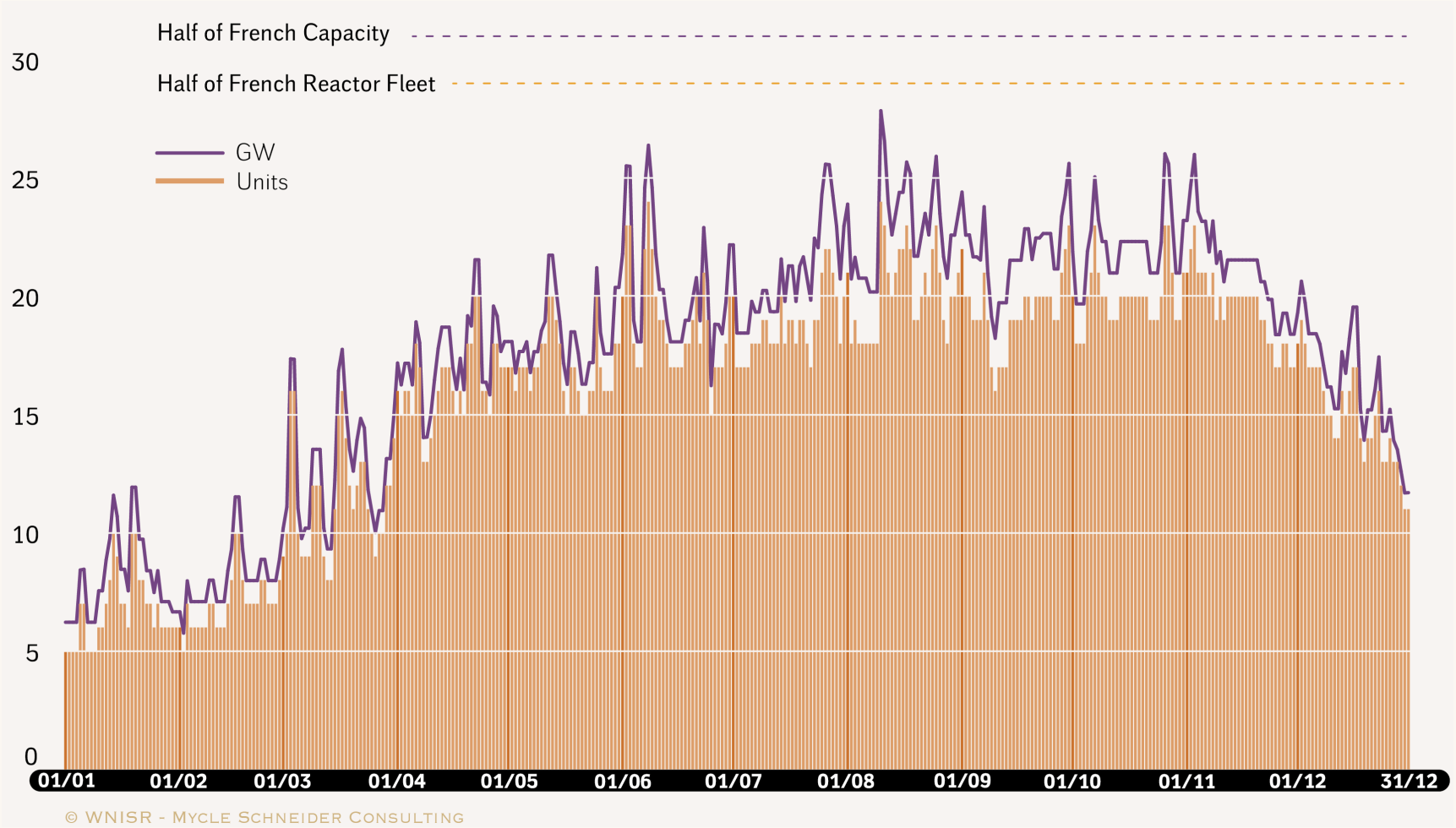
Sources: Compilation from EDF and RTE, 2019–2020



Sources: Compilation from EDF and RTE, 2018–2020

Unavailability of French Nuclear Reactors in 2019
Reactors Offline the Same Day (Zero Output)

in Units and Capacity



In 2019,

- on 303 days—83% of the year—10 reactors or more did not provide any power at least part of the day, of which 94 days —26% of the year—20 or more reactors;

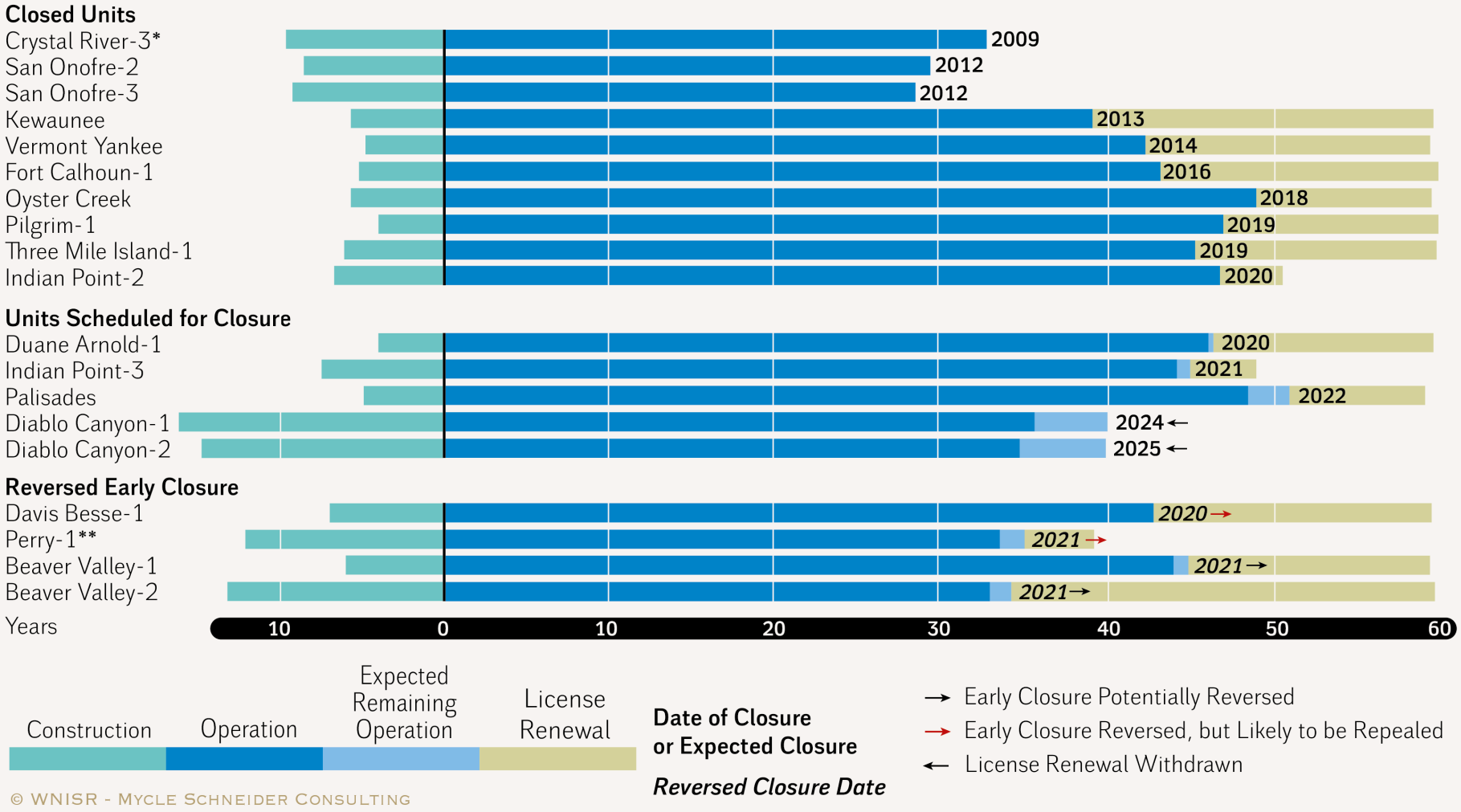
- at least 4 (4.8 GW) and up to 24 reactors (27.9 GW) were offline simultaneously;

- 20 reactors or more were simultaneously offline during the equivalent of 53 days.

Sources:, RTE and EDF, 2020

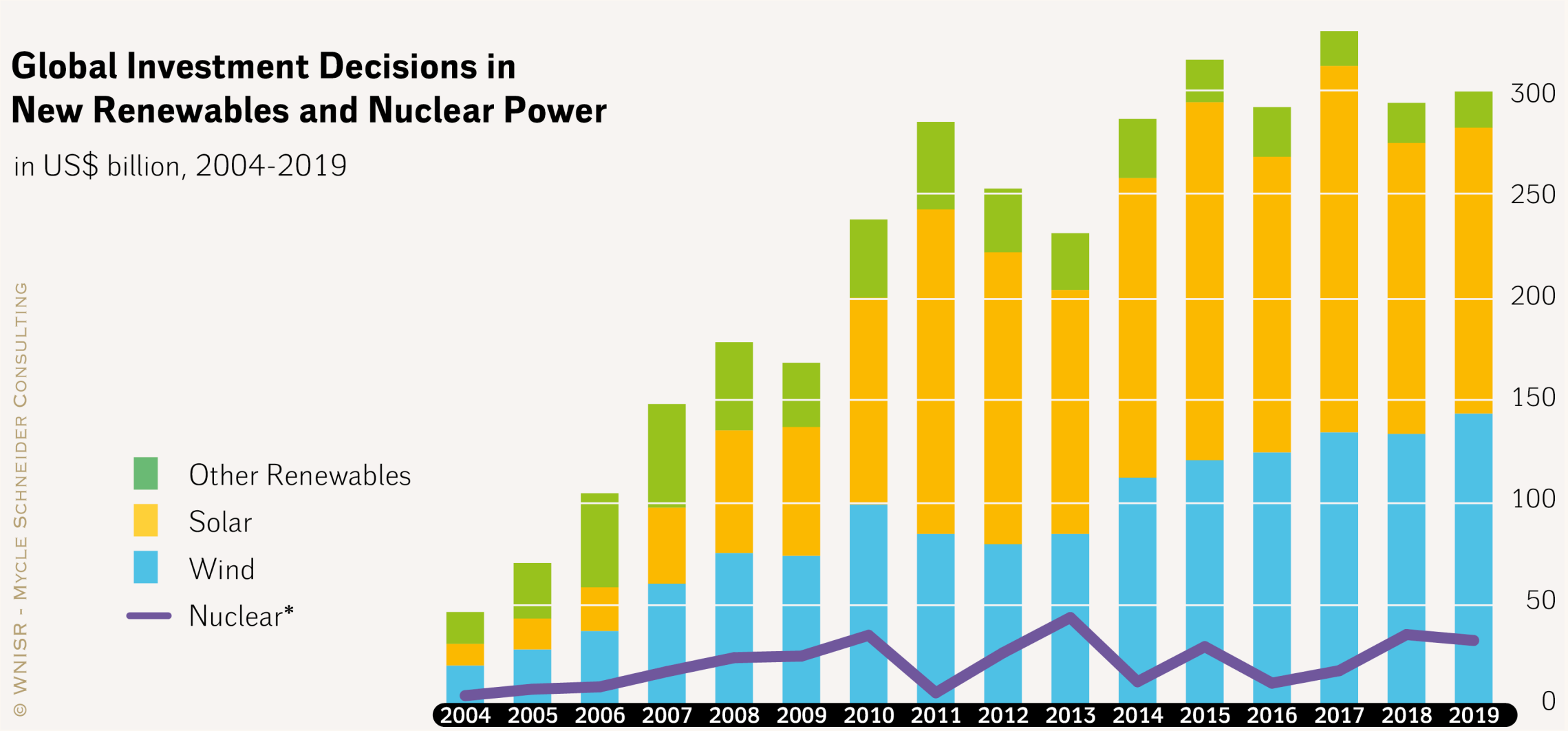
Timelines of 19 U.S. Reactors Subject to Early-Retirement 2009–2025

as of 1 July 2020



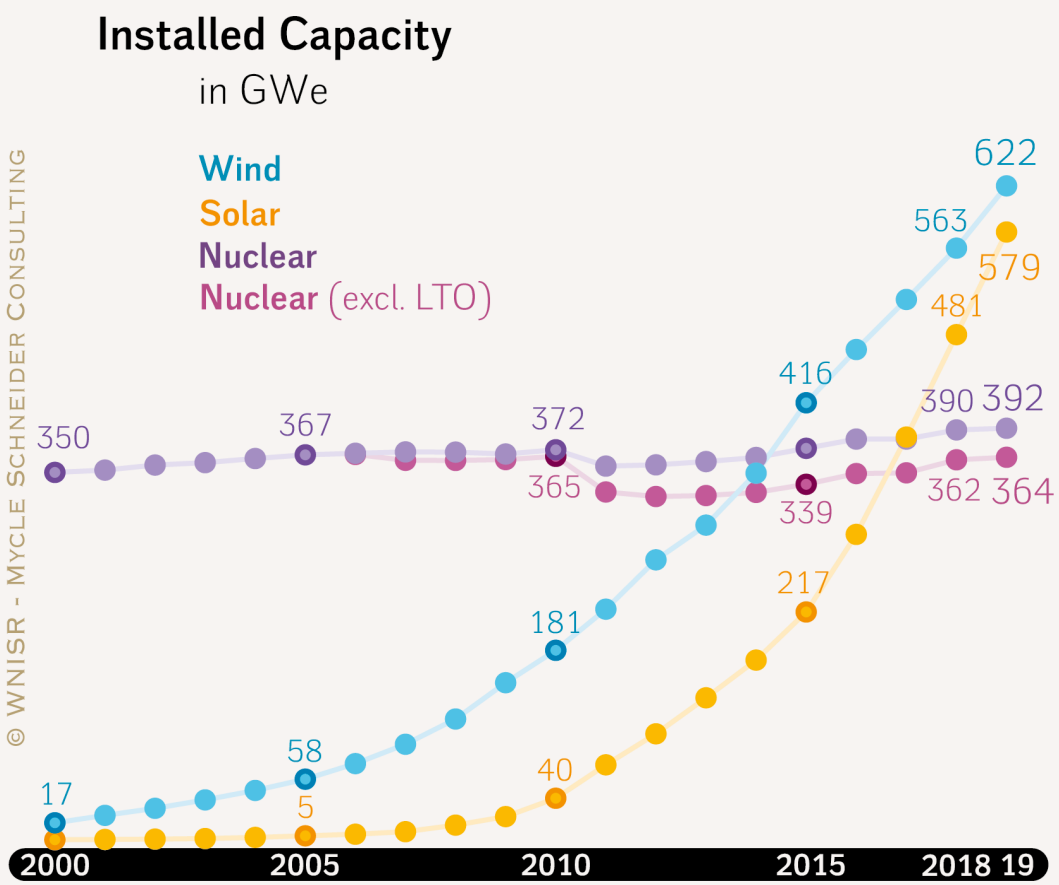
Sources: Various, compiled byWNISR, 2020

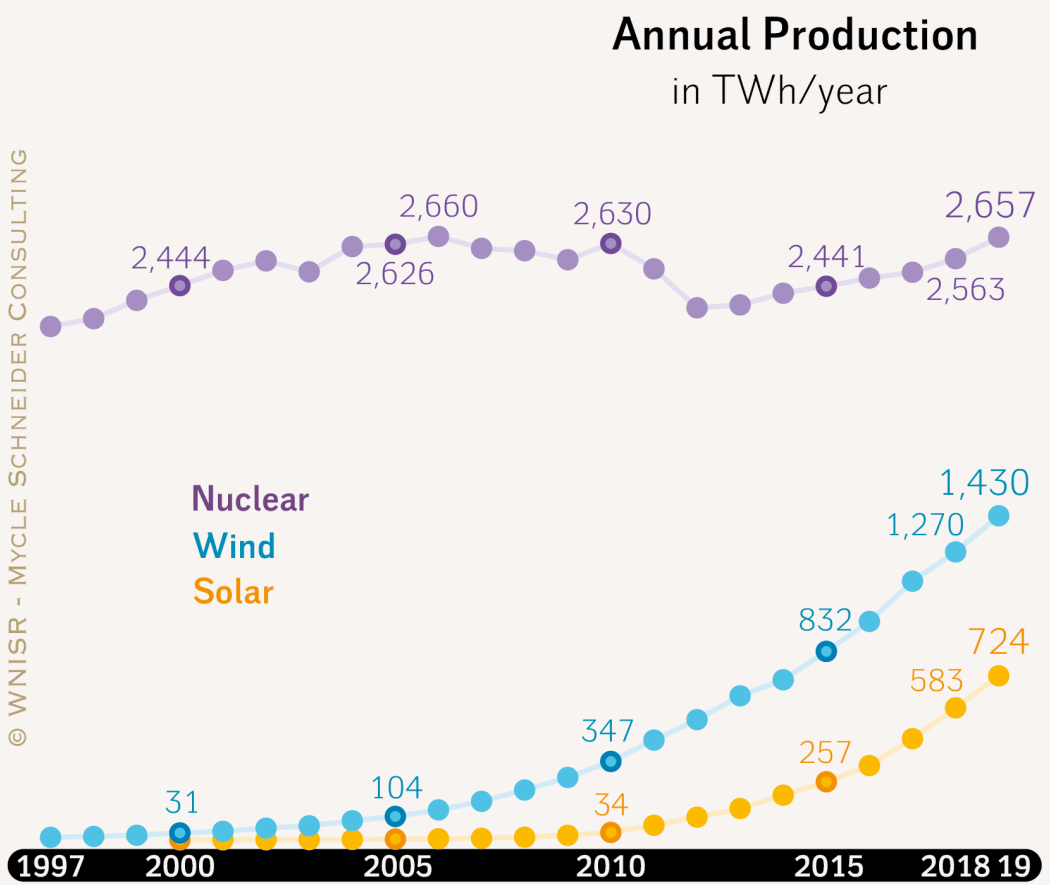
NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



Sources: FS-UNEP/BNEF 2020 and WNISR Original Research

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

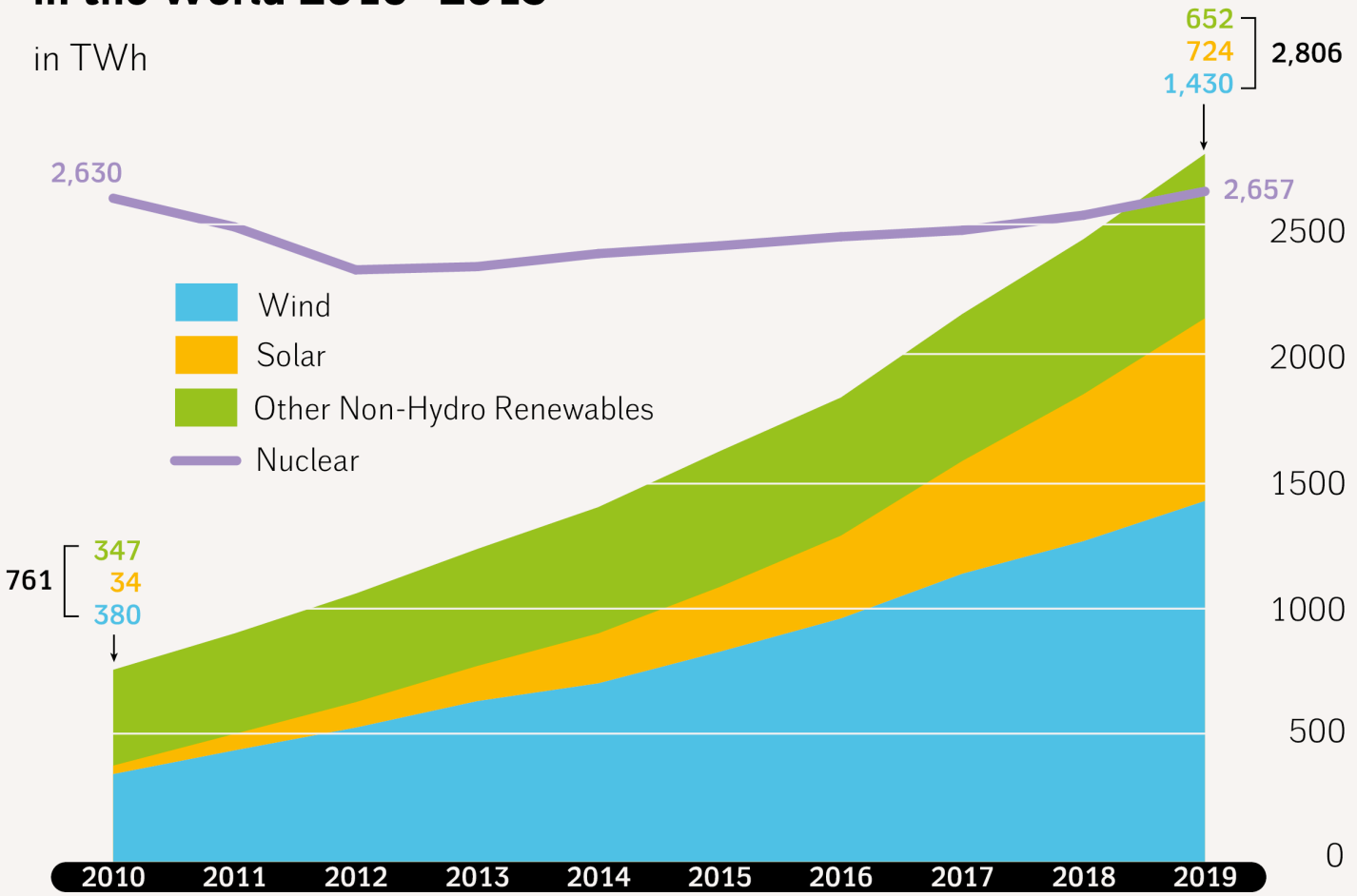




Sources: WNISR, IAEA-PRIS, IRENA, BP, 2020

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT

Nuclear vs. Non-Hydro Renewable Electricity Production in the World 2010–2019



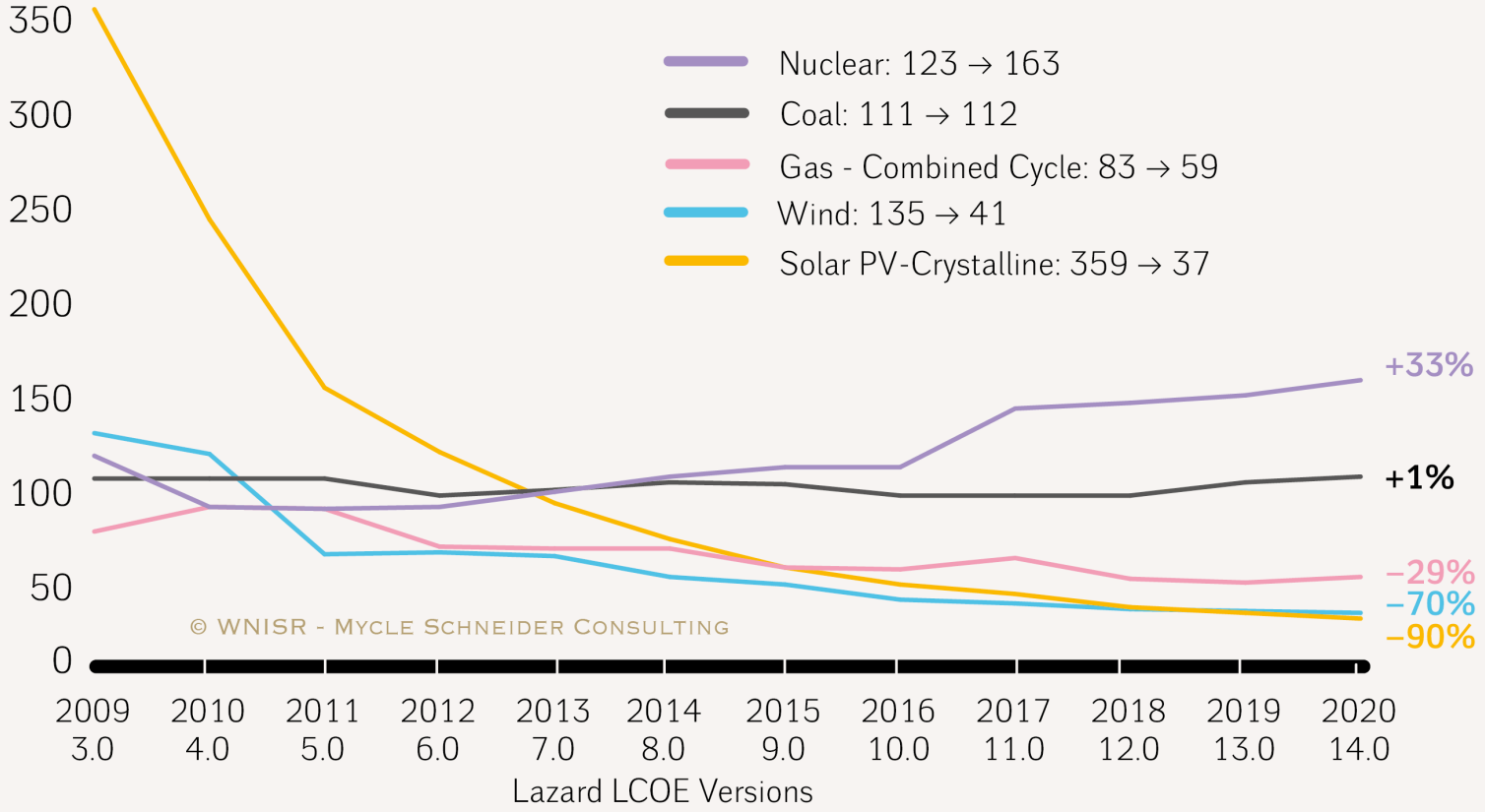
Note: The renewable energy numbers refer to gross production, according to BP, while the nuclear generation is net as provided by IAEA-PRIS.
Gross nuclear generation was 2,796 TWh, as calculated by BP.

Sources: BP Statistical Review and IAEA-PRIS, 2020

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT

Selected Historical Mean Costs by Technology

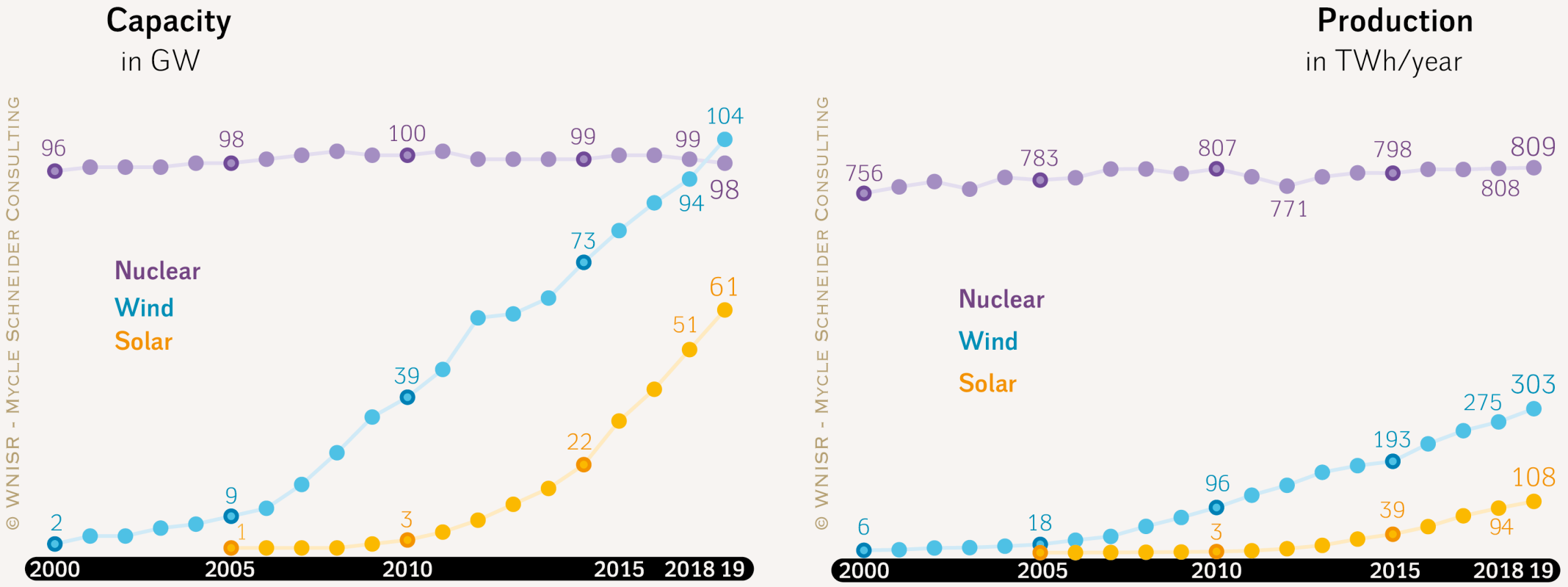
LCOE values in US$/MWh *



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

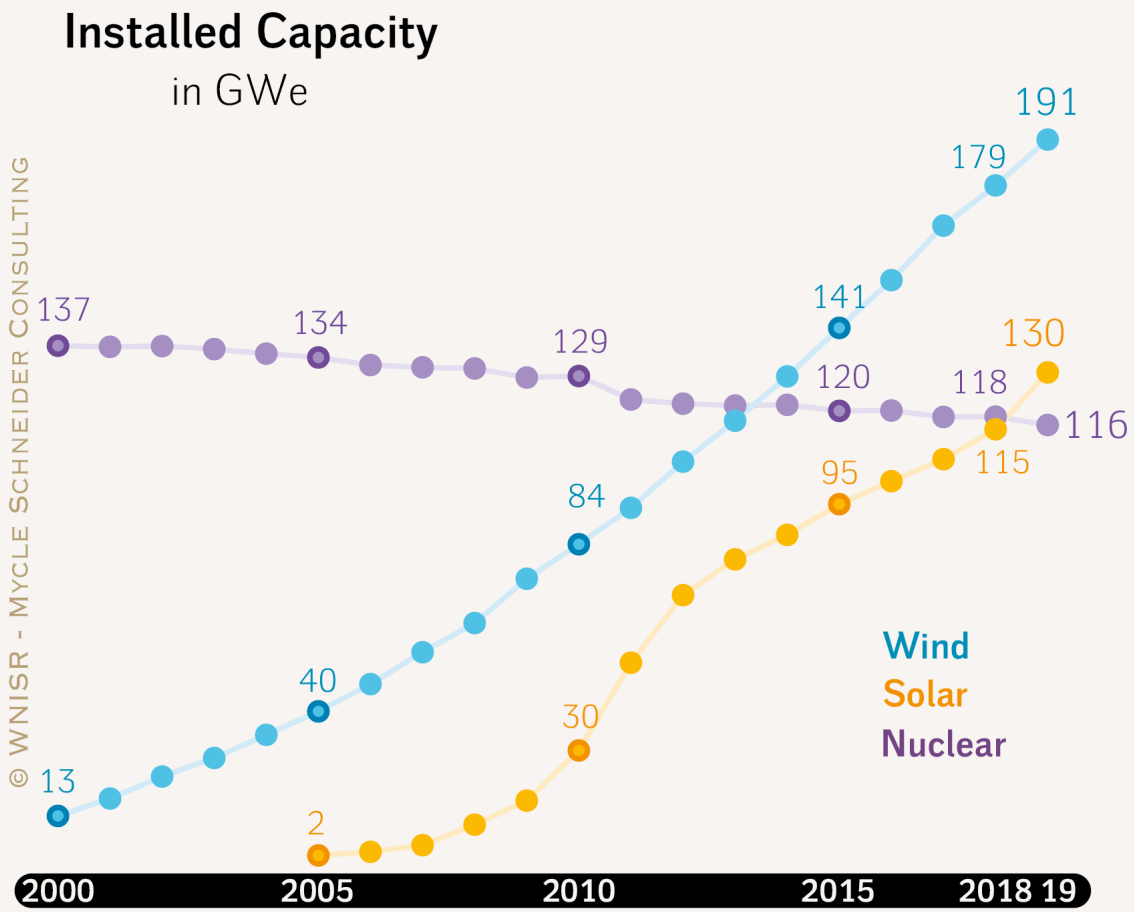
Sources: Lazard, 2020

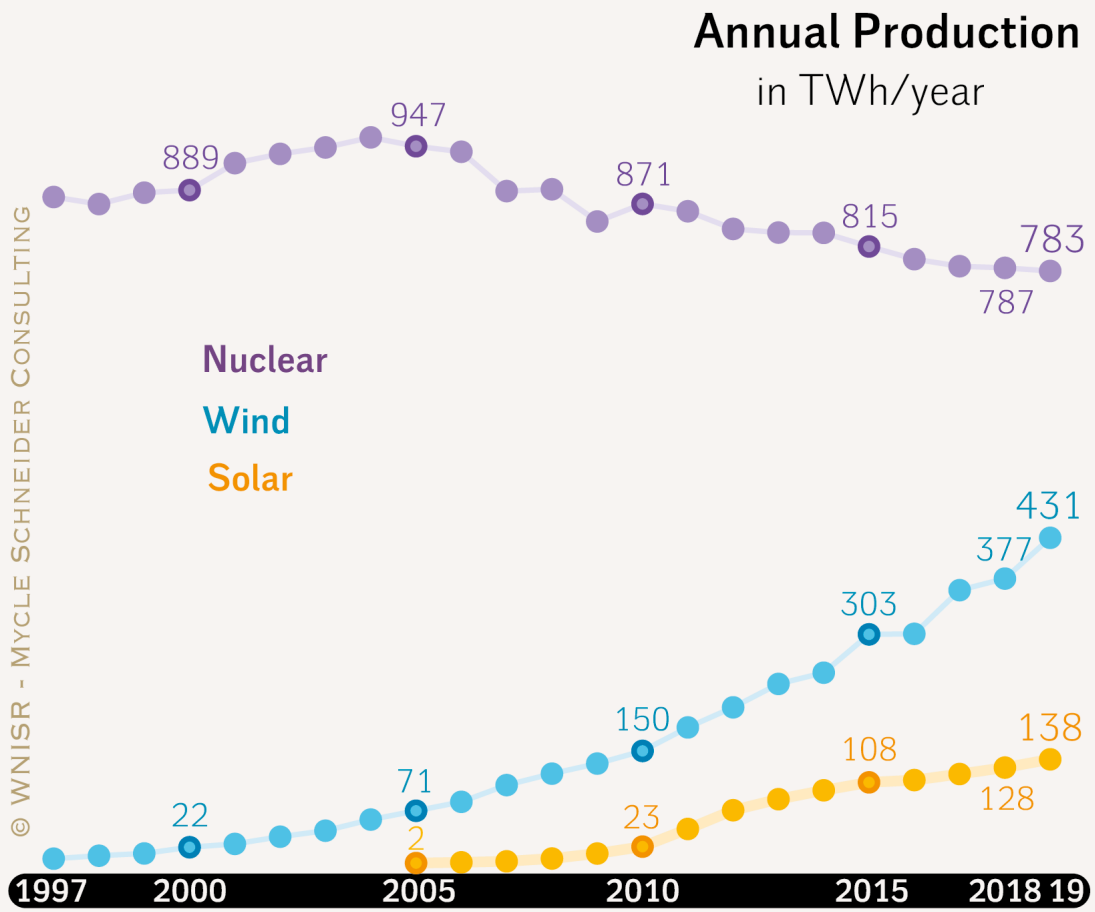
Installed Wind, Solar and Nuclear Capacity and Production in the U.S. 2000–2019



Sources: BP, IRENA, IAEA-PRIS, WNISR 2020

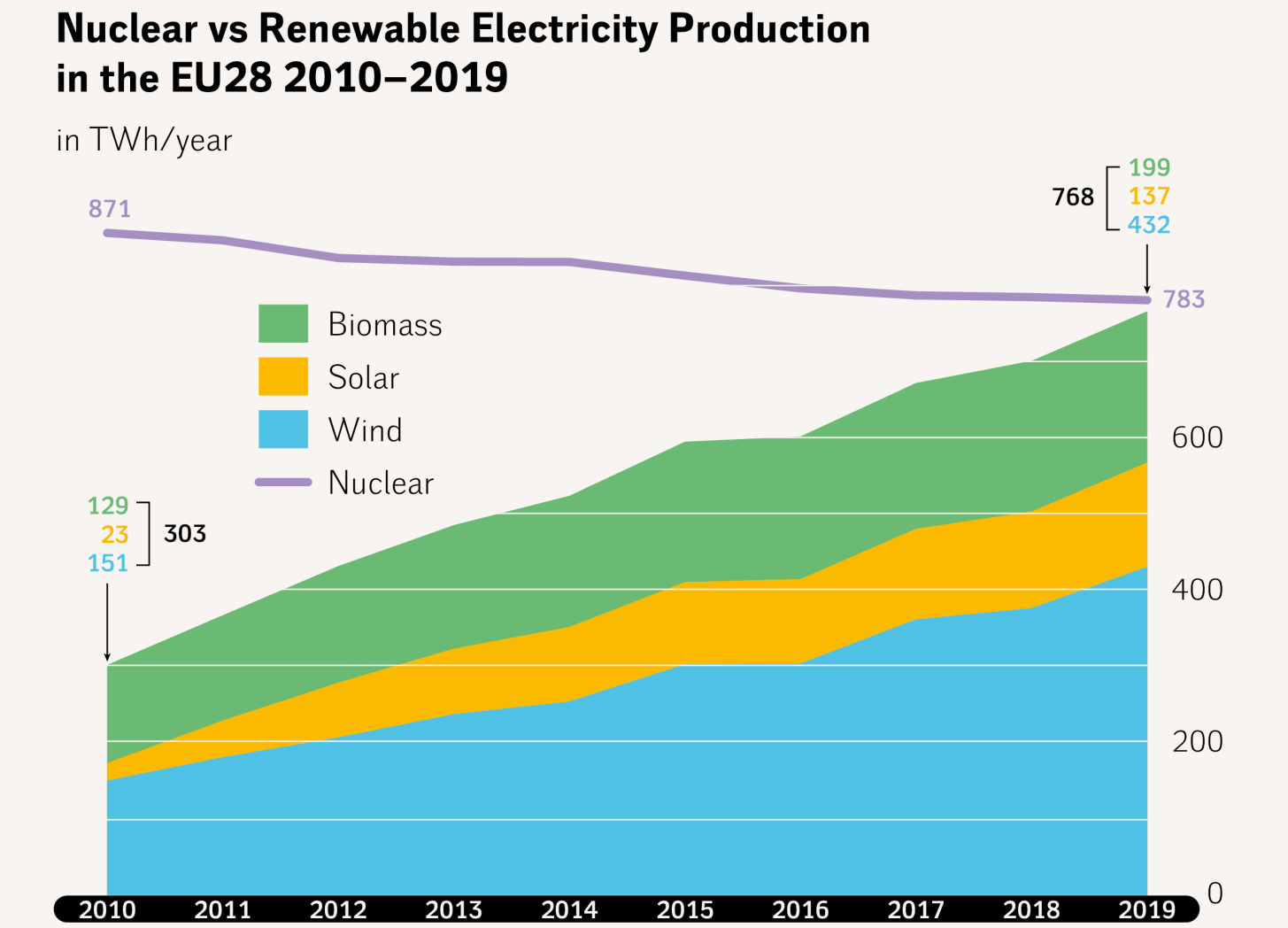
Installed Wind, Solar and Nuclear Capacity and Electricity Production in the EU28





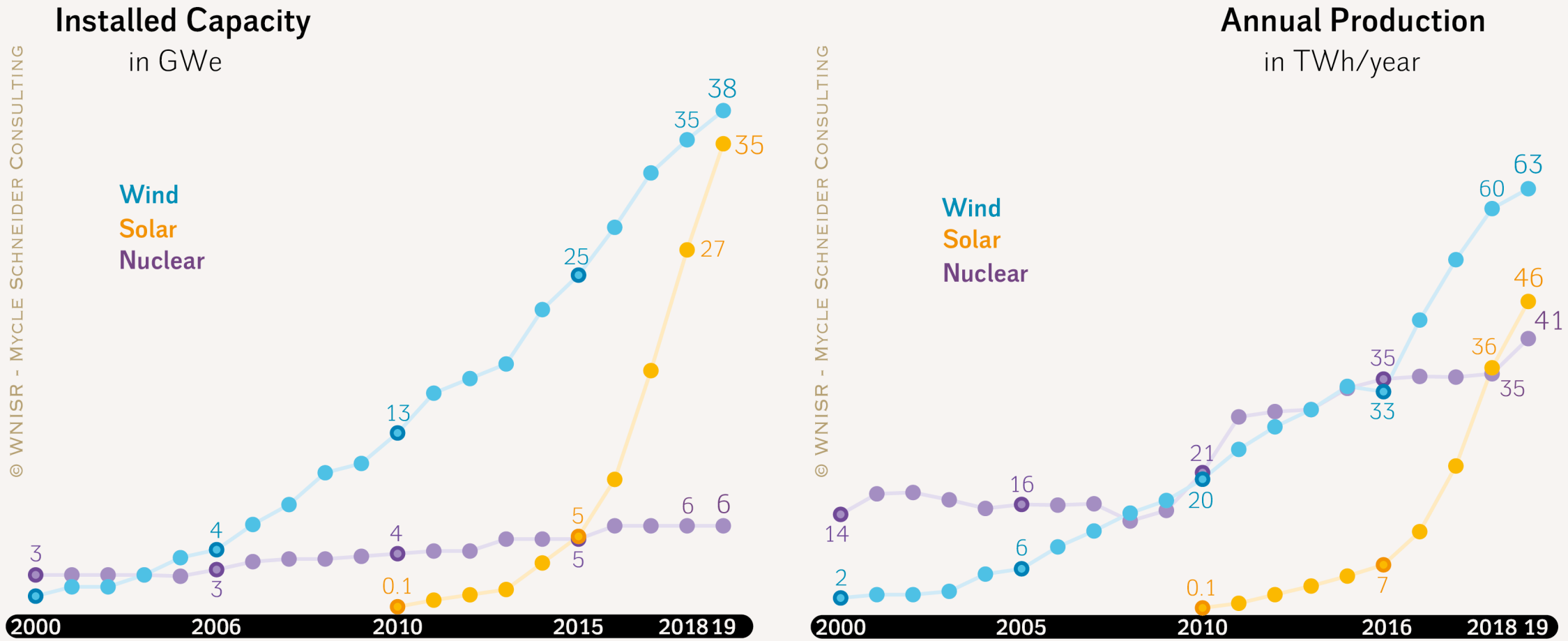
Sources: IRENA, BP, IAEA-PRIS, WNISR, 2020

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



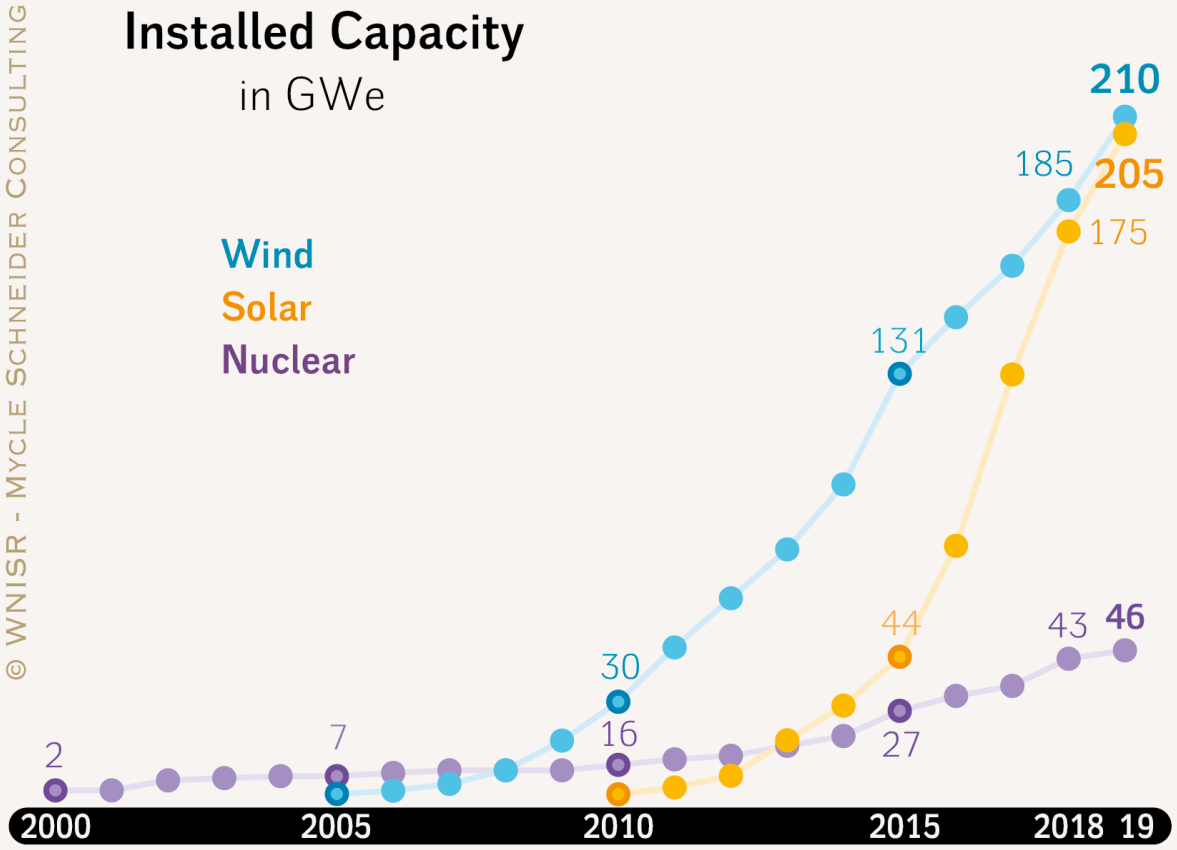
Sources: Sources: IAEA-PRIS, Agora Energiewende/Sandbag

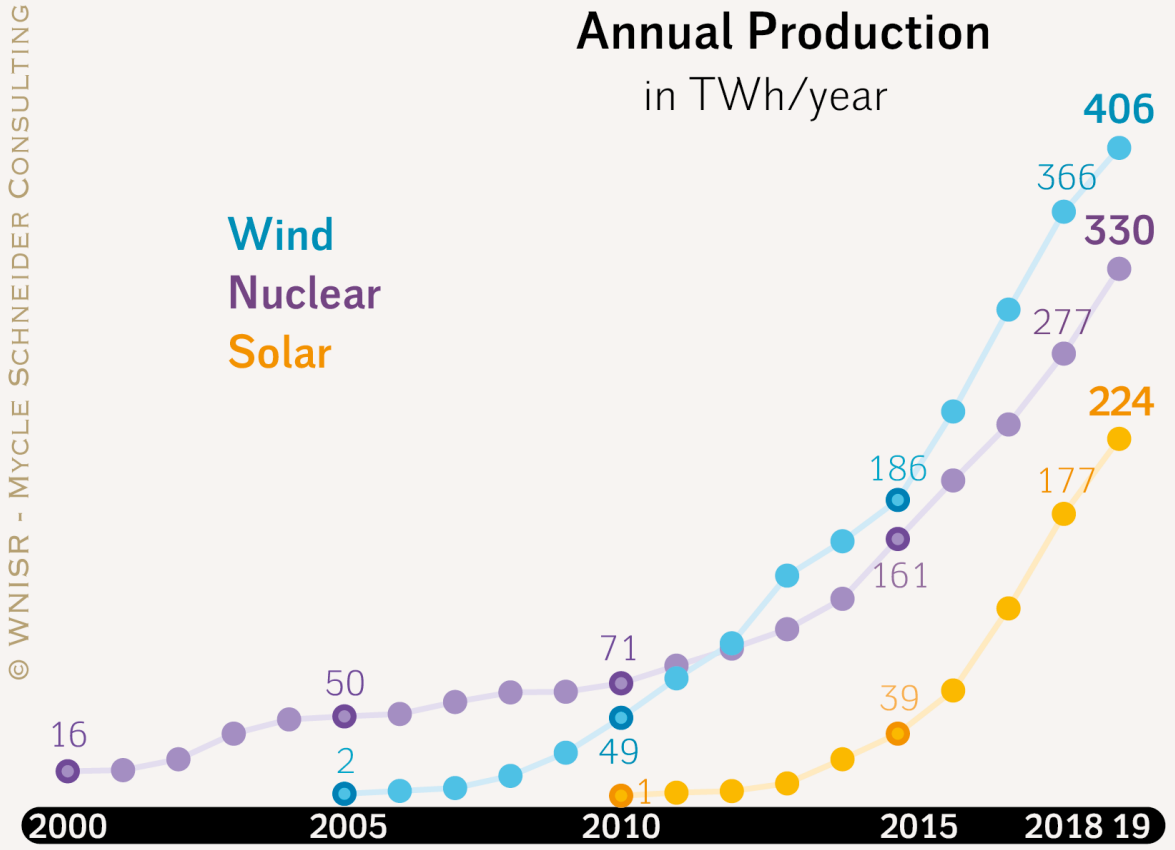
Installed Wind, Solar and Nuclear Capacity and Electricity Production in India 2000–2019



Sources: IRENA, BP, IAEA-PRIS, WNISR, 2020

Installed Wind, Solar and Nuclear Capacity and Electricity Production in China 2000–2019

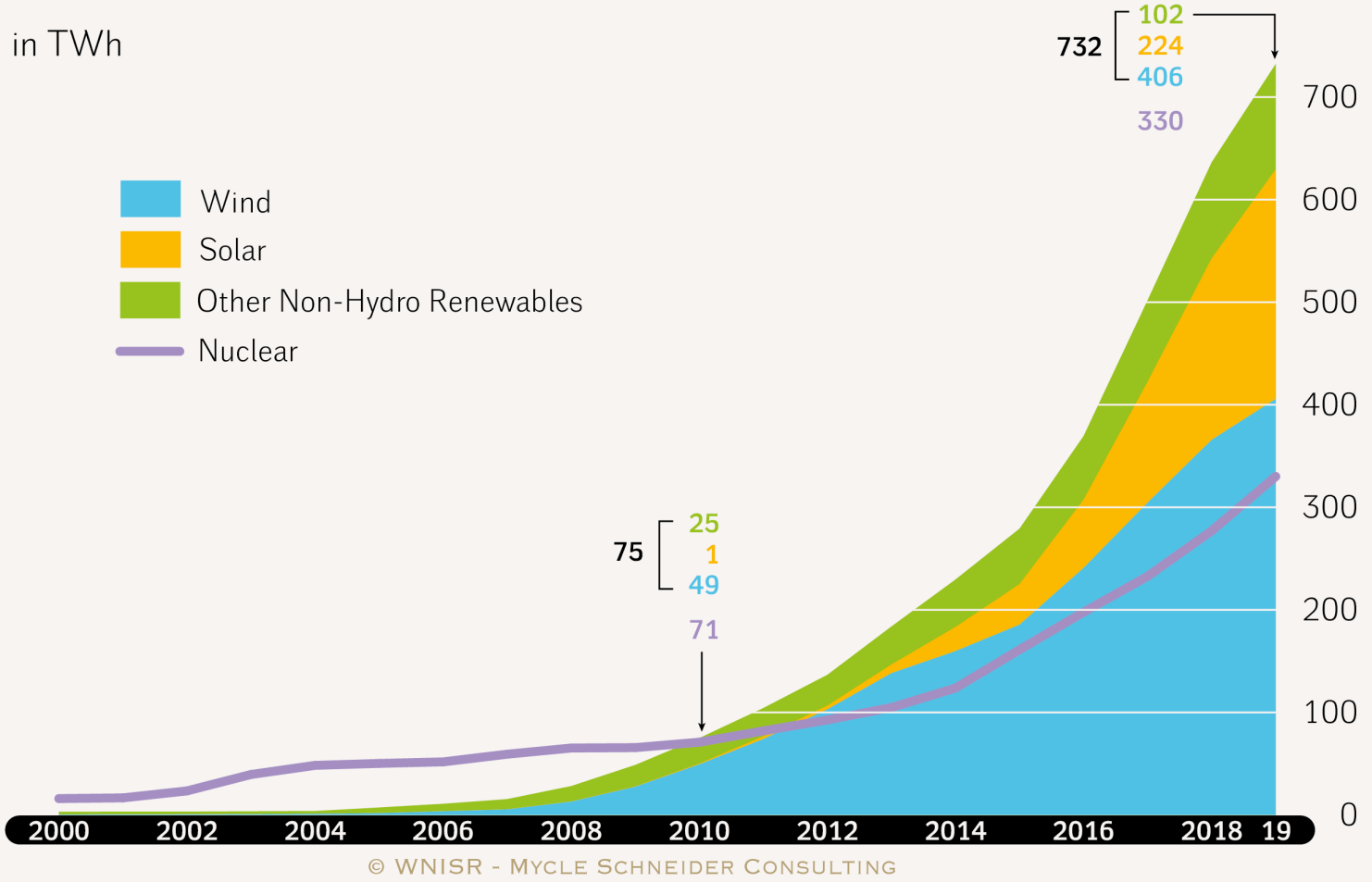




Sources: IRENA, BP, IAEA-PRIS, WNISR, 2020

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT

Nuclear vs. Non-Hydro Renewable Electricity Production in China 2000–2019



Note: The renewable energy numbers refer to gross production, according to BP, while the nuclear generation is net as provided by IAEA-PRIS.
Gross nuclear generation in 2019 was 349 TWh, as calculated by BP.

Sources: AIEA-PRIS, BP 2020

Atomindustrie und COVID-19

- Zum ersten Mal ist Atomindustrie von globaler Pandemie betroffen.
- Personal in Telearbeit, Mangel an Aufsicht vor Ort, wochenlanges Fehlen physischer Inspektionen
  --> Reduzierung von Sicherheit- und Sicherungsmargen.
- Die Durchführung von verschobenen Inspektionen und Wartungsarbeiten wird viel Zeit kosten, vielleicht ein oder zwei Jahre.
- Die finanziellen und wirtschaftlichen Auswirkungen auf den Atomsektor werden erheblich sein.

Die Atomindustrie im Nahen Osten

- Barakah in den Vereinigten Arabischen Emiraten wird wahrscheinlich eine Ausnahme bleiben.
- Der wirtschaftliche Vorteil der Solarenergie setzt sich zunehmend durch.

Weltweite Trends in der Atomkraft

- Anzahl der Reaktoren in Betrieb: 414 (Stand 24.2.21), weniger als 1989 (mit 418), 24 als Max. mit 438 in 2002.
- Produktion wieder auf pre-Fukushima Niveau, kapp unterhalb des Rekordjahres 2006 (war das peak-atom?)

Atomkraft versus Erneuerbare

- Rekordzuwachs der Erneuerbarenkapazität (ohne Wasserkraft) weltweit in 2019 mit +184 GW
  versus +2 GW Atom. 2020 wahrscheinlich neuer Rekord für Erneuerbare und Bilanz Atom negativ.
- Anteil Erneuerbare (ohne Wasserkraft) im Strommix weltweit zum ersten Mal höher als Anteil Atomkraft.

Mycle Schneider works as independent international consultant on energy and nuclear policy. He is the Coordinator and Editor of the World Nuclear Industry Status Reports. He is a Founding Board Member and the Spokesperson for the International Energy Advisory Council (IEAC). He is a Founding Member of the International Nuclear Risk Assessment Group (INRAG) and a member of the International Nuclear Security Forum (INSF), hosted by the Stimson Center, Washington D.C. He is also 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 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 over the past 30+ years. He has given lectures or had teaching appointments at over 20 universities and engineering schools in 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.