The World Nuclear Industry Status Report 2020

(WNISR2020)

www.WorldNuclearReport.org

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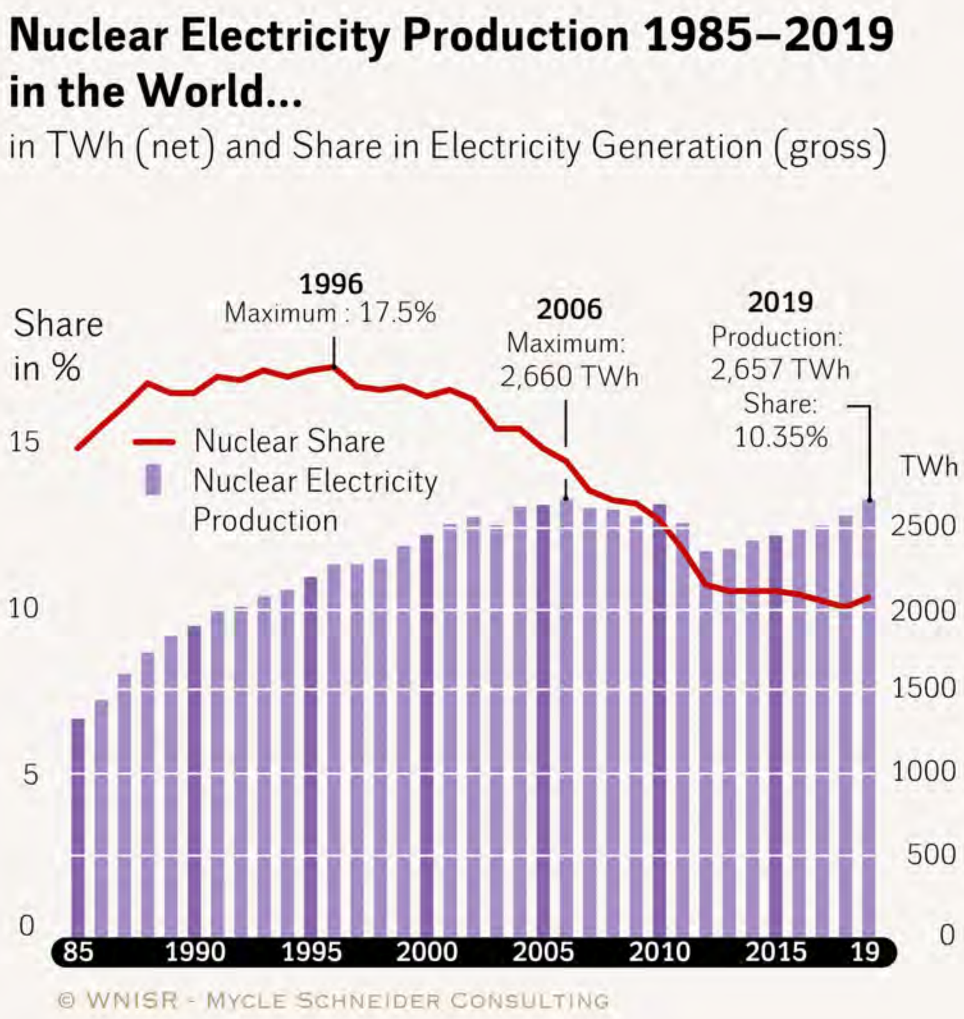
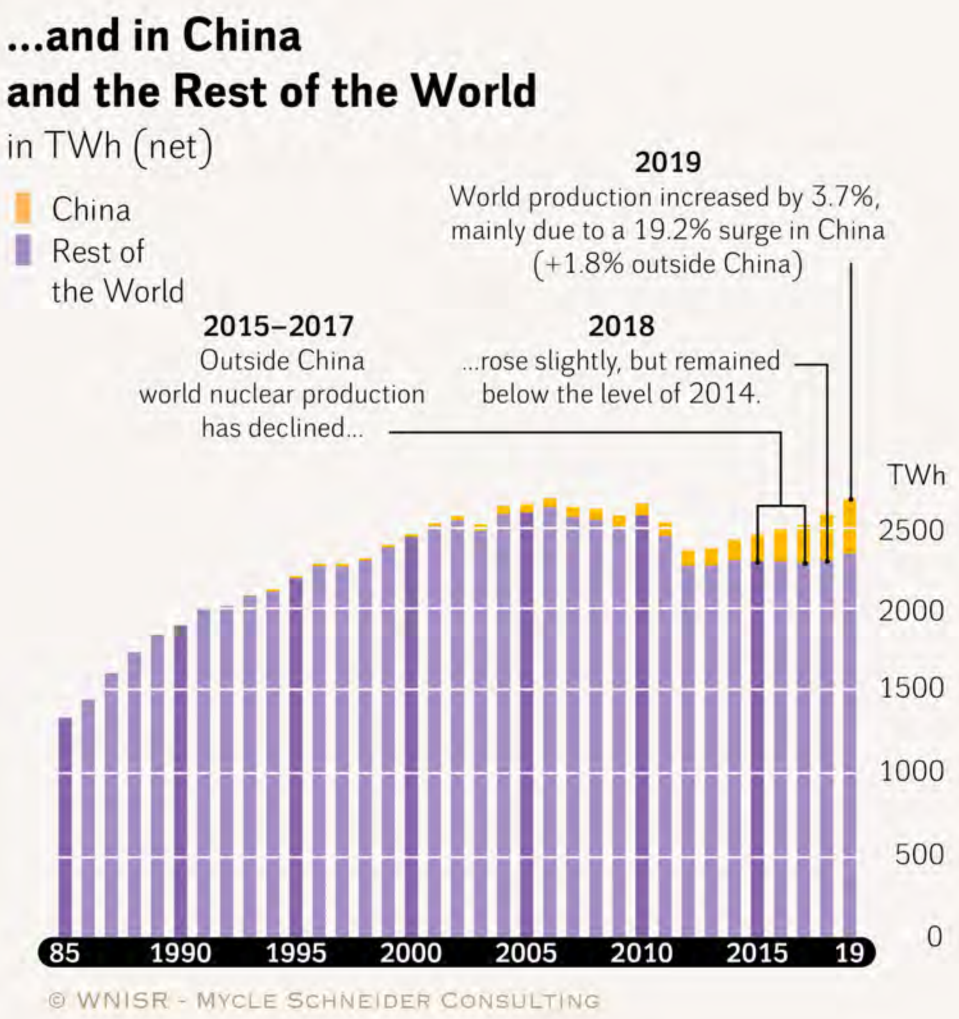
Washington D.C. — Paris — Beirut — Vancouver, 24 September 2020

GLOBAL OVERVIEW – ROLE OF NUCLEAR POWER





Sources: IAEA-PRIS, BP, 2020

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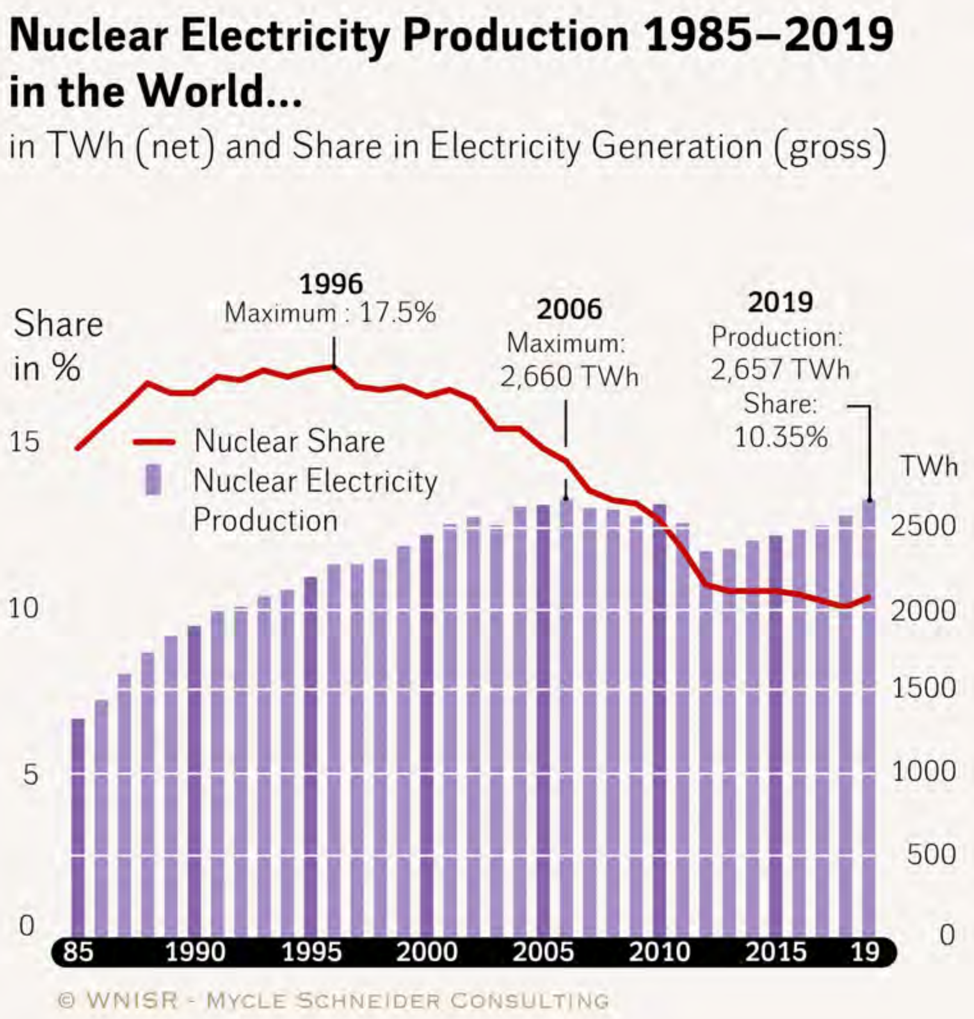
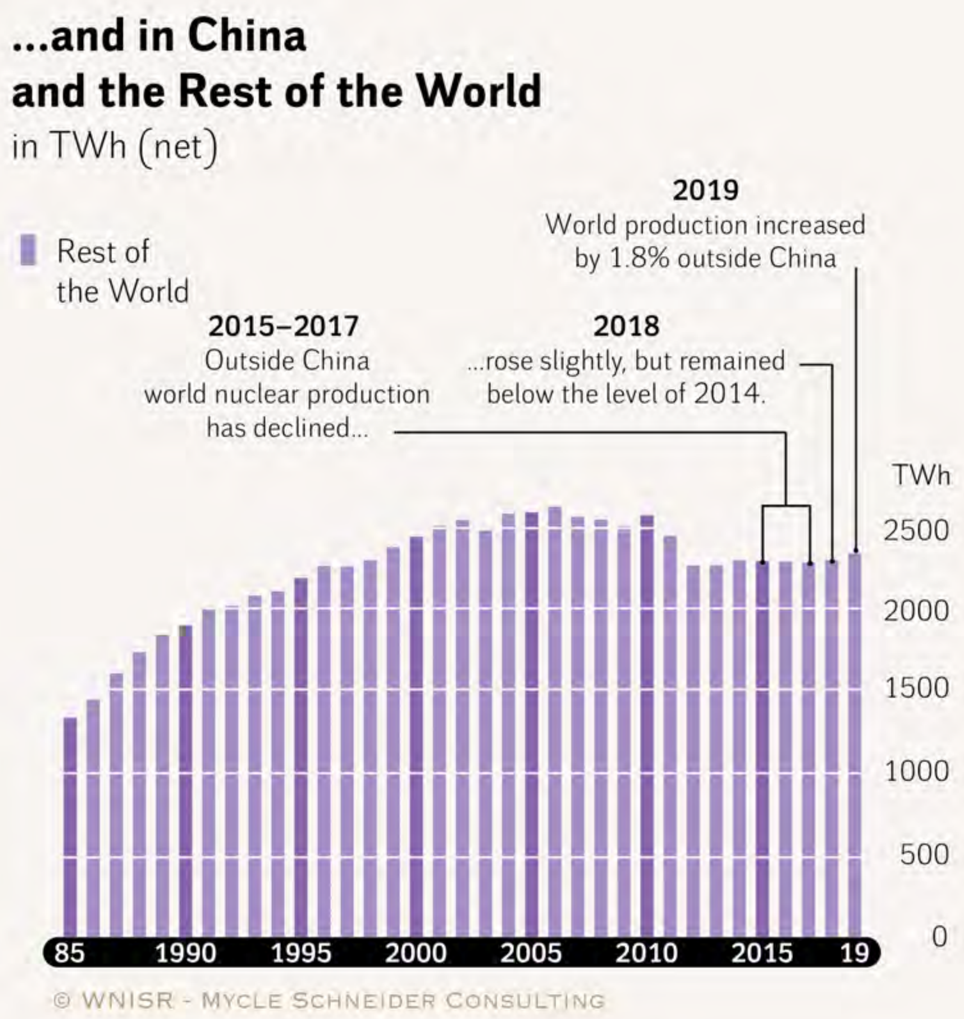
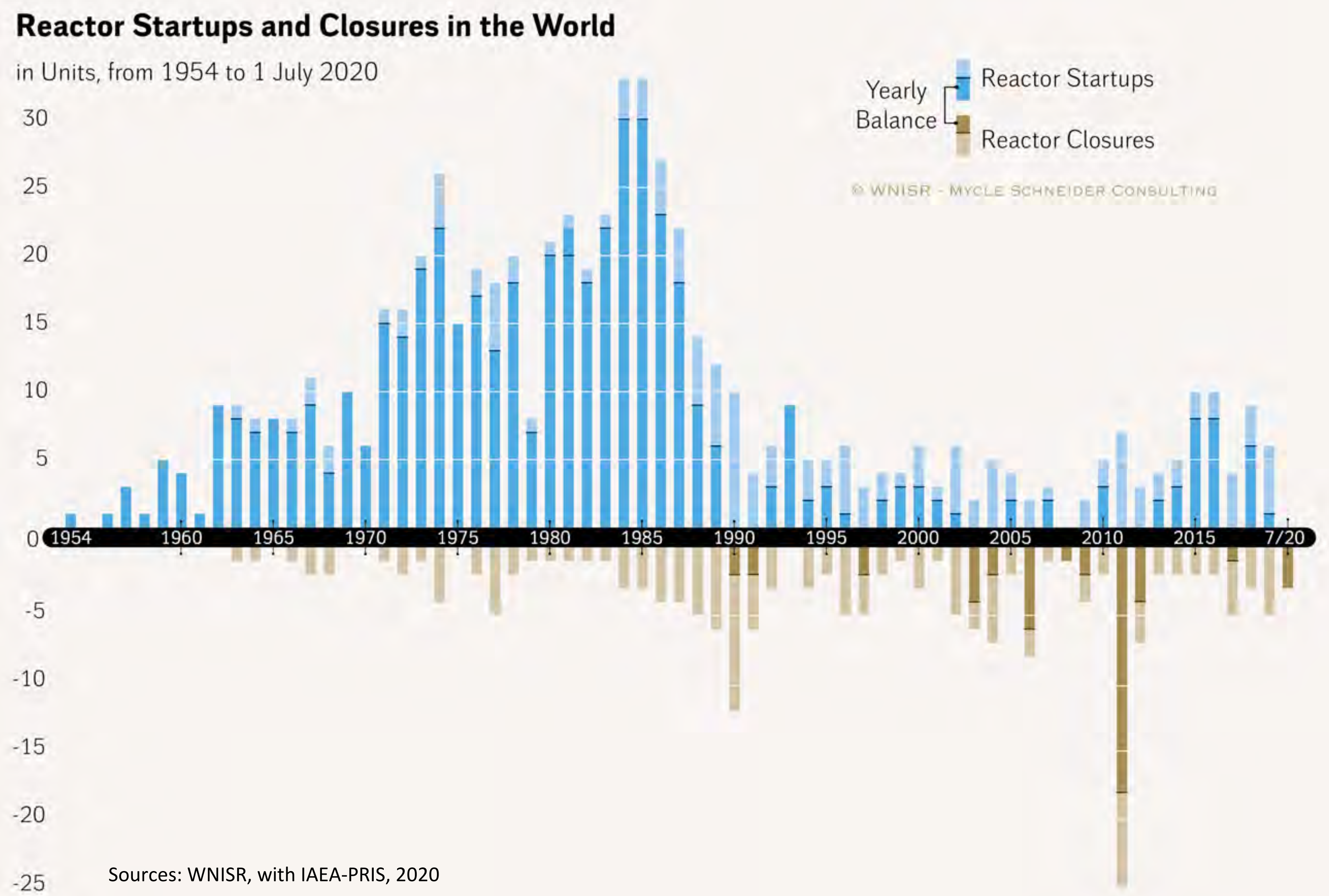




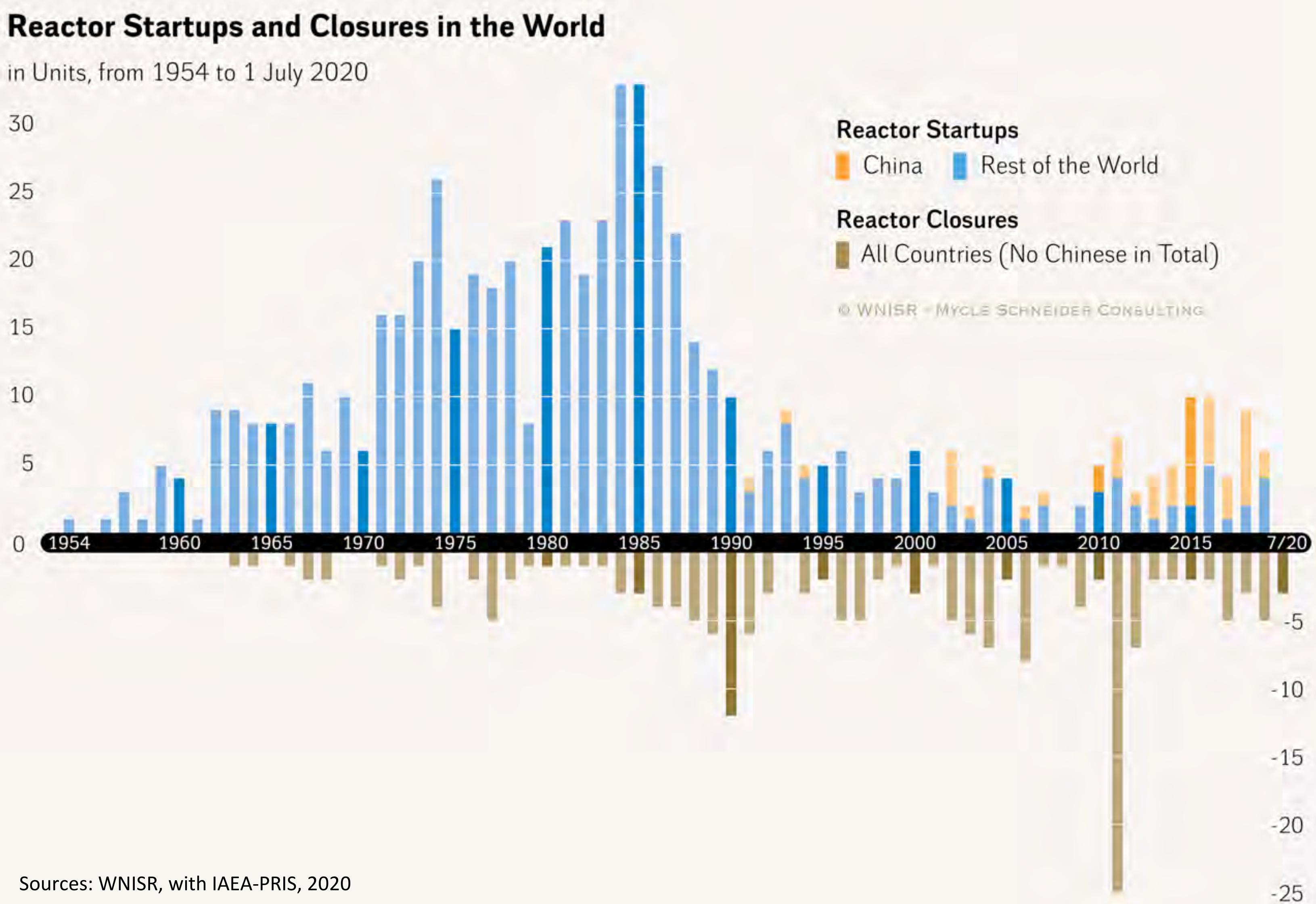
Sources: IAEA-PRIS, BP, 2020

GLOBAL OVERVIEW – STARTUPS AND CLOSURES



Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – STARTUPS AND CLOSURES



Sources: WNISR, with IAEA-PRIS, 2020

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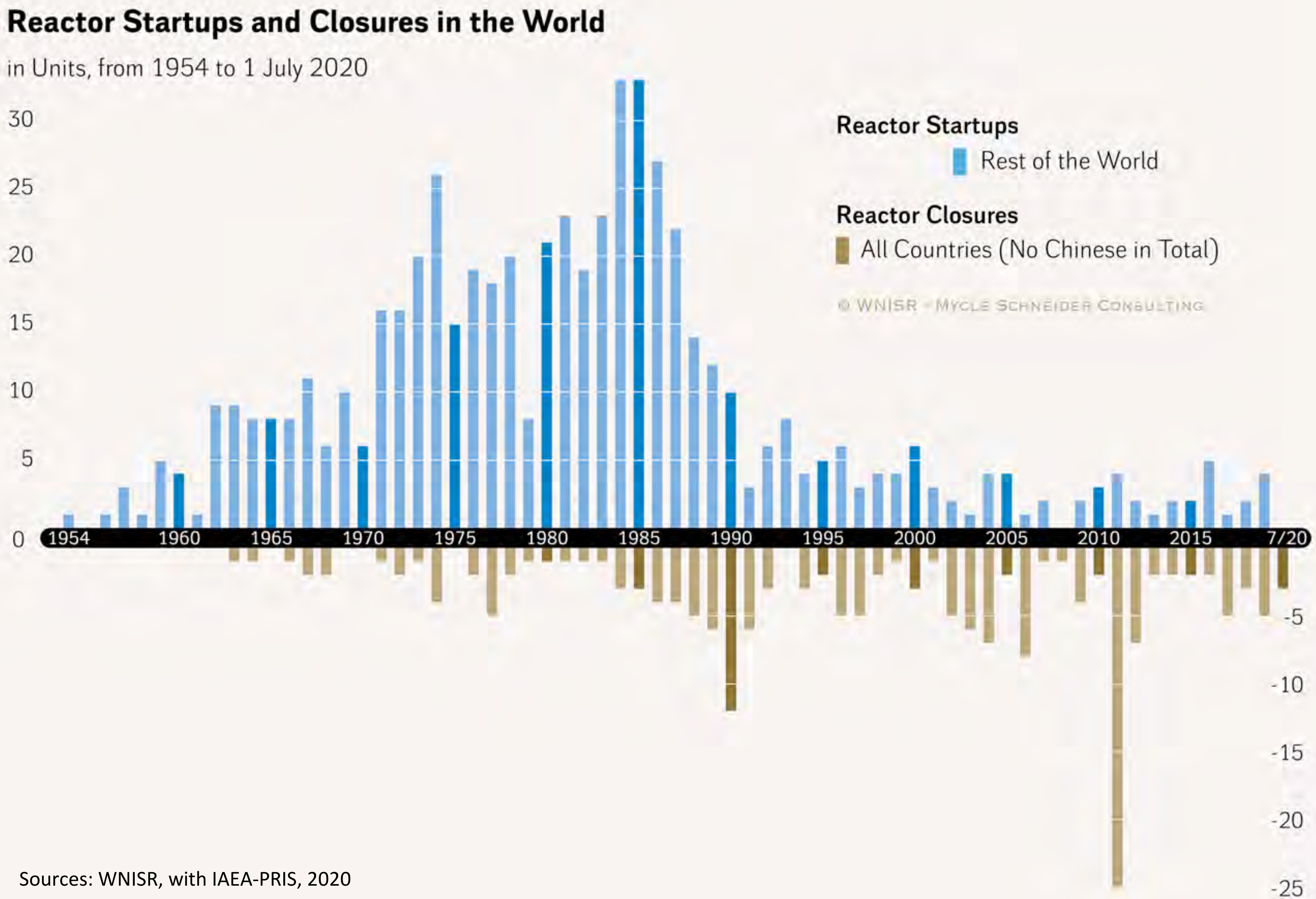
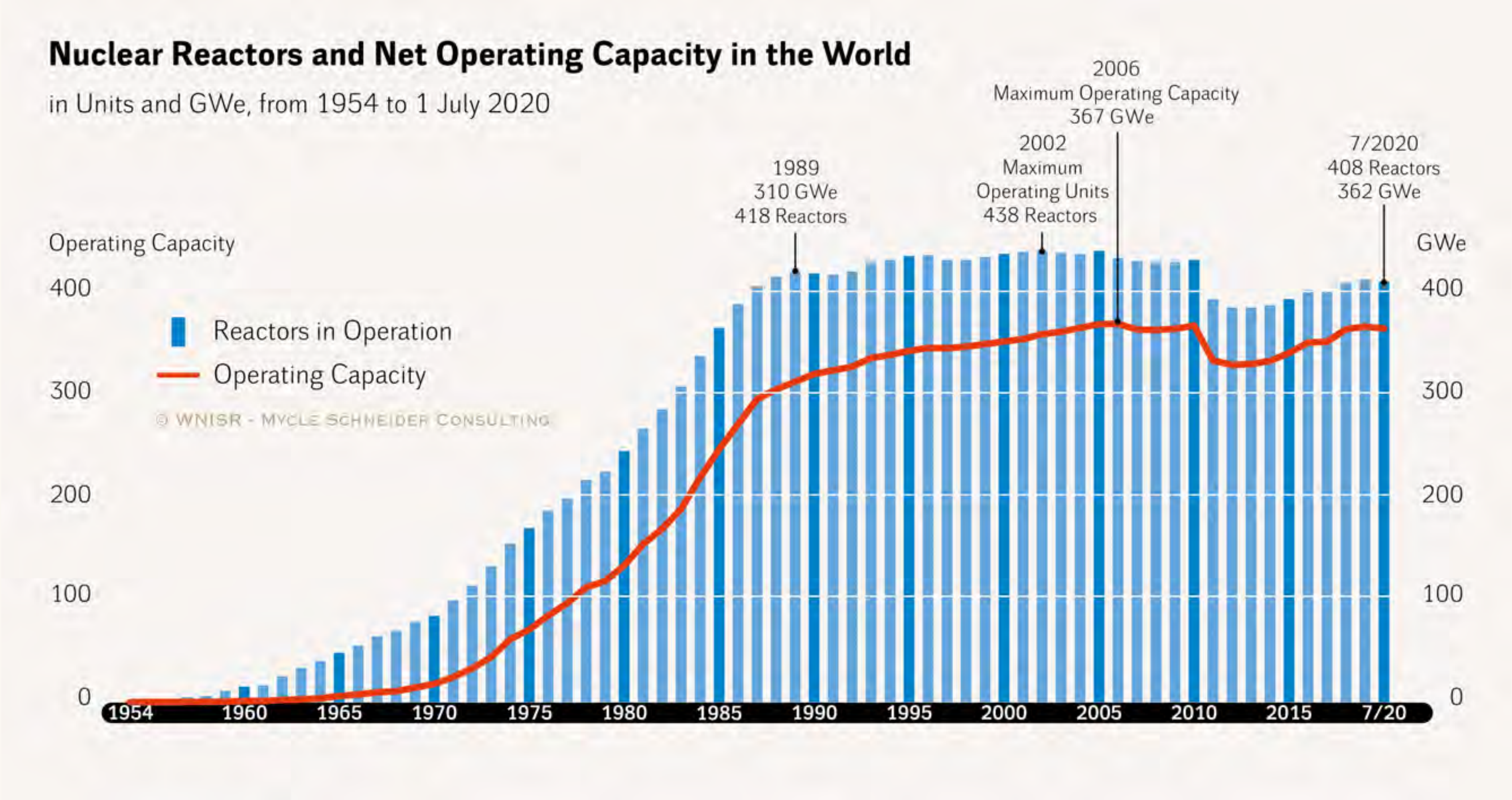


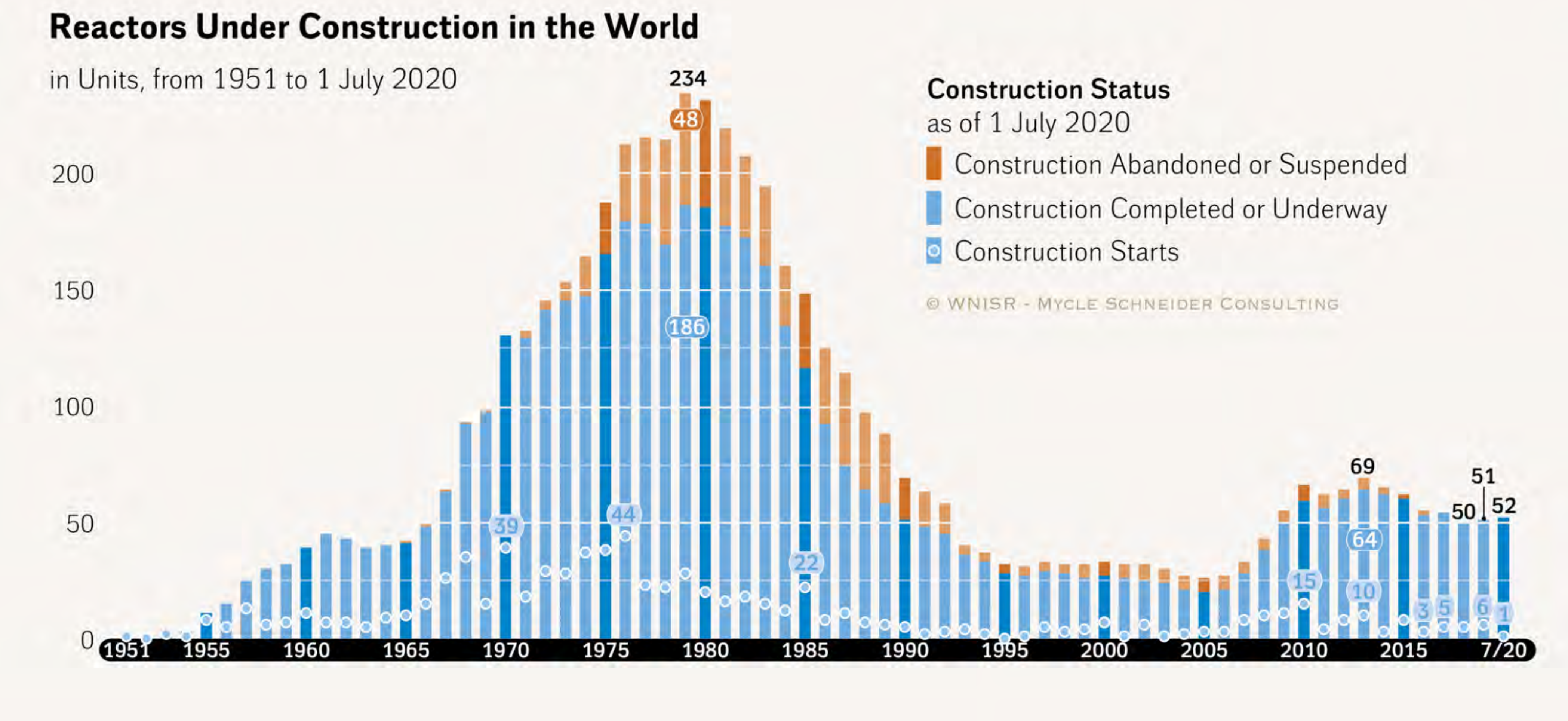
Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW — WORLD FLEET



Sources: WNISR, with IAEA-PRIS, 2020

GENERAL OVERVIEW — CONSTRUCTIONS



Sources: WNISR, with IAEA-PRIS, 2020

Nuclear Reactors "Under Construction" (as of 1 July 2020)

Country	Units	Capacity (MW net)	Construction Start	Grid Connection	Units Behind Schedule
China	15	13 842	2012 - 2019	2020 - 2025	6
India	7	4 824	2004 - 2017	2020 - 2023	5
South Korea	4	5 360	2012 - 2018	2020 - 2024	4
UAE	4	5 380	2012 - 2015	2020 - 2023	4
Russia	3	3 315	2010 - 2019	2021 - 2023	1
Bangladesh	2	2 160	2017 - 2018	2023 - 2024	0
Belarus	2	2 218	2013 - 2014	2020 - 2021	2
Pakistan	2	2 028	2015 - 2016	2021	1
Slovakia	2	880	1985 - 1985	2020 - 2021	2
Turkey	2	2 228	2018 - 2020	2024 - 2025	1
UK	2	3 260	2018 - 2019	2025 - 2026	0
USA	2	2 234	2013	2021 - 2022	2
Argentina	1	25	2014	2021	1
Finland	1	1 600	2005	2021	1
France	1	1 600	2007	2022	1
Iran	1	1 196	1976	2024	1
Japan	1	1 325	2007	?	1
Total	**52**	**53 475**	**1976 - 2020**	**2020 - 2026**	**33**

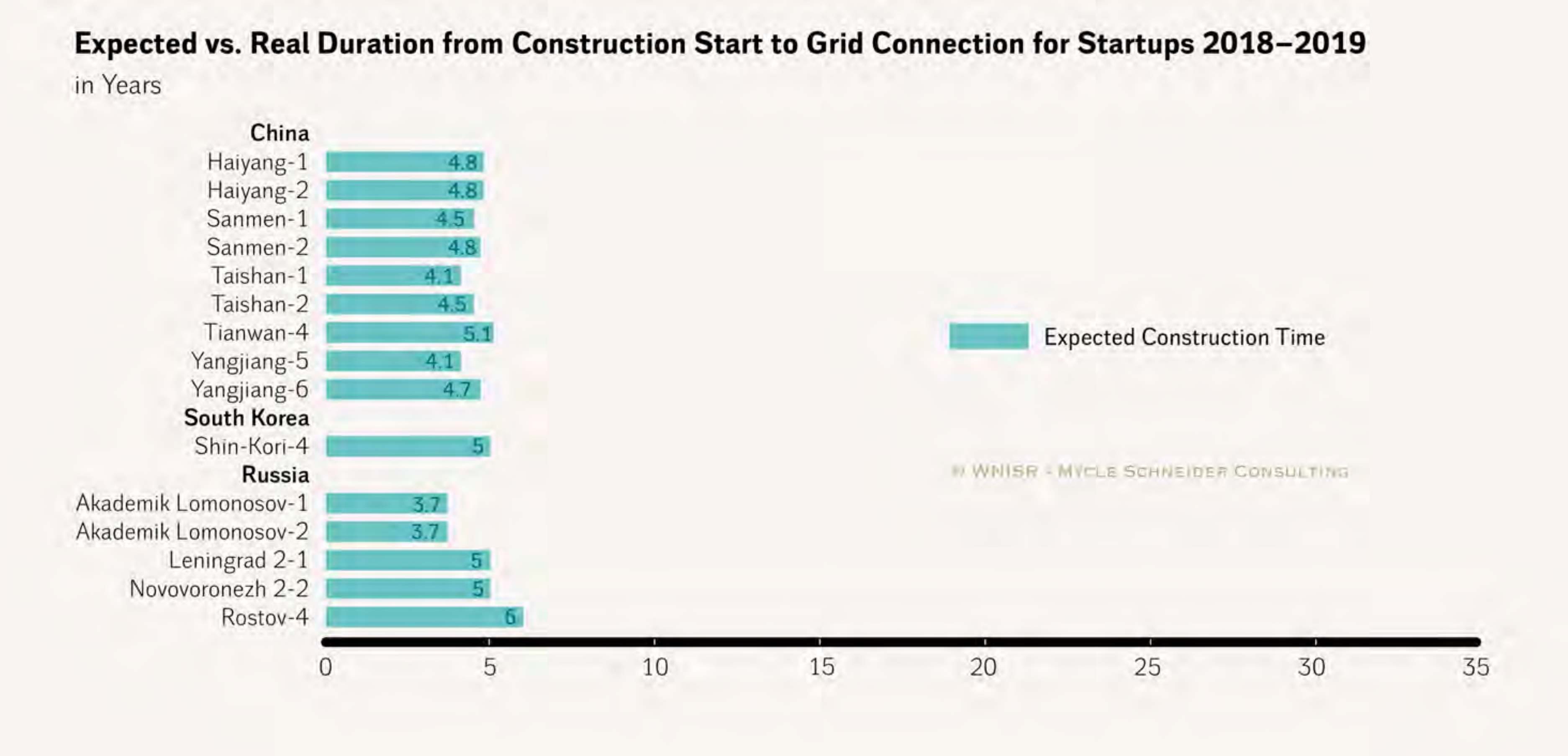
Sources: WNISR, with IAEA-PRIS, 2020

Duration from Construction Start to Grid Connection 2010–2019

Construction Times of 63 Units Started-up 2010–2019				
Country	**Units**	**Construction Time (in Years)**		
		Mean Time	**Minimum**	**Maximum**
China	37	6.0	4.1	11.2
Russia	10	20.3	8.1	35.1
South Korea	6	6.0	4.1	9.6
India	4	10.4	7.2	14.2
Pakistan	3	5.4	5.2	5.6
Argentina	1	33	33.0	
Iran	1	36.3	36.3	
USA	1	43.5	43.5	
World	**63**	**10.0**	**4.1**	**43.5**

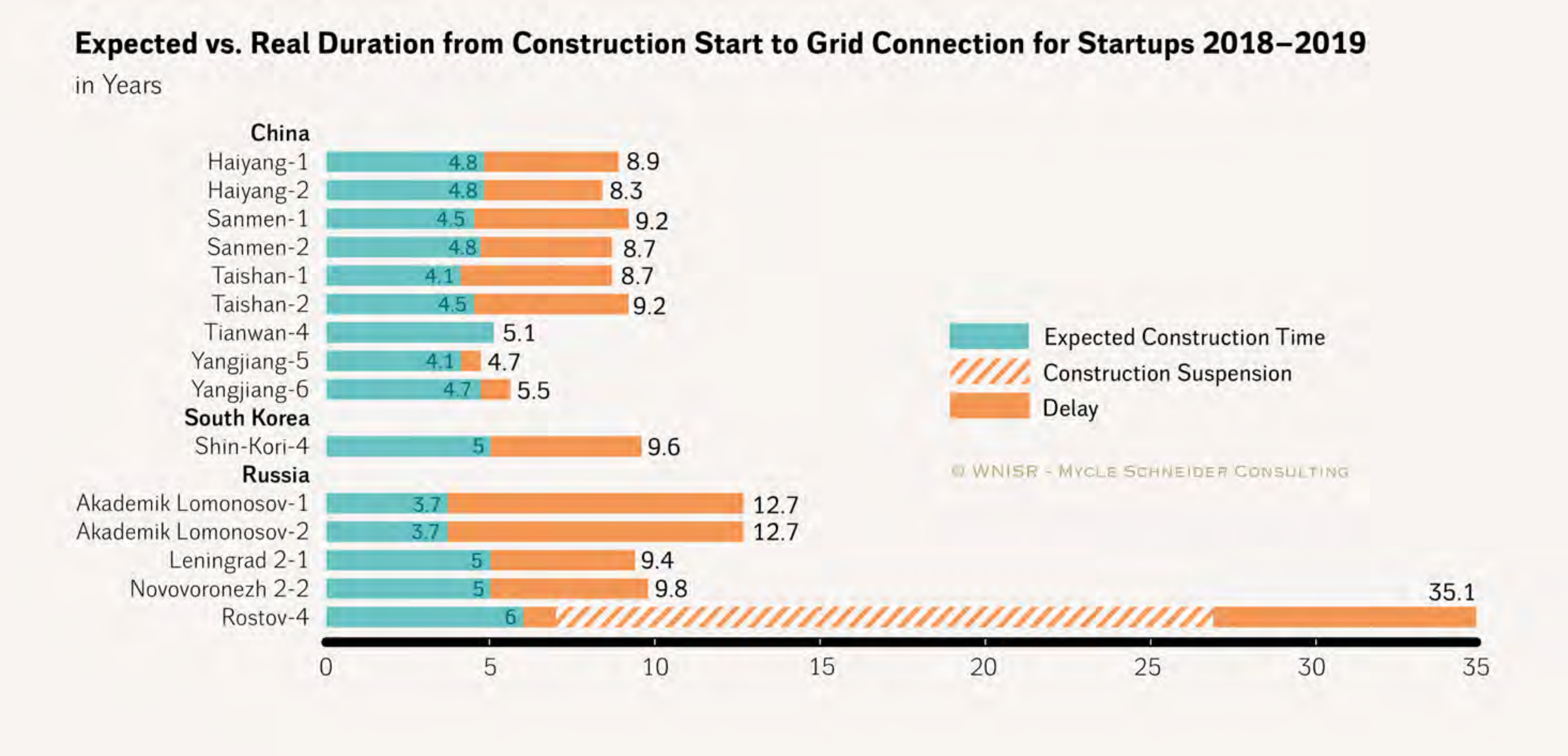
Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS



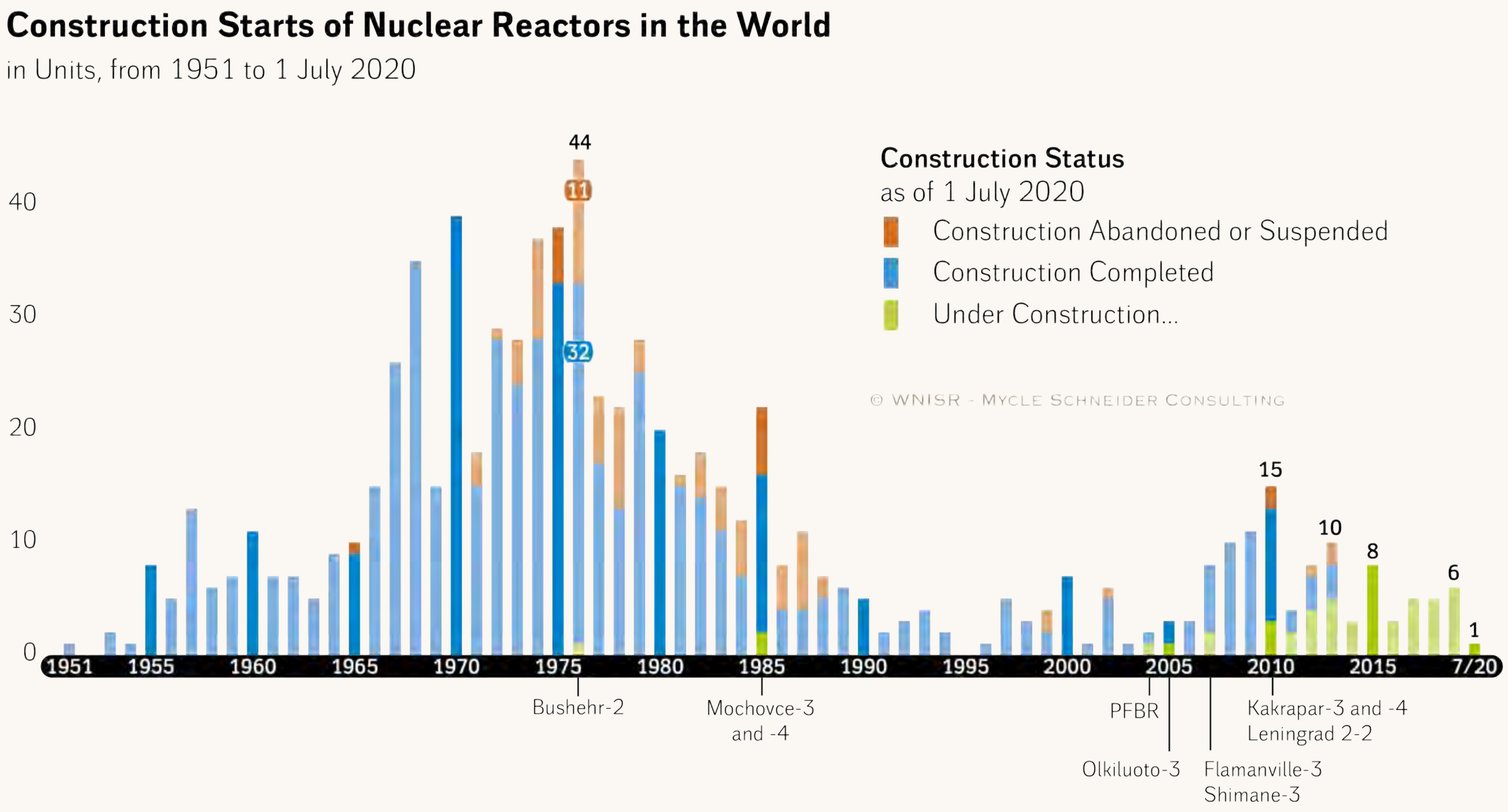
Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS



Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – CONSTRUCTIONS



Sources: WNISR, with IAEA-PRIS, 2020

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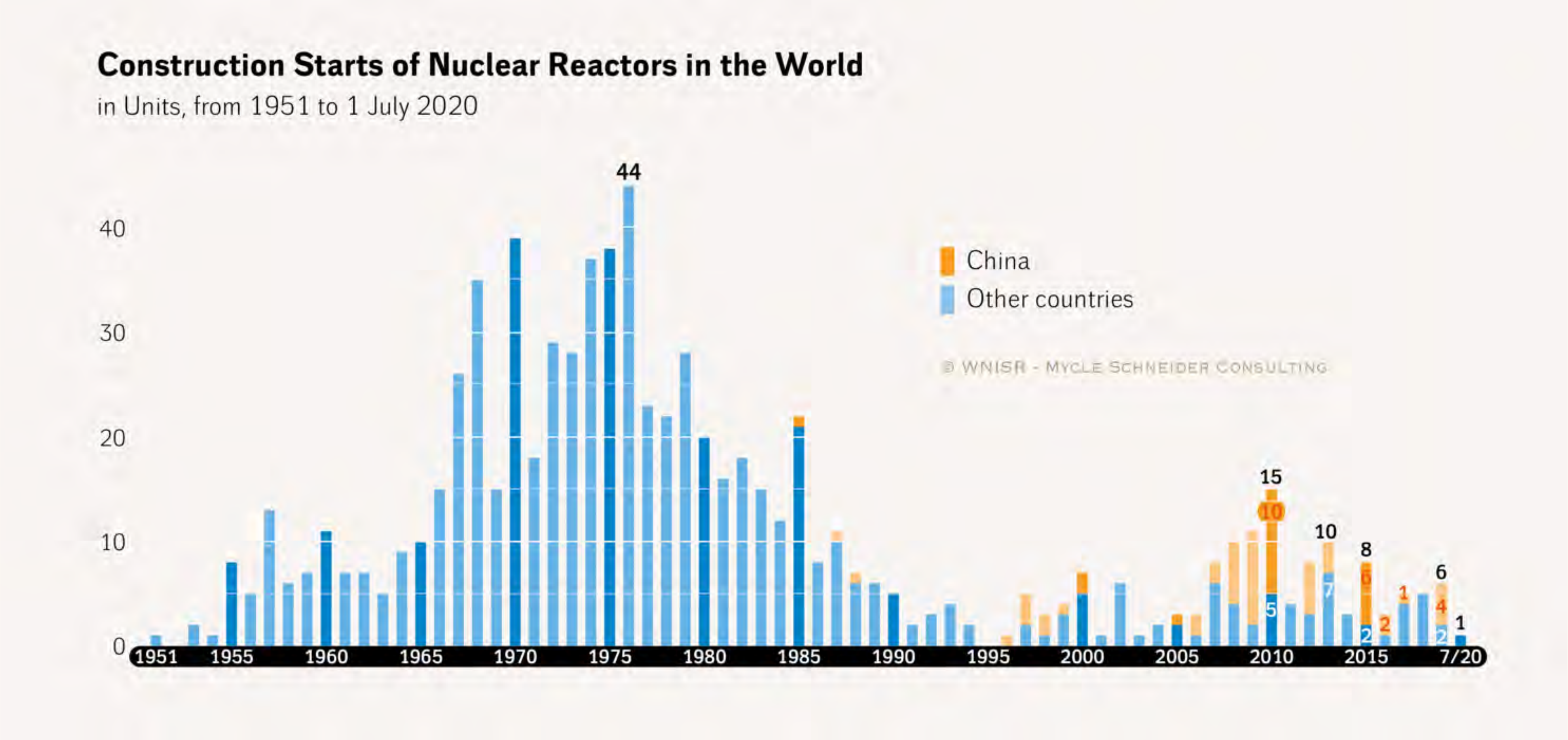
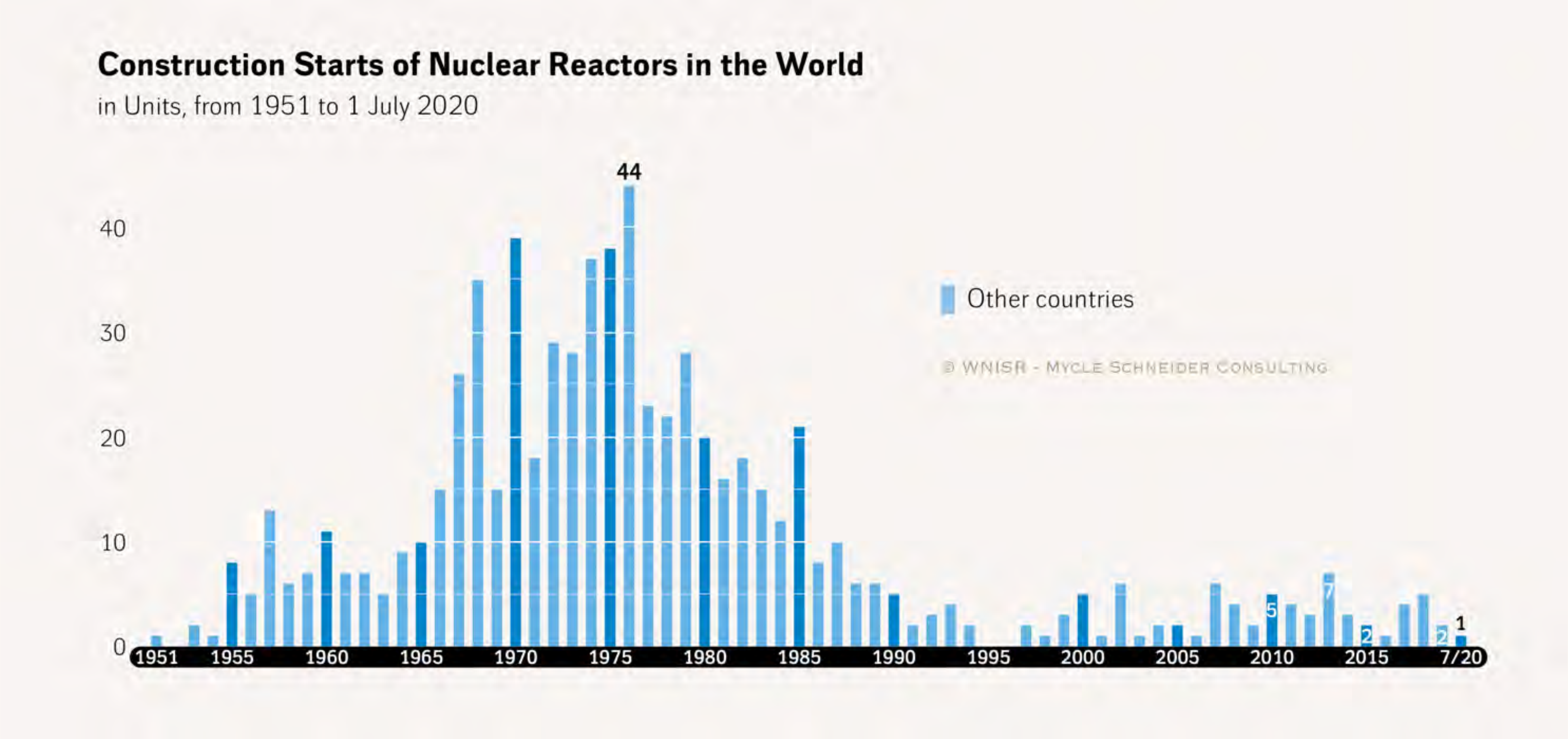


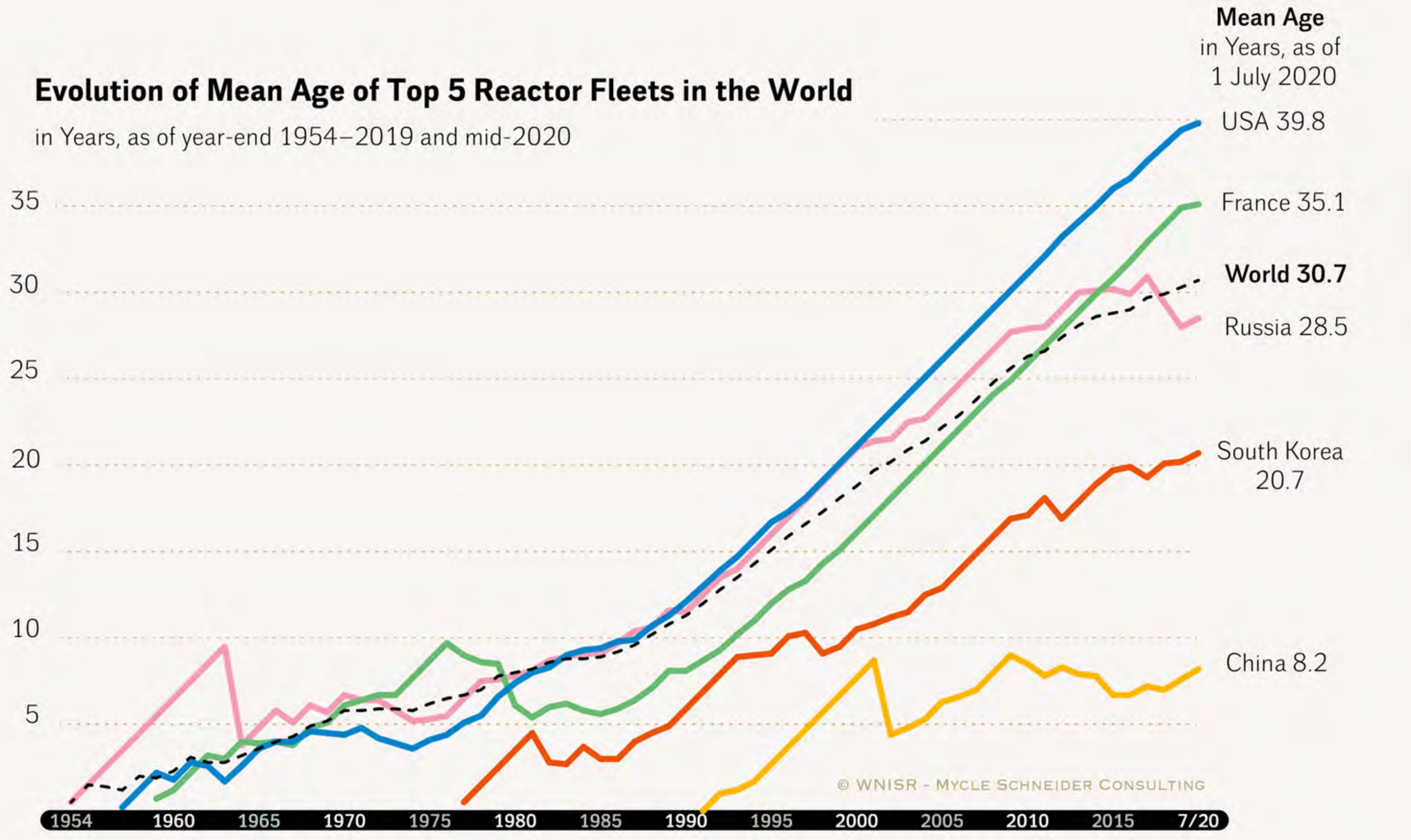
Sources: WNISR, with IAEA-PRIS, 2020

GLOBAL OVERVIEW – CONSTRUCTIONS & DELAYS



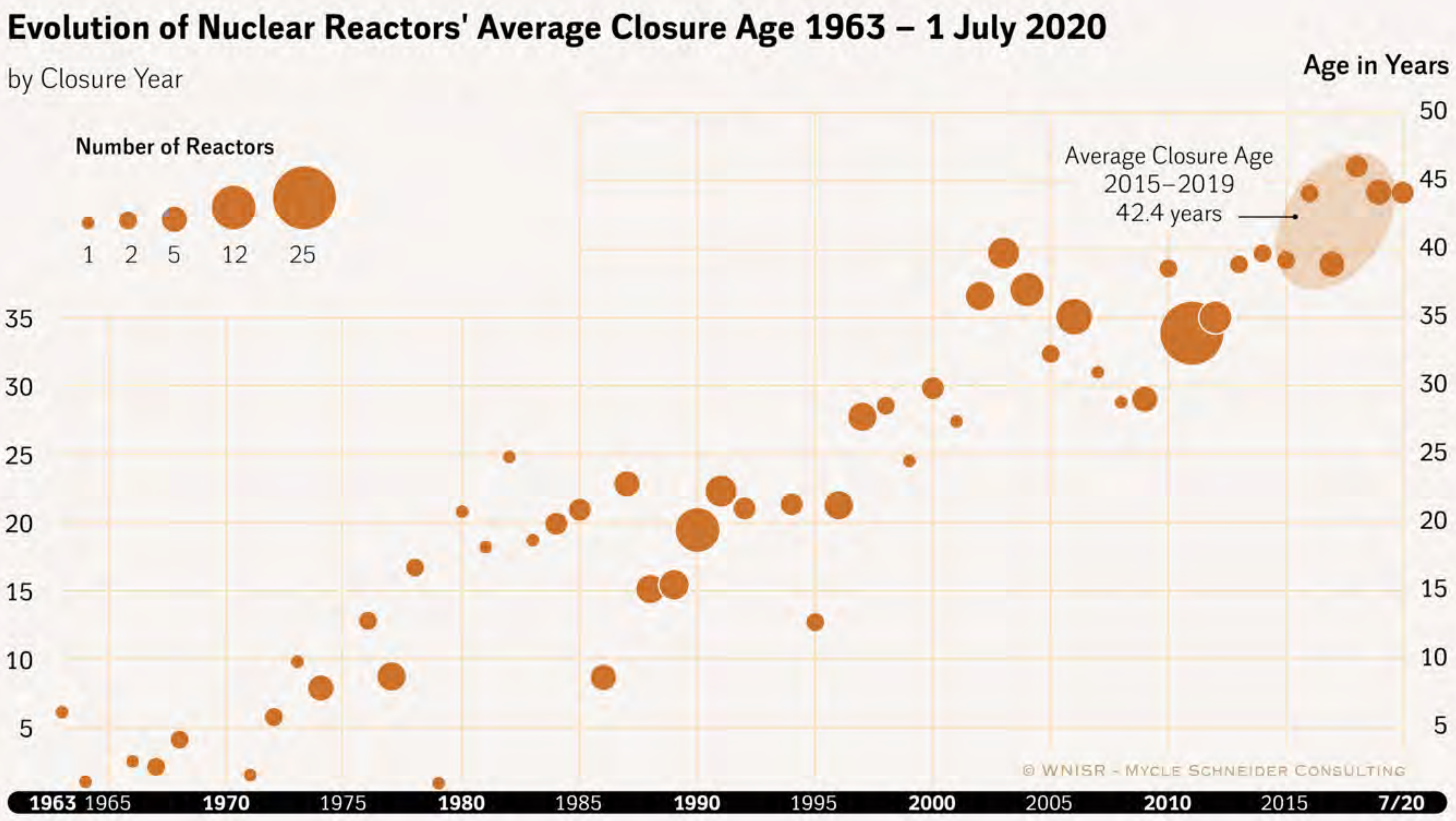
Sources: WNISR, with IAEA-PRIS, 2020

WORLD FLEETS - OPERATING AGE



Sources: WNISR, with IAEA-PRIS, 2020

WORLD FLEET – CLOSED REACTORS AGE



Sources: WNISR, with IAEA-PRIS, 2020

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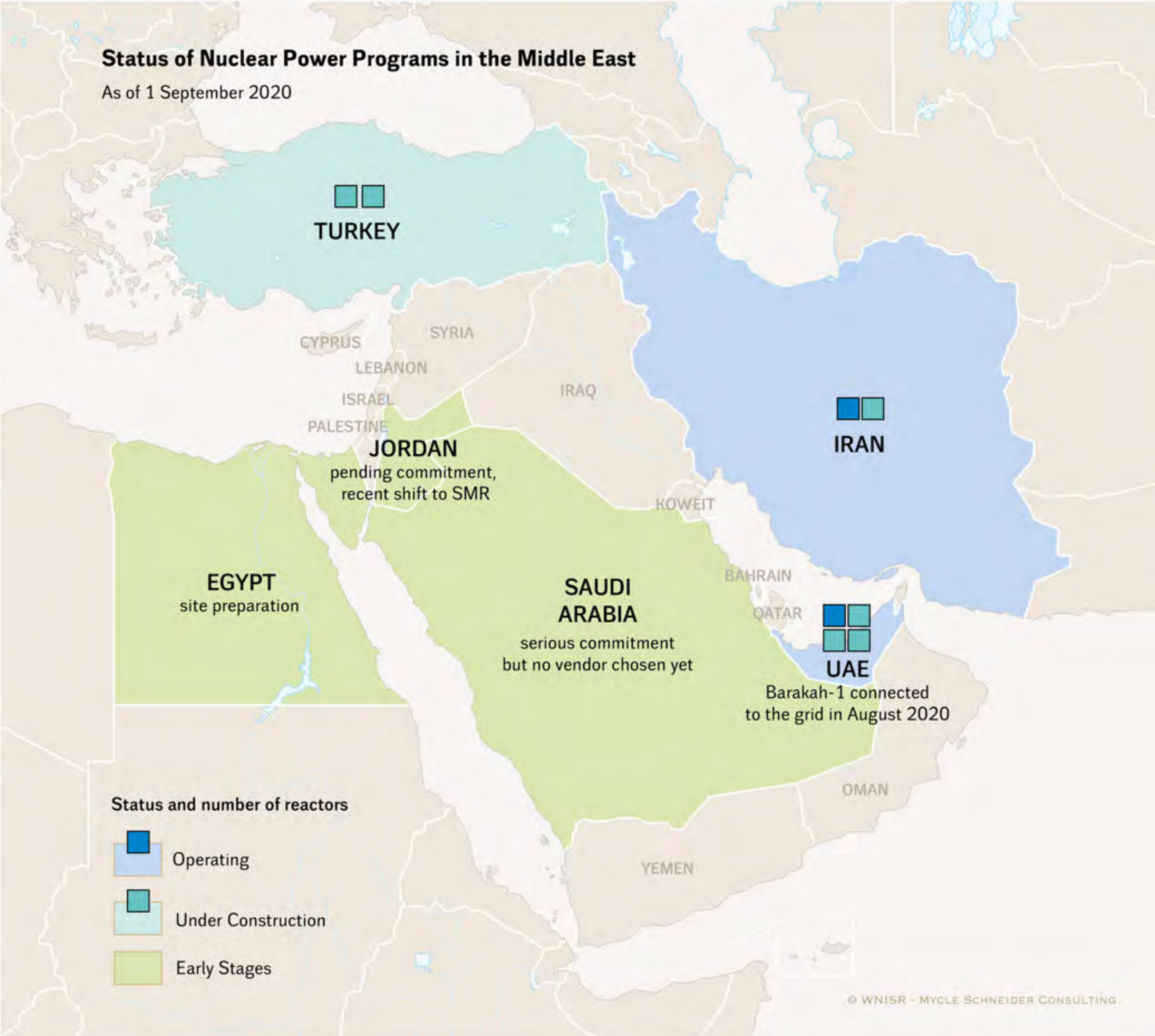
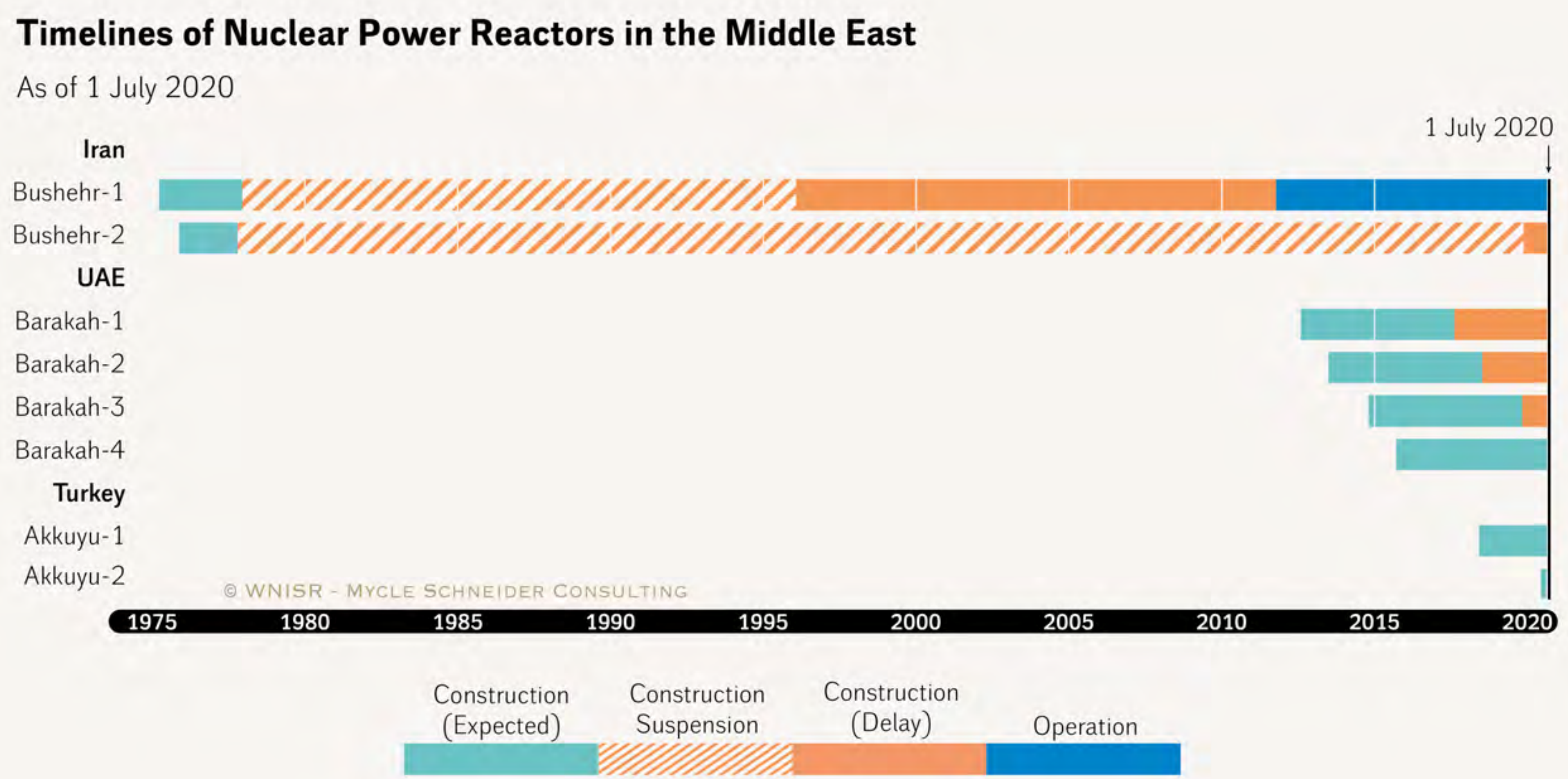
Ali Ahmad is a Research Fellow studying energy policy at Harvard Kennedy School's Project on Managing the Atom and International Security Program. His research interests include energy security and resilience and the political economy of nuclear energy in newcomer markets, with focus on the Middle East. Prior to joining MTA, Ali served as Director of the Energy Policy and Security Program at the American University of Beirut. From 2013 to 2016, Ali was a postdoctoral fellow at Princeton University's Program on Science and Global Security where he worked on informing nuclear diplomacy with Iran. Ali holds a first degree in Physics from the Lebanese University and a PhD in Engineering from Cambridge University.

MIDDLE EAST FOCUS — Egypt, Iran, Jordan, Saudi Arabia, Turkey, UAE

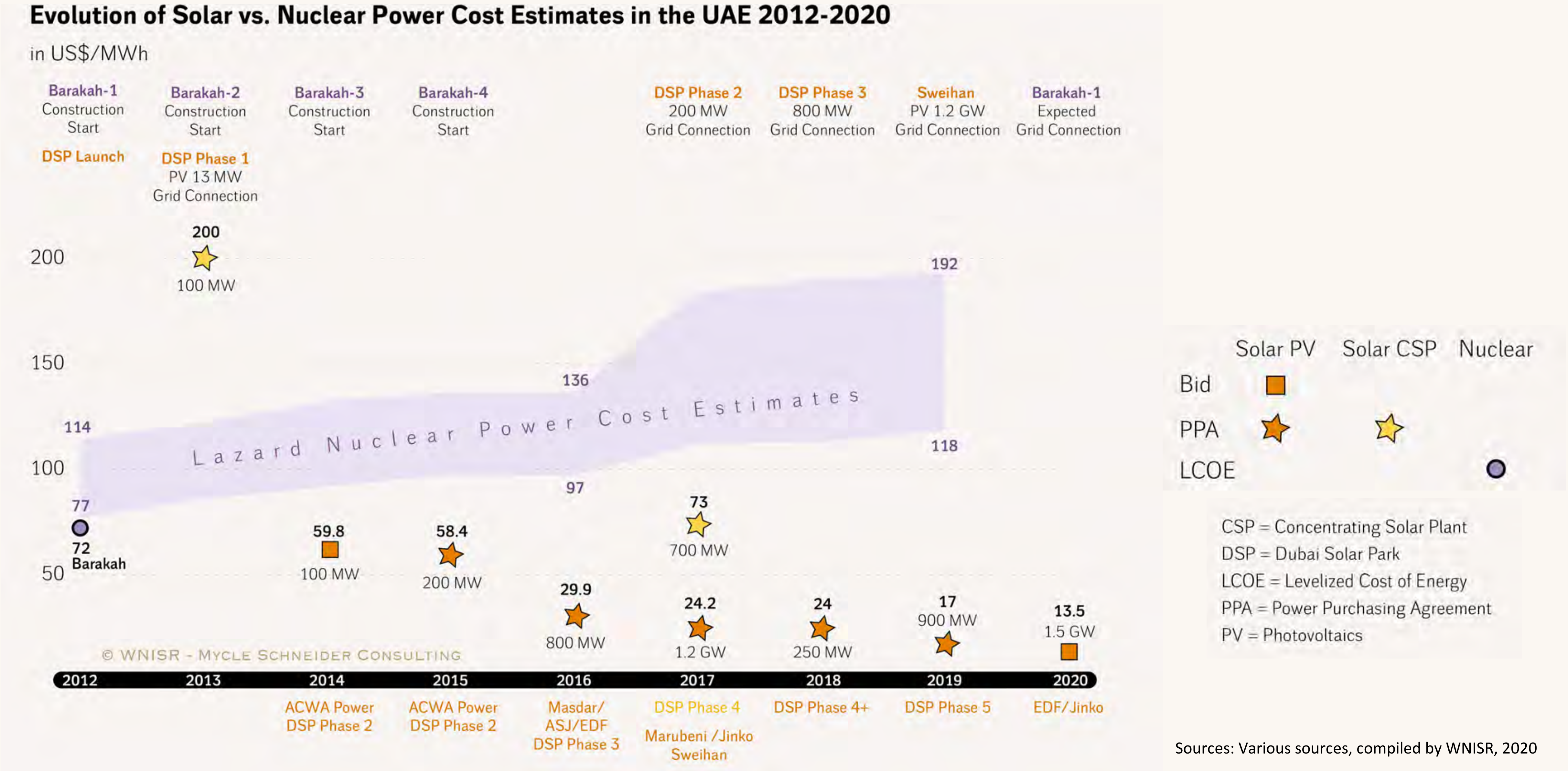


Sources: WNISR 2020

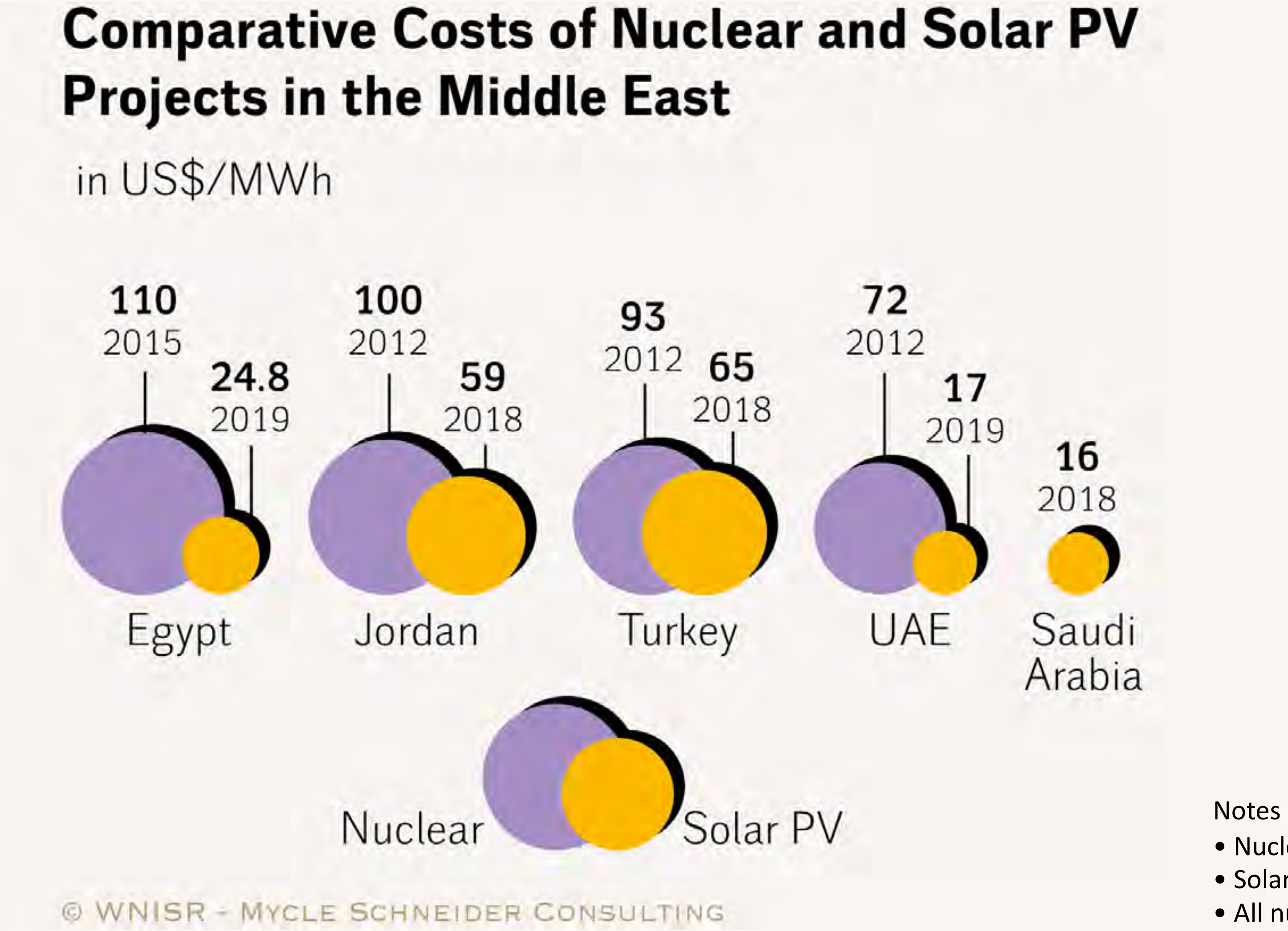
MIDDLE EAST FOCUS



Sources: Various sources, compiled by WNISR, 2020



Sources: Various sources, compiled by WNISR, 2020



Notes

- Nuclear numbers are LCOE estimates
- Solar numbers are PPAs
- All numbers in current US\$, except LCOE Turkey ($US\$_{2020}$)

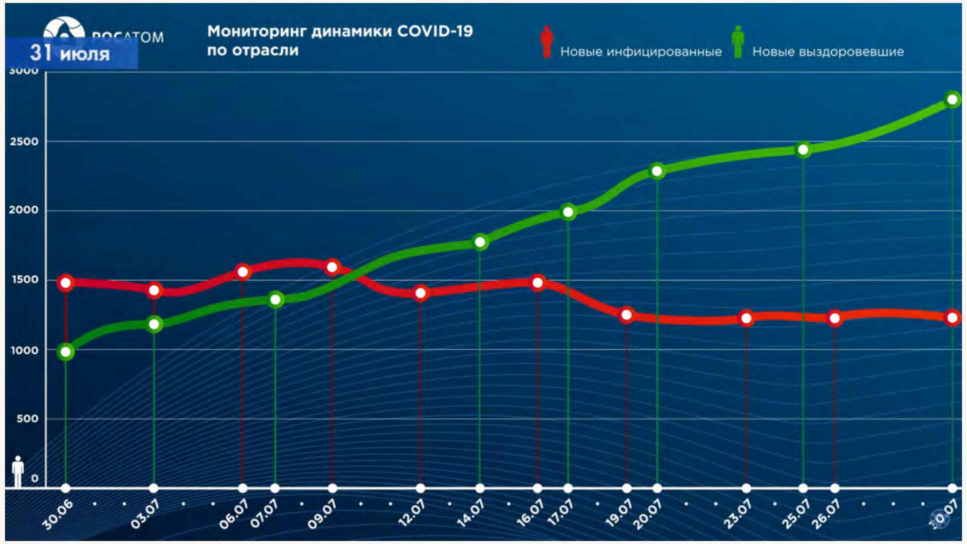
Sources: Various, compiled by WNISR, 2020

- **First global pandemic to hit the nuclear industry**.

- **Key safety and security issues in jeopardy.**
  - Periodic and frequent testing (emergency control room, emergency electricity supply, core cooling...).
  - Four-eyes principle.
  - Particular staff groups (control-room, security...).
  - Emergency situation management (fire, toxic gas buildup...).

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

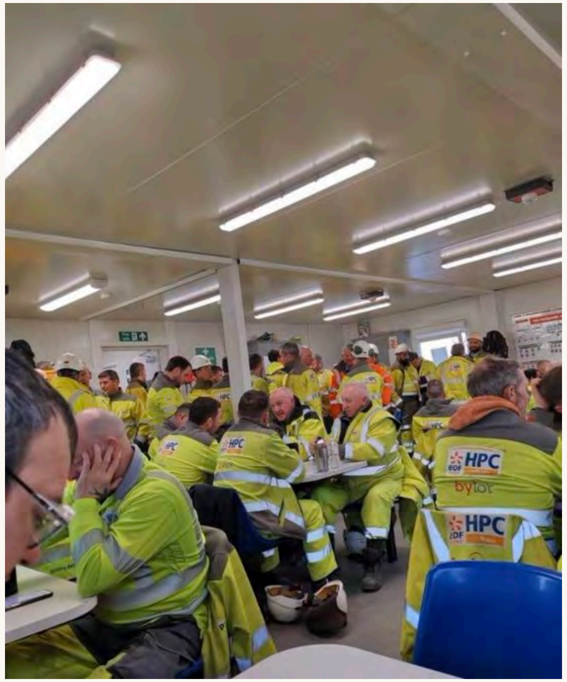
- No systematic national reporting systems, no comparative statistical basis.
- Rosatom (integrated holding): a total of 4,500 of which 1,200 active end of July 2020.



- EDF (French utility): around 600 over 12-week period as of mid-June.
- ASN (French regulator): none / IRSN (TSO) 9 infected of 13 tested (of 1,800 staff).
- Swedish regulator: “few cases”.
- U.K. Sellafield: ca. 1,000 employees self-isolated → shutdown of reprocessing plant
- U.K. Hinkley Point B: At least one dead, no other numbers released.
- U.S. nuclear power plants: several sites several dozens; 3 operators infected at Millstone; 200–300 at Fermi-2 outage; >800 infected at Vogtle construction site.

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

- Dramatically **reduced staff levels** in nuclear facilities, e.g. two thirds (15,000 of 22,500) of EDF nuclear staff on telework → problem of instruction/surveillance of contractors/sub-contractors.
- Regulatory permissions for operators to impose **extremely long work-hours:** e.g. in the U.S., up to 16 work-hours in any 24-hour period and up to 86 work-hours in any 7-day period.
- Social distancing and other **health protection measures** to vary considerably, e.g. workers walked off at least three French reactor sites considering their health and safety were not appropriately protected.



Photos: Canteens at Hinkley Point C, before and after social distancing measures, both pictures are from late March 2020.

A local paper quoted workers as saying: "They've done their best, but when anybody moves, they're inevitably immediately within two metres of someone else."

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

- Suspension of **force-on-force exercises** in the U.S. as well as many other security and safety training-sessions in several countries.
- Delays, alterations, deferrals for months of **refueling and maintenance outages** to eliminate "non- critical work".
- Delays in construction in at least 12 of the 17 countries **building** nuclear reactors.
- Halt of virtually all **physical site inspections** by safety authorities in many countries (e.g. Canada, Finland, France, U.S.); "pragmatic" regulator handling of operator requests for exemptions, exceptions and deferrals.

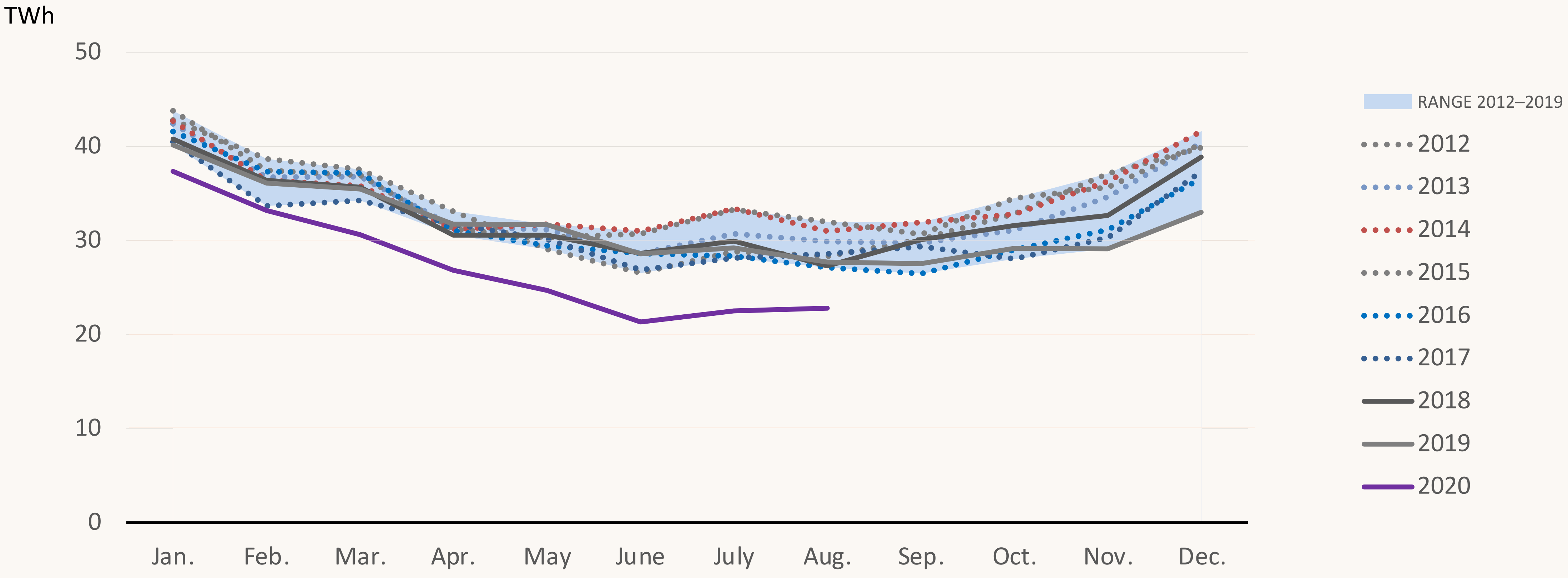
Degradation of Safety and Security

- No evidence for claims measures were taken "while maintaining the required level of safety" (ASN).
- Confidence is difficult to comprehend as
  - **working conditions clearly deteriorated**;
  - scheduled maintenance was not carried out or delayed for months;
  - operators of were left **without any physical regulatory oversight** as inspectors stayed home;
  - considering the **long list of fraud cases** in the industry, fully operational independent regulator and their TSOs remain a crucial ingredient to nuclear safety and security.
- Even if the pandemic slowed down—no guarantee to avoid a second wave—**significant improvement will take time**. Normality, let alone catching up, will be difficult in the medium term, could take years.
- **Large financial/economic impacts** hit utilities. Bulk prices plunged, operational costs went up, electricity consumption dropped. Cost cutting exercises will further exacerbate the pressure.

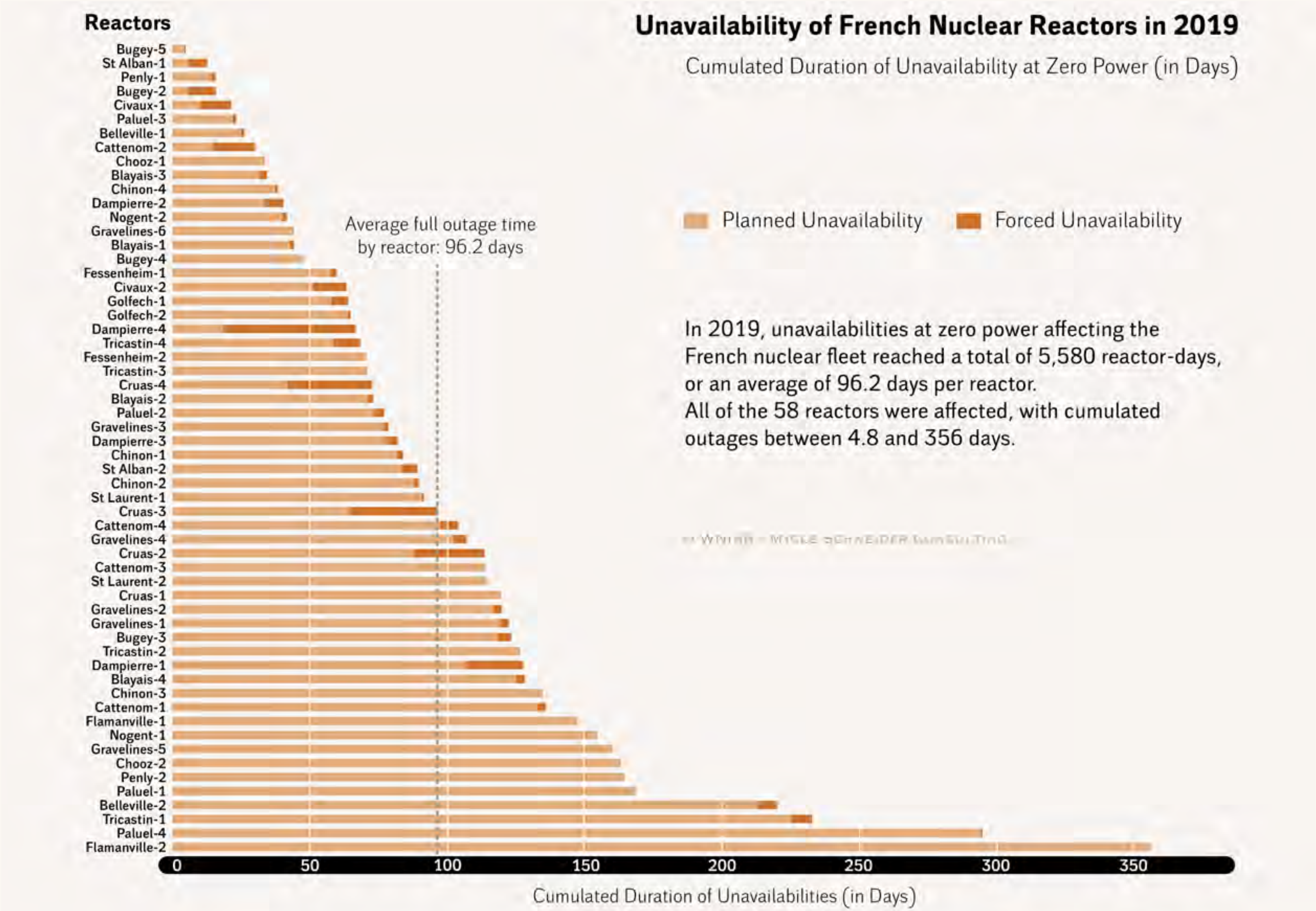
FOCUS: NUCLEAR POWER IN THE AGE OF COVID-19 – IMPACT FRANCE

Monthly Nuclear Production in France

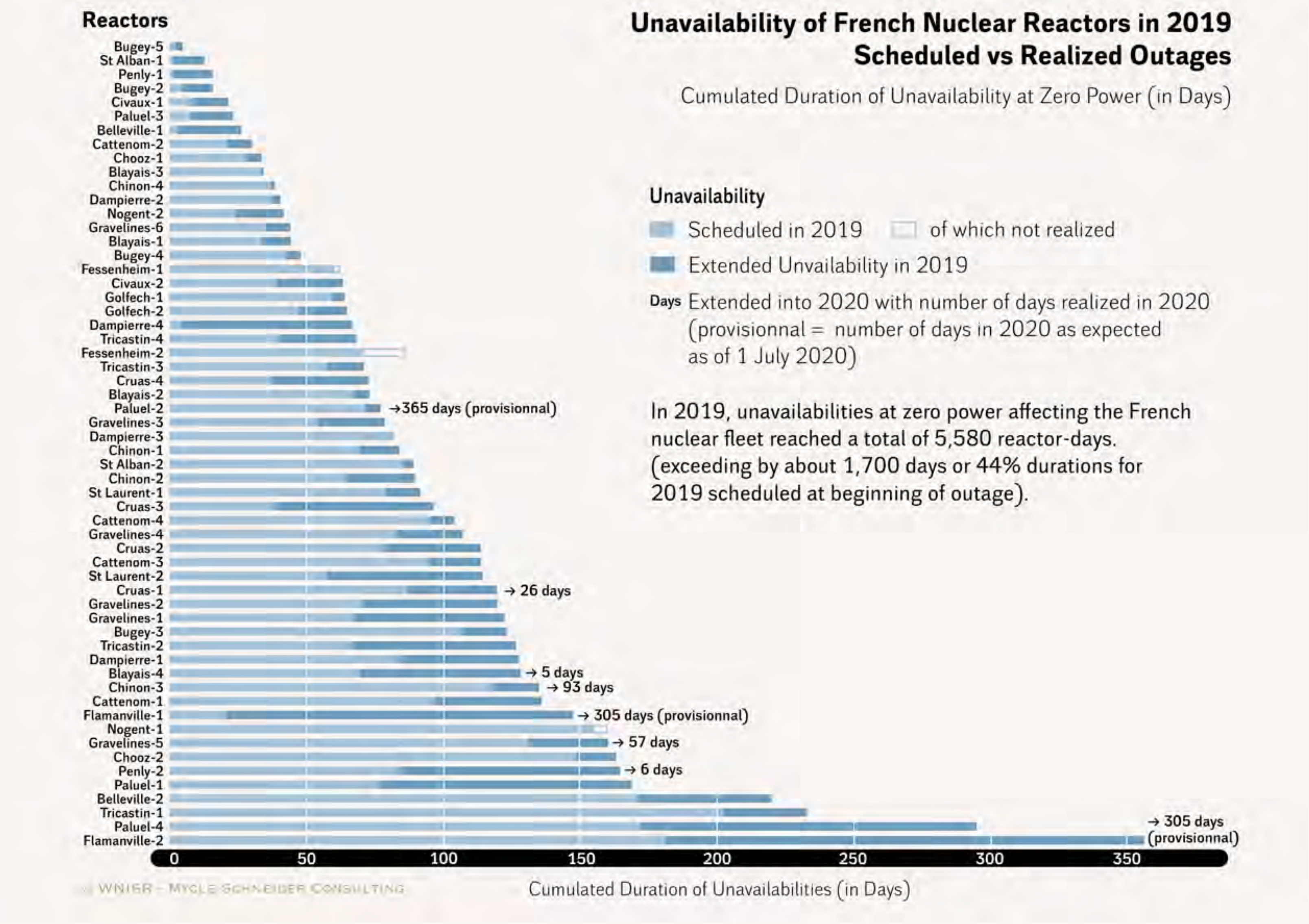
in TWh, 2012–2020



Sources: RTE, EDF, 2020



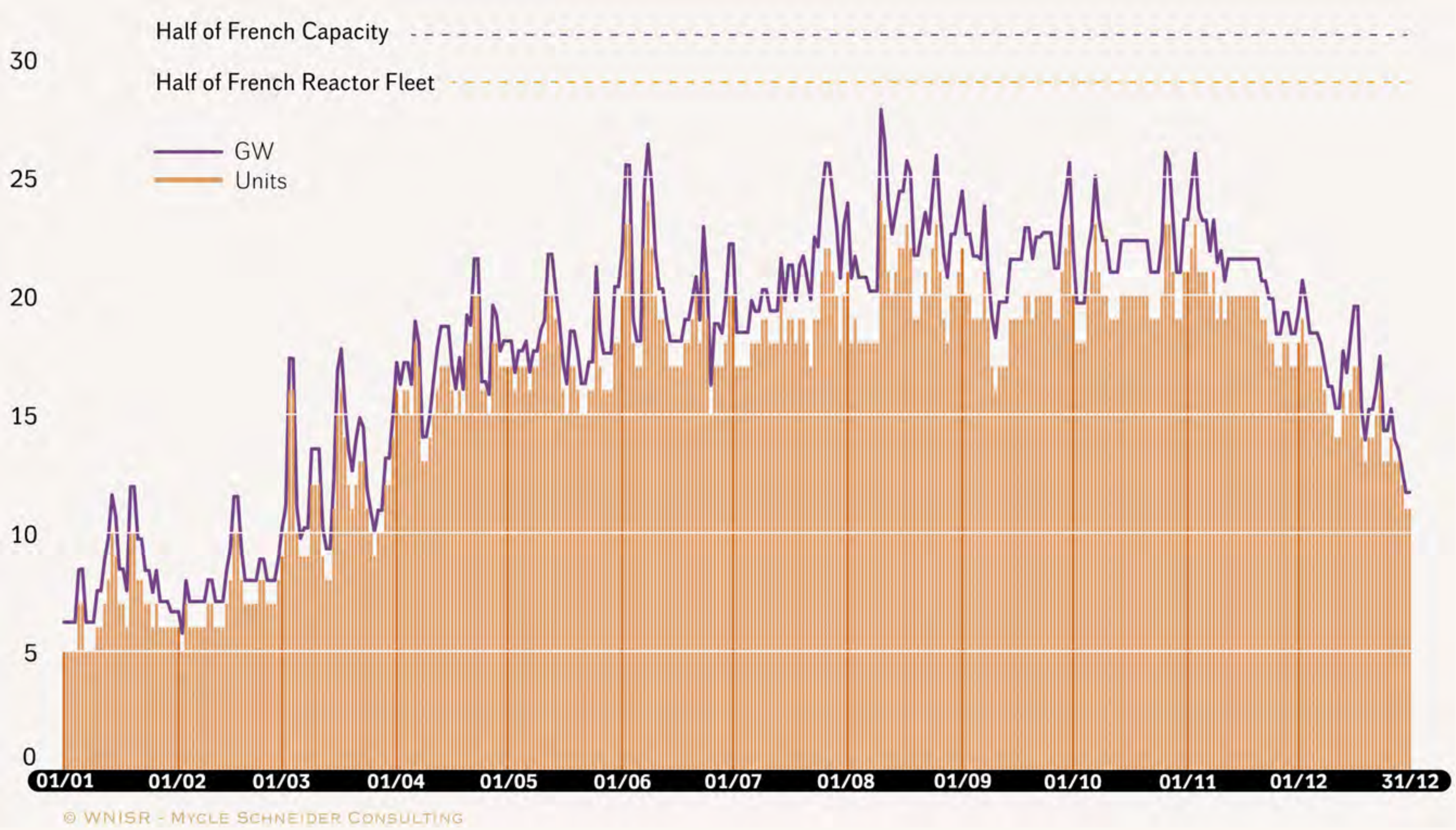
Sources: Compilation from EDF and RTE, 2019–2020



Sources: Compilation from EDF and RTE, 2018–2020

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

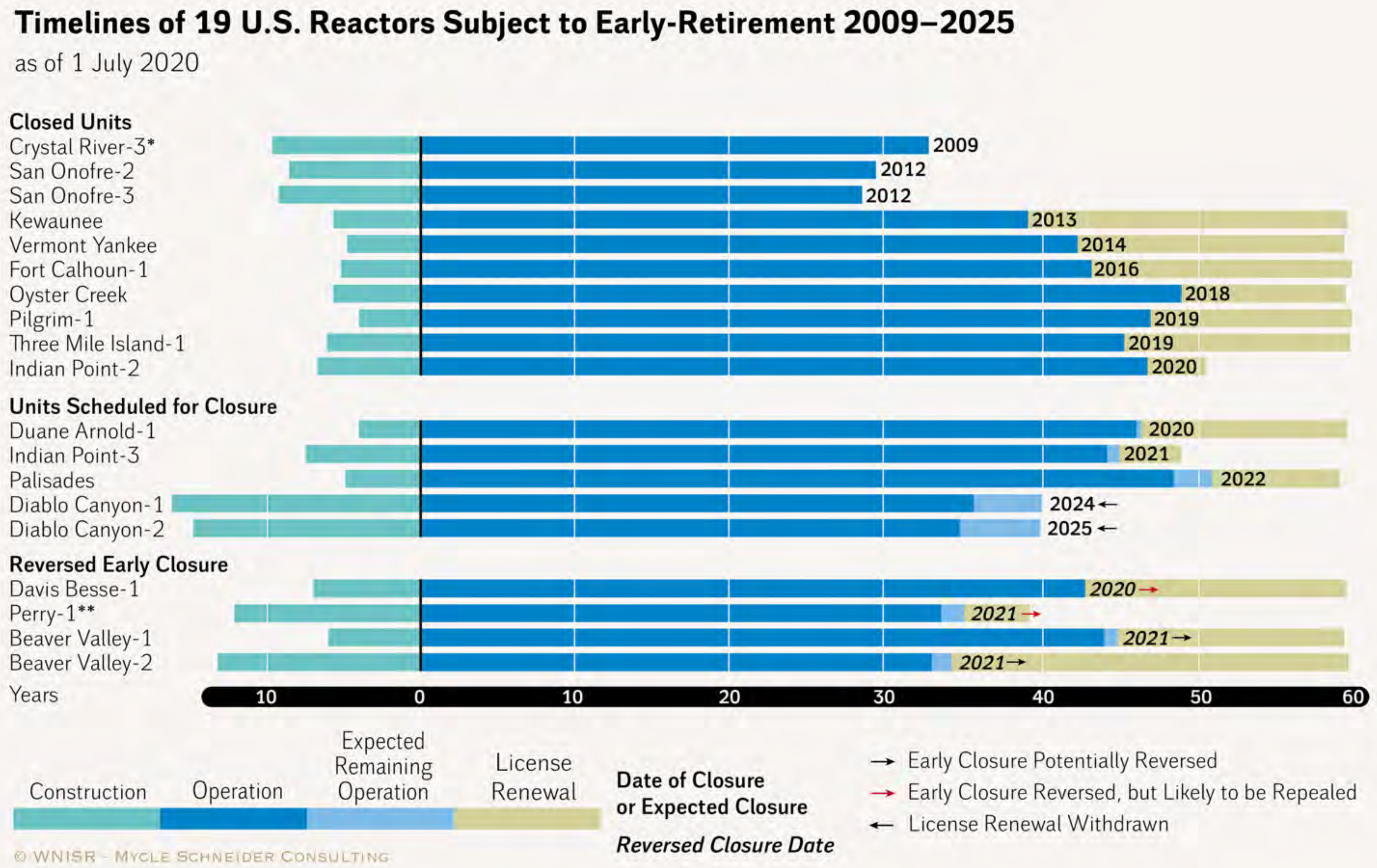
in Units and Capacity



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



Sources: Various, compiled byWNISR, 2020

M.V. Ramana, Vancouver - m.v.ramana@ubc.ca

M.V. Ramana is the Simons Chair in Disarmament, Global and Human Security and Director of the Liu Institute for Global Issues at the School of Public Policy and Global Affairs, University of British Columbia, Vancouver, Canada. During 2020–2021, he will be a Scholar at the Peter Wall Institute for Advanced Studies. He received his Ph.D. in theoretical physics from Boston University. Ramana is the author of "The Power of Promise: Examining Nuclear Energy in India" (Penguin Books, 2012) and co editor of "Prisoners of the Nuclear Dream" (Orient Longman, 2003). He is a member of the International Panel on Fissile Materials (IPFM), the International Nuclear Risk Assessment Group (INRAG) and the Canadian Pugwash Group. He is the recipient of a Guggenheim Fellowship and a Leo Szilard Award from the American Physical Society.

SMALL MODULAR REACTORS (SMR) — DELAYS

- **Argentina**

  Carem-25 construction start 2014; projected to receive first fuel load in 2017; July 2019: only 55 percent complete;

- **China**

  HTR-PM construction start 2012; projected to generate electricity in 2017; currently scheduled for 2021;

- **USA**

  NuScale 2008 projection: electricity generation by 2015-16; current projection: 2029-30; will likely be delayed further due to licensing and financing problems even before construction start

SMALL MODULAR REACTORS (SMR)— HIGH COSTS AND INCREASING

- **Argentina**
  CAREM-25: current estimate US$26,000/kW*,
  up from 2014-projection of US$17,000/kW
- **Russia**
  Akademik-Lomonosov, floating power plant : US$11,600/kW*
- **USA**
  NuScale current estimate: US$8,500/kW*,
  up from 2003-projection of US$$_{2019}$1,700/kW

* For reference: current cost estimate for the most expensive Gen III (Flamanville-3 EPR in France) is US$9,000/kW.

SMALL MODULAR REACTORS (SMR) — SAFETY CONCERNS, FURTHER DELAYS

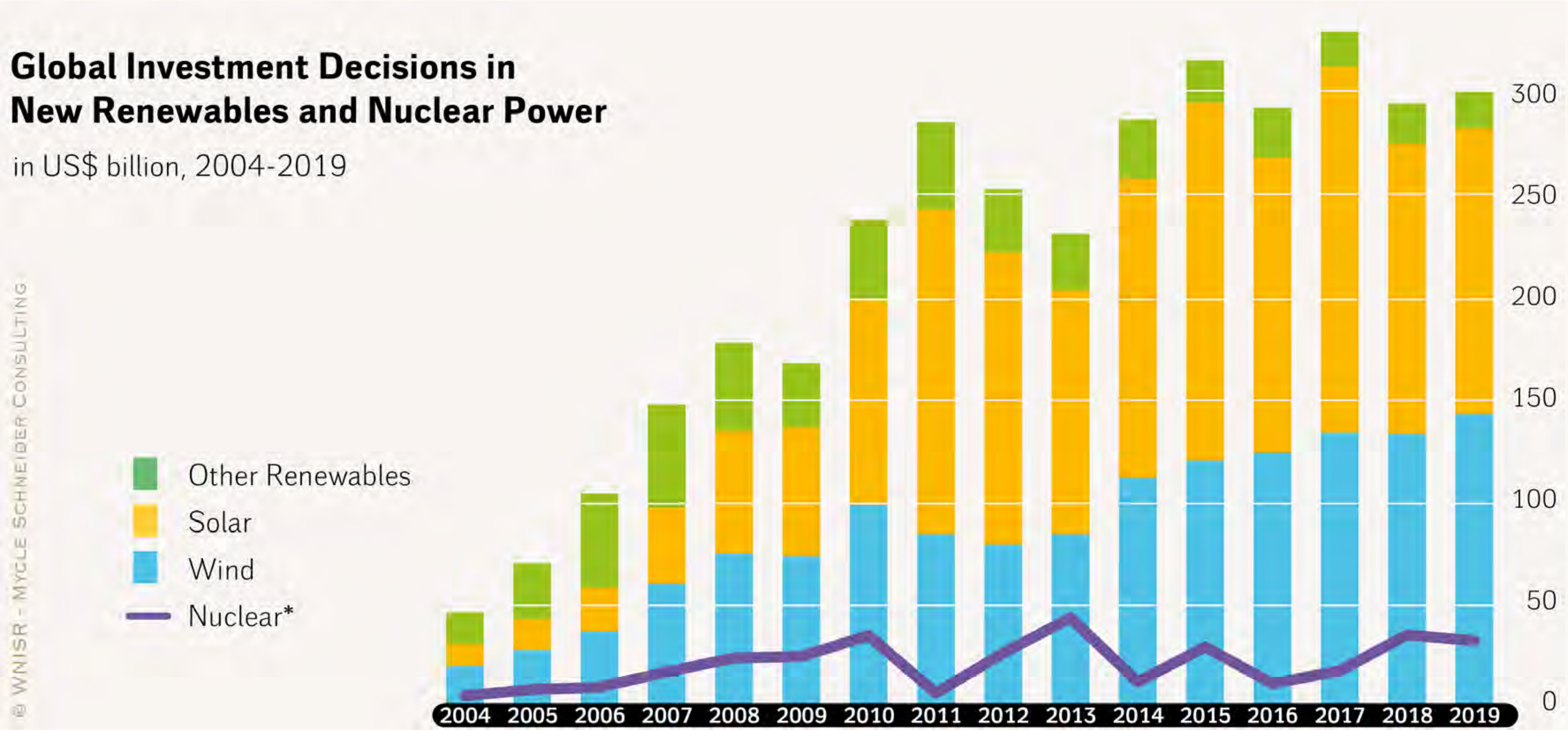
"Without clarity on the steam generator integrity, it would be **premature to conclude that the NuScale design ensures adequte protection of public health and safety**."

Advisory Committee on Reactor Safeguards Member Vesna B. Dimitijevic March 2020

"We identified a boron dilution issue that remains open. We are concerned that this class of events **could lead to a potential reactivity insertion accident and core damage**."

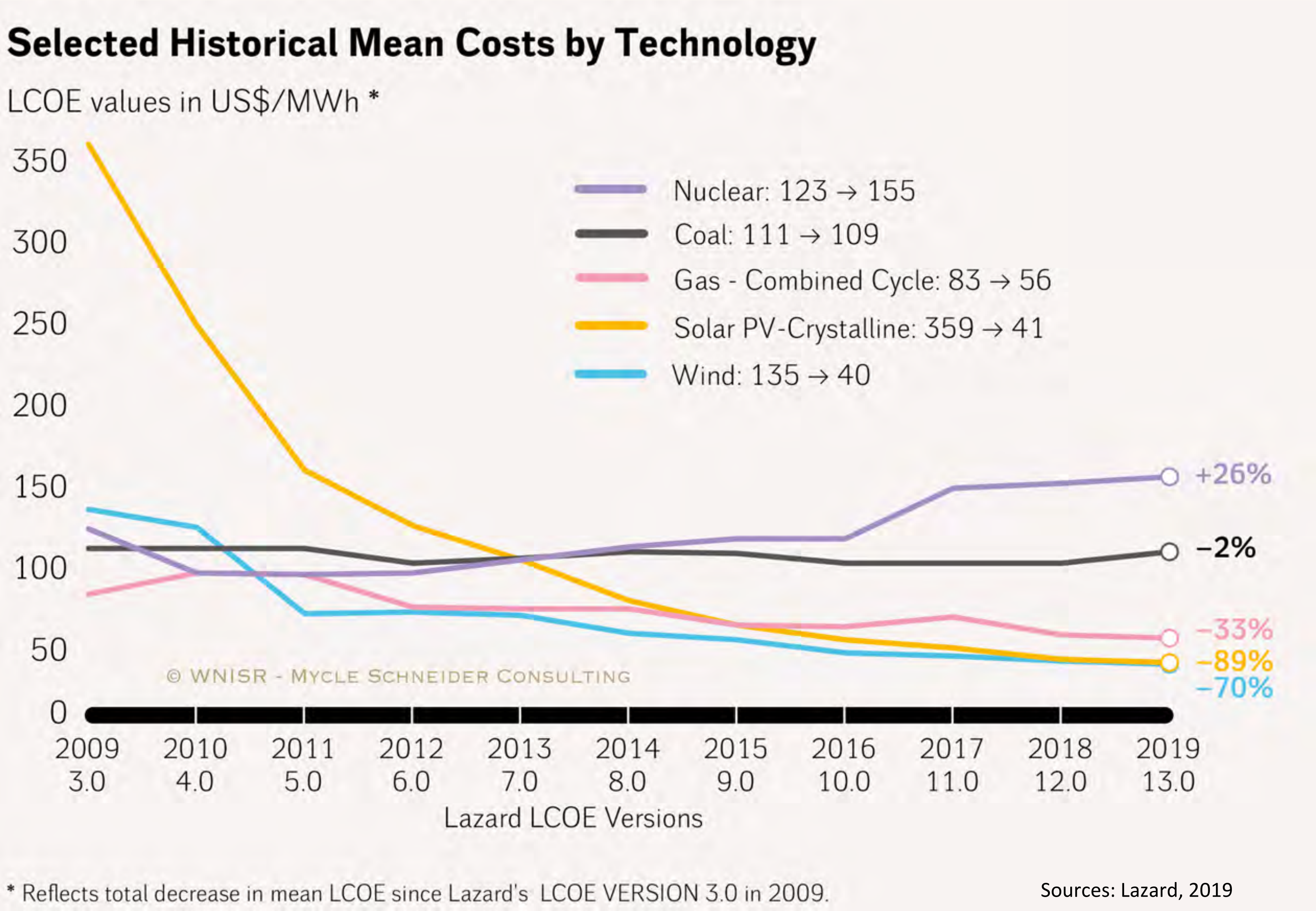
Advisory Committee on Reactor Safeguards letter June 2020

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



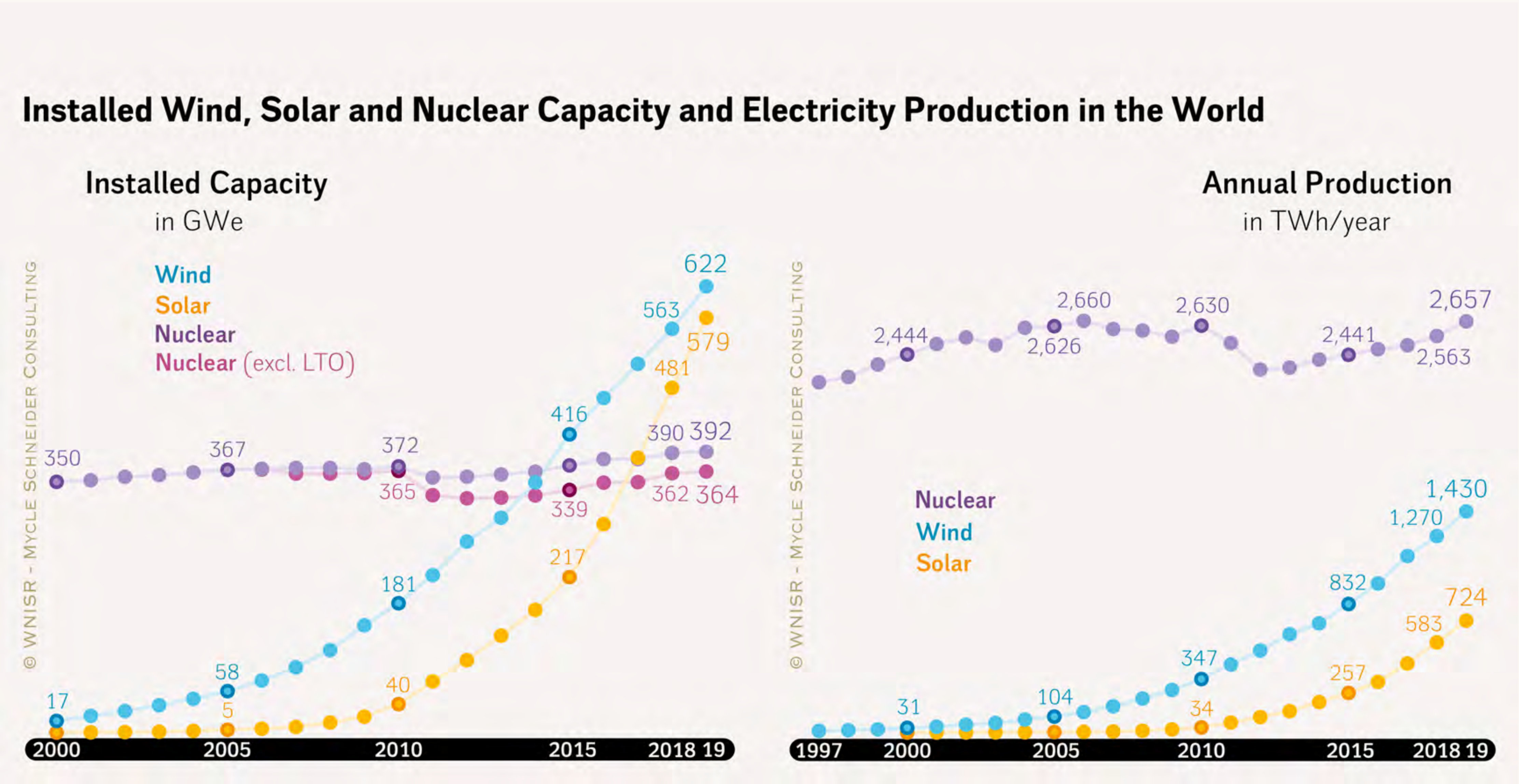
Sources: FS-UNEP/BNEF 2020 and WNISR Original Research

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



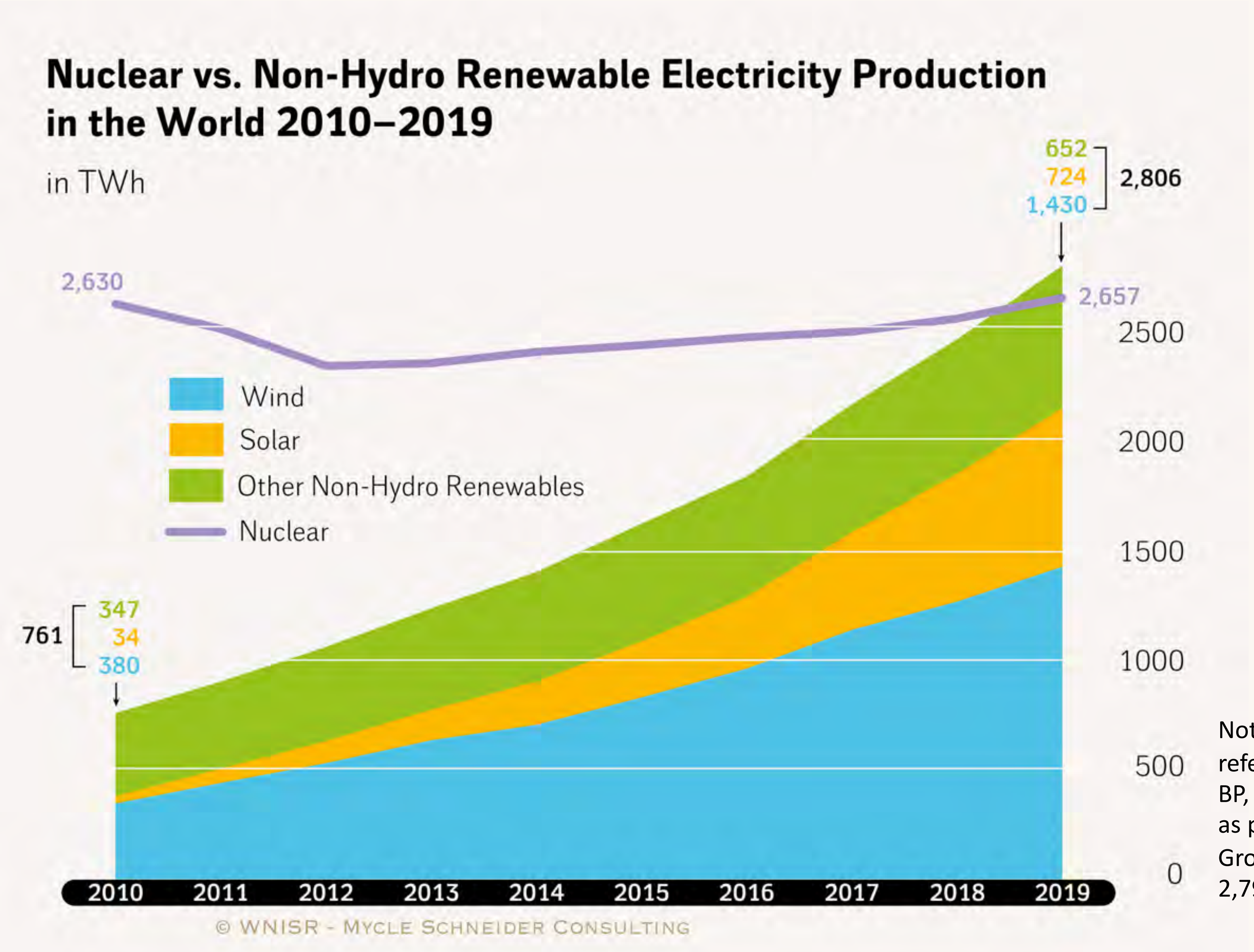
Sources: Lazard, 2019

NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



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

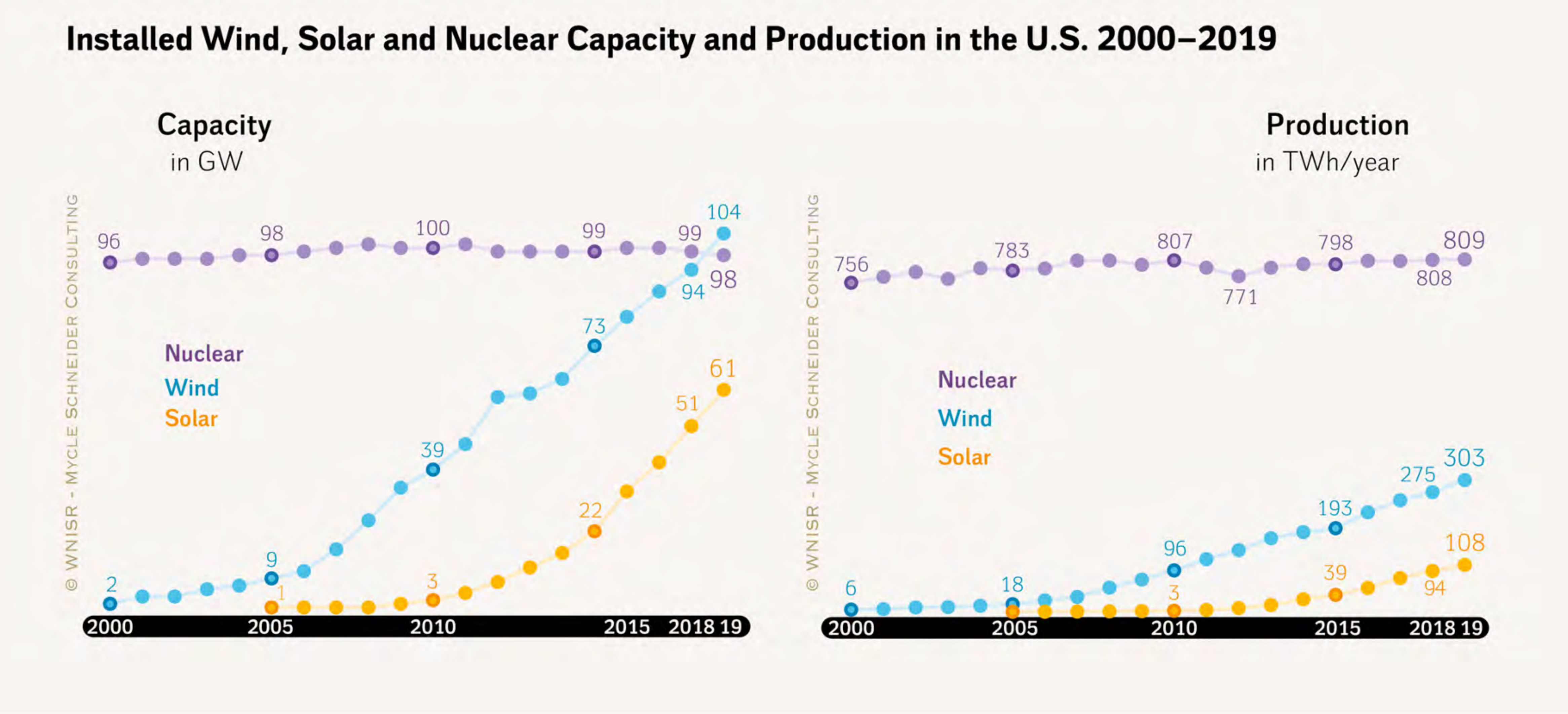
NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



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



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

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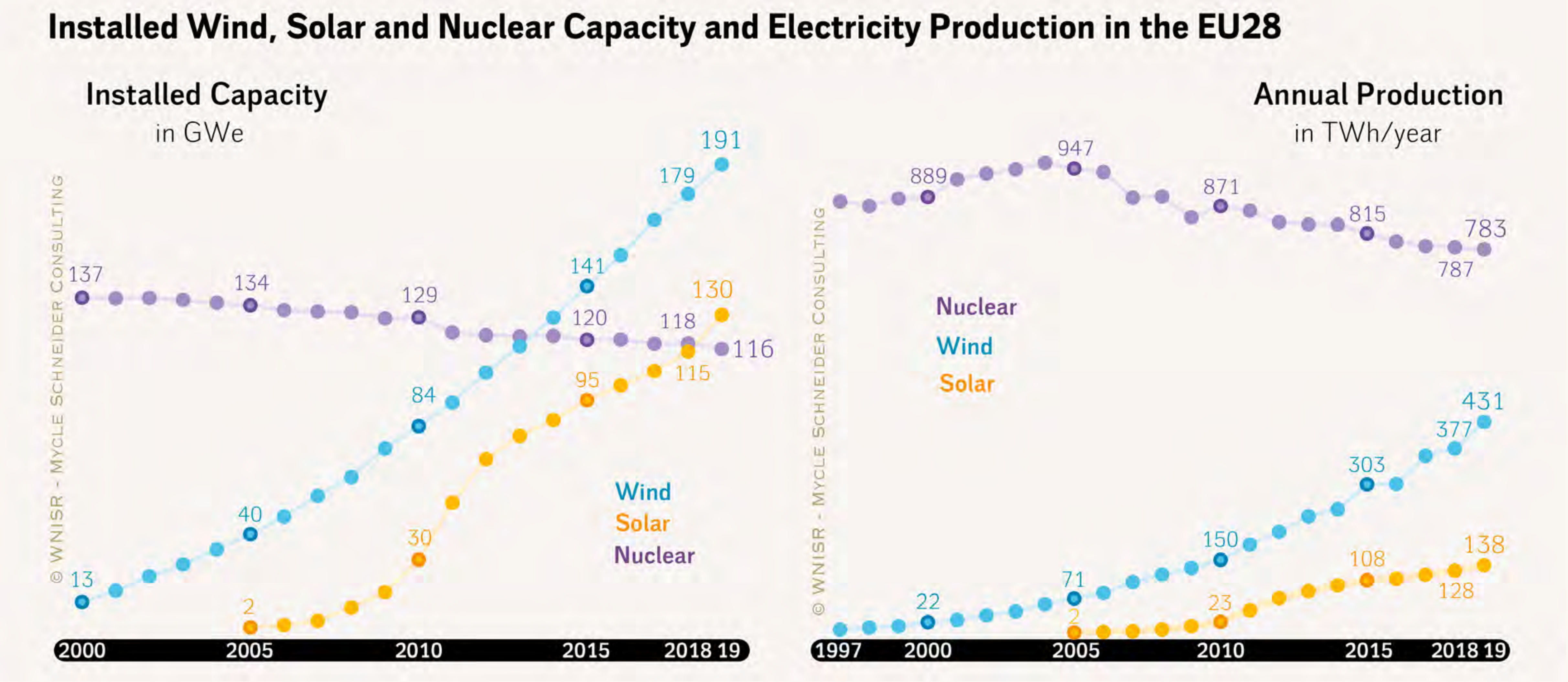

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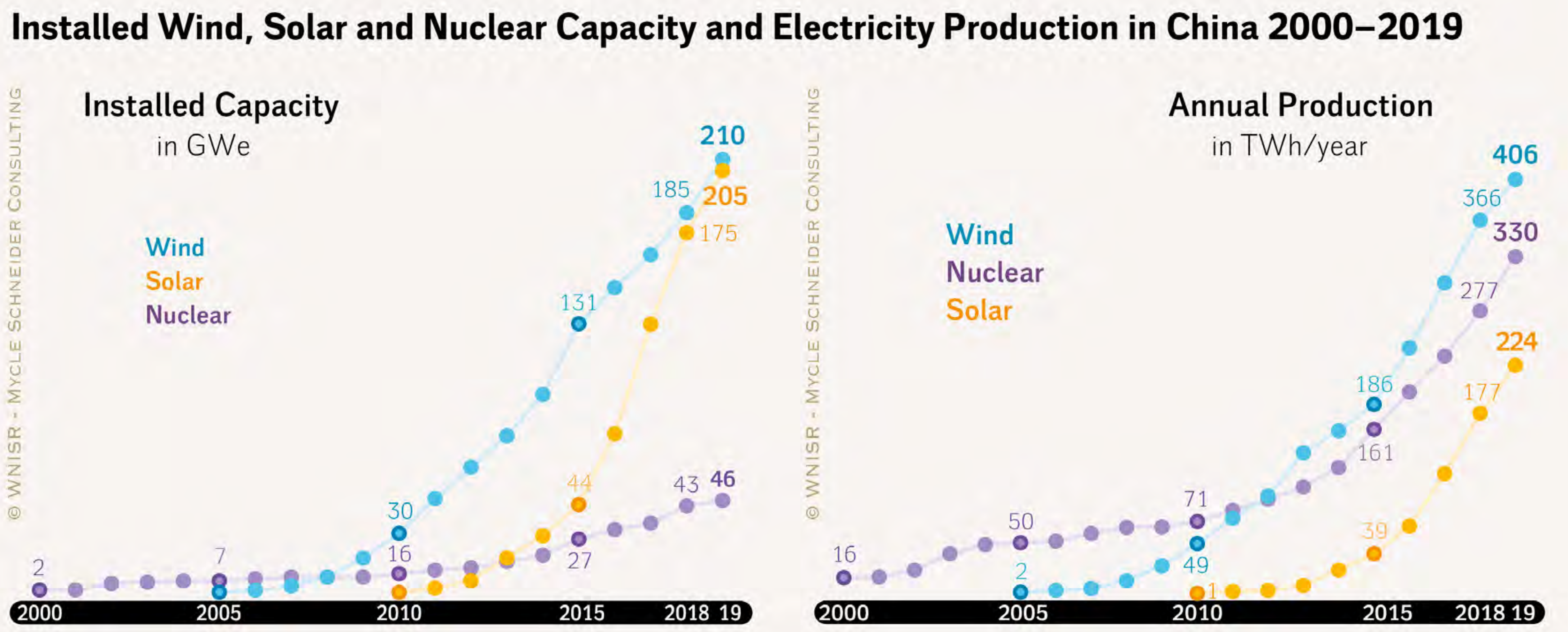

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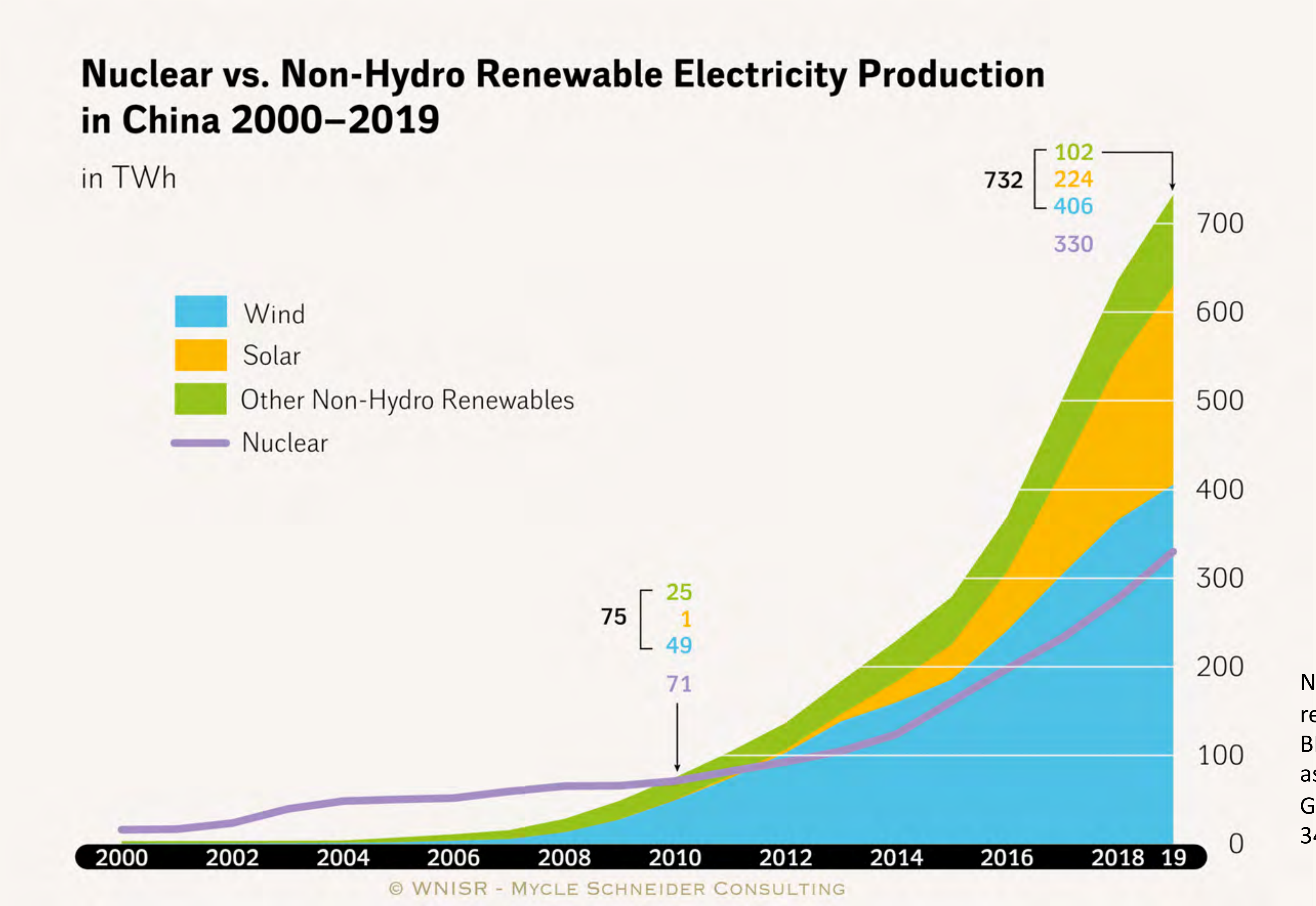
NUCLEAR POWER VS. RENEWABLES DEPLOYMENT



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

CONCLUSIONS

Nuclear Industry and COVID-19

- First global pandemic to hit the nuclear industry.
- Staff on telework, lacking oversight onsite, no physical inspections for weeks lowered safety and security margins.
- It will likely take one or two years to resorb delayed outages, maintenance and inspections.
- The financial and economic impact on nuclear utilities will be dramatic.

Nuclear Industry in the Middle East

- Barakah in the UAE will likely remain an exception.
- Economic advantage of solar has significantly widened in region.

Nuclear Power Trends

- Operating units down by 9 units to 408, lower than 1988, 30 below 2002-record of 438.
- Production back to pre-Fukushima level, just below 2006-record (has production peaked?).

Nuclear Power vs. Renewables

- Record non-hydro renewables' capacity additions in the world (+184 GW vs. +2 GW for nuclear).
- First time non-hydro renewables' share exceeds nuclear share in world electricity mix.

ANNEXES

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About the Coordinator

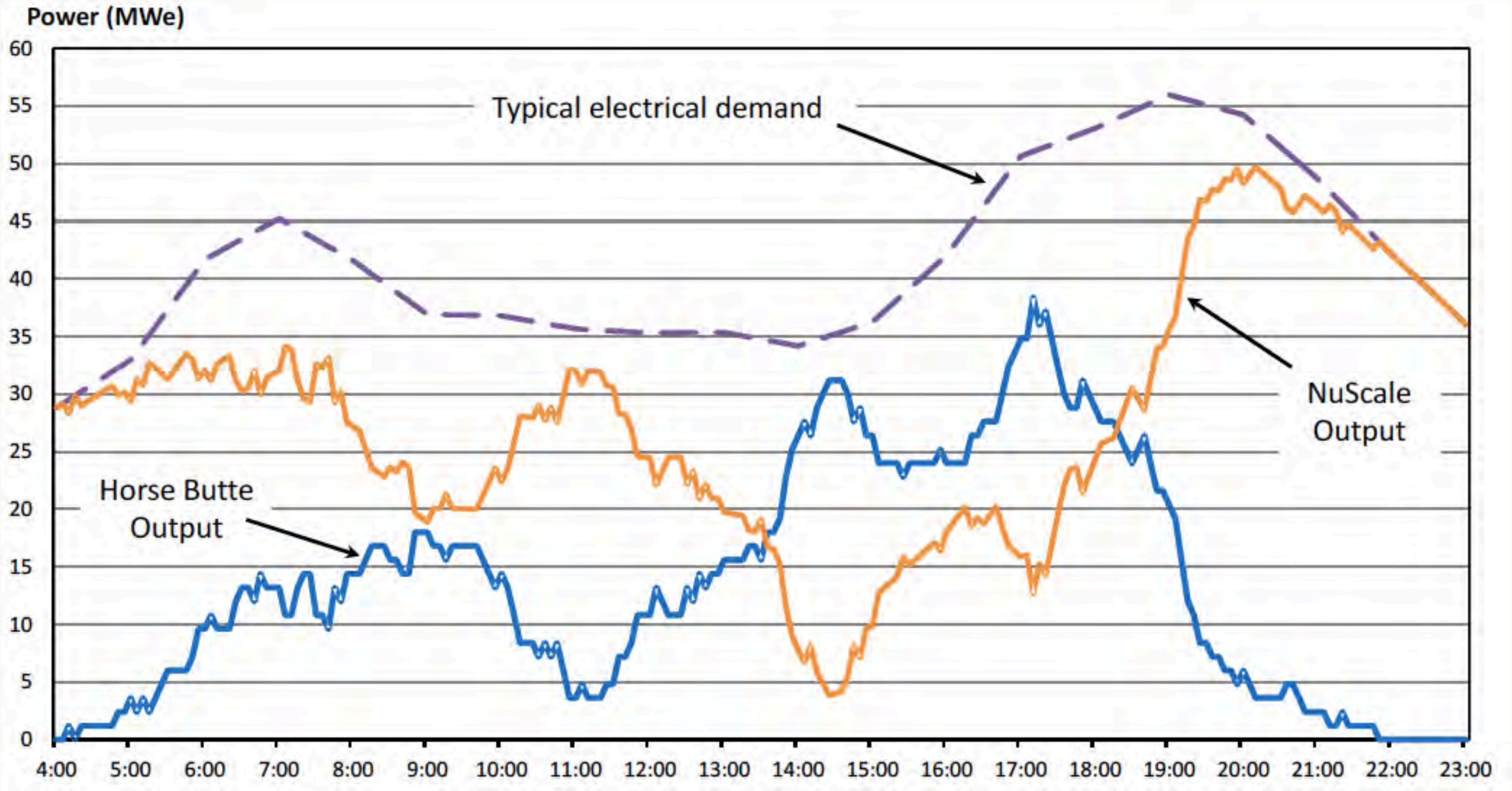
Photo: ©Nina Schneider

Mycle Schneider works as independent international analyst on energy and nuclear policy. He is the Coordinator and Publisher 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 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 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").

SMALL MODULAR REACTORS (SMR) — BACKUP POWER FOR RENEWABLES?

- Using SMR to back up intermittency of renewables will drive up cost (fewer kWh)
- Capacity factor of 75 percent => roughly 20 percent increase in levelized cost



Source: Ingersoll, D.T., C. Colbert, Z. Houghton, R. Snuggerud, J. W. Gaston, and M. Empey. 2015. "Can Nuclear Power and Renewables Be Friends?" In Proceedings of ICAPP 2015. Nice, France. https://www.nuscalepower.com/-/media/Nuscale/Files/Technology/Technical-Publications/can-nuclear-power-and-renewables-be-friends.ashx?la=en&hash=2A0EB3B5CA22BF25F90FF16BA060835A0B2DFDF2.