Global Launch

The World Nuclear Industry Status Report 2016

Chernobyl+30 / Fukushima+5

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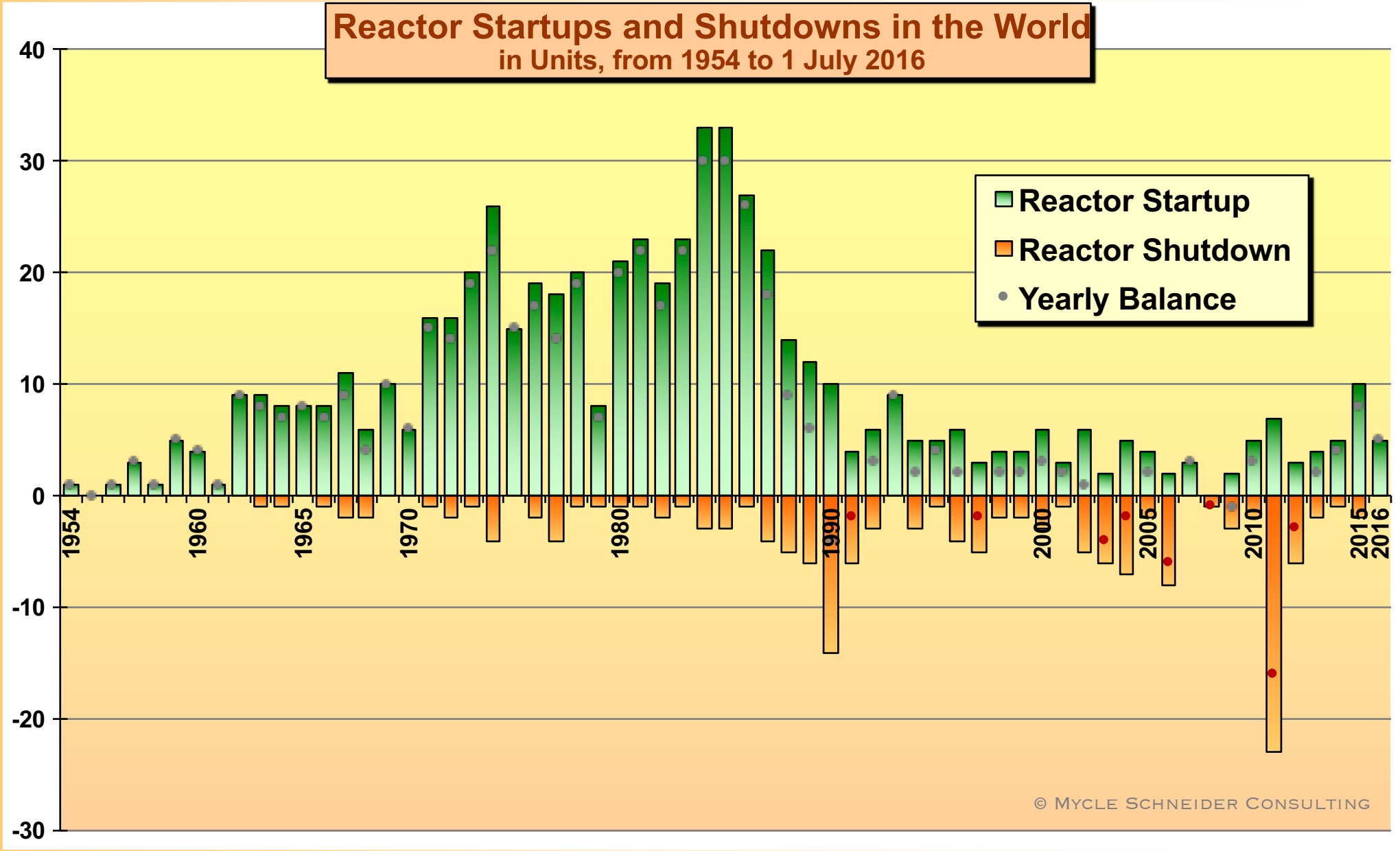
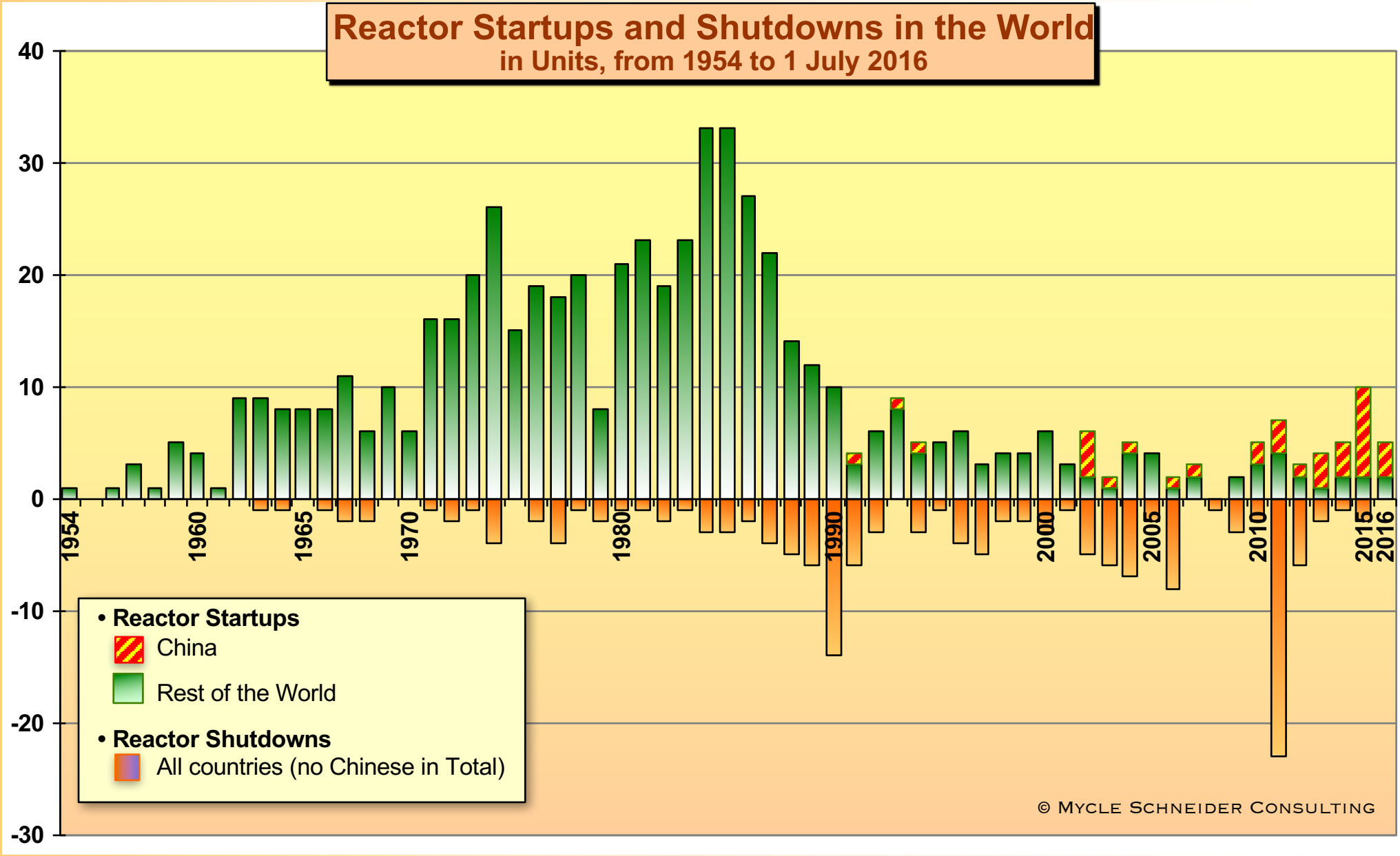
Foreign Correspondents' Club of Japan, Tokyo, 13 July 2016



Source: IAEA-PRIS, MSC, 2016



Source: IAEA-PRIS, MSC, 2016

Misleading Official Information on World Reactor Fleet

IAEA | PRIS Power Reactor Information System

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PRIS

The Database on Nuclear Power Reactors

The Power Reactor Information System (PRIS), developed and maintained by the IAEA for over four decades, is a comprehensive database focusing on nuclear power plants worldwide. PRIS contains information on power reactors in operation, under construction, or those being... READ MORE »

Registered User ENTRY | How to Register

SHORTCUTS

Select Country

Select Reactor

2016 edition of Nuclear Power...

2016 edition of Operating Experience...

PRIS-WEDAS User's Manual

OVERVIEW

Current Status:

446 NUCLEAR POWER REACTORS IN OPERATION

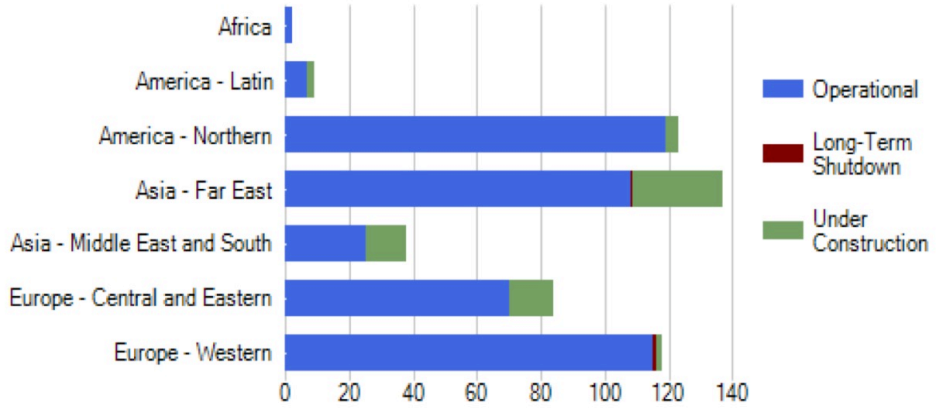
388 051 MW_e TOTAL NET INSTALLED CAPACITY

2 NUCLEAR POWER REACTORS IN LONG-TERM SHUTDOWN

63 NUCLEAR POWER REACTORS UNDER CONSTRUCTION

16753 REACTOR-YEARS OF OPERATION

Regional Distribution of Nuclear Power Plants (Click on the chart for more statistics)



Source: IAEA-PRIS, Screenshot, 13 July 2016

Misleading Official Information on Japan's Reactor Fleet

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COUNTRIES
Argentina
Armenia
Belarus
Belgium
Brazil
Bulgaria
Canada
China
Czech Republic
Finland
France
Germany

Japan

SUMMARY

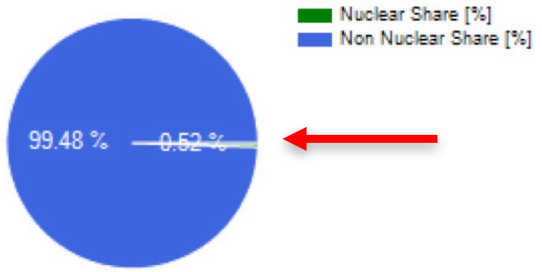
Nuclear Power Reactors

Under Construction	Operational	Long-Term Shutdown	Permanent Shutdown
2	43	1	16

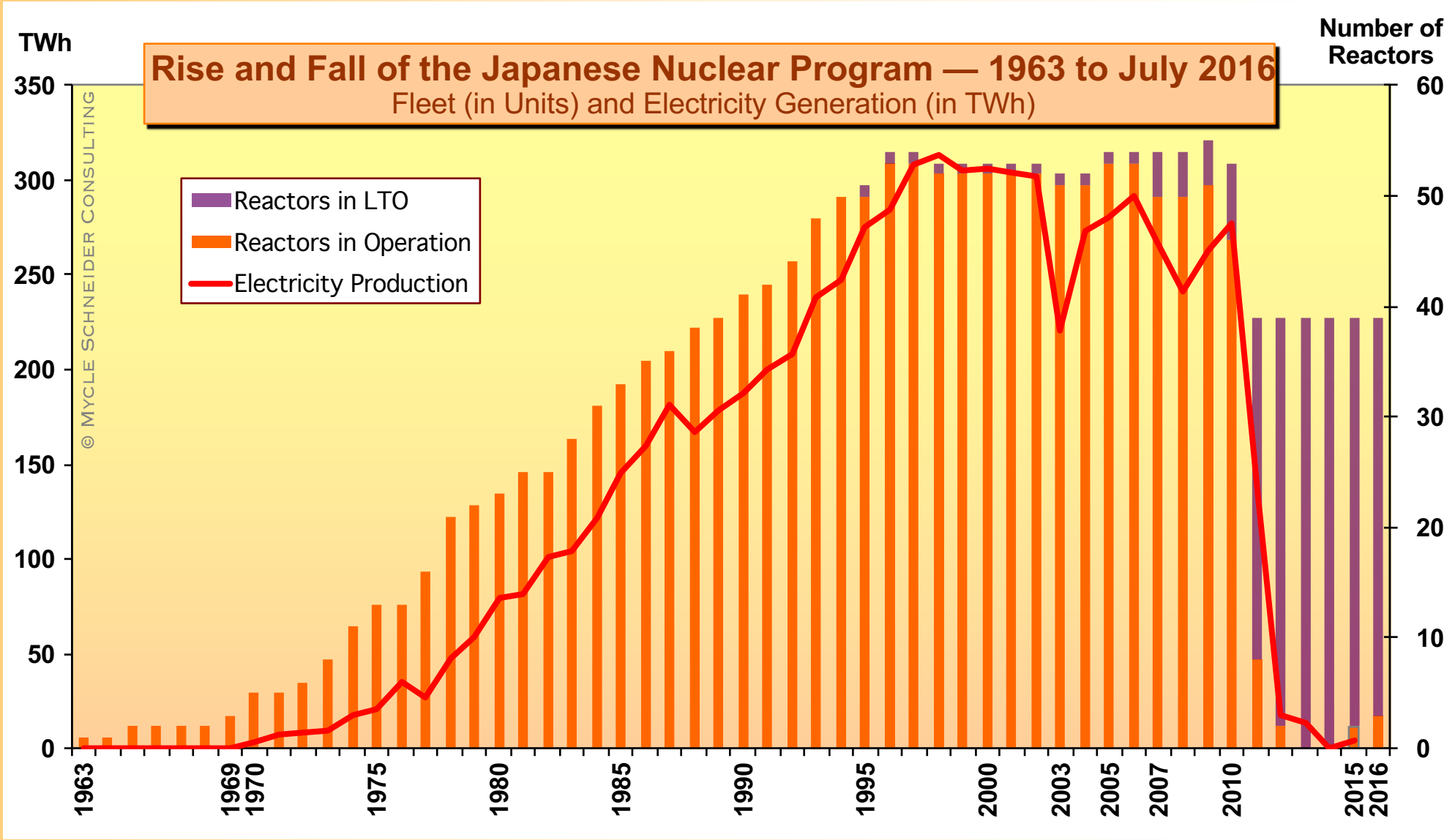
Annual Electrical Power Production

Total Electricity Production (including Nuclear)	Nuclear Electricity Production
829020.00 GW.h	**4346.49 GW.h**
(Net, 2015)	(Net, 2015)

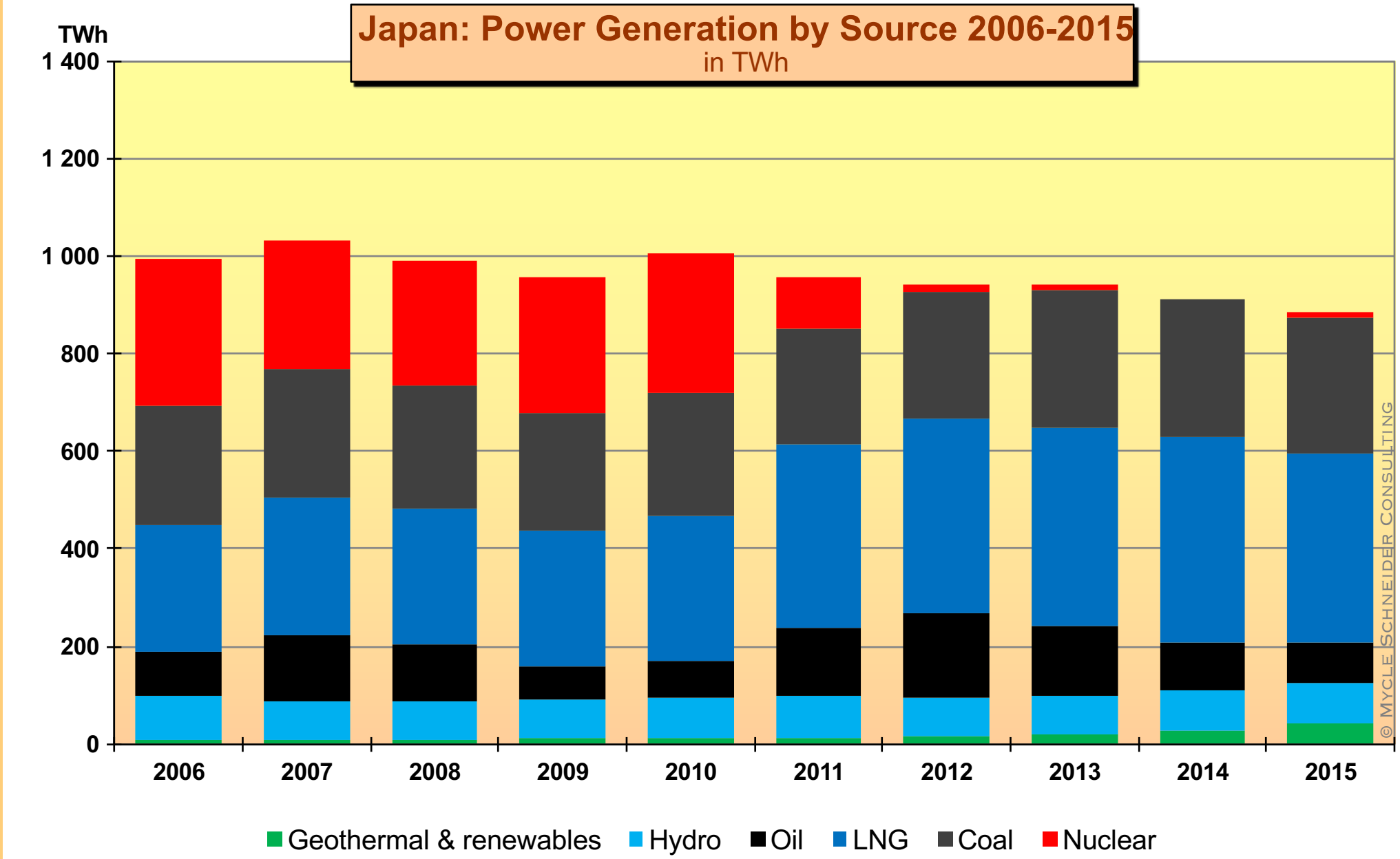
Electricity Production Share in 2015 Trend



Source: IAEA-PRIS, Screenshot, 13 July 2016



Source: IAEA-PRIS, MSC, 2016



Source: FEPC, "Summary of Press Conference Comments Made by Makoto Yagi, FEPC Chairman, on 20 May 2016"

The WNISR2014 Established New Reactor Status Category: Long-Term Outage or LTO

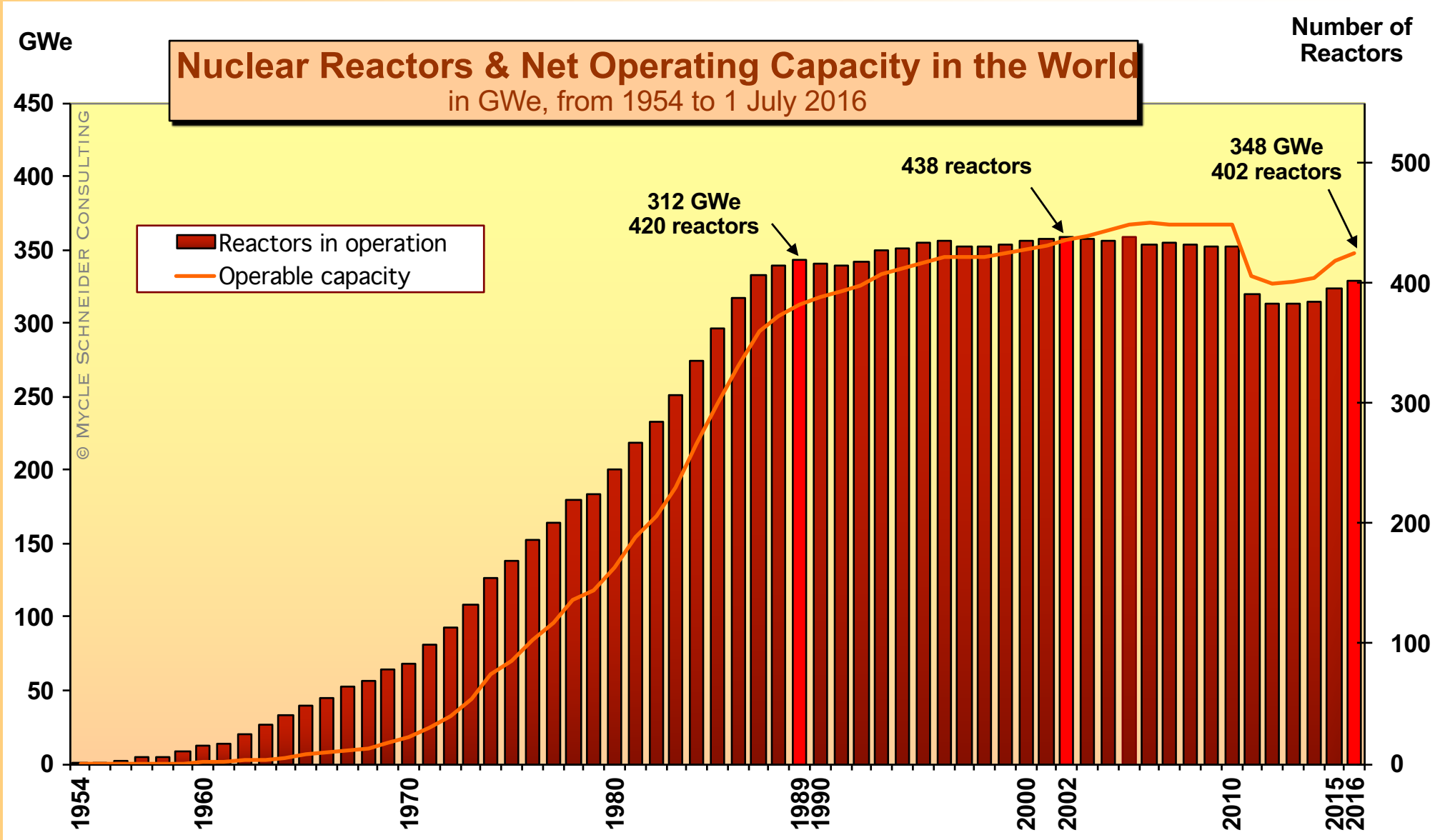
"A nuclear power reactor is considered in Long-Term Outage (LTO) if it has not generated any power in the entire previous calendar year and in the first semester of the current calendar year of the WNISR."

As of 1 July 2016

- 36 reactors in Japan in LTO, shut down between 1995 and 2012.

Only two currently operating (Sendai-1 and -2).
Takahama-3 restarted in October 2015; Takahama-4 failed restart in February 2016; both ordered to shut down in March 2016.

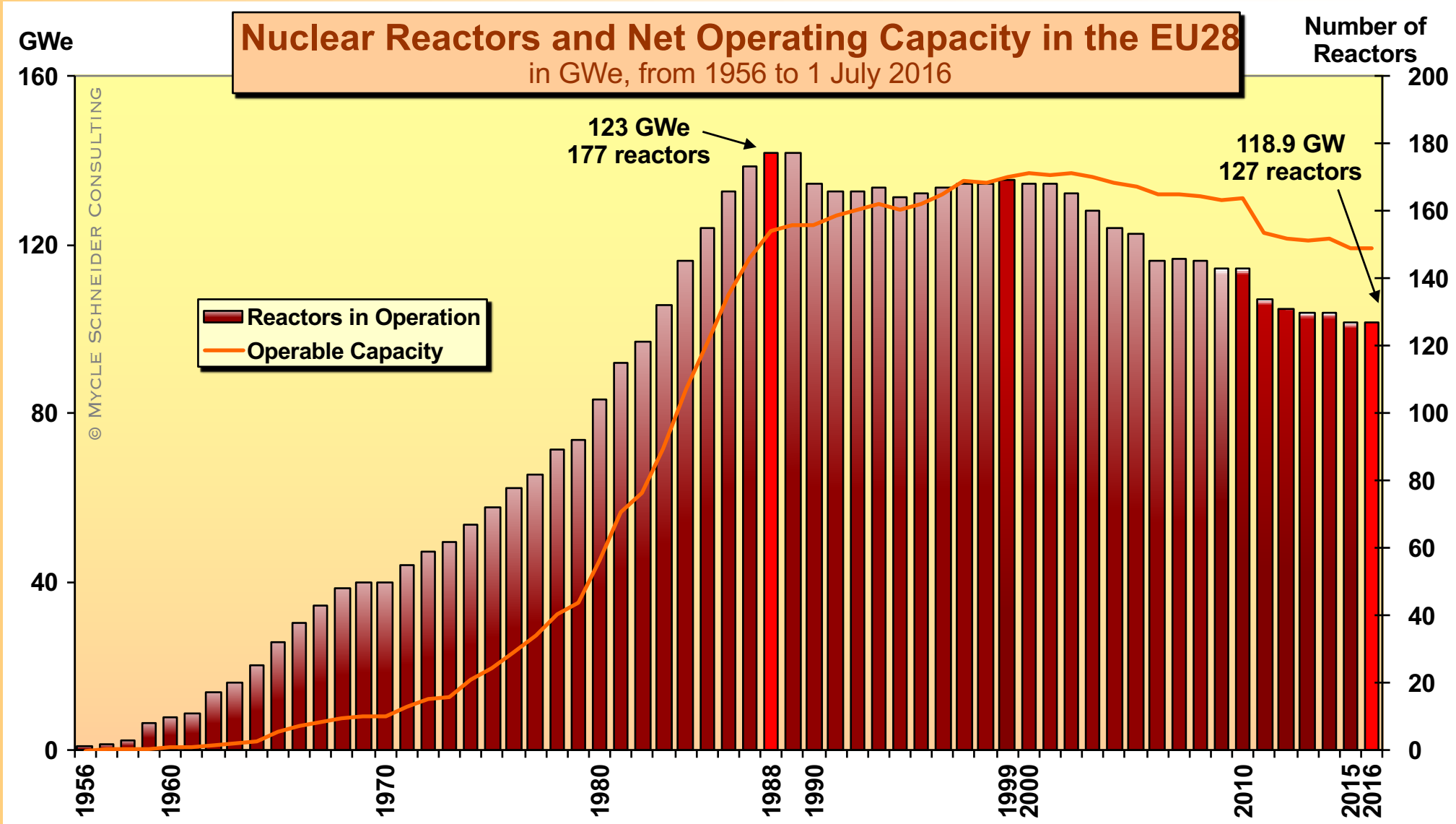
- 1 reactor in Sweden in LTO (Ringhals-2)
- 1 reactor in Taiwan in LTO (Chinshan-1)



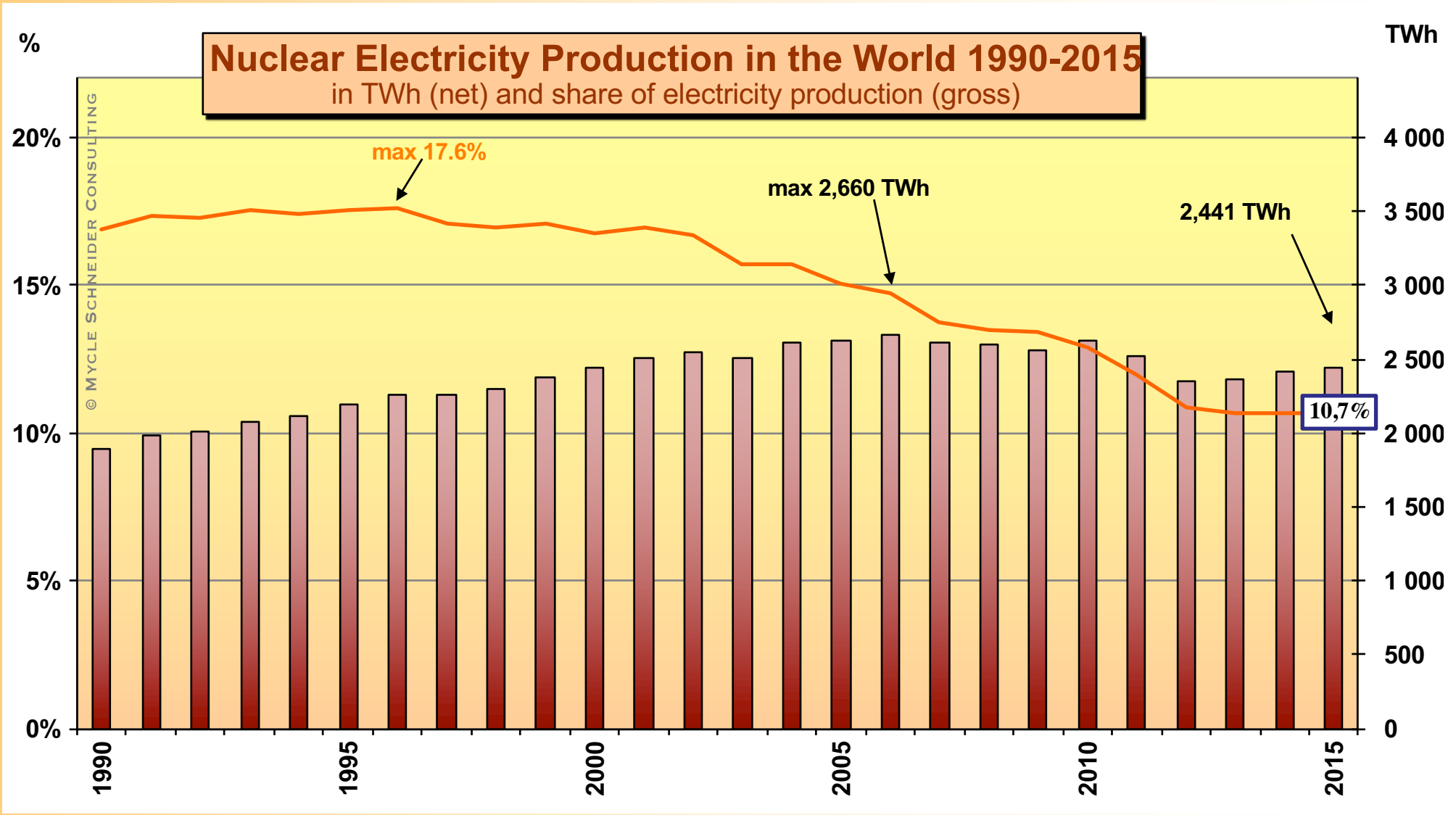
Source: IAEA-PRIS, MSC, 2016

Nuclear Reactors and Net Operating Capacity in the EU28

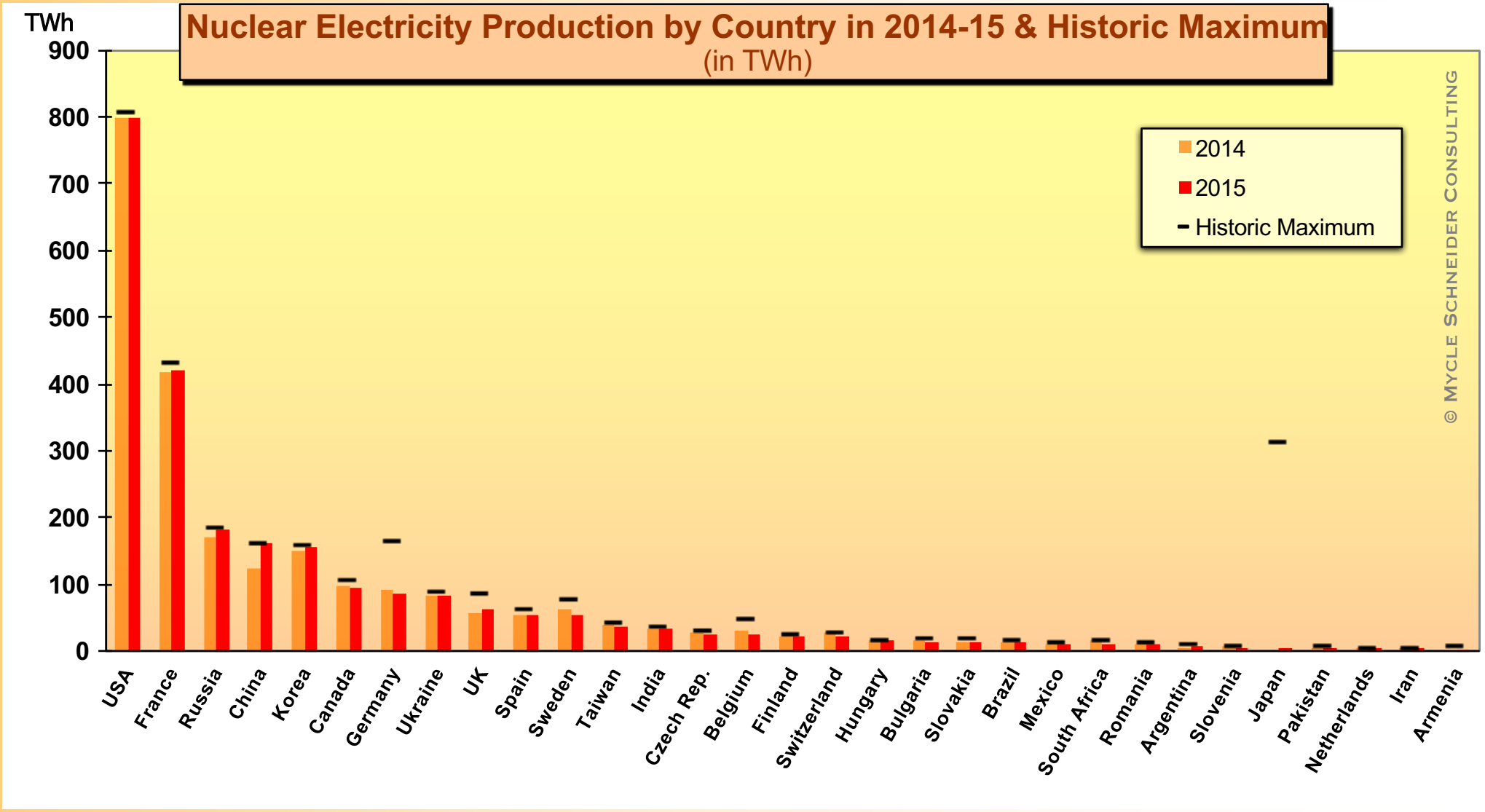
in GWe, from 1956 to 1 July 2016



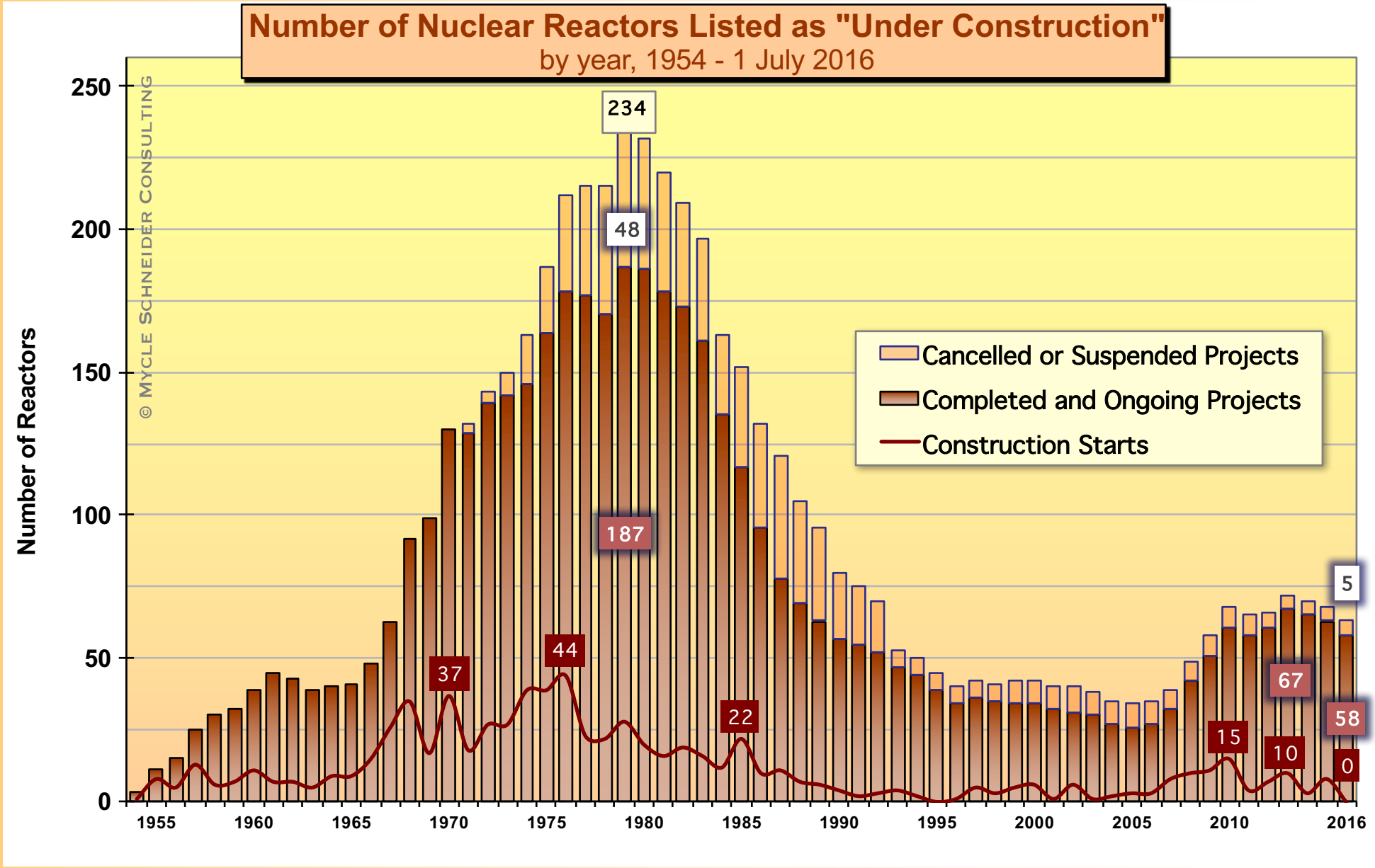
Source: IAEA-PRIS, MSC, 2016



Source: IAEA-PRIS, MSC, 2016



Source: IAEA-PRIS, MSC 2016

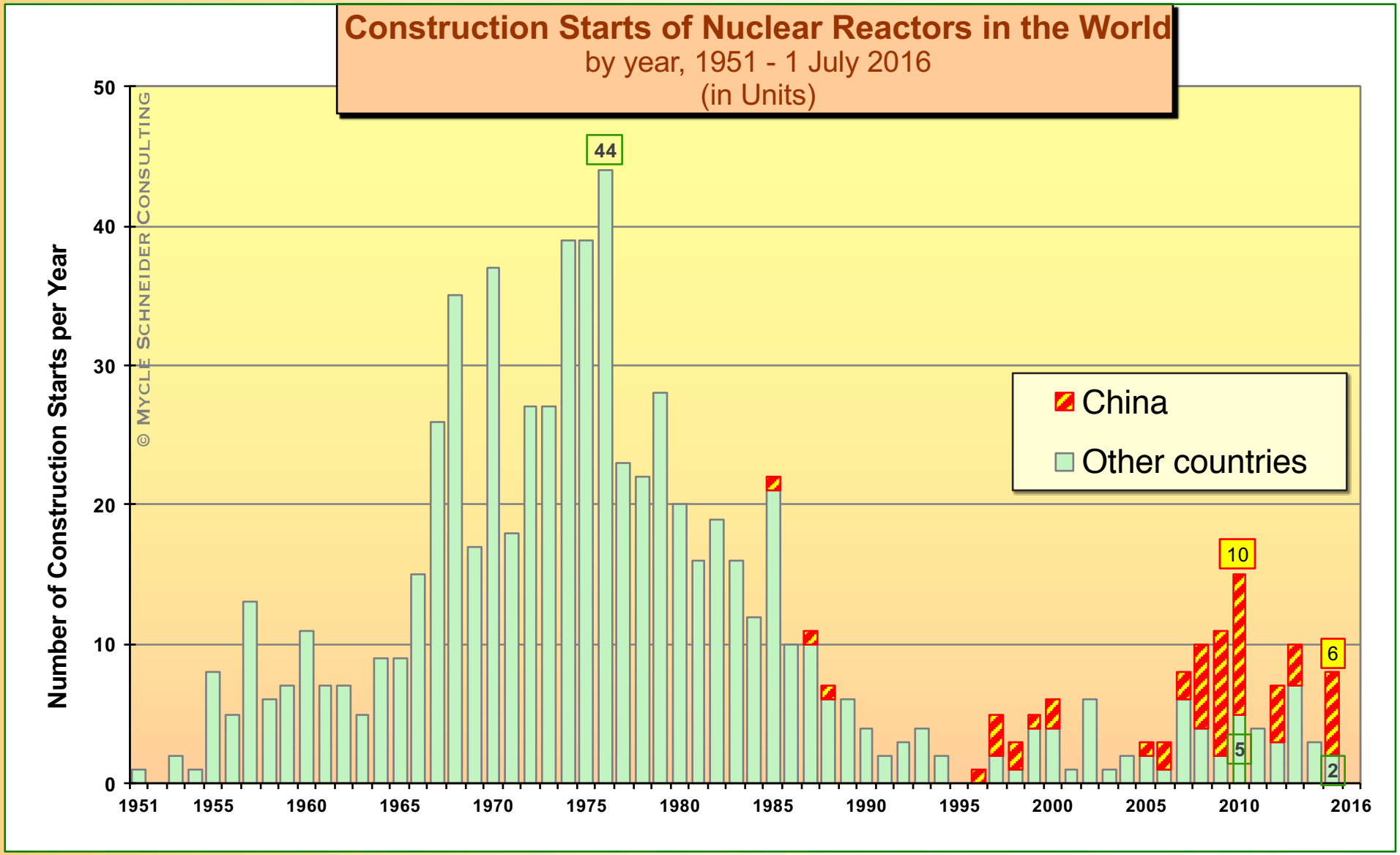


Source: IAEA-PRIS, MSC, 2016

Reactors Under Construction in the World (1 July 2016)

Country	Units	MW (nets)	Construction Starts	Grid Connections	Delayed Units
China	21	21 500	2009 - 2015	2016 - 2021	11
Russia	7	5 473	1983 - 2010	2016 - 2019	7
India	6	3 907	2002 - 2011	2016 - 2019	6
USA	4	4 468	2013	2019 - 2020	4
UAE	4	5 380	2012 - 2015	2017 - 2020	?
Pakistan	3	1 644	2011 - 2015	2016 - 2021	?
Korea	3	4 020	2009 - 2013	2017 - 2019	3
Slovakia	2	880	1985	2017 - 2018	2
Japan	2	2 650	2007 - 2010	?	2
Belarus	2	2 218	2013 - 2014	2018 - 2020	?
France	1	1 600	2007	2018	1
Argentina	1	25	2014	2018	?
Finland	1	1 600	2005	2018	1
Brazil	1	1 245	2010	2019	1
Total	58	56 610	1983 - 2015	2016 - 2021	≥38

Source: IAEA-PRIS, MSC, 2016



Source: IAEA-PRIS, MSC, 2016

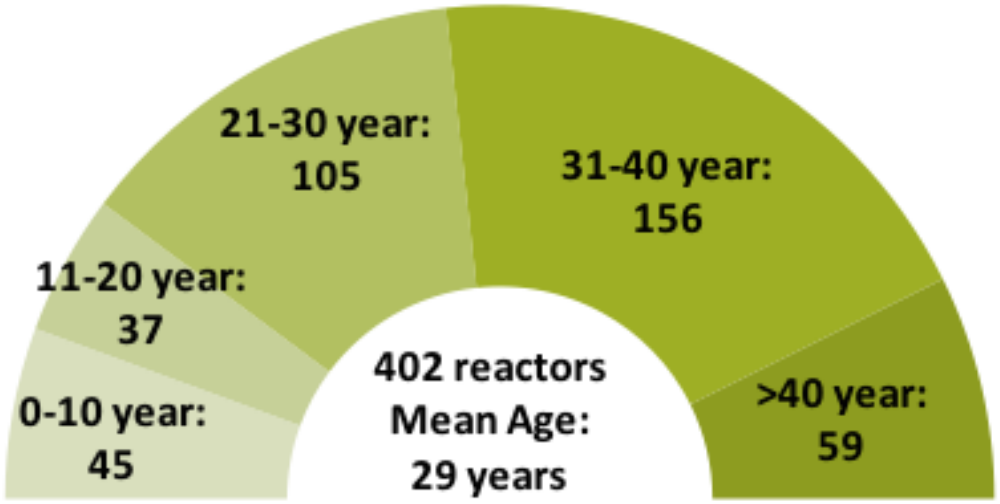
Construction Times – Startups Between 2006 and July 2016

(in years)

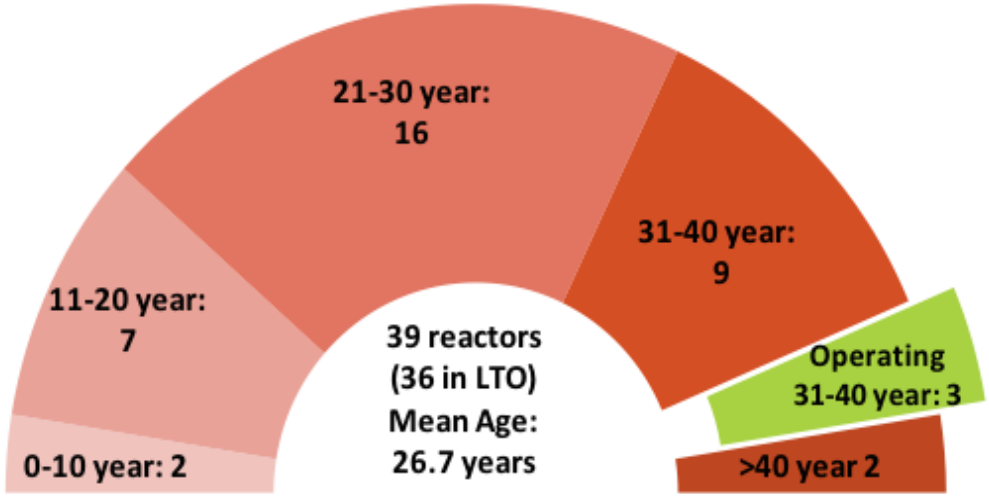
Country	Units	Mean Time	Min. Time	Max. Time
China	25	5.7	4.3	11.2
India	6	7.7	5.0	11.6
South Korea	5	5.3	4.0	7.2
Russia	4	28.8	25.3	32.0
Argentina	1	33.0	33.0	33.0
Iran	1	36.3	36.3	36.3
Japan	1	5.1	5.1	5.1
Pakistan	1	5.2	5.2	5.2
Romania	1	24.1	24.1	24.1
USA	1	43.5	43.5	43.5
Total	46	10.4	4	43.5

Source: IAEA-PRIS, MSC, 2016

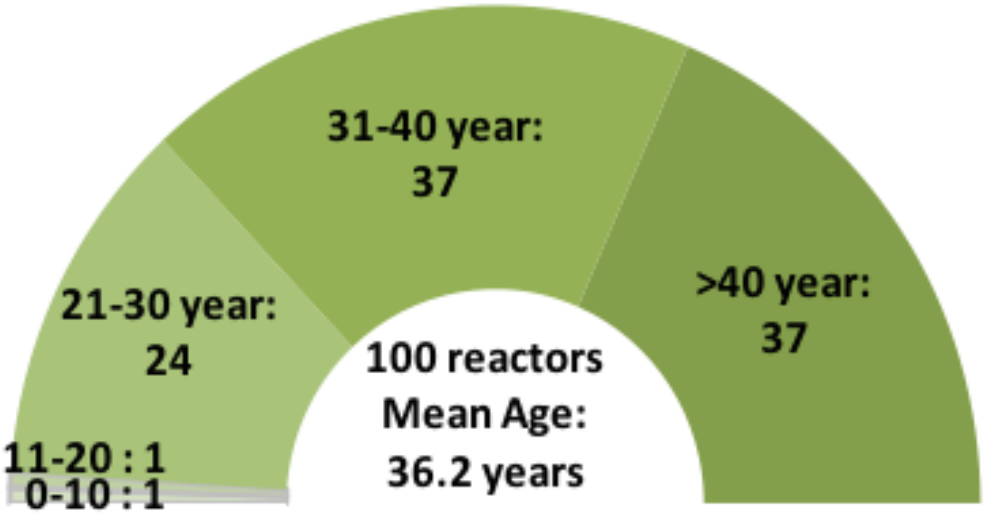
Age of World Nuclear Fleet
as of 1 July 2016



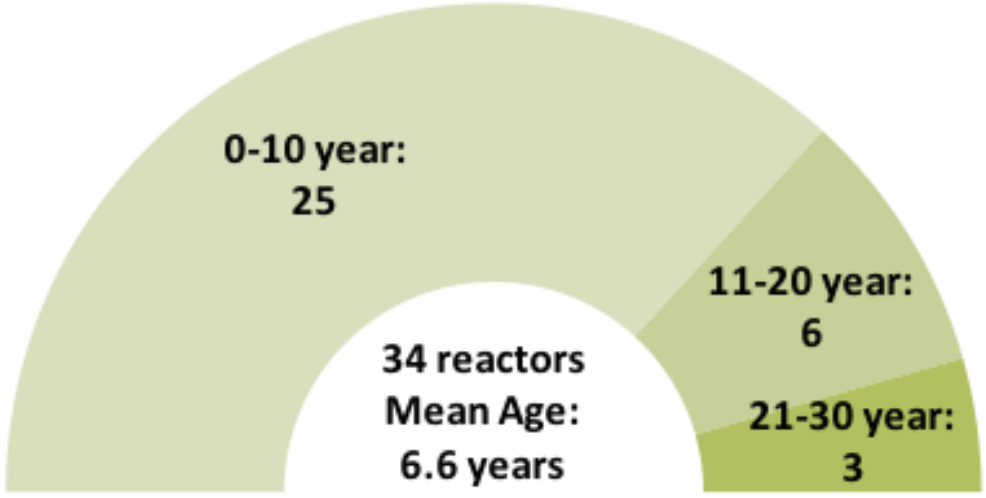
Age of Japanese Nuclear Fleet
as of 1 July 2016



Age of US Nuclear Fleet
as of 1 July 2016



Age of Chinese Nuclear Fleet
as of 1 July 2016



"Is Dismantling Reactors the Future of [Toshiba]-Westinghouse?"*

Early Closures Accelerate – Recent Cases from the US and Sweden

	Shutdown	Relicensed	Reason	Age
U.S.				
Crystal River-3:	2009	Underway	Containment damage	22
San Onofre-2 and -3:	2012	Yes	Steam gen. damage	28/29
Kewaunee	2013	Yes	Economics	39
Vermont Yankee	2014	Yes	Economics	42
Fort Calhoun	2016	Yes	Economics	
Clinton	2017	Yes	Economics	
Quad Cities	2017	Yes	Economics	
Fitzpatrick	2017	Yes	Economics	(41/42)
Pilgrim	2019	Yes	Economics	(45)
Sweden				
Oskarshamn-1	2015?	Upgraded	Economics	(44)
Oskarshamn-2	2013	Upgrade halted	Economics	39
Ringhals-1	2020	Upgraded	Economics	(46)
Ringhals-2	2019	Upgraded	Economics	(45)

India next? *Tarapur-1 and -2 face early closure*

*Sources: Various, compiled by MSC; *bizjournals.com, 2 Nov. 2015*

French Nuclear Companies in Trouble

EDF — World's Largest Nuclear Power Operator

- Steep operating cost increases
- Stock value plunged 87% since 2007
- High debt €37.4bn for turnover of €75bn

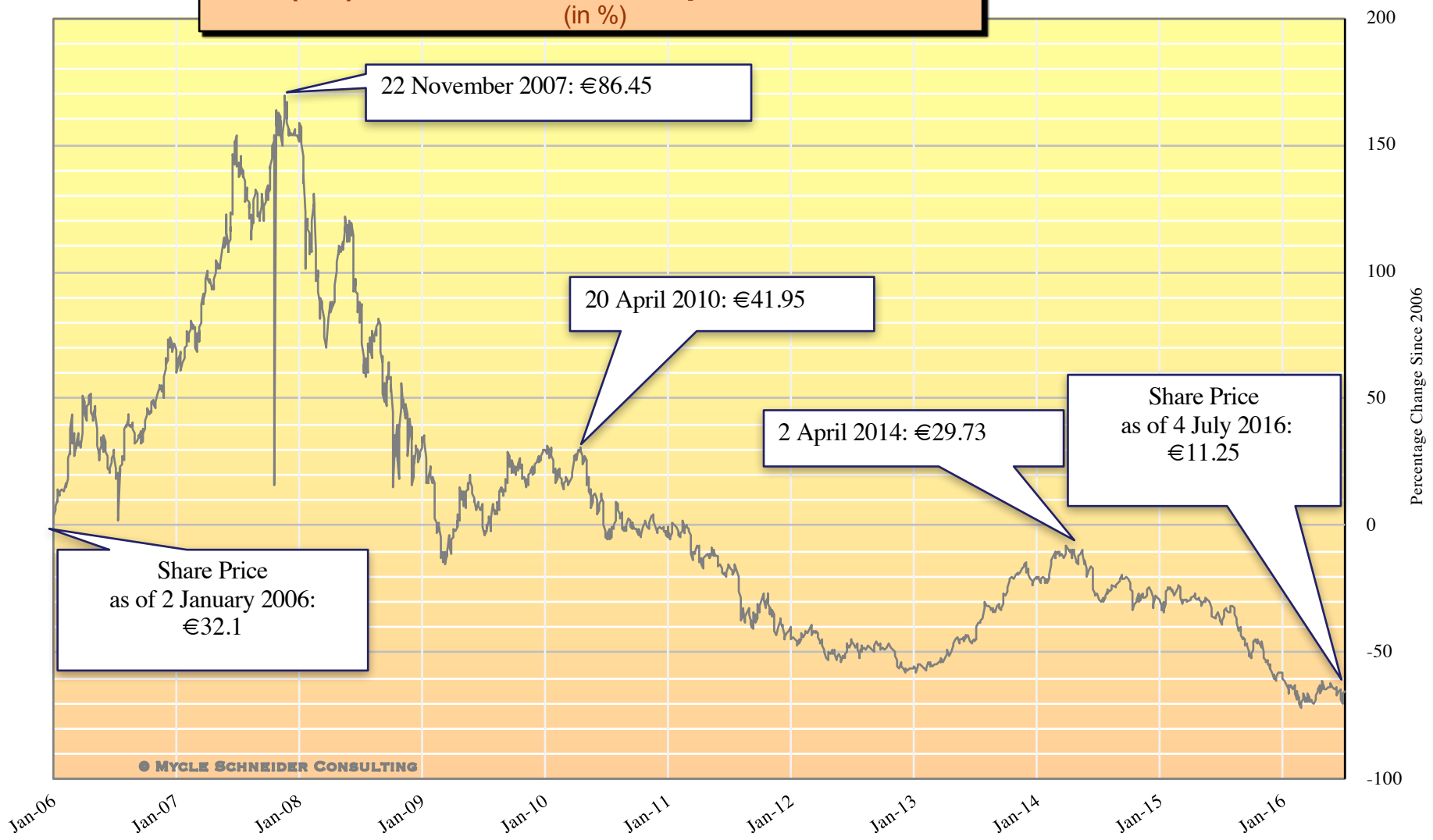
AREVA — "Global Leader in Nuclear Energy"

- Technically bankrupt
- Loss of €2bn in 2015 (€10bn in 5 years)
- High debt €6.3bn for revenues of €4.2bn
- Stock value plunged by up to 96% since 2007
- Standard & Poor's downgraded AREVA shares to BB+ ("junk") in November 2014 and again to BB- in March 2015

Sources: Company websites; Standard & Poor's

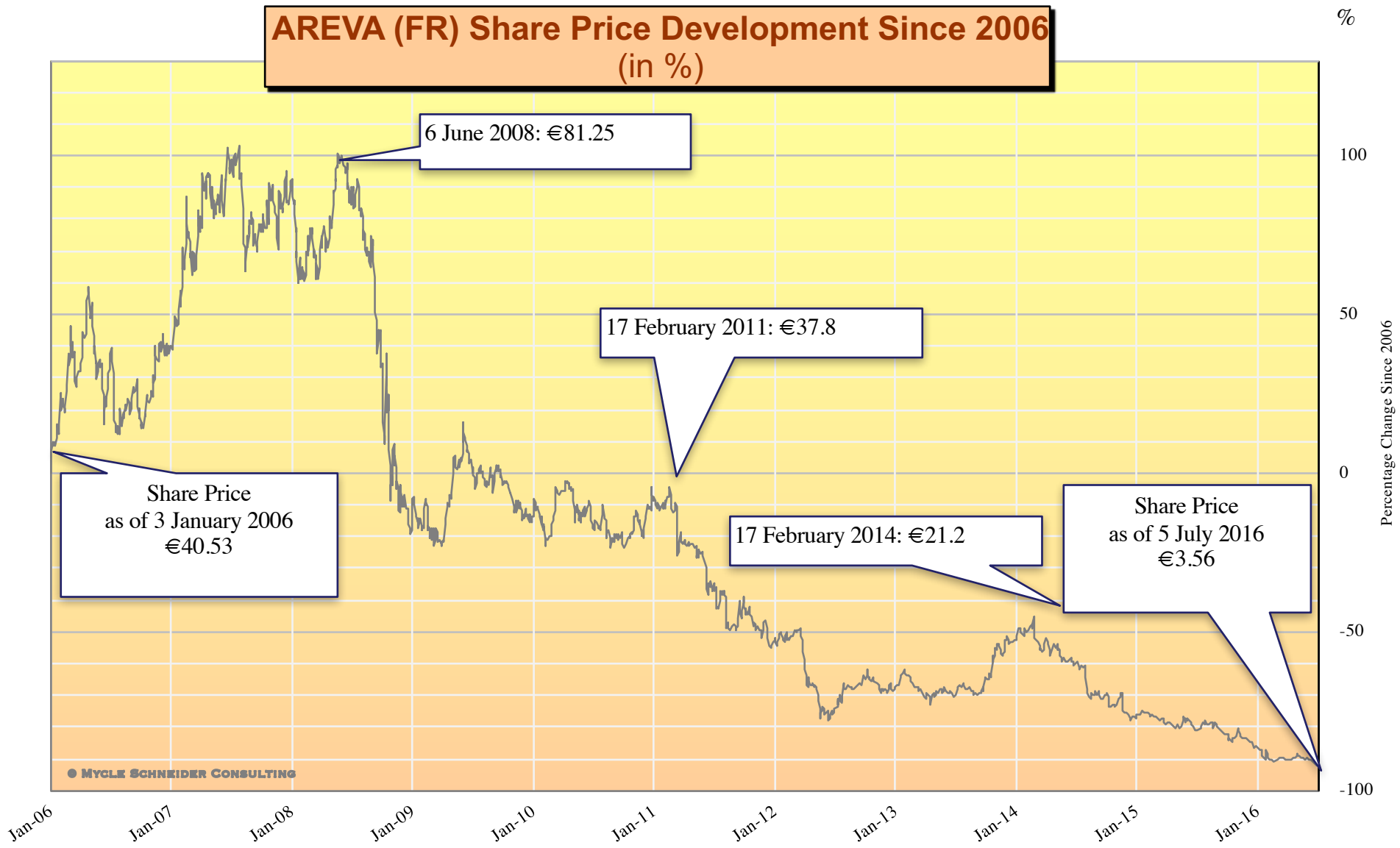
EDF (FR) Share Price Development Since 2006

(in %)



Source: Investing, 2016

AREVA (FR) Share Price Development Since 2006
(in %)



Source: Investing, 2016

Economics, Nuclear Safety and Nuclear Security

A major accident, like those of Chernobyl and Fukushima, cannot be excluded anywhere in the world, including in Europe

Pierre-Franck Chevet, President

French Nuclear Safety Authority

April 2016

We must not allow political and economical considerations to have a negative impact on the safety of the Swiss nuclear power plants

Hans Wanner, Director

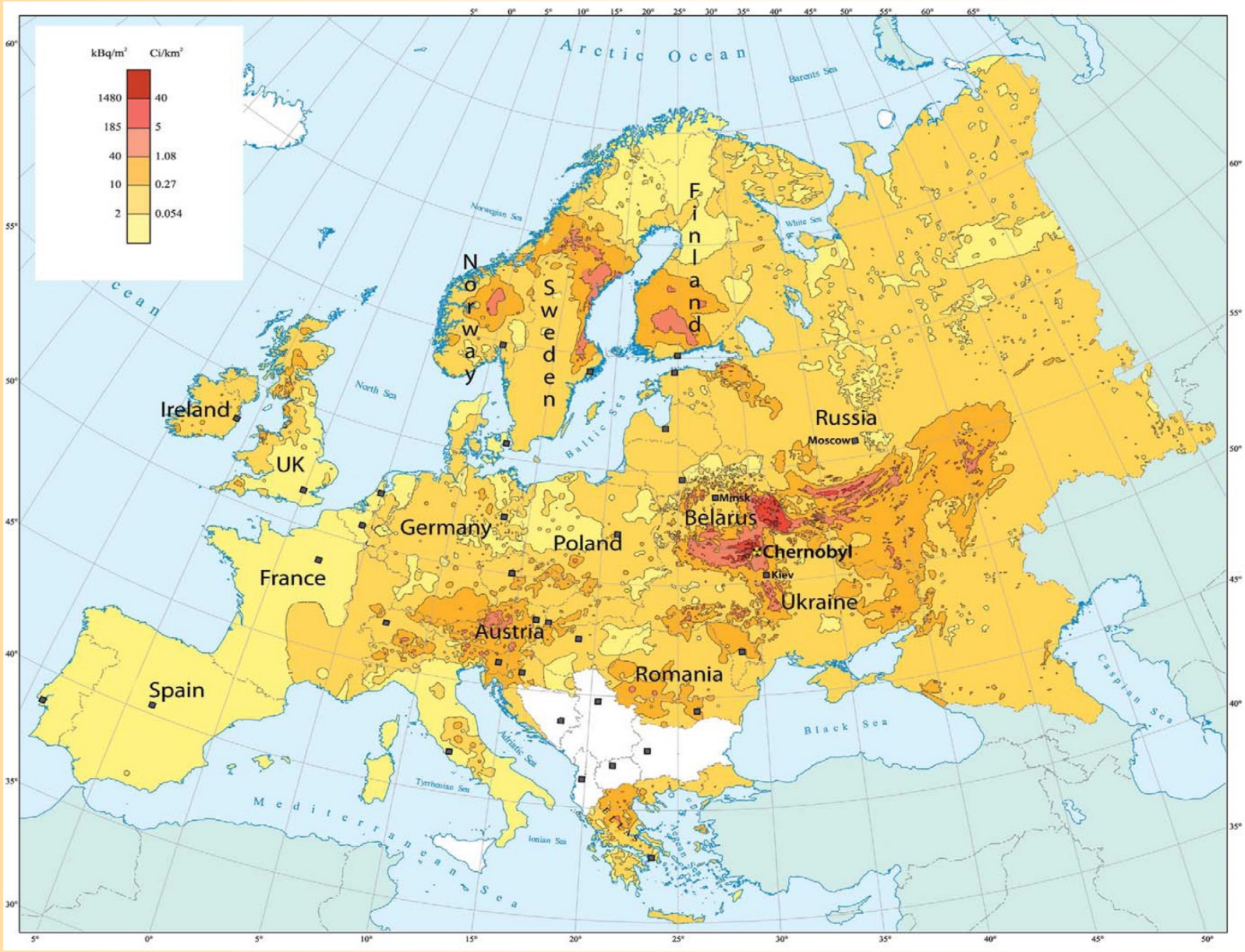
Swiss Nuclear Safety Inspectorate

March 2016

Sources: Le Monde, see http://www.lemonde.fr/energies/article/2016/04/22/un-accident-nucleaire-majeur-ne-peut-etre-exclu-nulle-part-dans-le-monde_4907303_1653054.html
www.energiestiftung.ch/files/pdf/20160321_npc_hans_wanner.pdf, accessed 30 June 2016.

Chernobyl+30 Status Report (1/3)

- *Thirty years after the explosion and subsequent fire at unit 4 of the Chernobyl nuclear power plant on 26 April 1986, then in the USSR, now in independent Ukraine, the consequences are still felt throughout the region.*



Chernobyl+30 Status Report (2/3)

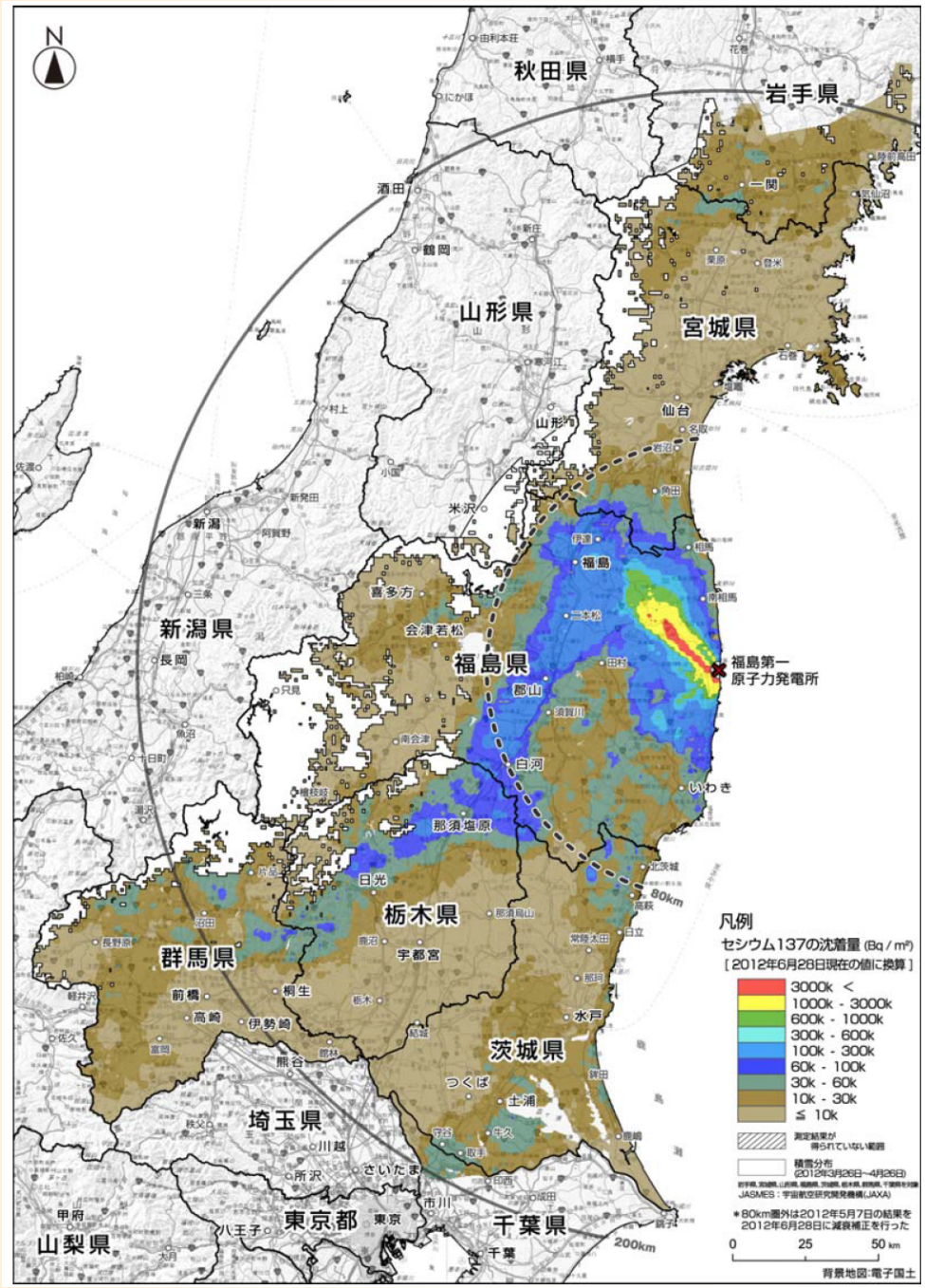
- **Accident Sequence.** A power excursion—output increased about 100-fold in 4 seconds—a hydrogen explosion and a subsequent graphite fire that lasted 10-days released about one third of the radioactive inventory of the core into the air.
- **Environmental Consequences.** The chimney effect triggered by the fire led to the ejection of radioactive fission products several kilometers up into the atmosphere. An estimated 40 percent of Europe's land area was contaminated (>4,000 Bq/m^2). Over six million people still live in contaminated areas in Belarus, Russia and Ukraine. A 2,800 km^2 exclusion zone with the highest contamination levels in a 30-km radius has been established in the immediate aftermath of the disaster and upheld ever since.
- **Human Consequences.** About 130,000 people were evacuated immediately after the initial event, and in total about 400,000 people were eventually dislocated. Around 550,000 poorly trained workers called "liquidators", engaged by the Soviet army in disaster management, received amongst the highest doses.

Chernobyl+30 Status Report (3/3)

- **Health Consequences.** A recent independent assessment expects a total of 40,000 fatal cancers over the coming 50 years caused by Chernobyl fallout. Over 6,000 thyroid cancer cases have been identified so far, another 16,000 are expected in the future. Similarly, 500 percent increases were observed in leukemia risk in both Belarus and Ukraine. Some new evidence indicates increased incidences of cardiovascular effects, stroke, mental health effects, birth defects and various other radiogenic effects in the most affected countries. Strong evidence has been published on Chernobyl related effect on children, including impaired lung function and increased breathing difficulties, lowered blood counts, high levels of anemias and colds and raised levels of immunoglobulins.
- **Remediation Measures.** In 1986, under extremely difficult conditions, the liquidators had built a cover over the destroyed reactor called the "sarcophagus" that quickly deteriorated. Under the Shelter Implementation, Plan financed by 44 countries and the EU, a US$ 2 billion New Safe Confinement (NSC) has been built. The NSC is a gigantic mobile cover that will be pushed over the old sarcophagus and serve as protection during the dismantling of the ruined nuclear plant.
- **Waste Management.** The largest single risk potential at the Chernobyl site remains the spent fuel from all four units that is to be transferred to a recently completed dry storage site between end of 2017 and April 2019. Construction of a liquid and solid waste treatment facilities were completed in 2015.

Fukushima+5
Status Report (1/4)

- *Over five years have passed since the Fukushima Daiichi nuclear power plant accident (Fukushima accident) began, triggered by the East Japan Great Earthquake on 11 March 2011 (also referred to as 3/11 throughout the report) and subsequent events. This assessment includes analyses of onsite and offsite challenges that have arisen since and remain significant today.*
- **Onsite Challenges.** In June 2015, the Japanese government revised the medium- and long-term roadmap for the decommissioning of the Fukushima Daiichi site. Key components include spent fuel removal, fuel debris evacuation and limitation of contaminated water generation.



Fukushima+5 Status Report (2/4)

- **Spent Fuel Removal.** Spent fuel is to be removed from unit 3 between Financial Years (FY) 2017 and 2019, from unit 2 between 2020 and 2021 and from unit 1 between 2020 and 2022.
- **Molten Fuel Removal.** Radiation levels remain very high inside the reactor buildings (about 4-10 Sievert per hour) and make human intervention impossible. No conclusive video footage is available and it remains unknown where the molten fuel is actually located. Commencement of work on fuel debris removal is planned for 2021. However, no methodology has been selected yet.
- **Contaminated Water Management.** Large quantities of water (about 300 cubic meters per day) are still continuously injected to cool the fuel debris. The highly contaminated water runs out of the cracked containments into the basement where it mixes with water that has penetrated the basements from an underground river. The commissioning of a dedicated bypass system and the pumping of groundwater has reduced the influx of water from around 400 m^3/day to about 150 to 200 m^3/day.
- An equivalent amount of water is decontaminated to some degree—it contains still very high levels of tritium (over 500,000 Bq/l) and stored in large tanks. The storage capacity onsite is 800,000 m^3. A frozen soil wall that was designed to further reduce the influx of water was commissioned at end of March 2016. Its effectiveness is under review.

Fukushima+5 Status Report (3/4)

- **Offsite Challenges.** Amongst the main offsite issues are the future of tens of thousands of evacuees, the assessment of health consequences of the disaster, the management of decontamination wastes and the costs involved.
  - **Evacuees.** According to government figures, the number of evacuees from Fukushima Prefecture as of May 2016 was about 92,600 (vs. 164,000 at the peak in June 2013). About 3,400 people have died for reasons related to the evacuation, such as decreased physical condition or suicide (all classified as "earthquake related deaths"). The government plans to lift restrict on orders for up to 47,000 people by March 2017. However, according to a survey by Fukushima Prefecture, 70 percent of the evacuated people do not wish to return to their homes (or what is left of them) even if the restrictions are lifted, while 10 percent wish to return and 20 percent remain undecided.
  - **Health Issues.** Conflicting information has been published concerning the evolution of thyroid cancer incidence. While a Fukushima Prefectural committee concluded that "it is unlikely that the thyroid cancers discovered until now were caused by the effects of radiation", but it did not rule out a causal relationship. In contrast, an independent study from Okayama University concluded that the incidence of childhood thyroid cancer in Fukushima was up to 50 times higher than the Japanese average.

Fukushima+5 Status Report (4/4)

- **Decontamination.** Decontamination activities inside and outside the evacuation area in locations, "where daily activities occur" throughout Fukushima Prefecture, have been carried out on 80 percent of the houses, 5 percent of the roads and 70 percent of the forests, according to government estimates. However, the efficiency of these measures remain highly questionable.

- **Cost of the Accidents.** The Japanese Government has not provided a comprehensive total accident cost estimate. However, based on information provided by TEPCO, the current cost estimate stands at US$133 billion, over half of which is for compensation, without taking into account such indirect effects as impacts on food exports and tourism.

Fukushima vs. Chernobyl (1/2)

- Every industrial accident has its own very specific characteristics and it is often difficult to compare their nature and effects. The large explosions and subsequent 10-day fire at inland Chernobyl led to a very different release pattern than the meltdowns of three reactor cores at coastal Fukushima.

- The dispersion of radioactivity from Chernobyl led to wide-spread contamination throughout Europe, whereas about four fifths of the radioactivity released from Fukushima Daiichi came down over the Pacific Ocean. Radioactivity in the soil mainly disappears with the physical half-lives of the radioactive isotopes (30 years for the dominant cesium-137).

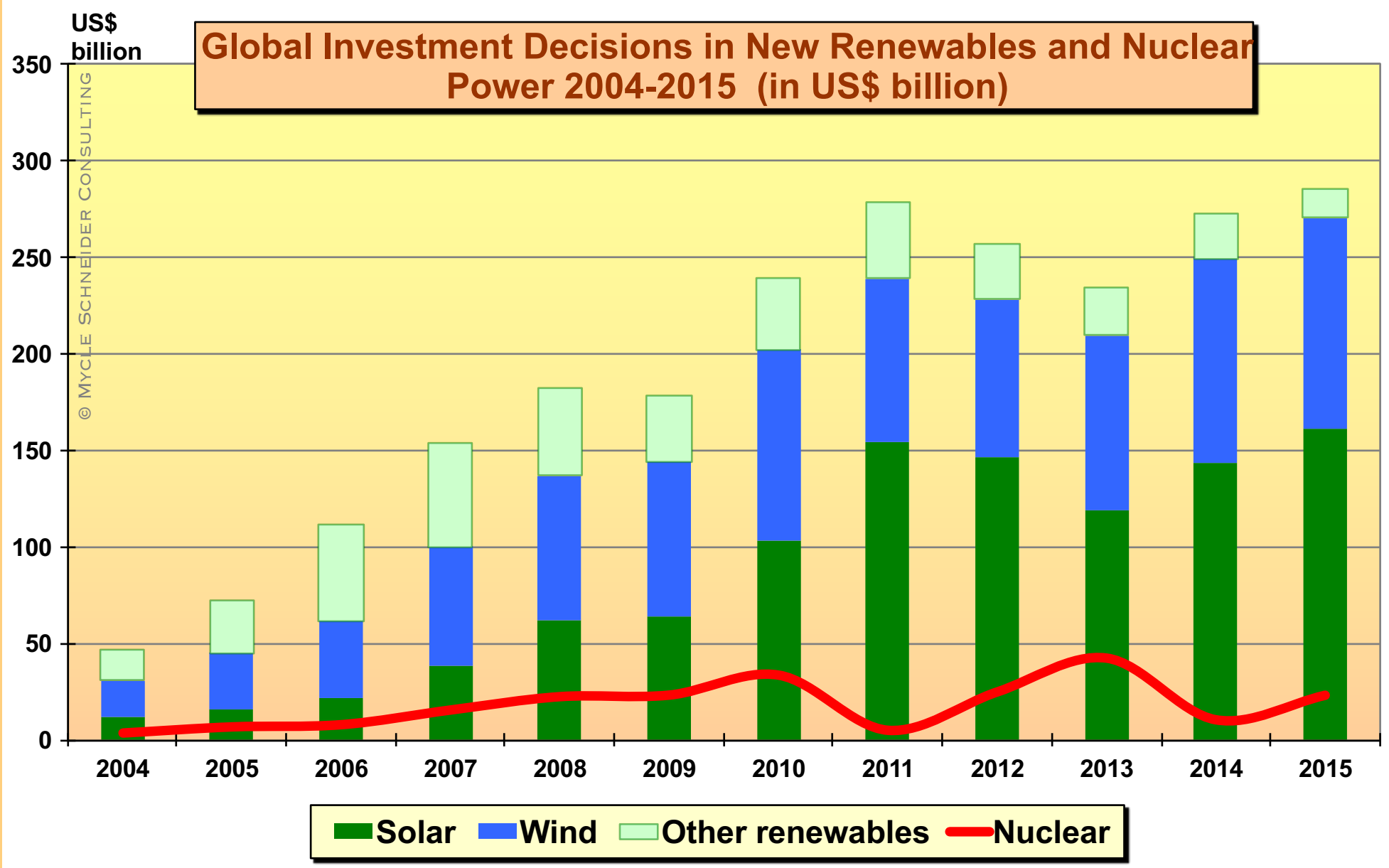
- Radioactive particles are greatly diluted in the sea and many isotopes, including cesium-137, are water soluble. This does not mean that radioactivity released to the ocean does not have effects, particularly in fish species near the coast, but further away any effects are difficult to identify.

Fukushima vs. Chernobyl (2/2)

- Some parameters can be compared, and some are model estimates based on calculations and assumptions: care needs to be taken in interpreting their conclusions.

- Under practically all criteria, the Chernobyl accident appears to be more severe than the Fukushima disaster: 7 times more cesium-137 and 12 times more iodine-131 released, 50 times larger land surface significantly contaminated, 7–10 times higher collective doses and 12 times more clean-up workers.

- More people were evacuated in the first year at Fukushima than at Chernobyl. However, the number has tripled over time to about 400,000 at Chernobyl because more and more people were displaced as more hotspots were identified.

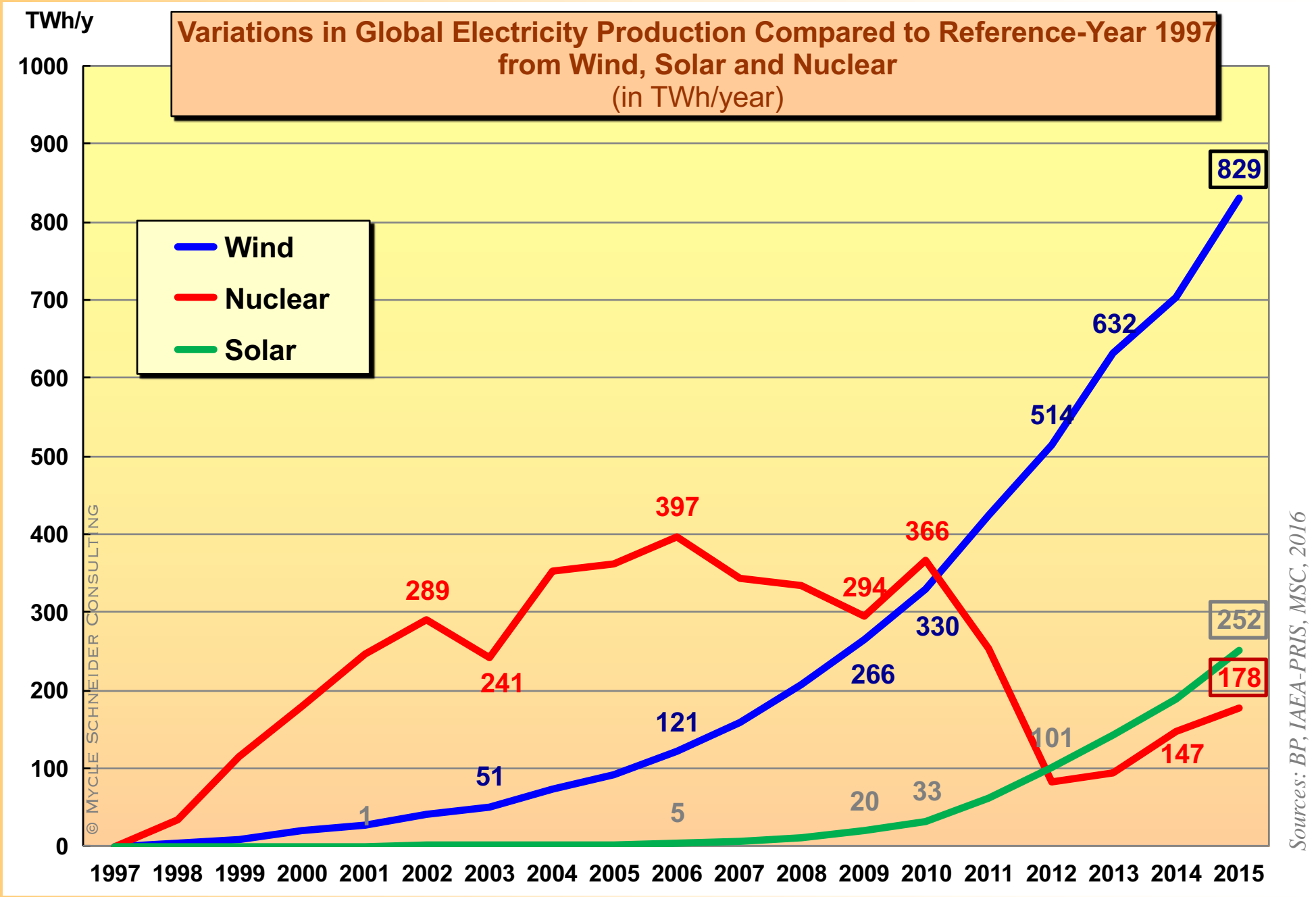


Sources: FS-UNEP 2016 and WNISR original research

Top-Ten Renewable Energy Investors

	2015 US$ bn	2014 US$ bn	2013 US$ bn
China	102.9	81.0	54.2
United States	44.1	36.3	33.9
Japan	36.2	34.3	28.6
United Kingdom	22.2	13.9	12.1
India	10.2	7.1	6.0
Germany	8.5	11.4	9.9
Brazil	7.1	7.4	3.0
South Africa	4.5	5.5	4.9
Mexico	4.0	2.1	1.5
Chile	3.4	1.4	1.6

Source: FS-UNEP 2016, 2015, 2014


TWh/y
Variations in Global Electricity Production Compared to Reference-Year 1997
from Wind, Solar and Nuclear
(in TWh/year)
1000
900
800
700
600
500
400
300
200
100
0
Wind
Nuclear
Solar
829
632
514
397
366
330
289
294
266
252
241
178
147
121
101
51
33
20
5
1
1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
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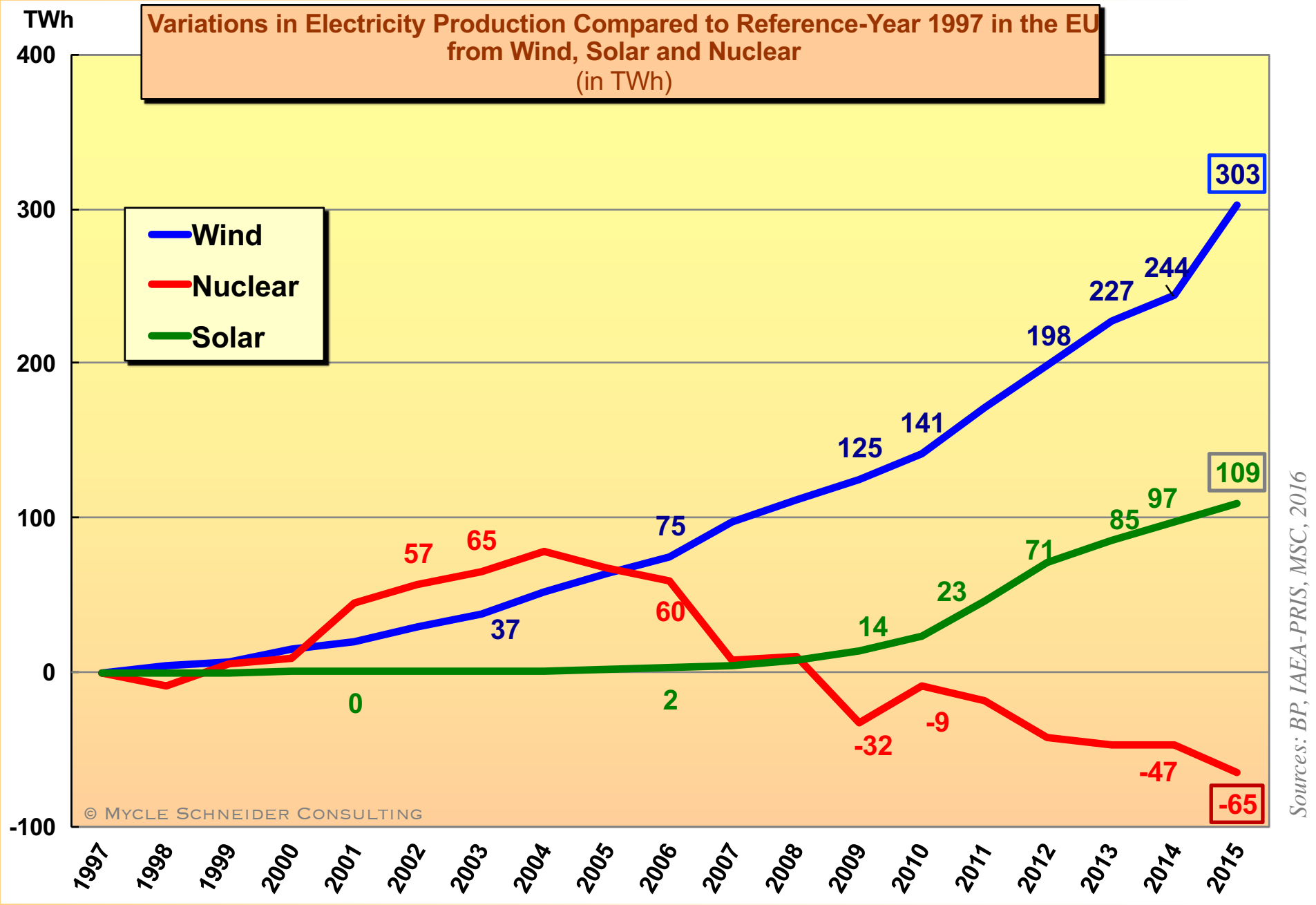
Sources: BP, IAEA-PRIS, MSC, 2016


Variations in Electricity Production Compared to Reference-Year 1997 in the EU
from Wind, Solar and Nuclear
(in TWh)
TWh
400
300
200
100
0
-100
Wind
Nuclear
Solar
303
244
227
198
141
125
109
97
85
75
71
65
57
60
37
23
14
0
2
-9
-32
-47
-65
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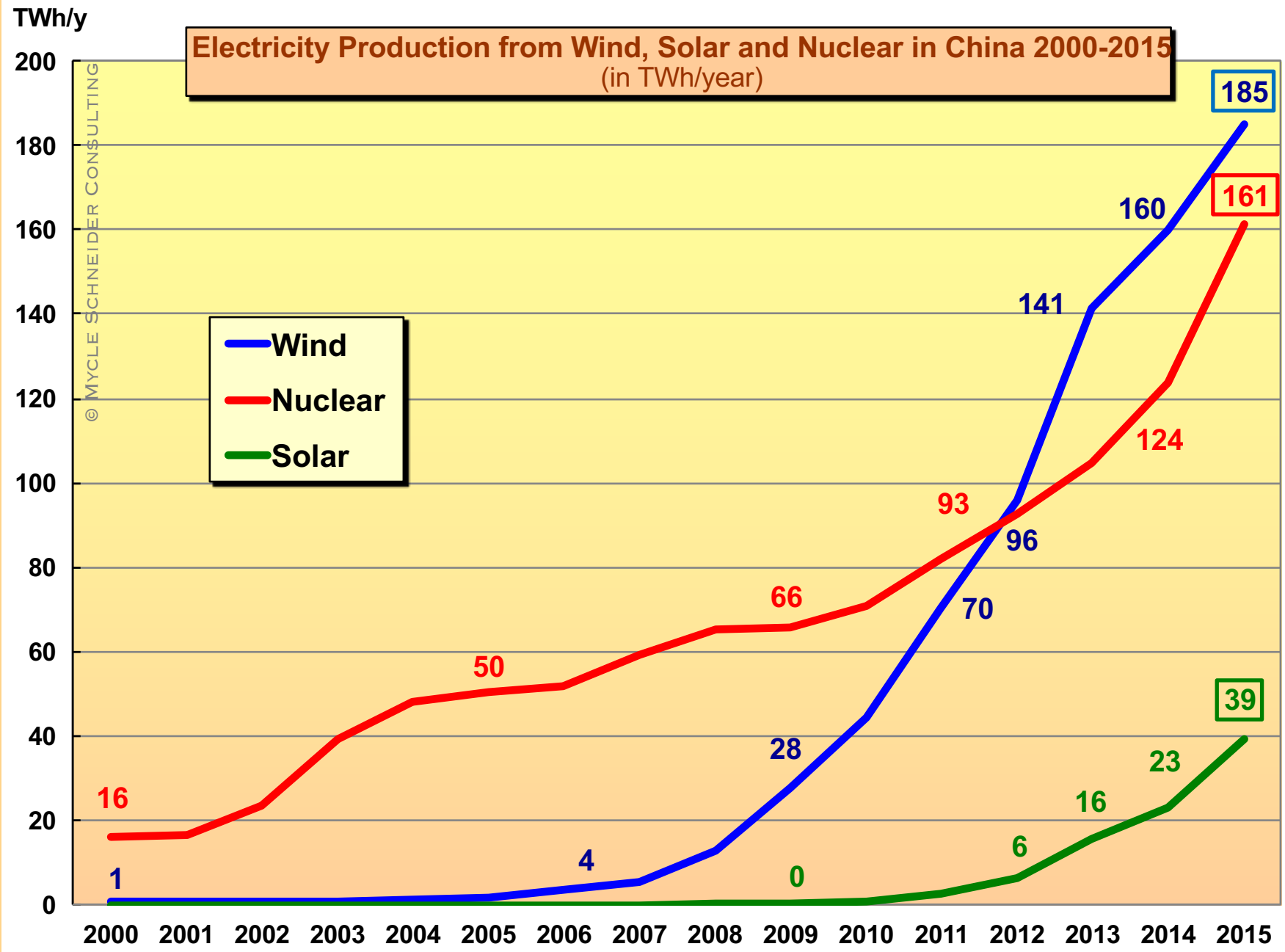
Sources: BP, IAEA-PRIS, MSC, 2016


TWh/y
Electricity Production from Wind, Solar and Nuclear in China 2000-2015
(in TWh/year)
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Wind
Nuclear
Solar
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180
160
140
120
100
80
60
40
20
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
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161
160
141
124
96
93
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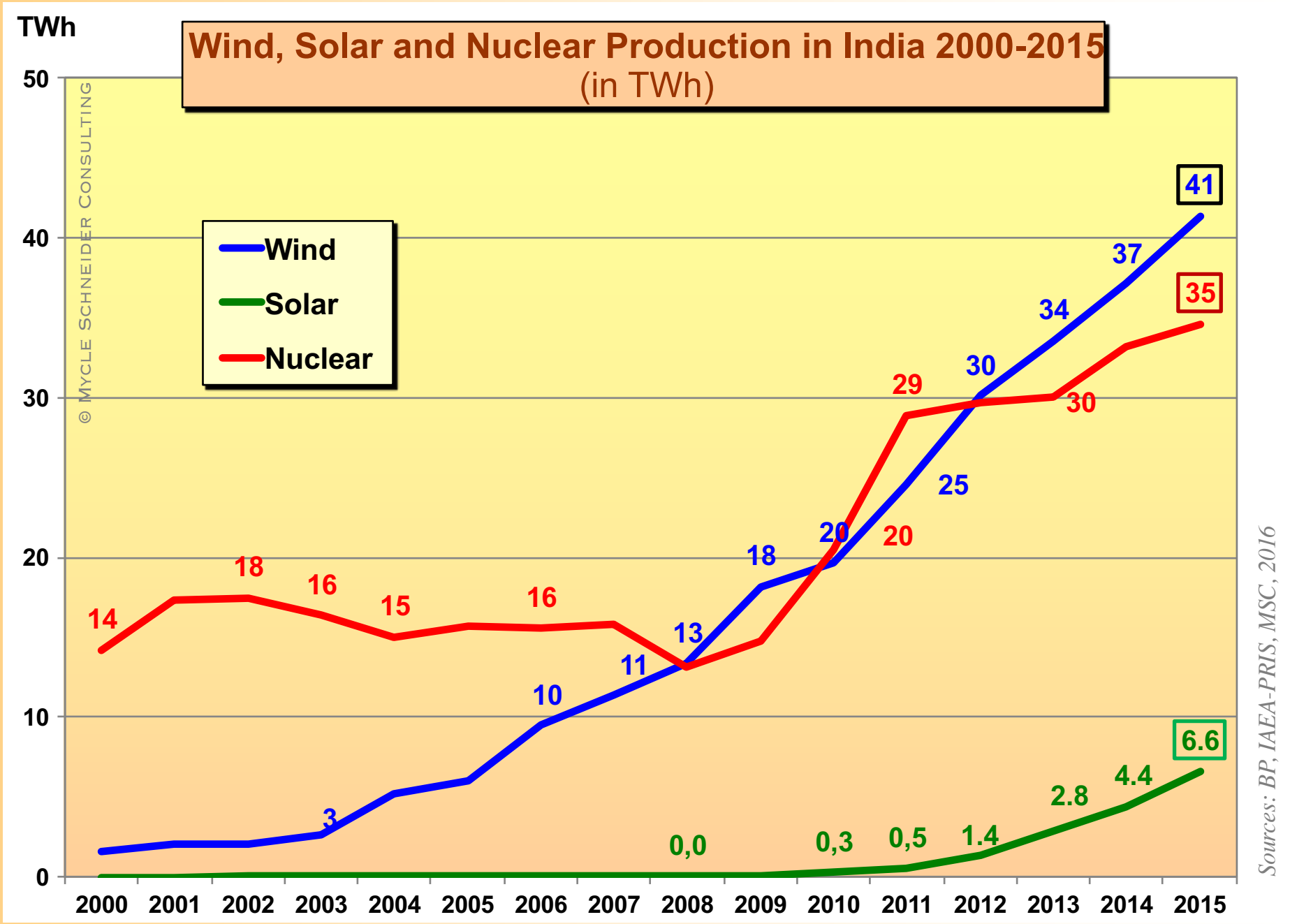
39
28
23
16
16
6
4
1
0
Sources: BP, IAEA-PRIS, MSC, 2016


Wind, Solar and Nuclear Production in India 2000-2015
(in TWh)
TWh
© Mycle Schneider Consulting
Wind
Solar
Nuclear
50
40
30
20
10
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
14 18 16 15 16 13 20 29 30 35
3 10 11 18 20 25 30 34 37 41
0,0 0,3 0,5 1.4 2.8 4.4 6.6
Sources: BP, IAEA-PRIS, MSC, 2016

Concluding Remarks

• Nuclear power has passed its historic maximum for most of the indicators: operating reactors, electricity generation, reactors under construction, new construction sites, etc. China is the exception to the global declining trend.

• Nuclear's position in the power market is increasingly threatened by a shrinking client base, increasing production costs, stagnating electricity consumption, and ferocious competitors, especially from the renewable energy sector.

• Nuclear industry companies and utilities are struggling with high debt loads, shrinking profit margins and decreasing prices on the wholesale power market. The situation raises questions on potential impacts on nuclear safety and security.