Nuclear worldwide: Where we stand 3 years after Fukushima

Second Roland Berger study on the global nuclear market

Roland Berger
Strategy Consultants

March 2014

Roland Berger study on the 2030-2050 global nuclear market – Lessons learned

- **The global nuclear market continues to grow**, driven mainly by Russia and China
- **Since Fukushima** (March 2011) and despite decisions in some countries to phase out nuclear energy in the short or long term
  - **About 70 reactors are currently under construction** around the world in 2014, half of them in China and Russia
  - **Installed base decreased by only 9 units**: +13 new operations, +2 restarts and -24 shutdown, of which 16 were driven by the disaster and 8 were at the end of their operating lifecycles
- **The Roland Berger study shows that global nuclear installed capacity could increase 26%** by 2030 in a low scenario (from 435 units today to 489 units, or 372 GW vs. 470 GW)
- Roland Berger estimates that of **581 nuclear projects planned or announced** and assuming highly favorable circumstances, **only 123 to 224 are likely to materialize**
- The nuclear market is at a crossroads: **By 2030, 70% of nuclear reactors will be between 40 and 60 years old, and governments will have to decide whether to renew or make a transition**
  - Regarding nuclear power's lifecycle (decisions, construction, commissioning), the 2015-2030 period is a critical time for the replacement market
  - Successful players will have current experience in the construction of new plants, suitable product portfolios and strong financial backing
- The Roland Berger study shows that in **2050**, assuming a conservative case, nuclear's share of global electricity capacity may be lower than in 2030 (by approx. 1%). However, installed capacity may increase by 35 GW. These assumptions depend on both the replacement rates in major nuclear countries (France, Russia and possibly the United States) and nuclear development by new entrants (Middle East or Asian countries)

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A. Overview of the NPP base as of 2014 and main developments since 2011

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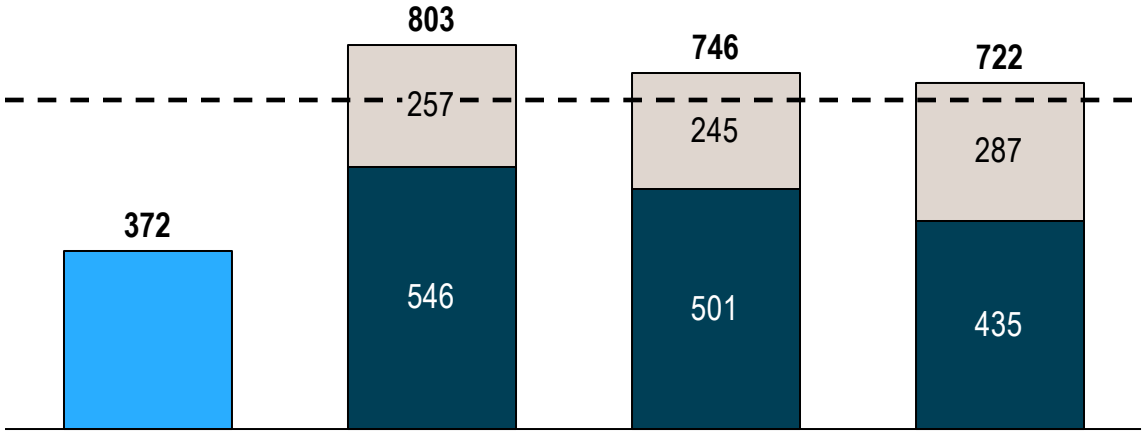
Public forecasts on nuclear capacity (IAEA) have been revised downward in the recent past, but still indicate growth in installed capacity

Approach used – Nuclear capacity in GWe



Key facts

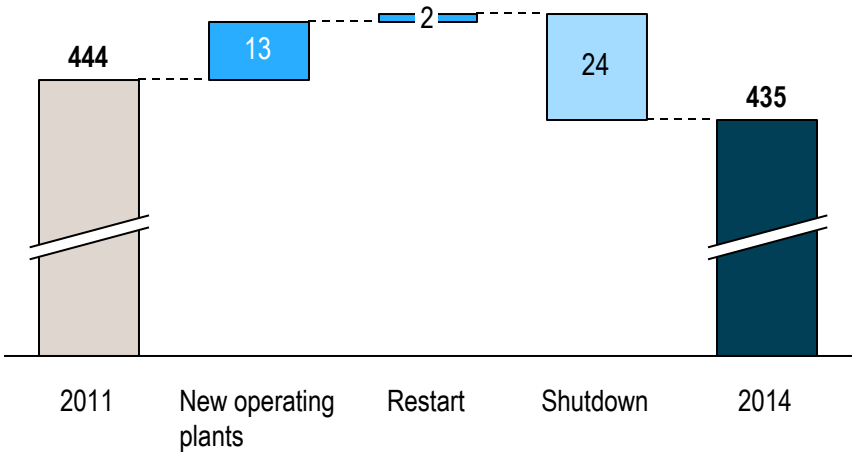
- Public estimates were revised downward following the Fukushima accident with a scenario between **546 GWe to 803 GWe adjusted downward** to a range of **501 GWe to 746 GWe**
- IAEA continued to lower its estimates over the past two years – 722 GW in a high scenario and 435 in a low scenario
- However, **nuclear is still expected to grow** from its current level
- In 2011, RB estimated global nuclear generating capacity would grow to **688 GWe by 2030**

Source: IAEA, Roland Berger analysis

Although the installed base of operating reactors has decreased since Fukushima, construction of 18 new reactors has started

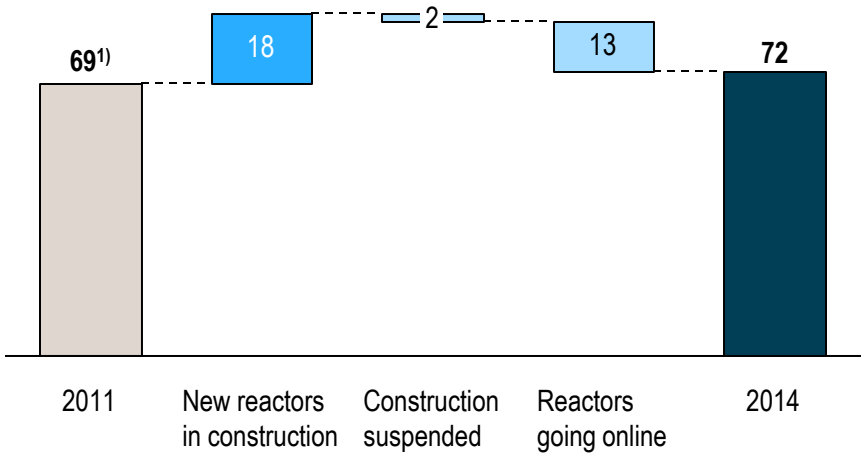
Nuclear fleet evolution [no. of reactors]

Operating



> **Comments:**
- 13 projects under construction went online, including an experimental reactor in China (not taken into account in the 2011 RB view)
- 2 reactors restarted after long-term shutdown (Canada)
- 24 shut down, of which 22 are permanent shutdowns

Under construction



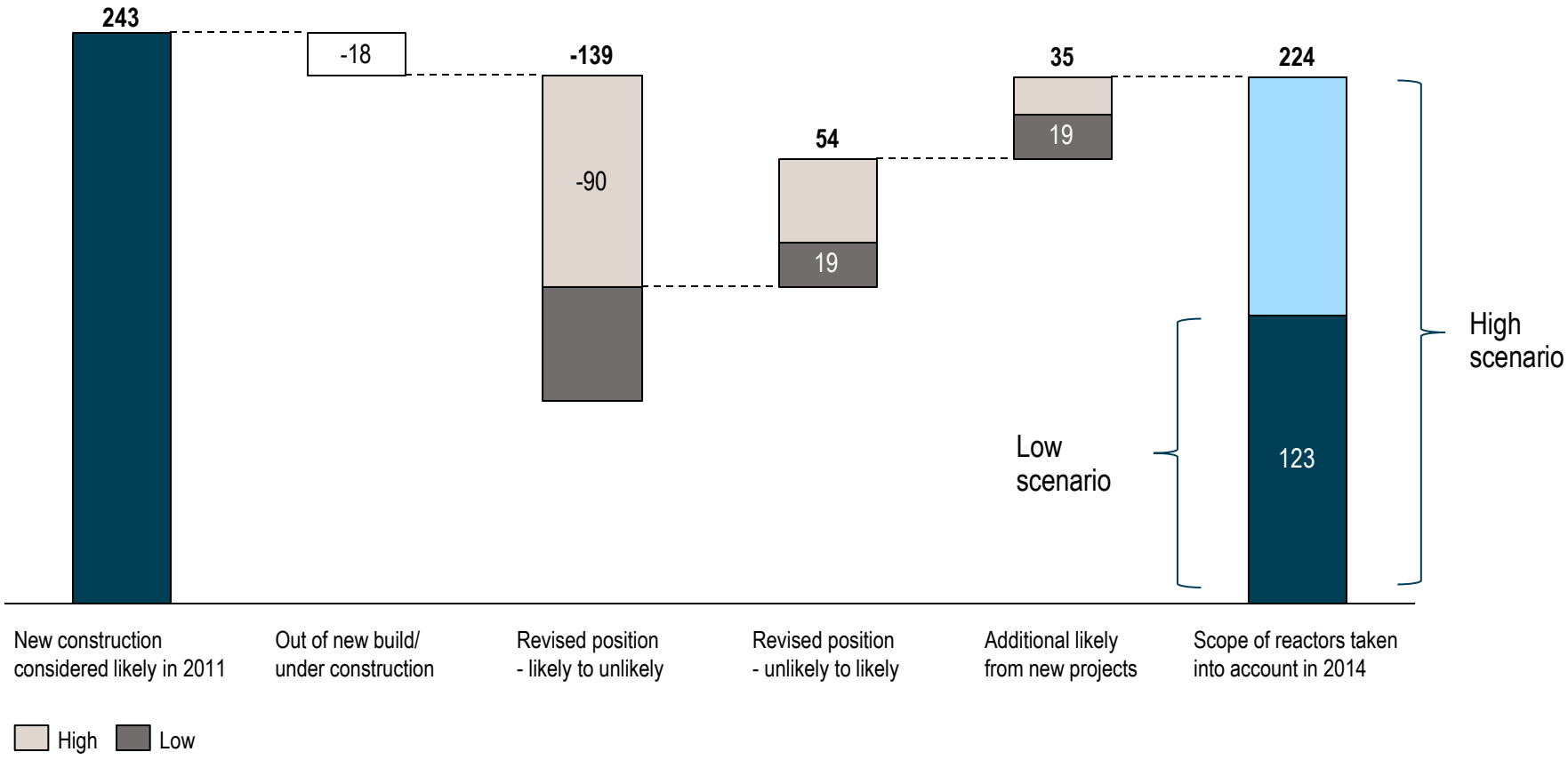
> **Comments:**
- 54 reactors still under construction during 2011-2014
- 18 projects planned in 2011 started construction phase (including the CAREM prototype in Argentina)
- Construction of two reactors was halted (Bulgaria)
- 13 reactors went online, mainly in China

1) Includes the Chinese Experimental Fast Reactor (CEFR) not taken into account in 2011

Source: WNA, PRIS, Roland Berger analysis

We revised our assumptions on planned and announced projects – Decrease in projects considered likely depending on scenario (1/2)

New nuclear reactors considered likely by 2030 [no. of reactors] – RB's view



Source: WNA, PRIS, Roland Berger analysis

We revised our assumptions on planned and announced projects – Decrease in projects considered likely depending on scenario (2/2)

New nuclear reactors considered likely by 2030 [no. of reactors] – RB's view

Reactors not "likely" anymore

- No new nuclear reactors in **Italy** (5 units)
- No new nuclear reactors in **Switzerland** (3 projects cancelled)
- Unlikely Sellafield 1 & 2 will be developed in the **UK**
- Unlikely renewal at Darlington 1 & 2 in **Canada**
- Unlikely renewal of some **US** reactors
- Suspension of Fukushima I-7&8 in **Japan**
- Several projects reconsidered in **India (18)**

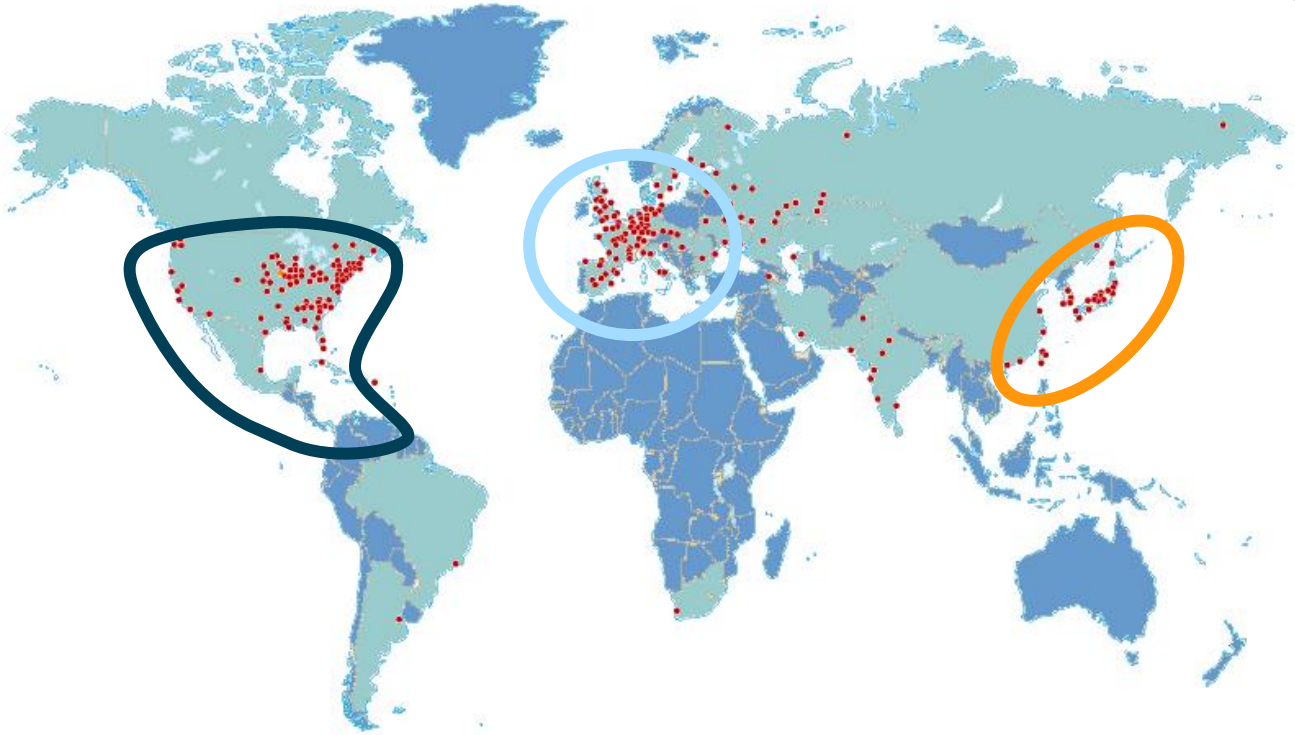
Reactors (re)stated as "likely"

- 9 projects expected to become operational in **China** by 2030 (of which 4 additional units in Fanchenggang and 2 in Taishan)
- Projects Barakah 3 & 4 expected to be added soon to current units 1 and 2 under construction in the **UAE**
- Four projects expected to become operational in **South Korea** by 2025 (Shin Hanul 3 & 4, Shin Kori 7 & 8)
- Planned projects in **Turkey** (Akkuyu and Sinop) are being seriously considered
- Additional projects mainly in **Bangladesh, India, Egypt, Netherlands** and the **UK**

Source: WNA, PRIS, Roland Berger analysis

Nuclear installed base is mainly concentrated in a few countries (1/2)

World map of nuclear installed base as of February 2014



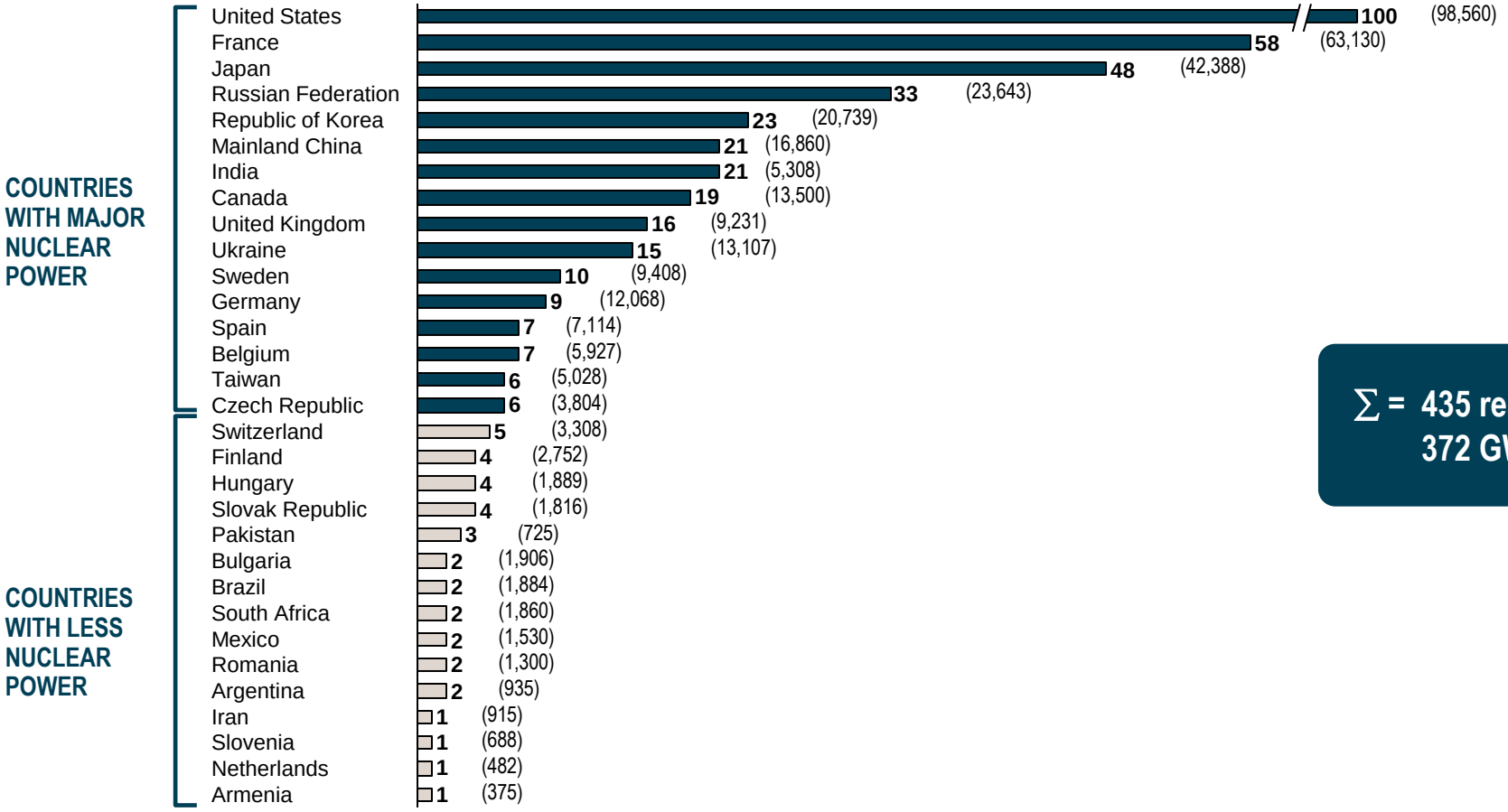
Key figures

- **435 operating reactors** in **31 countries**
- **372 GWe** net capacity
- **61% of reactors** (**68% of capacity**) located in the US, Western Europe and Japan
- Average reactor age: **27 years**

Source: IAEA, WNA, Roland Berger analysis

Nuclear installed base is mainly concentrated in a few countries (2/2)

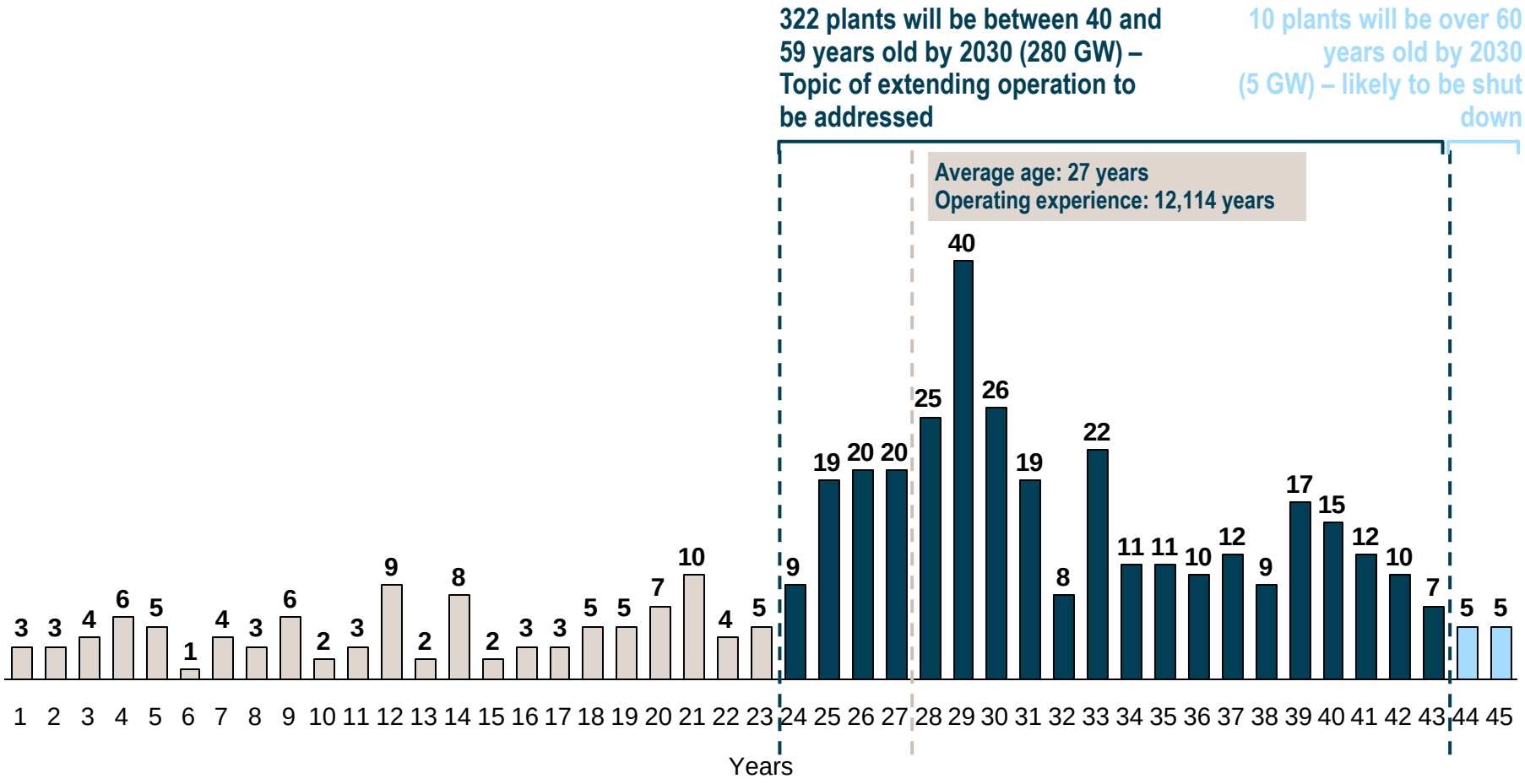
Country breakdown of installed base [no. of units, MWe net]



Source: IAEA, WNA, Roland Berger analysis

With a current average age of 27 years, more than 70% of the existing installed base will be between 40 and 59 years old by 2030

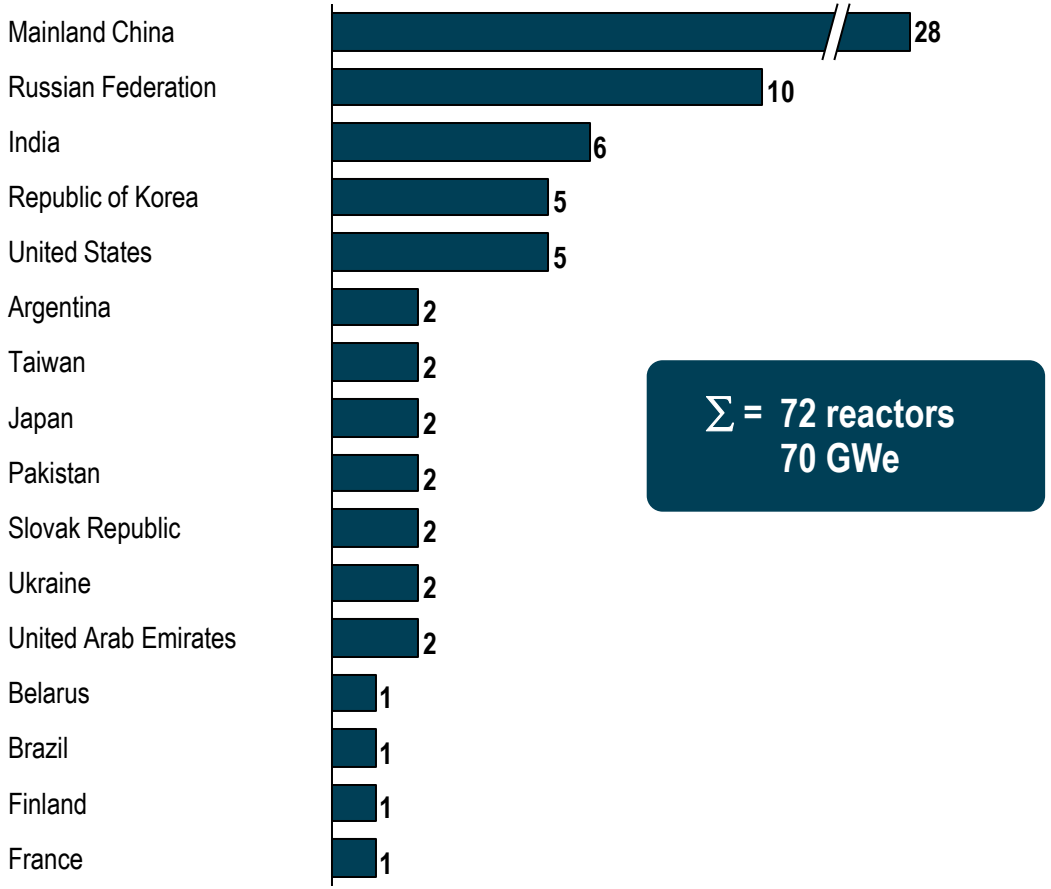
Age of nuclear power plants in operation worldwide as of 2014 [no. of units]



Source: WNA, IAEA, Roland Berger analysis

70 GW of nuclear capacity is under construction around the world, half of this in China and Russia

Country breakdown of the NPPs under construction [no. of units, MWe net]



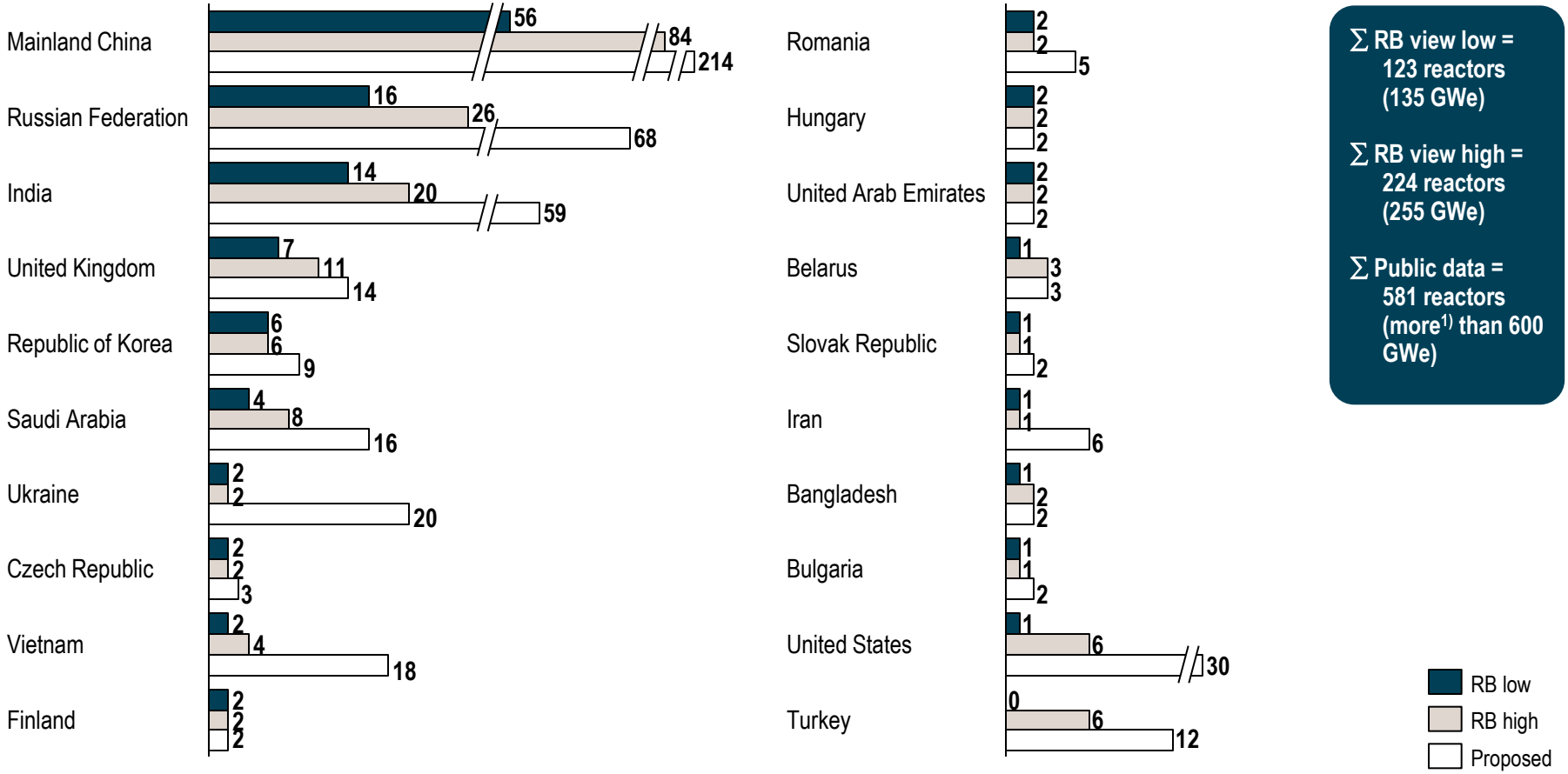
Comments

> Most of the NPPs under construction are located in **East Asia and Eastern Europe**:
  – **China** (28 units) and **Russia** (10 units) have the lion's share
  – Very few projects in mature developed countries
> All NPPs under construction should be **in operation by 2020**

Source: IAEA, WNA, Roland Berger analysis

We used public data to identify over 581 proposed projects – Only 123 to 224 considered as "likely" to be operating by 2030 (1/2)

Country breakdown of NPPs planned or announced [no. of units]



∑ RB view low = 123 reactors (135 GWe)

∑ RB view high = 224 reactors (255 GWe)

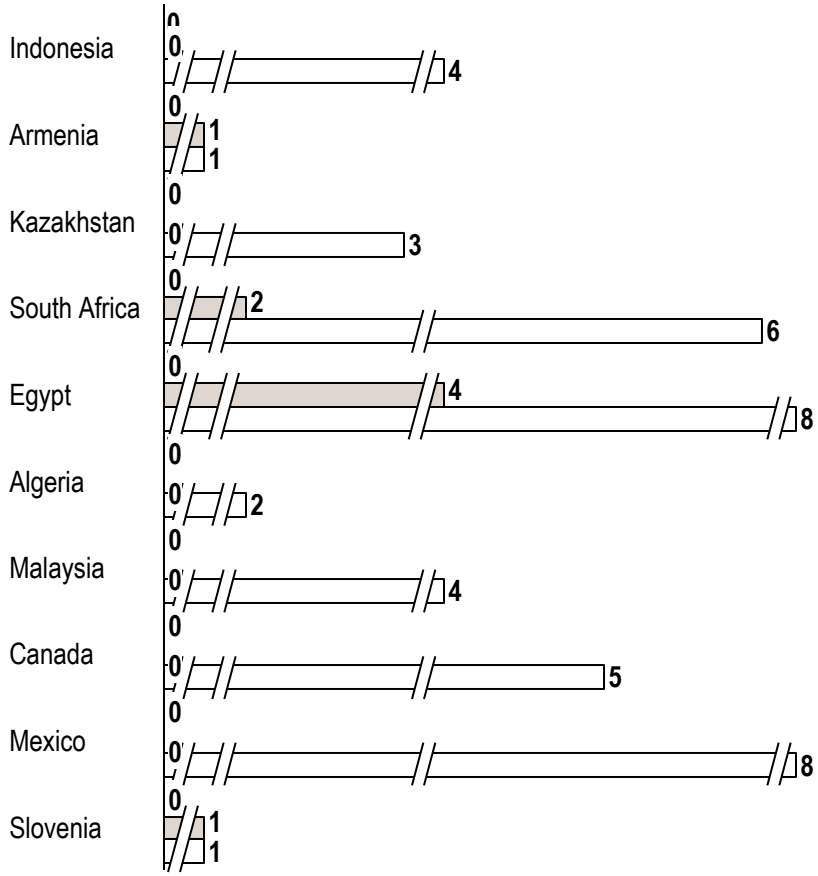
∑ Public data = 581 reactors (more[1] than 600 GWe)

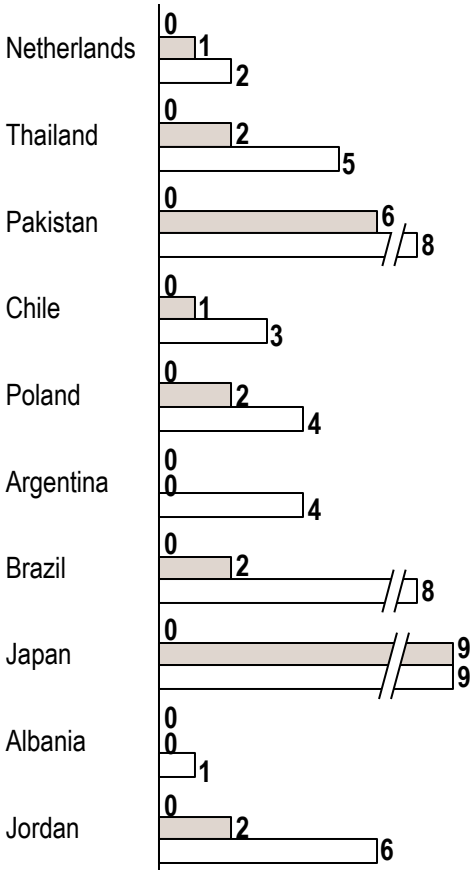
1) Some projects did not report net capacity

Source: IAEA, WNA, Roland Berger analysis

We used public data to identify over 581 proposed projects – Only 123 to 224 considered as "likely" to be operating by 2030 (2/2)

Country breakdown of the NPPs planned or announced [no. of units]





∑ RB view low = 123 reactors (135 GWe)

∑ RB view high = 224 reactors (255 GWe)

∑ Public data = 581 reactors (more[1] than 600 GWe)

RB low
RB high
Proposed

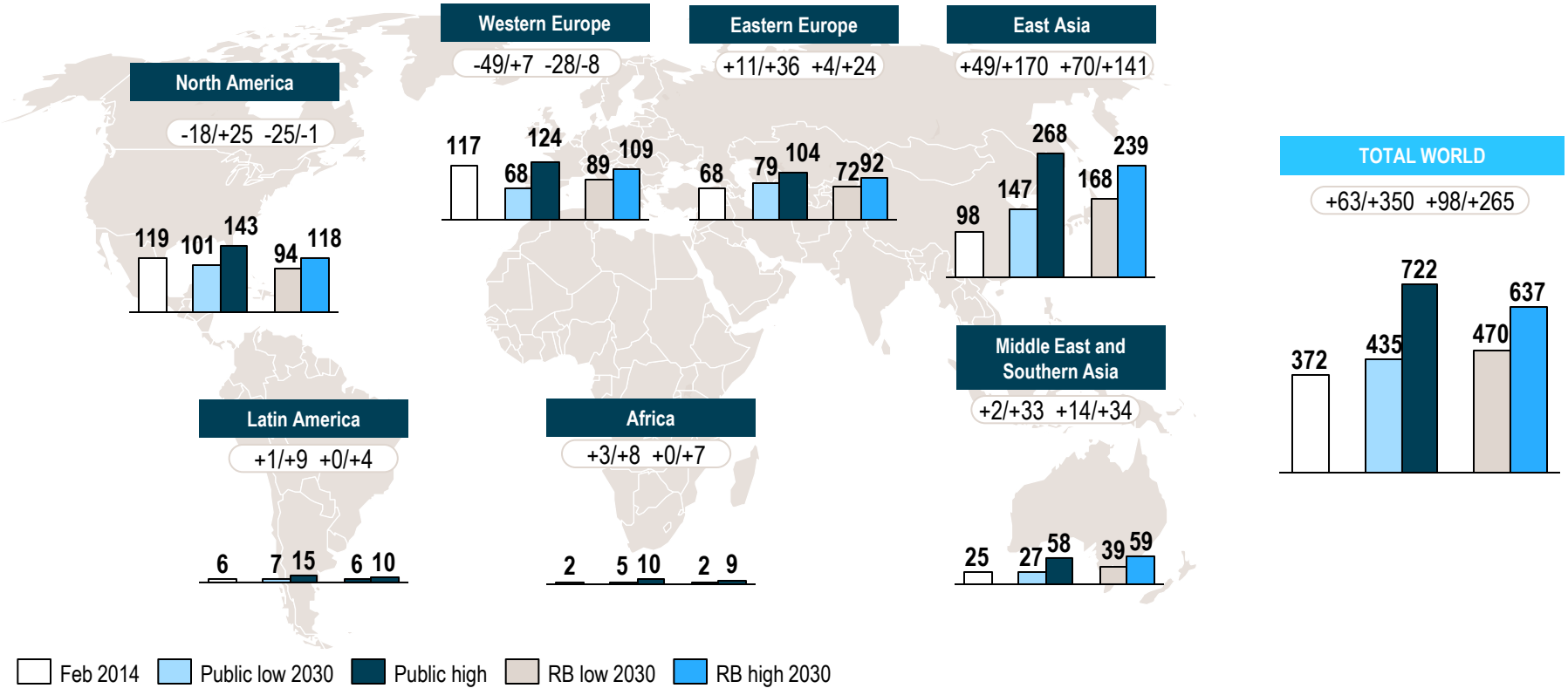
1) Some projects did not report net capacity

Source: IAEA, WNA, Roland Berger analysis

B. Forecast of global nuclear development up to 2030

We estimate global installed nuclear capacity to grow from 372 GWe to between 470 GWe and 637 GWe from 2014 to 2030

NPP development scenarios to 2030 [2014-2030, GWe]

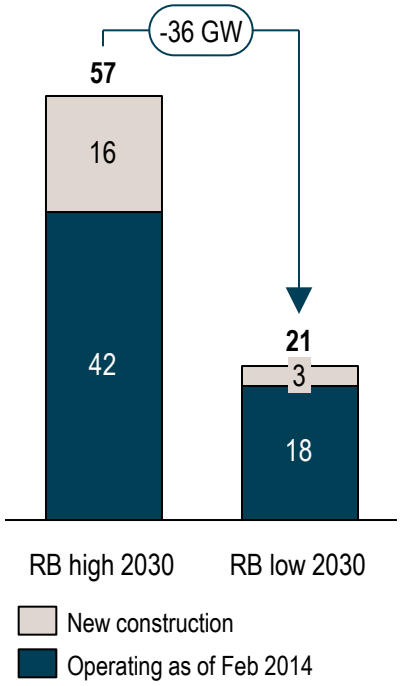


Source: IAEA , Roland Berger analysis

Japan and China represent 40% of the total deviation between the low and high scenarios with a gap of approx. 35 GW between the two

Countries with significant variation between RB estimates low-high [2030, GWe]

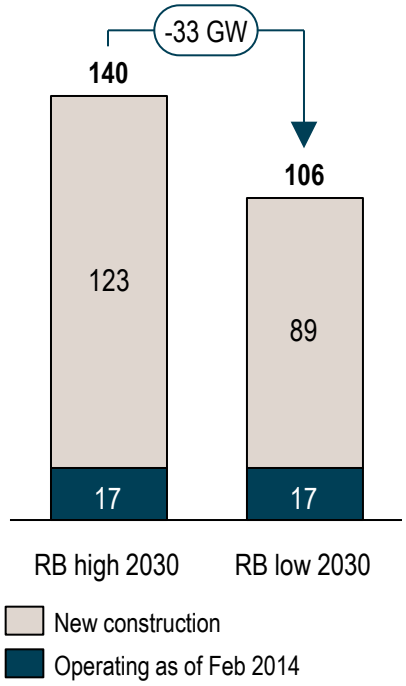
Japan



Comments

> Low estimates are more conservative in terms of the potential for extending the operating life of the installed base and completion of planned projects
  - We estimate the operation extension of existing plants to 60 years could be impacted if safety inspections produce negative results
  - Planned NPPs could be scrapped due to a political shift toward less nuclear (driven by strong public opinion)

China



Comments

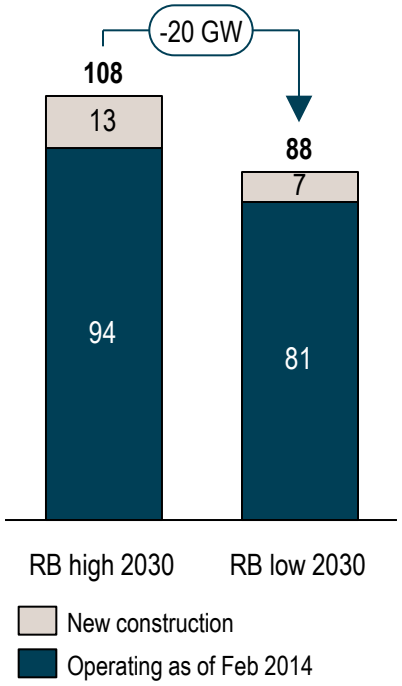
> Low estimates are more conservative in terms of the potential for new plants likely to be operational by 2030
  - Among potential operational starts by 2030, we estimate that NPP sites with existing plants are more likely to be extended with additional units than other sites being built from the ground up in a high perspective – this results in 33 GW additional new starts vs. the low case

Source: World Nuclear Association, Roland Berger

Sensitivities for US mainly driven by lifetime extension of installed base, whereas Russia has been challenged on new construction

Countries with significant variation between RB low and high estimates [2030, GWe]

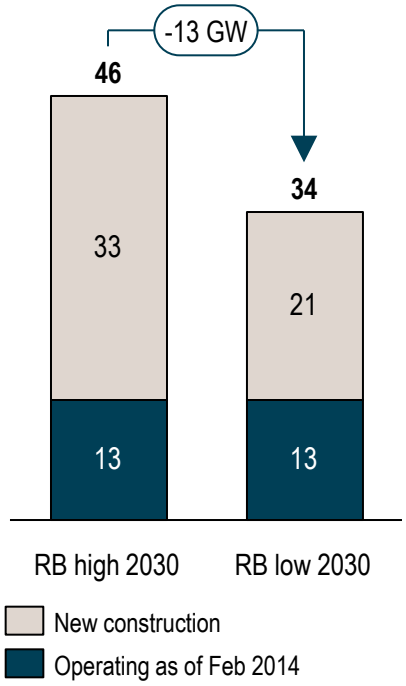
United States



Comments

> Low estimates are more conservative in terms of the potential for extending the operational life of the installed base and completing planned projects
  - We estimate the operational life extension of existing plants to 60 years can be implemented for 18 plants that have not yet received license extension, which means a difference of approx. 13 GW
  - Planned NPPs are not considered in a low scenario in terms of a strong incentive to develop gas, which means a difference of approx. 6 GW

Russia



Comments

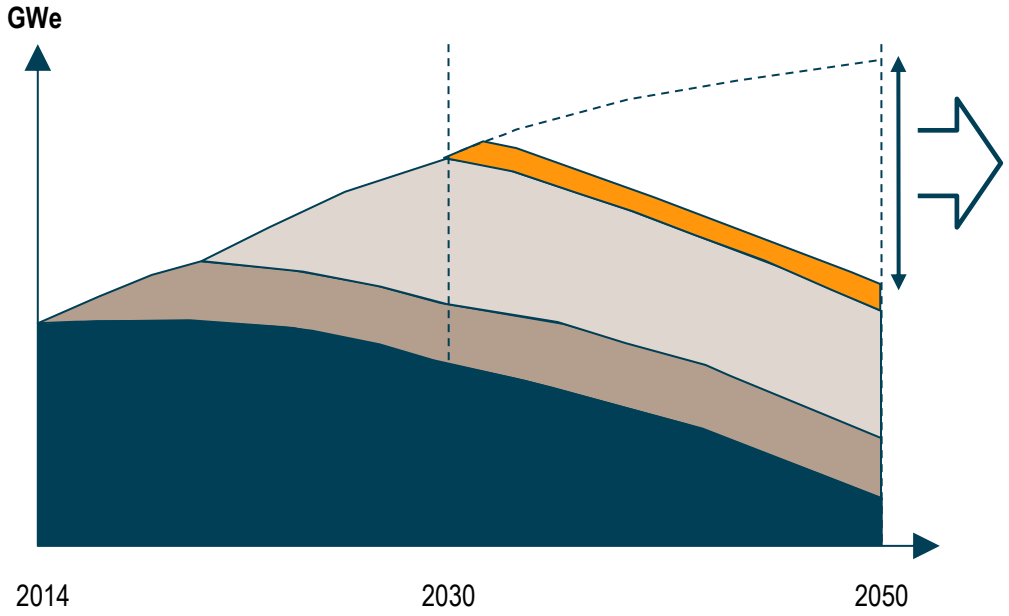
> Low estimates are more conservative in terms of the potential for new constructions likely to be operational by 2030
  - We estimate that the 3rd and 4th blocks of Leningrad 2 will be completed 5 years later
  - Only 2 blocks of Kursk 2 will be built by 2030
  - Nizhniy Novgorod is not planned in the low scenario

Source: World Nuclear Association, Roland Berger

C. Forecast of global nuclear development up to 2050

Global nuclear capacity development up to 2050 will mainly depend on renewal in mature countries and unannounced new projects

Development of nuclear installed capacity to 2050 [GWe]



Additional nuclear capacity resulting from

> Installed base
  – Additional extension of the current installed base's operational life (40/60/80 years)
  – Replacement of reactors scheduled to be shutdown
> New construction projects
  – Extension of existing nuclear sites
  – New projects/new plants/new nuclear sites

> 2 scenarios

1 Low scenario

2 High scenario

Source: Roland Berger analysis

We used both general trends and drivers at country level to assess nuclear development up to 2050

Key questions to be addressed when preparing scenarios to 2050

	General questions
Current mature nuclear countries	> Do we believe in total/partial renewal of existing nuclear capacities? > What can we assume regarding extending operational life?
Entrants/ emerging nuclear countries	> Do we believe in further expansion of the nuclear installed base?
Newcomers/ greenfield	> Do we see new entrants in developing regions such as Africa or Southeast Asia?

Drivers at country level

1. Ambition to maintain/develop nuclear
2. Evolution of electricity demand forecast up to 2050 in each country – taking into account current energy savings trends
3. Alternatives to nuclear power
4. Position regarding extending operational life
5. Trade-off between developing accessible energy, environmental sustainability and energy security

Transversal issue

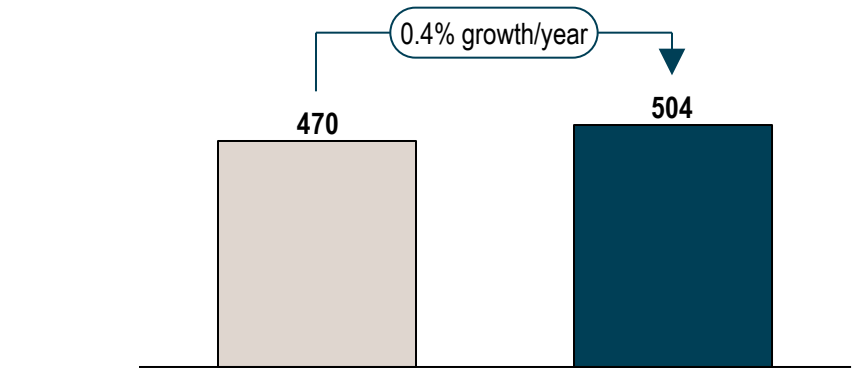
> What potential developments are there in **nuclear technology** and which of these could support the renaissance of nuclear power?

Source: Roland Berger analysis

We estimate global installed nuclear power generating capacity between 504 GWe & 1020 GWe by 2050, depending on the scenario

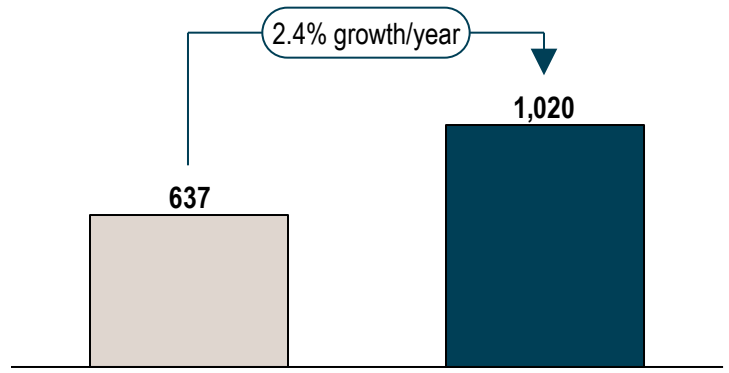
Nuclear installed base capacity from 2030 to 2050 [GWe]

Low scenario



	2030	2050
World total of installed generating capacity[1)]	8,922 GW	12,280 GW
% nuclear	5.2%	4.1%

High scenario



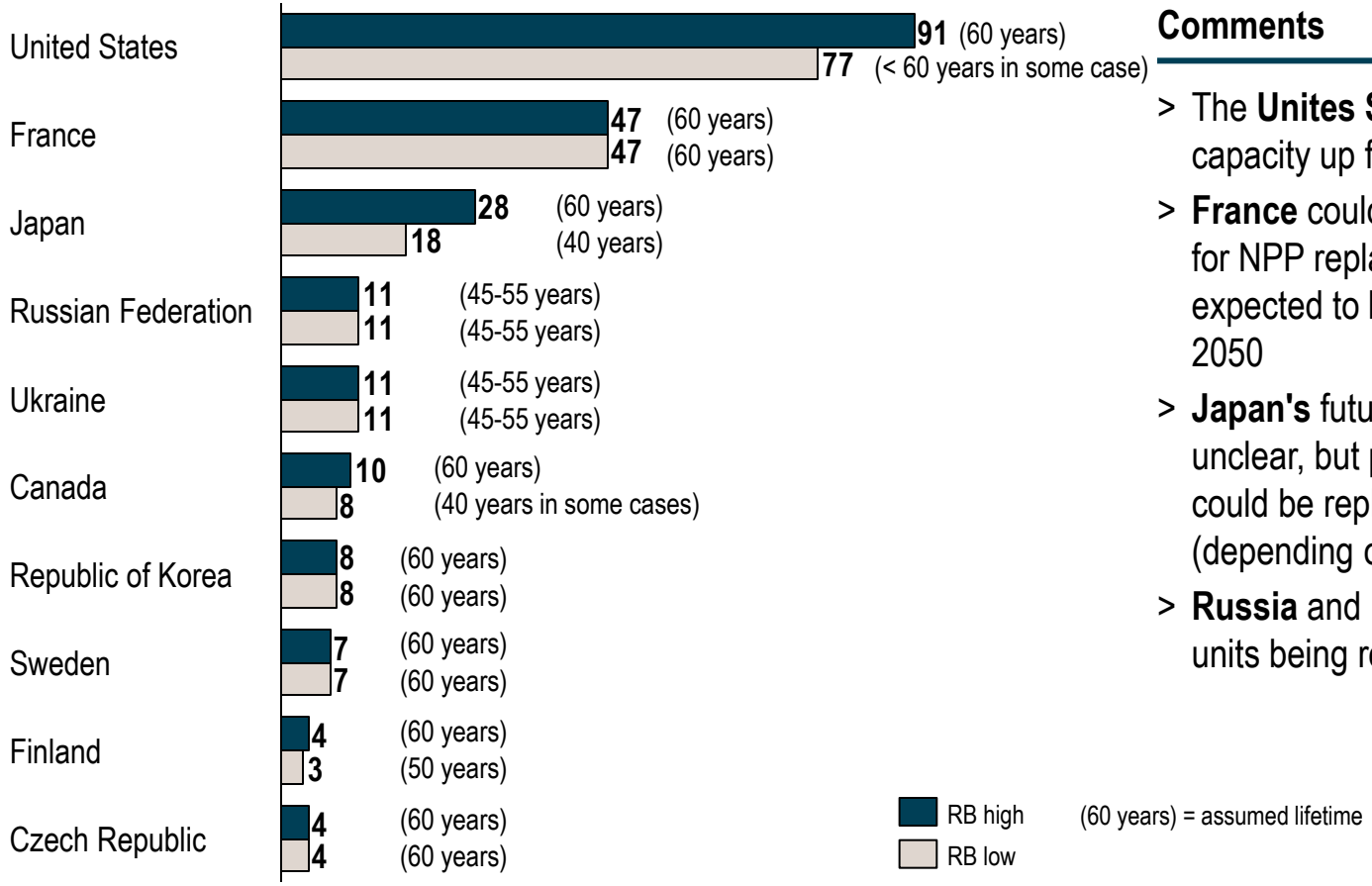
	2030	2050
World total of installed generating capacity[1)]	8,922 GW	12,280 GW
% nuclear	7.1%	8.3%

1) IEA data for 2030 – For 2050, RB assumption based on IEA data to 2035 (additional capacity p.a. over 2030-35 maintained up to 2050)

Source: IEA World Energy Outlook 2013 Roland Berger analysis

Beyond 2030, there might be a huge market for nuclear replacement, mainly driven by the US, France and Japan

Number of reactors to be potentially renewed 2030-2050 – Top 10 countries

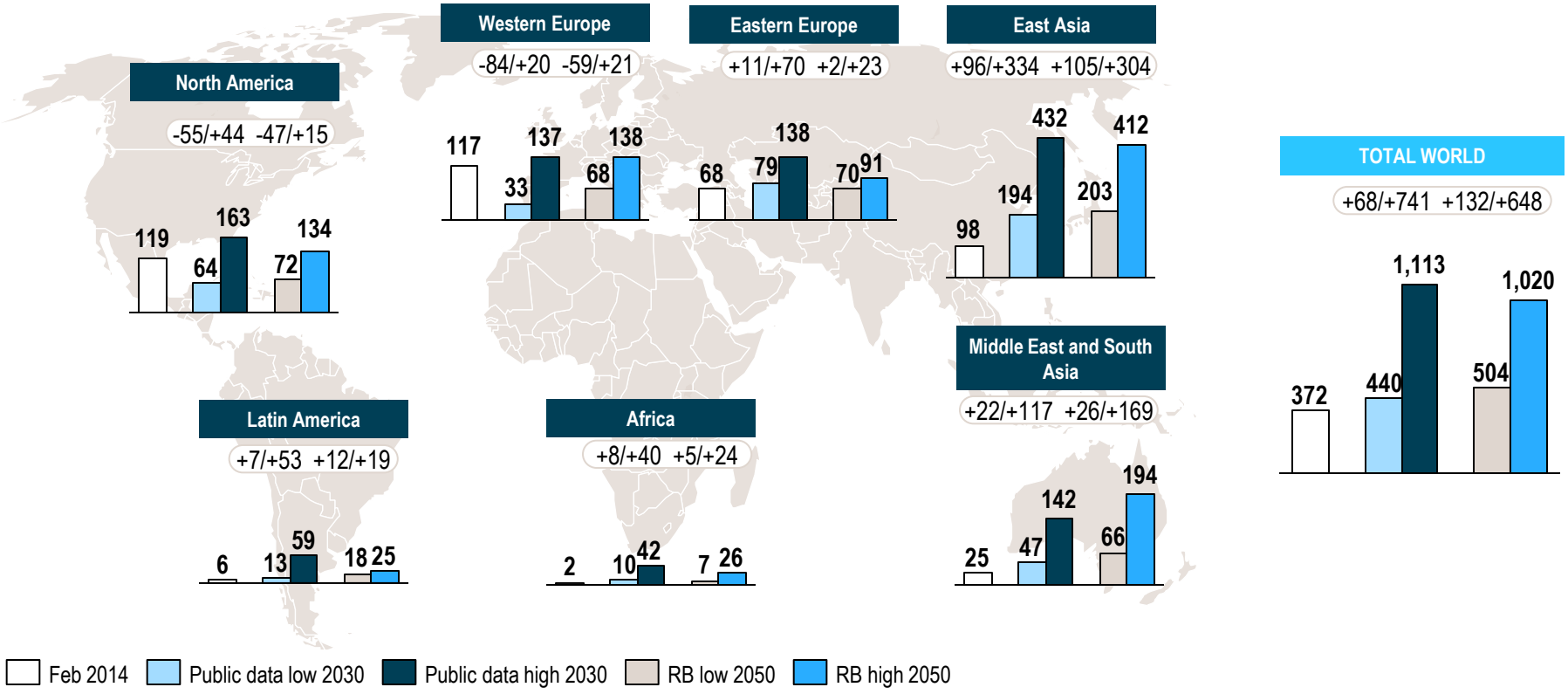


Comments

- The **Unites States** will see 90% of their capacity up for renewal by 2050
- **France** could represent a huge market for NPP replacement with 47 units expected to be ready for renewal by 2050
- **Japan's** future energy policy is still unclear, but possibly 18 to 28 reactors could be replaced between 2030-2050 (depending on operating life extension)
- **Russia** and **Ukraine** each could see 11 units being renewed 2030-2050

Our low estimate is less pessimistic than IAEA – Main differences are found in Western Europe and Middle East/South Asia

NPP development scenarios by 2050 [2014-2050, GWe]



Source: IAEA , Roland Berger analysis

It's character that creates impact !

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