Harmony
Technology perspective 2050

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WORLD NUCLEAR ASSOCIATION

HARMONY

TECHNOLOGY PERSPECTIVE 2050

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CURRENT STATUS

OF NUCLEAR ENERGY

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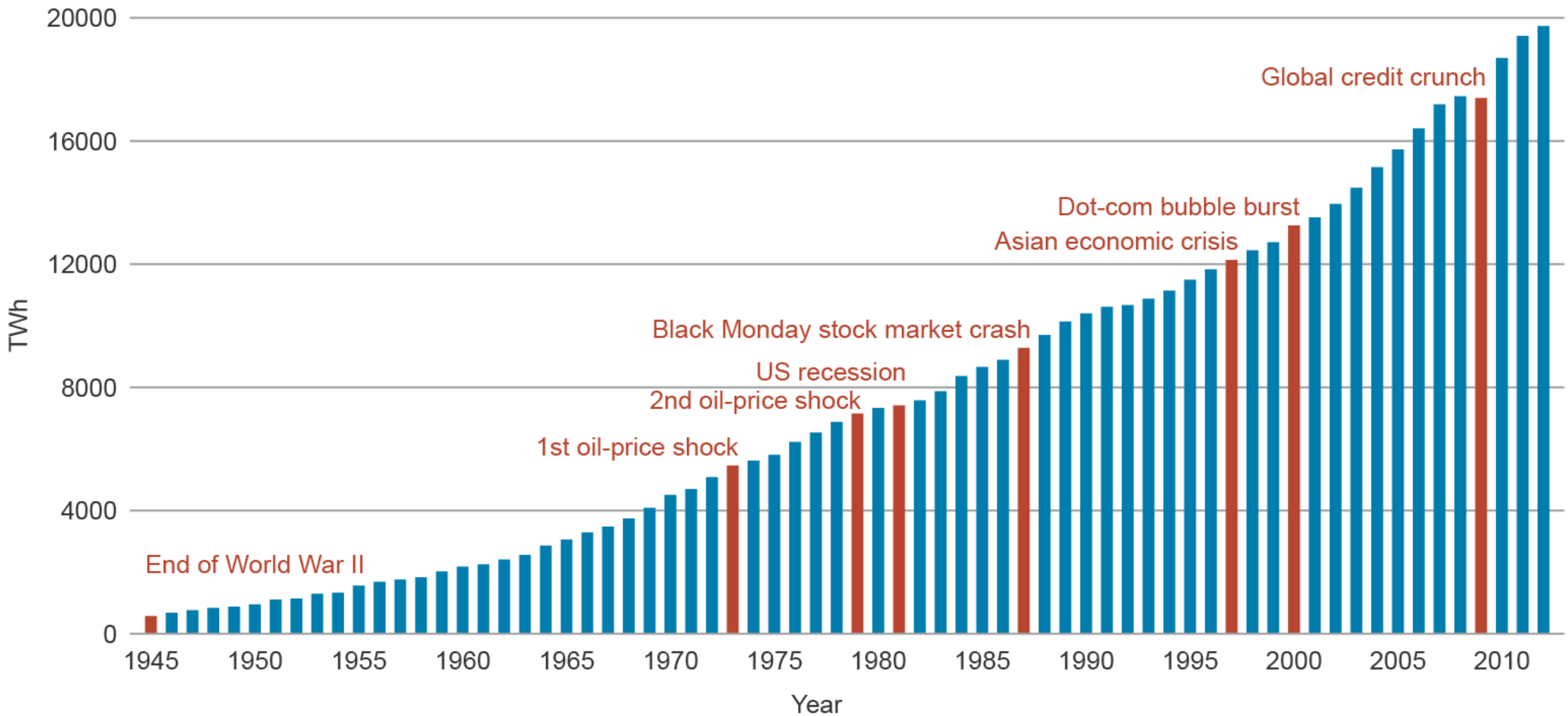
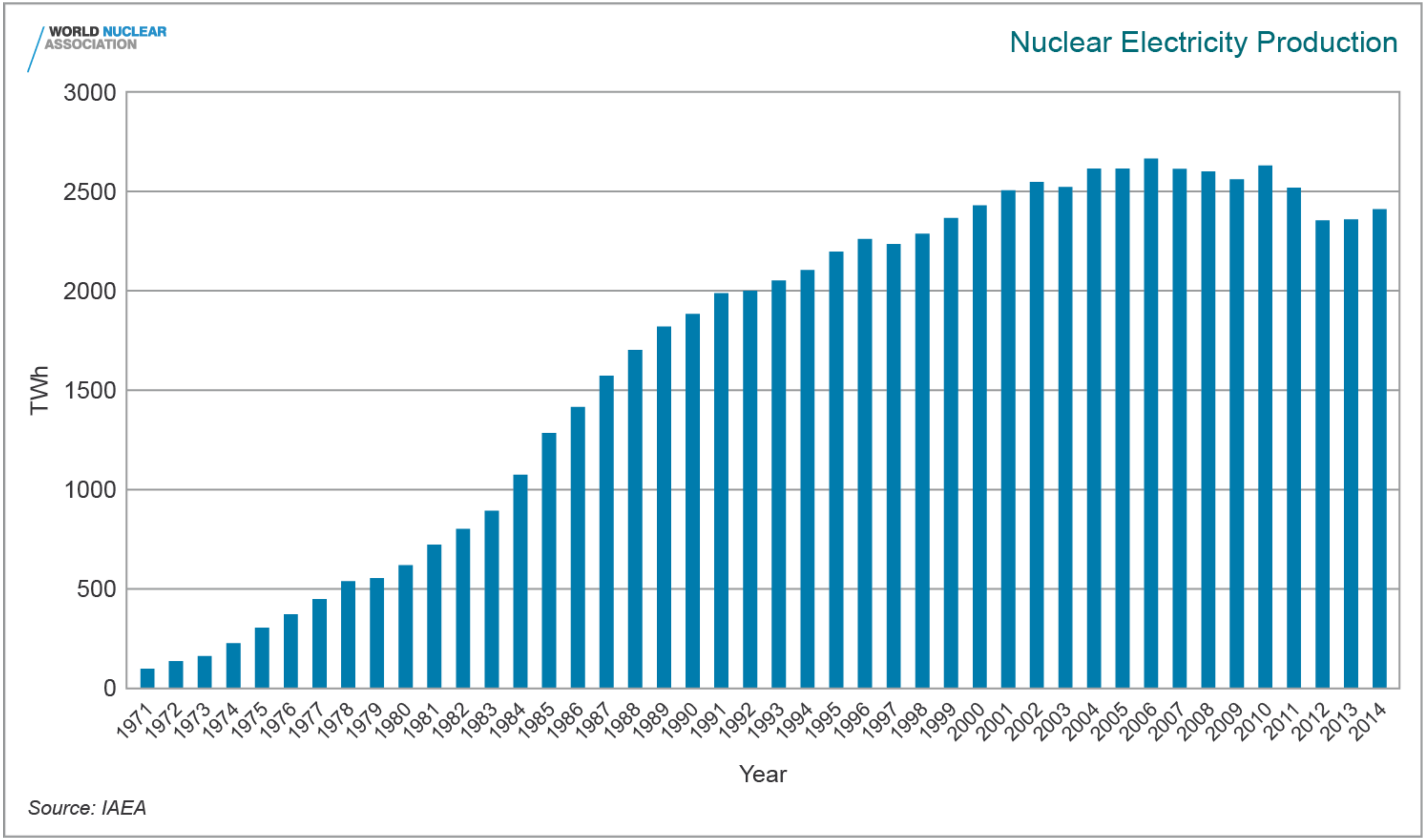
Accelerating rise in world electricity consumption

Global consumption of electricity



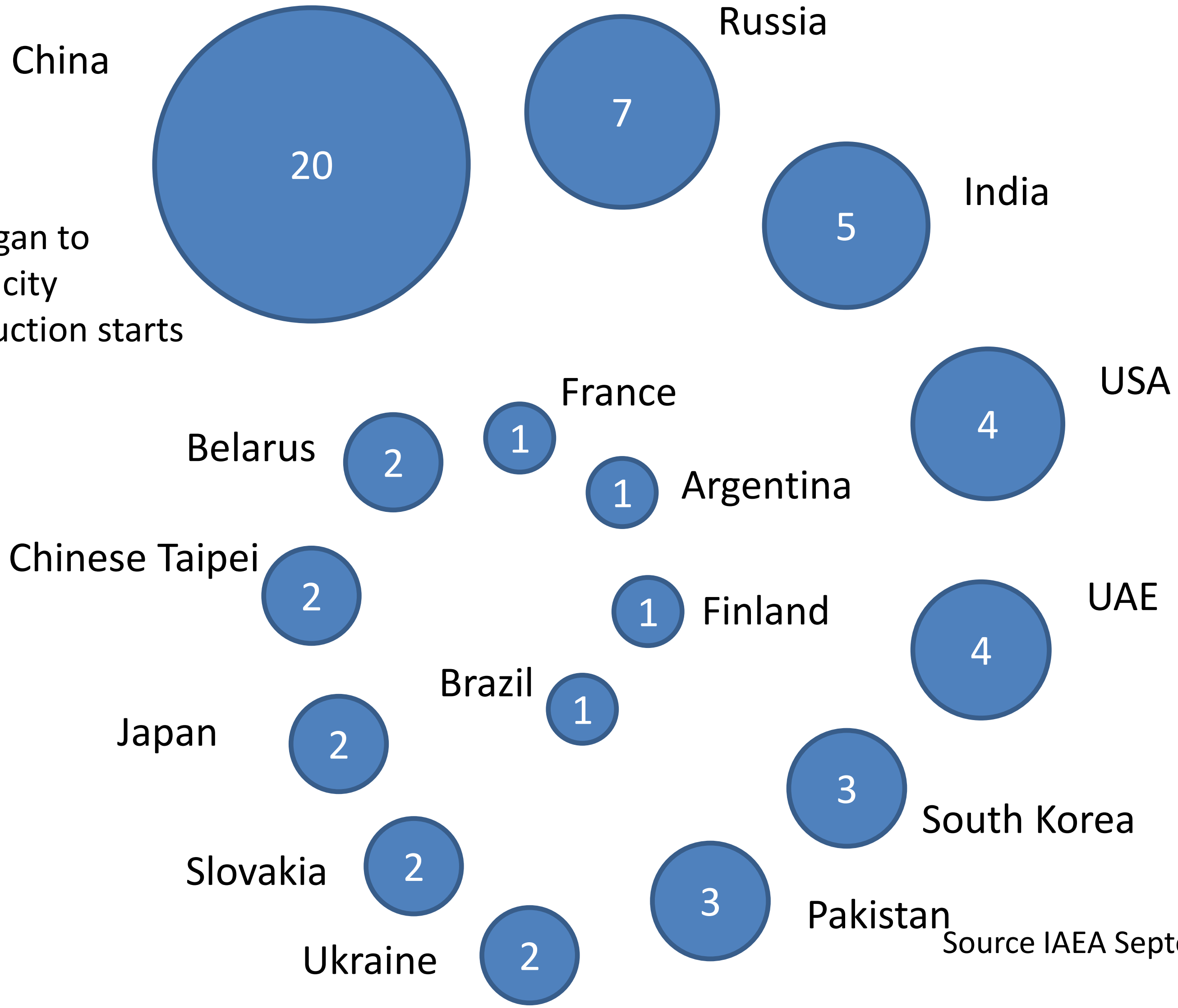
Source: 1945-1979, International Energy Agency databases and analysis
1980-2012, Energy Information Administration

Global nuclear generation



Highest level of construction in twenty five years: 60 reactors worldwide

China 2015:
8 reactors began to deliver electricity
6 new construction starts



Source IAEA September 2016

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NUCLEAR ENERGY

TO DECARBONIZE

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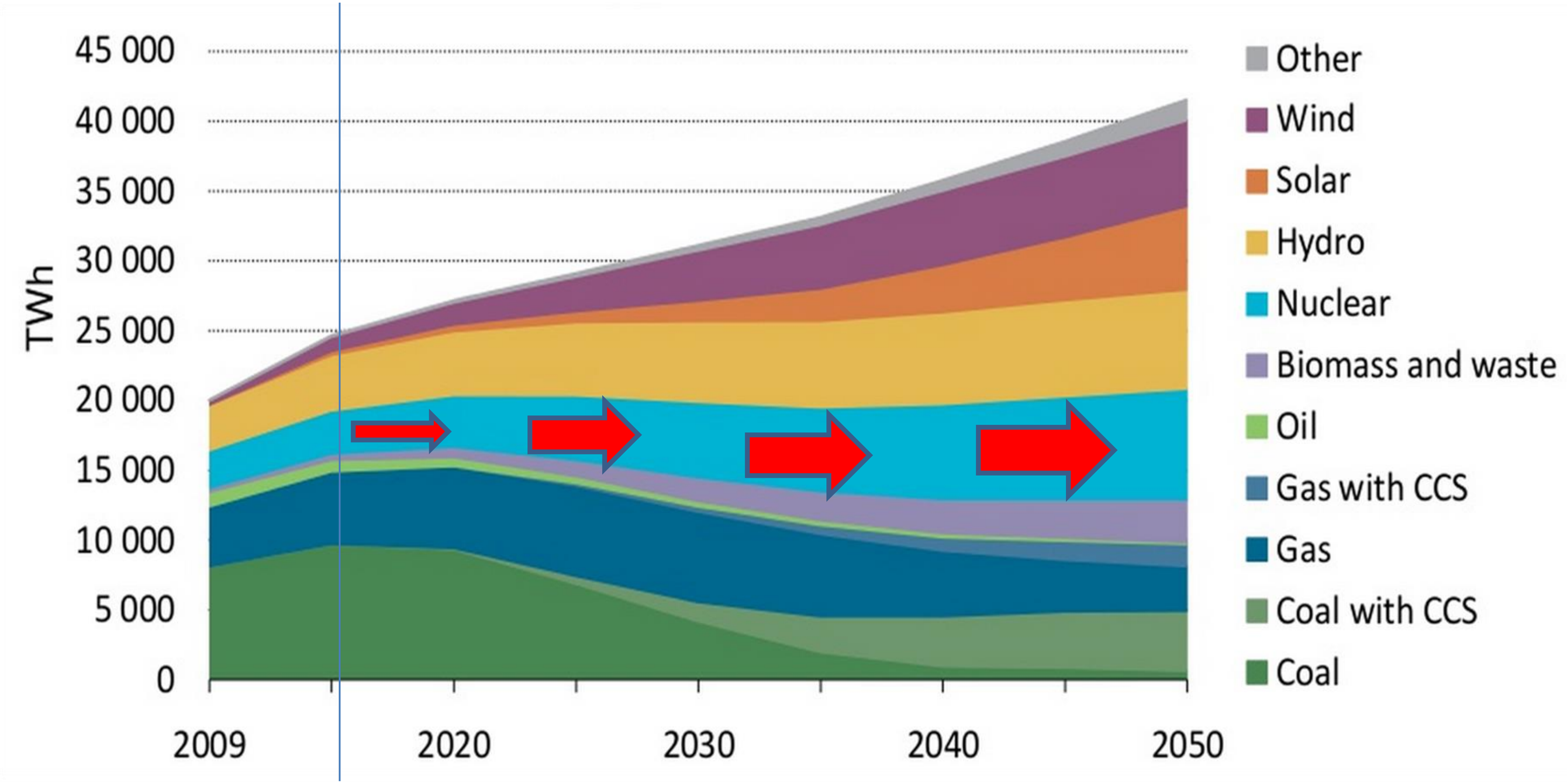
IEA 2degree scenario: Nuclear is required to provide the largest contribution to global electricity in 2050



Source: International Energy Agency

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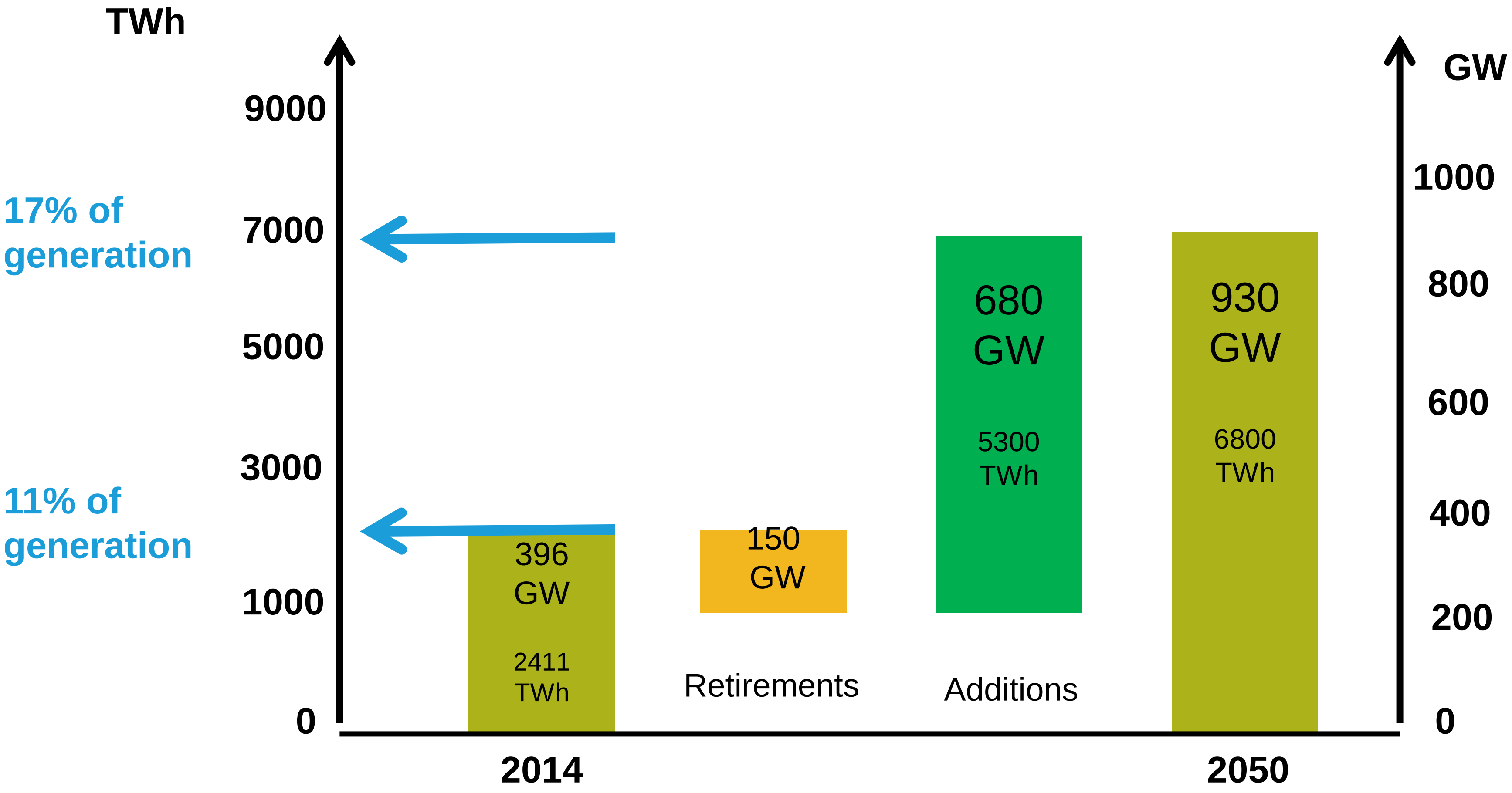
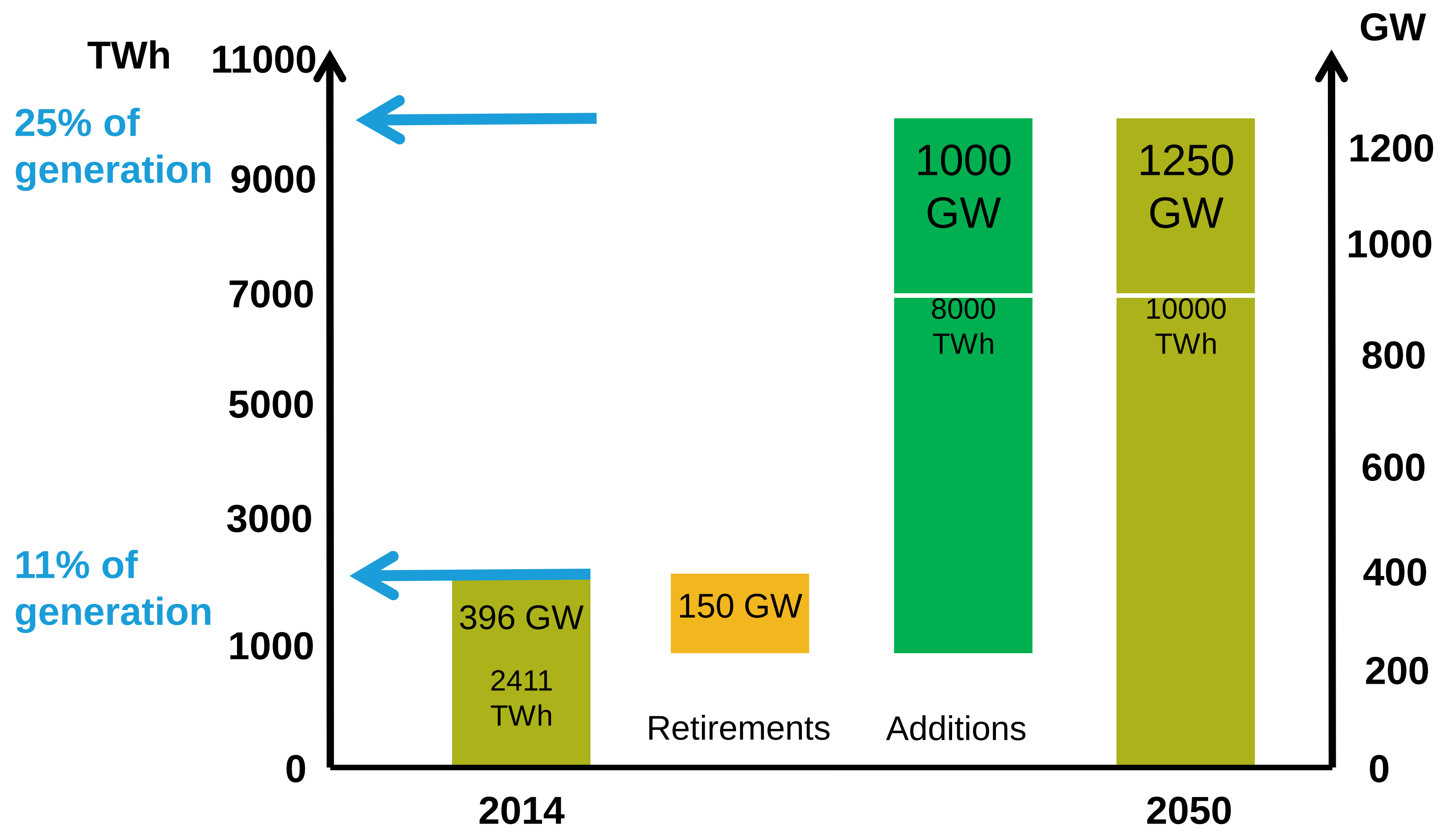
Nuclear: IEA 2degree scenario
Substantial growth required to meet demand



Source: IEA-NEA, 2015, Technology Roadmap: Nuclear Energy, Paris: OECD-IEA: pp. 21-22; IEA, 2015, Energy Technology Perspectives 2015, Paris: OECD-IEA

Nuclear should deliver more than IEA goal

Harmony aims for 1000 GW new build, towards 1.5°C goal



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HOW TO ACHIEVE
THE REQUIRED NUCLEAR NEW BUILD,
- AND A BIT MORE, TOWARDS 1.5°C GOAL

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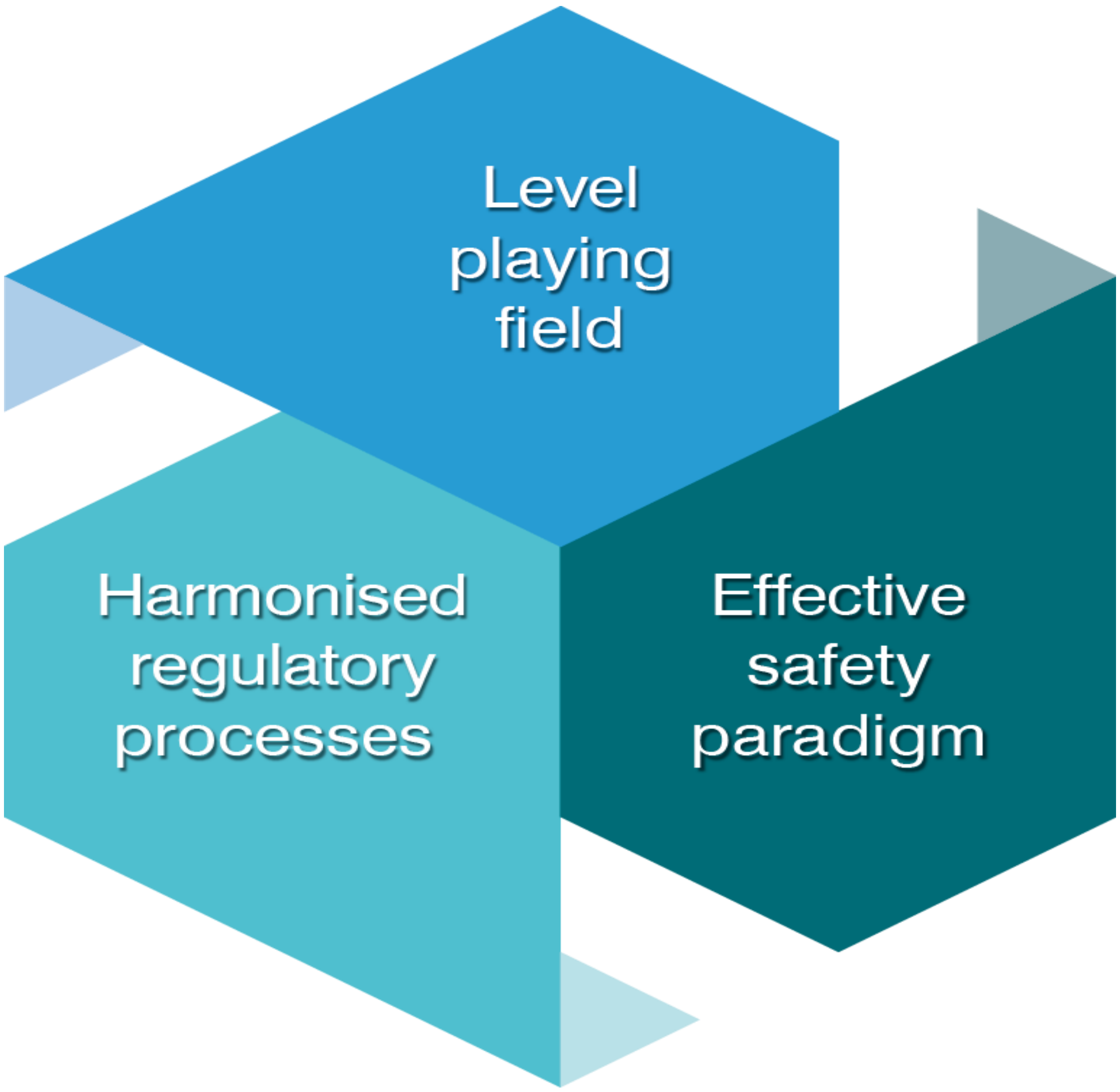
Harmony objectives



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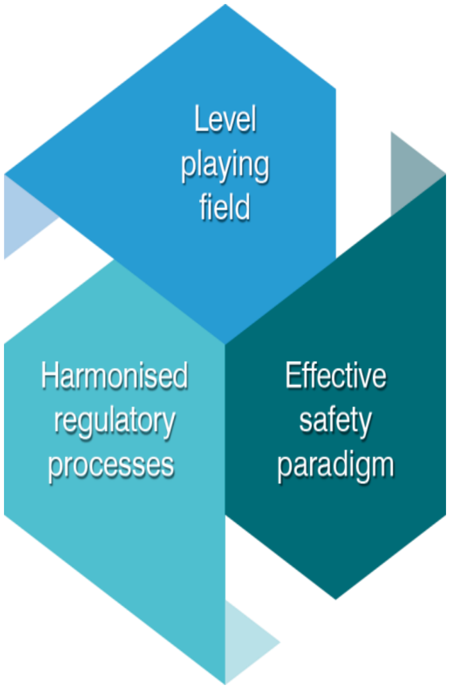
Level playing field

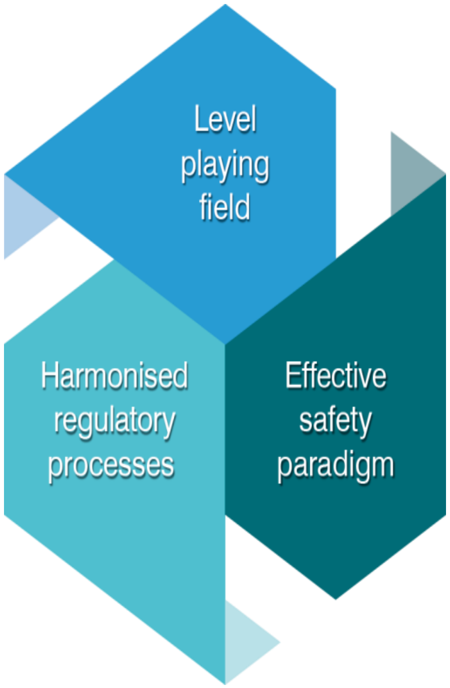


Markets should be reformed to:

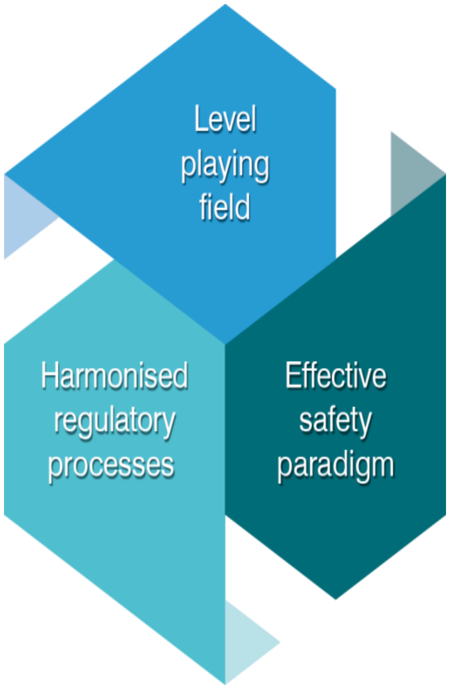
- support capital investments
- include grid system costs
- eliminate nuclear-only taxes
- reform subsidies
- give credit for low carbon emissions
- value 24/7 reliability
- support innovative finance solutions

Harmonised regulatory processes

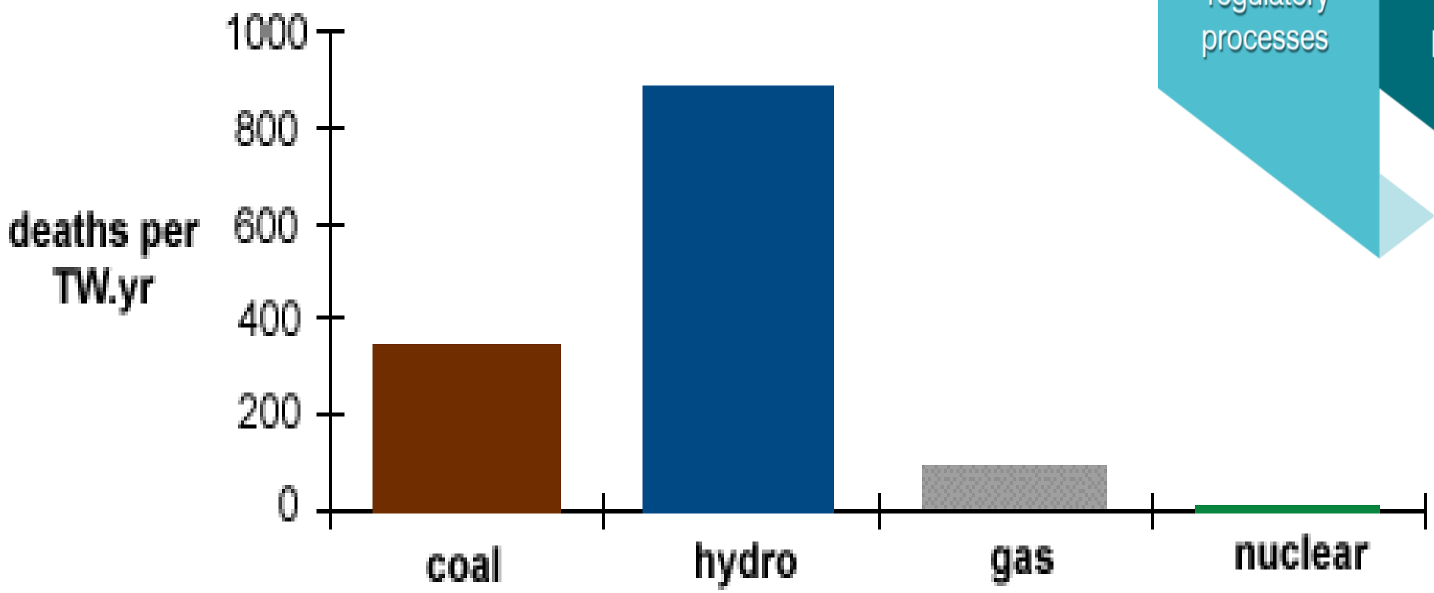
- enhance standardisation
- streamline licensing processes
- harmonise and update global codes and standards
- enabling international trade
- ensure efficient and effective safety regulation
- nuclear innovation: enable development and timely licensing of new technologies



Effective safety paradigm



The alternatives to nuclear are far more dangerous – even including accidents



Paul Scherrer Institut 1998: considering 1943 accidents with more than 5 fatalities

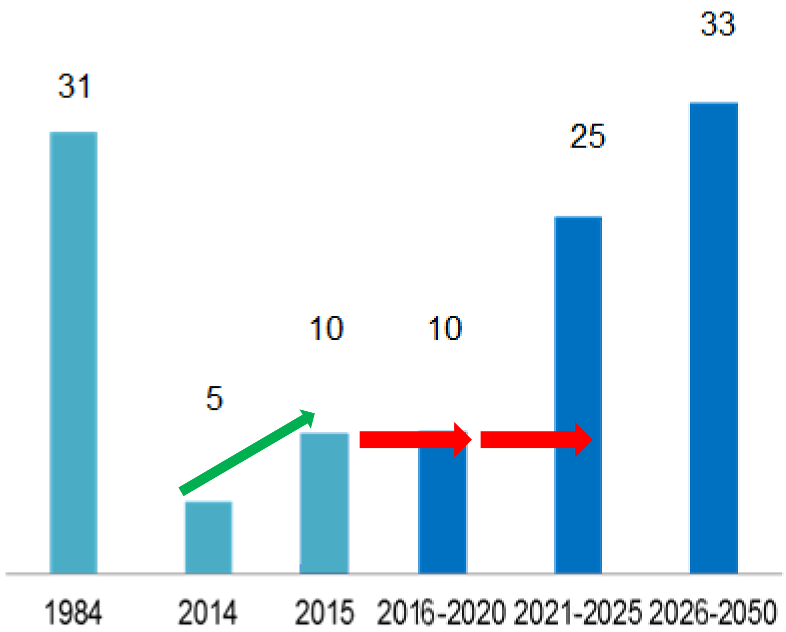
To deliver 1000 GW new nuclear capacity to 2050

Period	Connection rate	Added capacity
	GW per year	GW
2016-2020	10	50
2021-2025	25	125
2026-2050	33	825
Total new nuclear capacity		1000 GW

Yearly connection of new nuclear:

- Below 5 GW the last 15 years
- Doubled to 10 GW in 2015
- Historically 31 GW in mid 1980s

Connection rate



Source: World Nuclear Association, Nuclear Fuel report 2015

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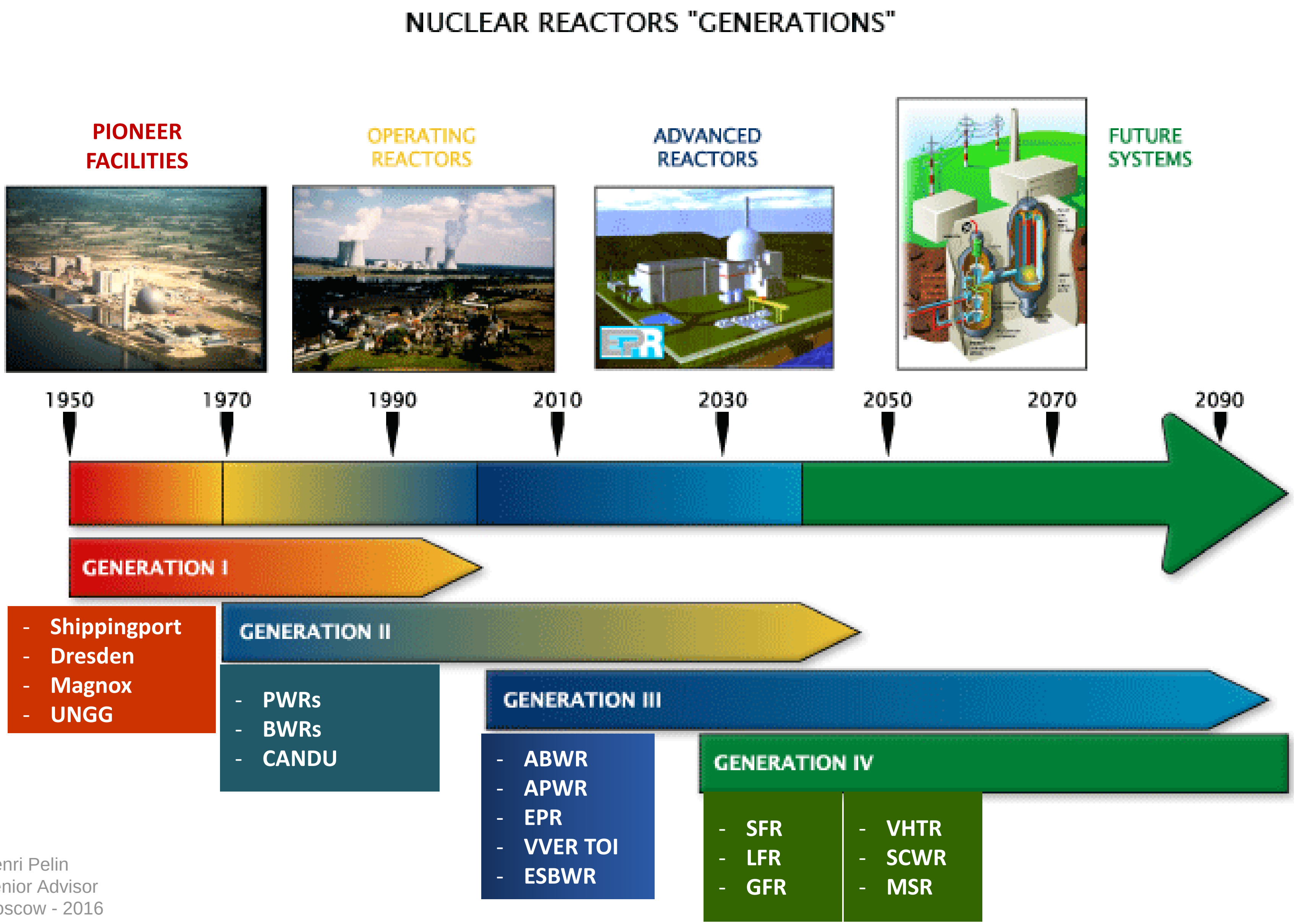
Generations



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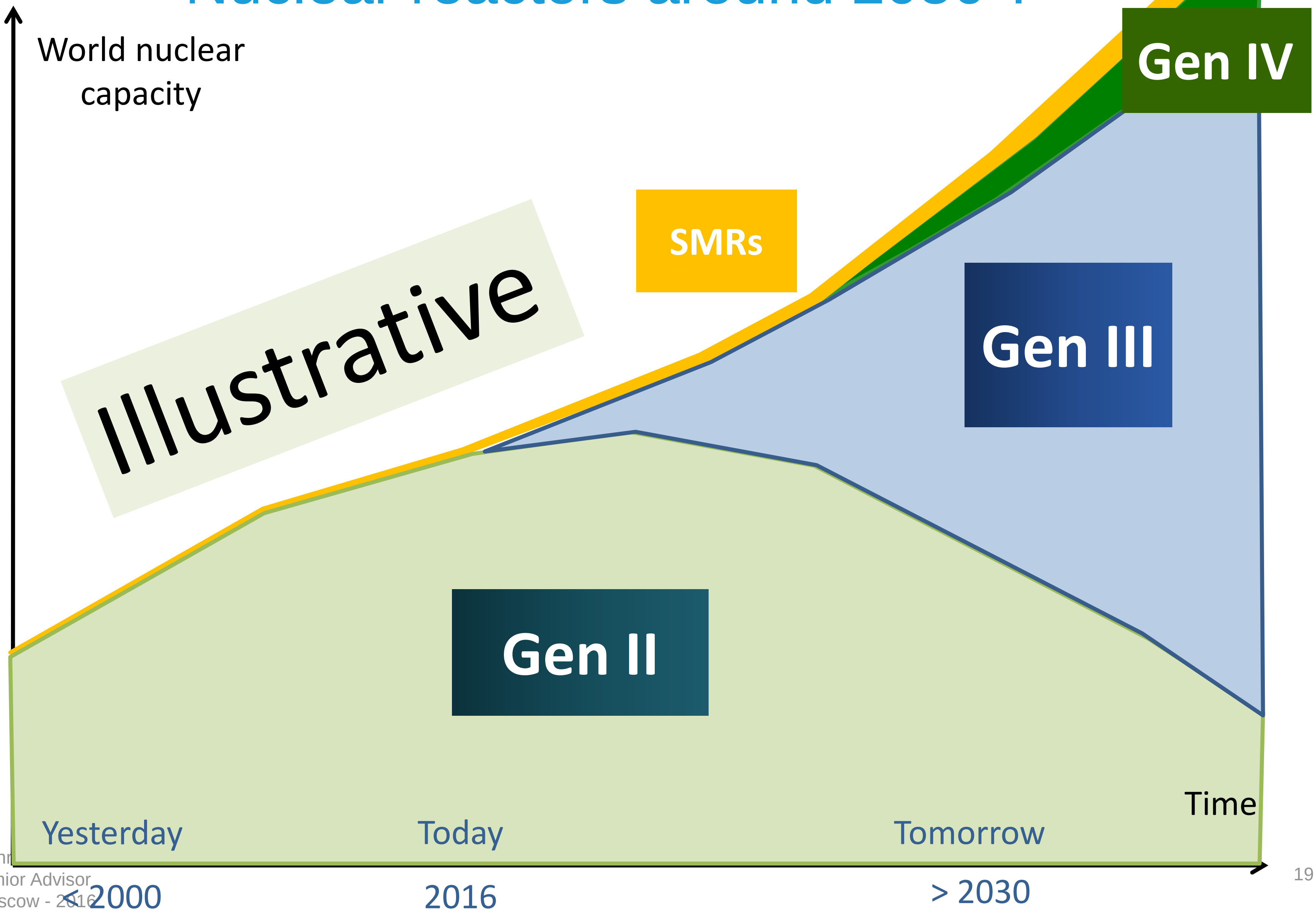
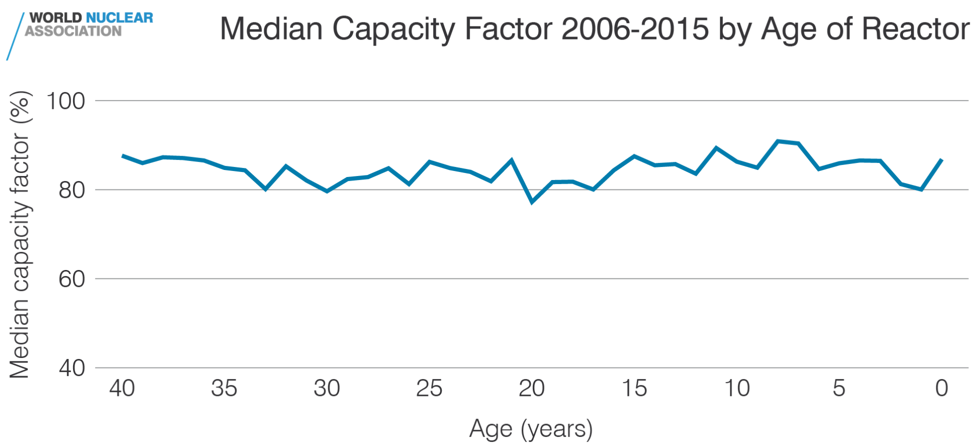
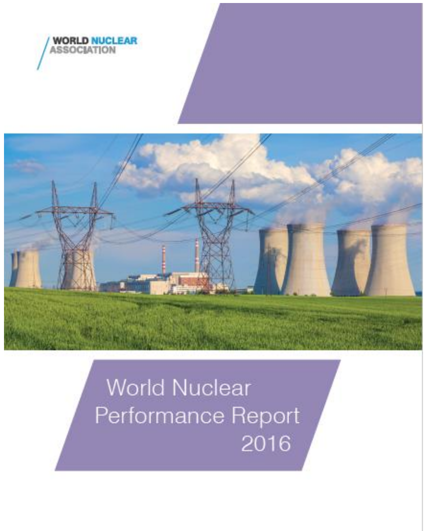
Technology perspective
Nuclear reactors around 2050 ?



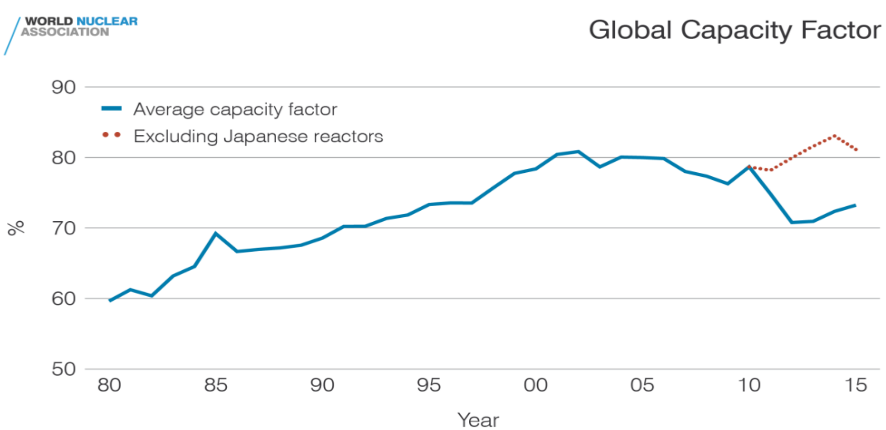
Generation II reactors

- Good performance (not age-related)

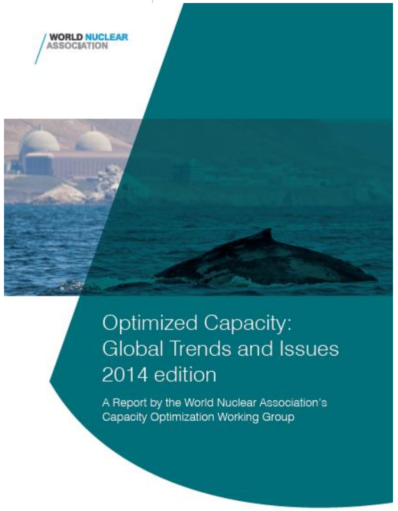




- Capacity Factor evolution in time

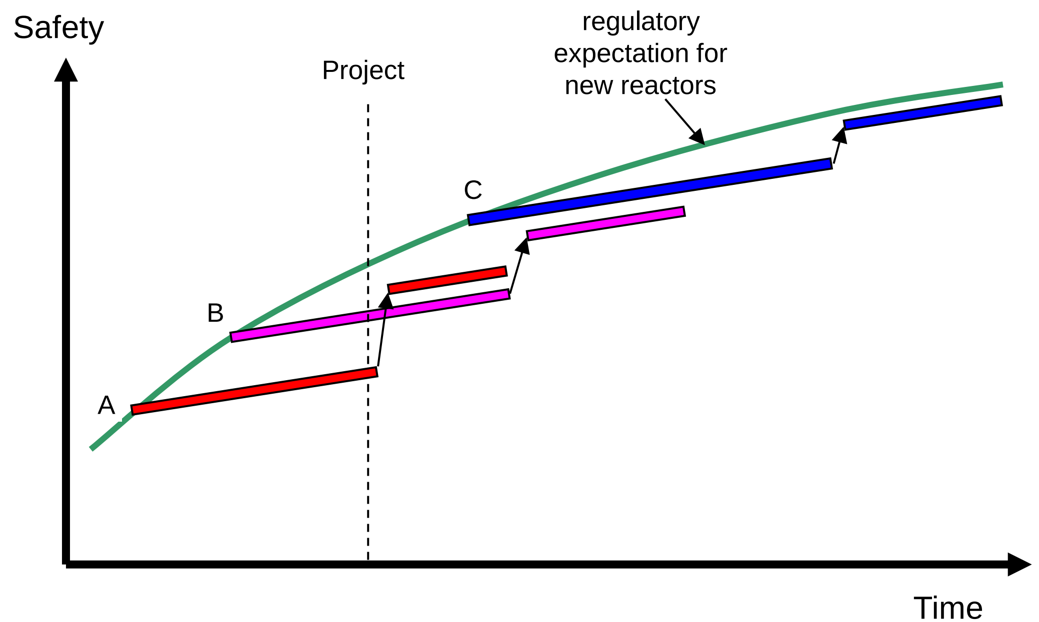


Source: IAEA PRIS



Source: WNA Performance report 2016 – based on IAEA data PRIS

Generation II reactors
Safety evolution



IAEA standards:

- ✓ Periodic Safety Reviews (PSR)
- ✓ Existing plant should aim at obtaining a safety level similar to new build (Vienna declaration Feb.2015, complementing CNS)

>>> Reflected in EU Nuclear Safety Directive

US Regulation (10 CFR 54): Licence renewal

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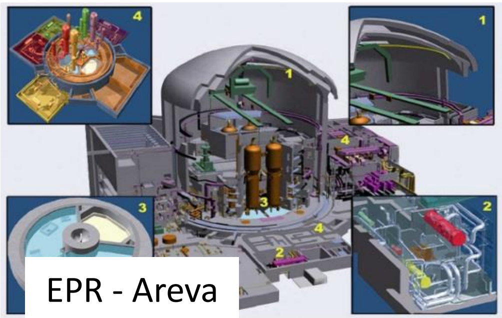
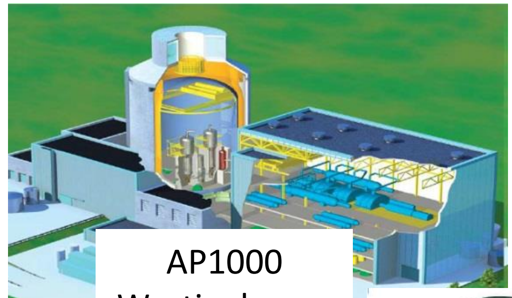
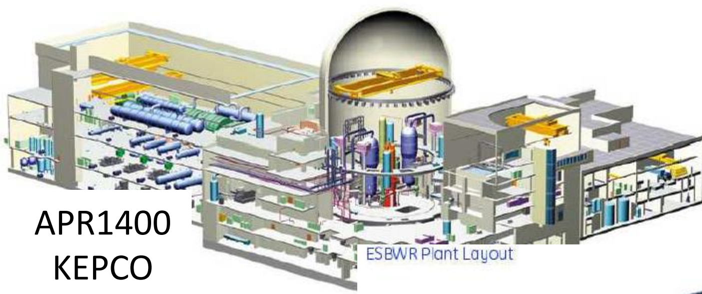
Today and tomorrow
Generation III reactors


EPR - Areva


AP1000
Westinghouse

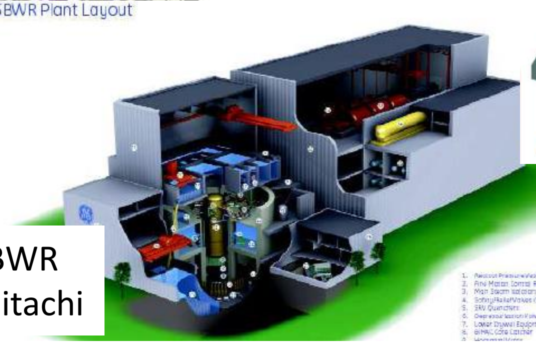
US APWR



APR1400
KEPCO


CANDU
ACR1000
AECL

AES2006
Gidropress


ESBWR
GE-Hitachi

+ more reactors under construction and development
(VVER TOI (Russia), Hualong One (China), EPR NM (France), etc.)

Tomorrow: Generation IV reactors Towards a more sustainable nuclear energy and many new applications

Goals for Gen IV reactors

(excerpts and synthesis from the 8 goals retained in GIF)

Sustainability: minimize waste

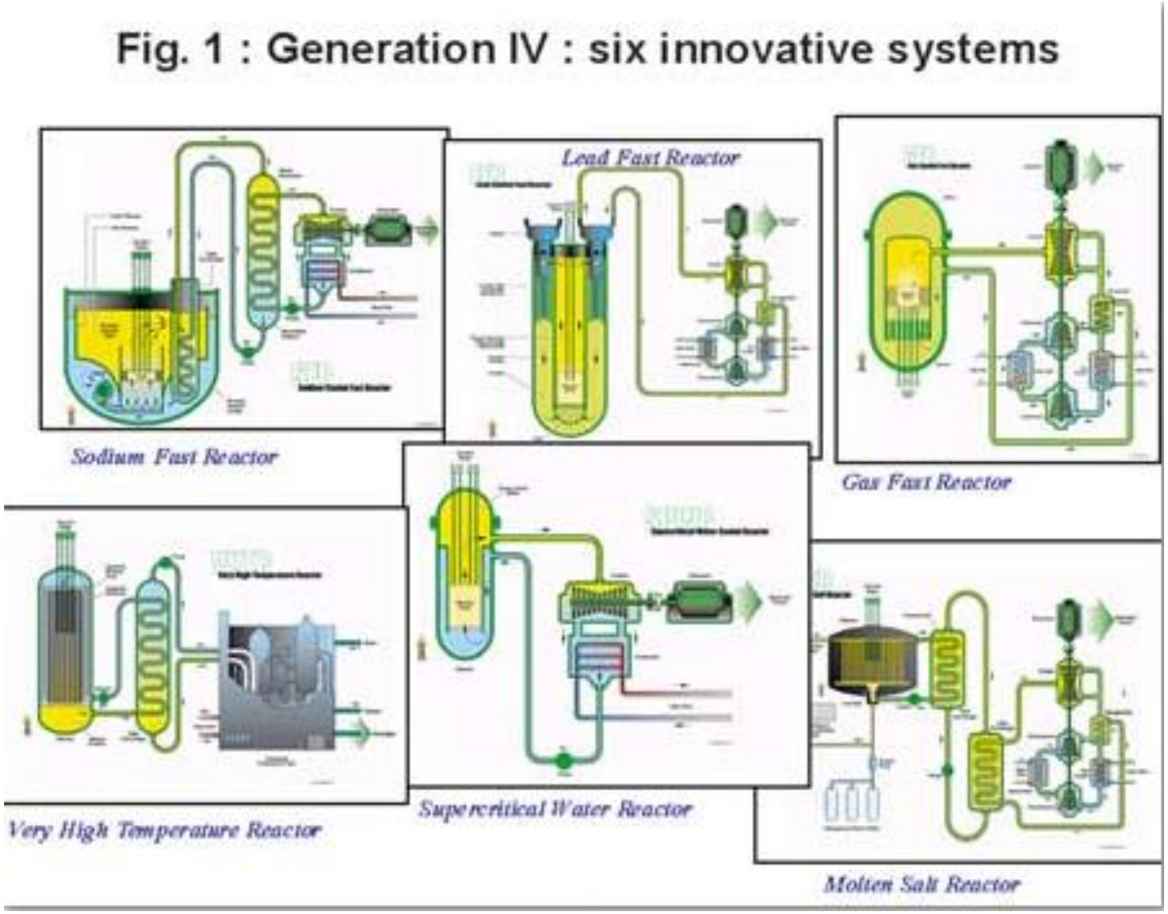
Economics: life-cycle cost advantage over other energy sources

Safety and Reliability:

Excellence – Elimination of the need for off-site emergency response

Proliferation resistance and physical protection:

Maximum level



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Yesterday, today and tomorrow Small Modular Reactors

Nuclear-powered Icebreaker *Yamal*
2 x 170 MWt reactors

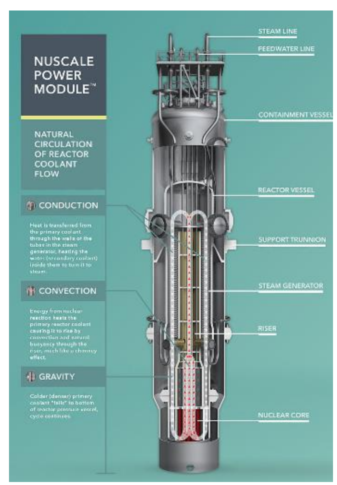
Nuclear submarines use reactors up to 200 MWt

Overview of some on-going SMRs development

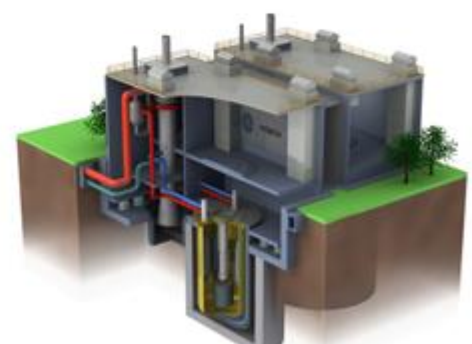
China: ACP100 – planned; HTR PM
India: PHWR-220 – in operation
Russia: KLT-40s – civil version for floating NPPs, being built
Argentina: CAREM-25 – being built at Atucha
USA - GB: NuScale 50 MWe – planned
USA: mPower 160 MWe– planned
Russia: SVBR-100 fast reactor - planned
USA-Japan - GB: GE H PRISM 311 MWe fast breeder reactor – planned
Korea – SMART 100 Mwe – planned

(non exhaustive list)

Russian floating nuclear power plant
(2 x 40 Mwe reactors)



NuScale Module



PRISM - GE Hitachi

www.world-nuclear.org

Generations – no precise definition

Generation I reactors:

Early prototypes, research reactors, non-commercial power producing reactors.

Generation II reactors:

Most current nuclear power plants 1970–2000, designed in 1960-70.

Generation III reactors:

Evolutionary improvements of existing designs 2000-now (such as digital computing).
By design: safer, and at least 60 years of operation.

Generation IV reactors:

Technologies still under development unknown start date, possibly from 2030.

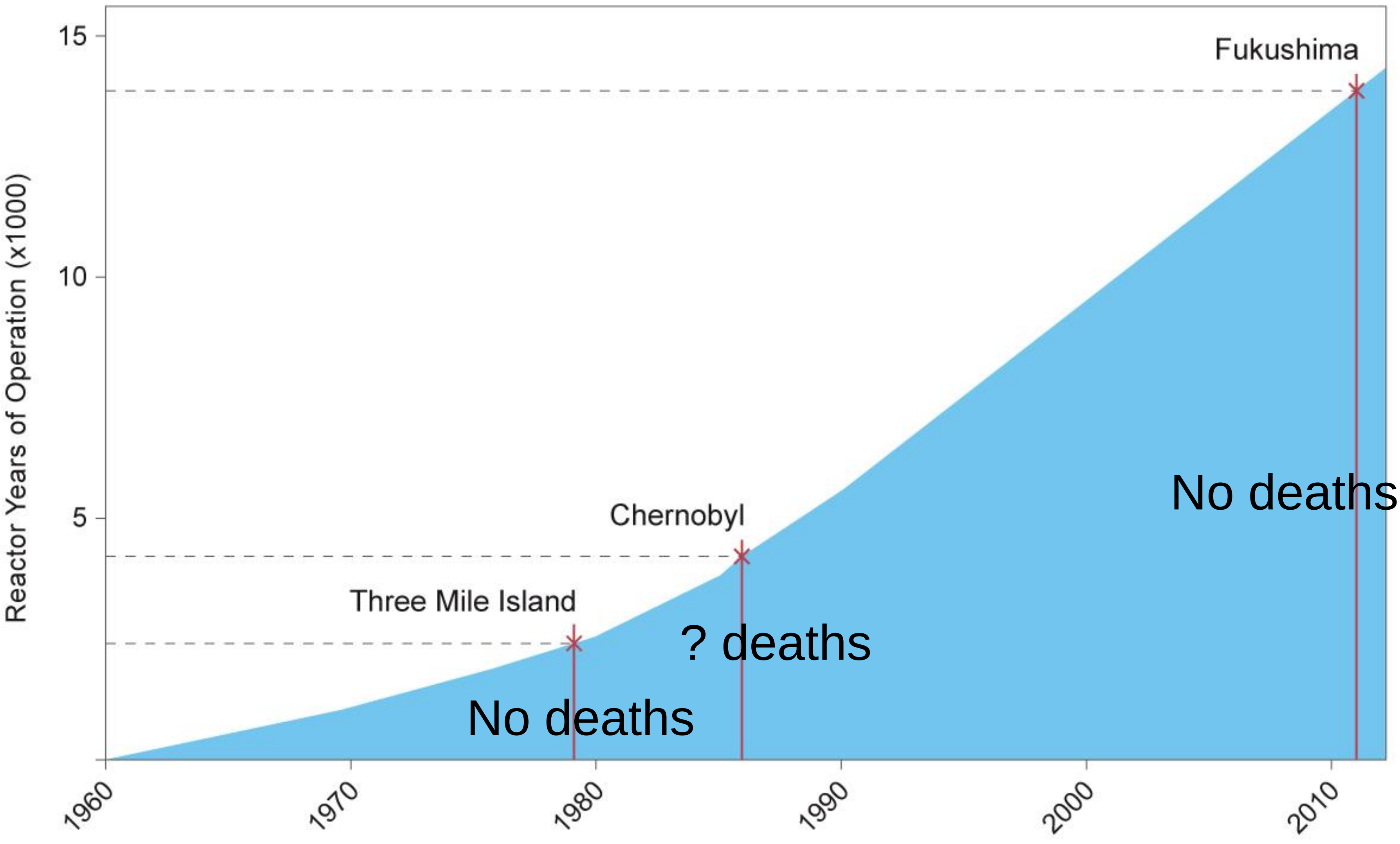
Towards a more sustainable nuclear energy.

In 2003, the French Commissariat à l'Énergie Atomique (CEA) was the first to refer to "Gen II" types in Nucleonics Week.

The first mentioning of "Gen III" was in 2000, in conjunction with the launch of the Generation IV International Forum (GIF) plans.

"Gen IV" was named in 2000, by the United States Department of Energy (DOE) for developing new plant types.

Cumulative Reactor Years of Operation



An impressive safety record!

Now 16,700+ reactor-years