Outlook on Advanced Reactor Technologies and Their Role in Future Energy Markets

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JAIF 52nd Annual Conference
Session 2: Prospects for Development of Innovative Technology

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Outline

- OECD Nuclear Energy Agency
- Nuclear energy today
- Future Low C electricity systems
- Advanced reactor technologies, flexibility & innovations
- Conclusions
- Panel discussion today

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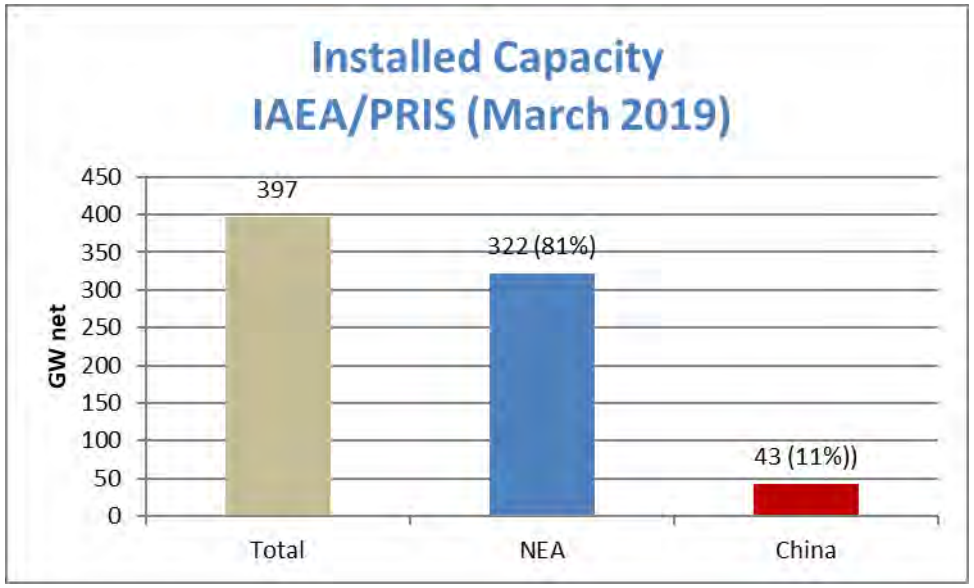
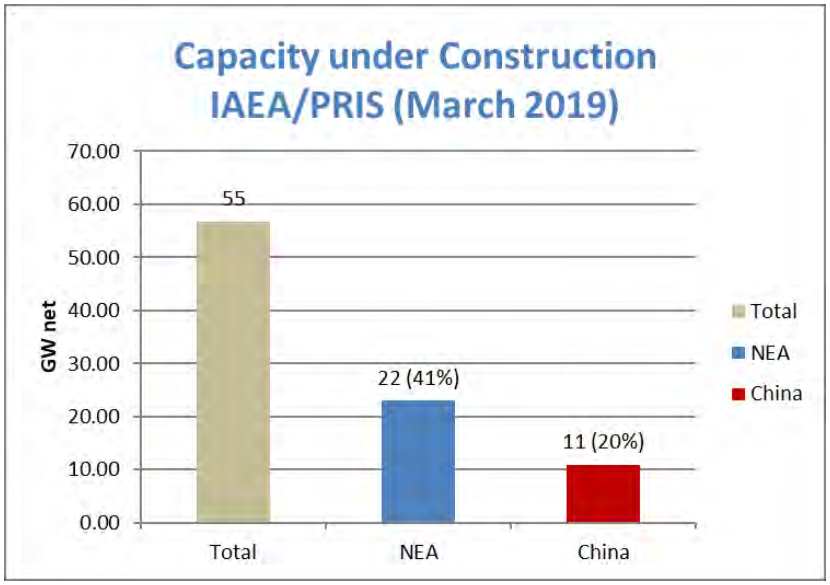
OECD/NEA:

- 8 standing technical committees
- 75 working parties and expert groups
- 24 international joint projects
- Secretariat staff: ~ 125
- Technical Secretariat for: MDEP, GIF and IFNEC





81% of world installed capacity - **41%** of capacity under construction

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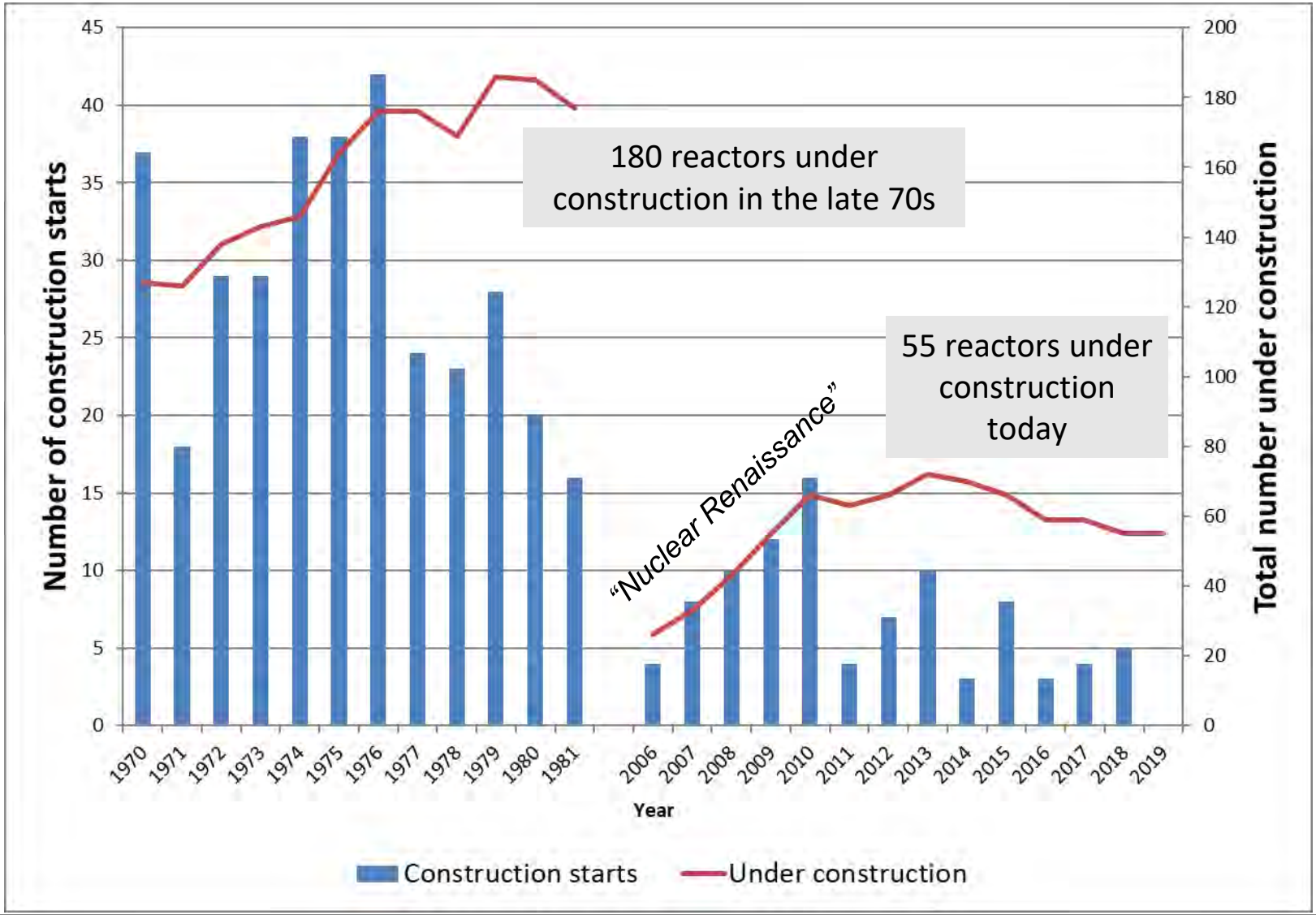
Reactor Construction – Comparison with the Past



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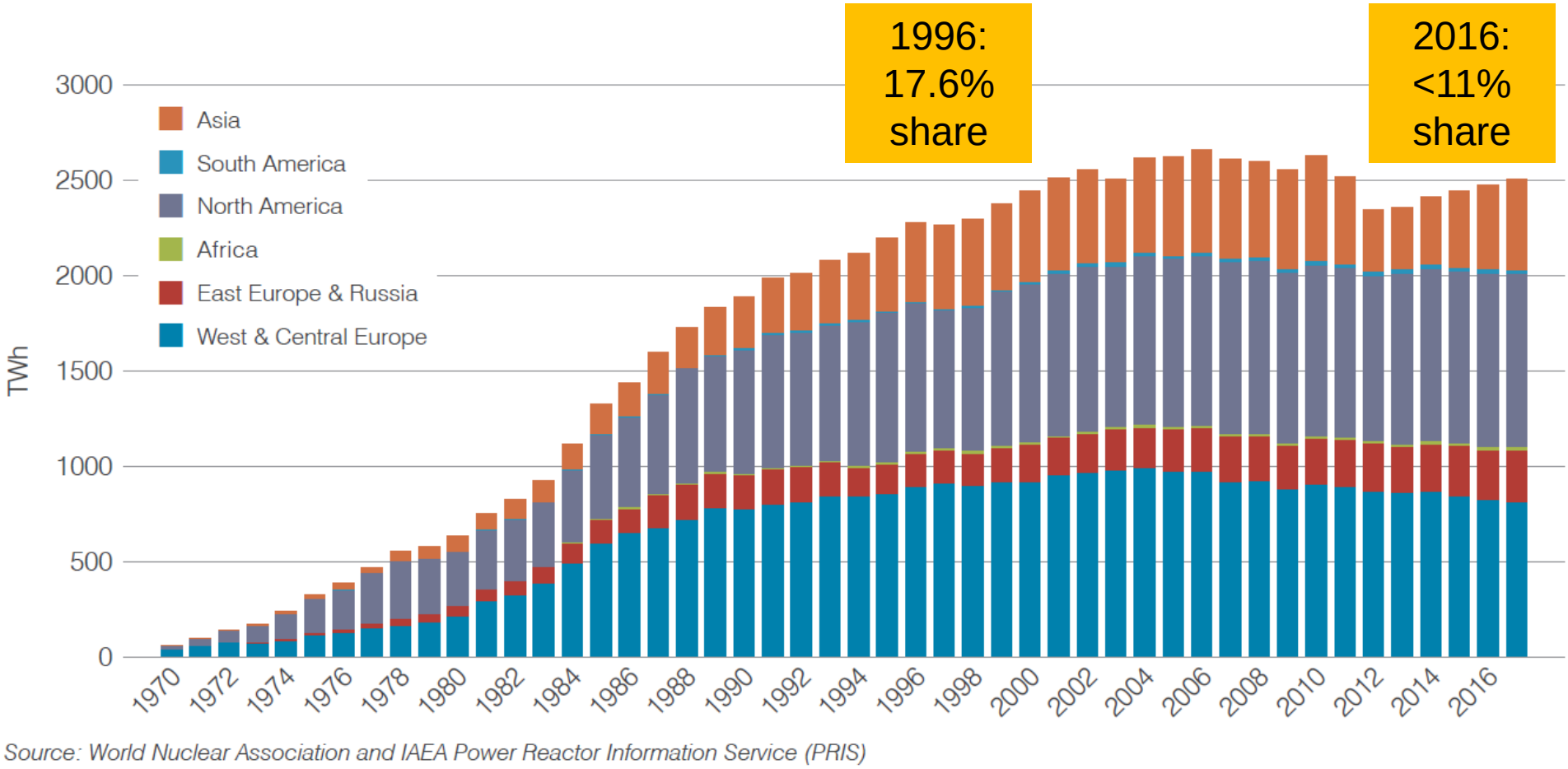
Nuclear electricity production



Source: IAEA/PRIS, figure from WNA

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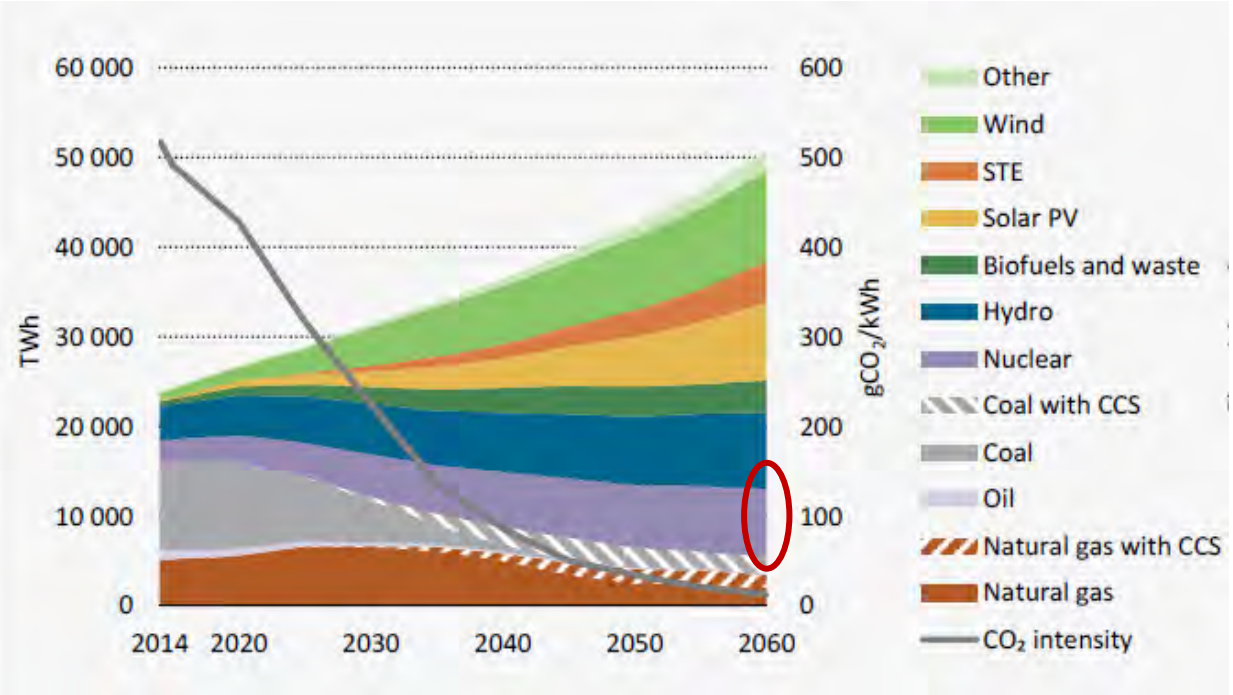
Future low carbon electricity systems?

IEA projects an increase in the share of nuclear electricity (from 10% to 16%), as well as a massive increase in renewables, together with a *complete phase-out* of coal and oil, a drastic decrease of gas & the deployment of CCS, to meet " 2°C or less" objectives.



Nuclear (and other "baseload" generators) will need to co-exist with large shares of variable renewables.

Source: IEA Energy Technology Perspectives, 2017 – (2 degree scenario (2DS)

67% renewables incl. 30% wind/solar
16% nuclear

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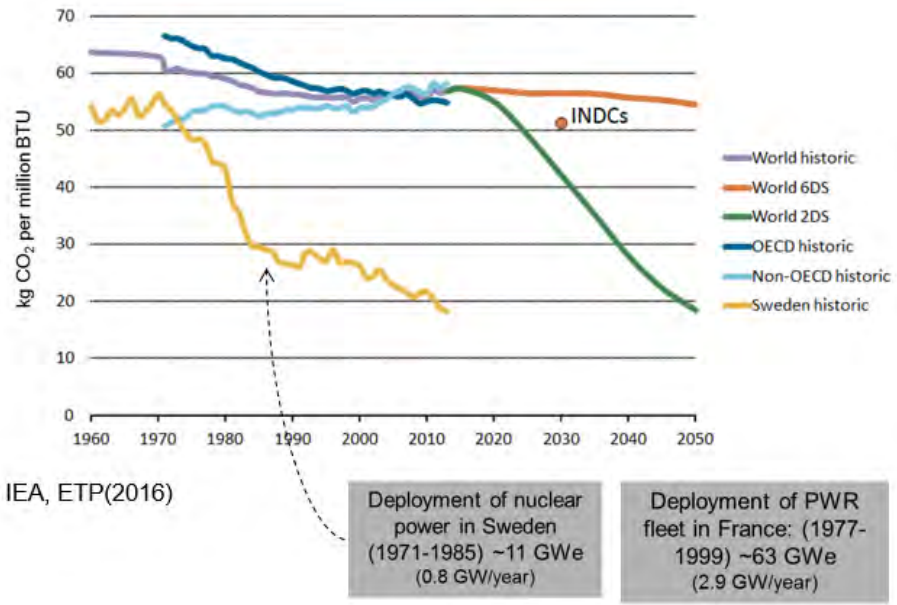
Policies supporting decarbonisation?

- In many countries, policies are more often directed at achieving deployment targets of selected technologies than at GHG reduction targets.
  - "technological neutrality" of policies in question → effectiveness of current policies?
- Very few support mechanisms for nuclear (LTO or new build).
  - EU Parliament voted to exclude nuclear from "green credits".
  - US 'Green New Deal' & nuclear
- Historically, nuclear has proven to be a **very effective technology** at reducing carbon intensity.



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Nuclear Reactors: Generations I to IV

Generation I

Early prototype reactors

- Shippingport
- Dresden
- Magnox

Generation II

Commercial power reactors

- PWRs
- BWRs
- CANDU

Generation III

Advanced LWRs

Generation III+

Evolutionary designs

Larger

Generation IV

Revolutionary designs

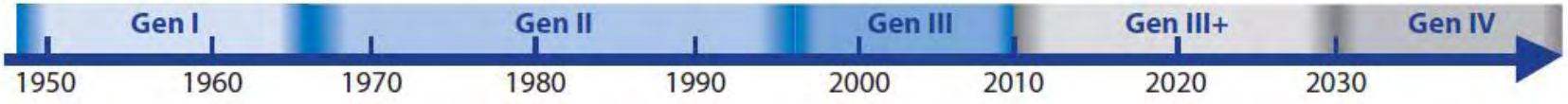
- Enhanced safety
- Minimisation of waste and better use of natural resources
- More economical
- Improved proliferation resistance and physical protection

New build (essentially after Fukushima Daiichi accident)

Bulk of today's nuclear fleet

Smaller

Small Modular Reactors



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Evolutionary Gen III/III+ … cost overruns, delays, …

Westinghouse Files for Bankruptcy, in Blow to Nuclear Power

By DIANE CARDWELL and JONATHAN SOBLE MARCH 29, 2017

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U.S. Nuclear Comeback Stalls as Two Reactors Are Abandoned

By BRAD PLUMER JULY 31, 2017

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Flamanville: EDF annonce un nouveau retard dans la construction de l'EPR

Par Nicolas Orliac | Mis à jour le 25/07/2018 à 14:35 / Publié le 25/07/2018 à 11:34

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fichait sa « grande
», salue « une très bonne

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Court approves Westinghouse reorganisation plan

28 March 2018

Westinghouse Electric Company's reorganisation plan - including its sale to Brookf
approved by the US Bankruptcy Court. Westinghouse said the court's approval of t
"significant milestone in the company's strategic restructuring".

EDF board approves buying 75.5 percent of Areva NP by end 2017 - sources

Geert De Clercq 3 MIN READ

PARIS (Reuters) - The board of French state-owned utility EDF has given final approval for the acquisition of a 75.5 percent stake in Areva NP, the nuclear reactor construction unit of fellow state-owned nuclear group Areva, by year-end, three sources said.

Cost overruns & delays for some FOAKs – restructuring of the nuclear industry

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Evolutionary Gen III/III+… positive developments in 2018!

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First AP1000 unit begins generating power

02 July 2018

Unit 1 of the Sanmen nuclear power plant in China has been connected to the grid, becoming the world's first AP1000 to achieve grid connection and power generation. The milestone came just one day after Taishan 1, also in China, became the first EPR to reach the same milestone.

Sanmen units 1 and 2 (Image: CNNC)

Sanmen 1 v
June, Westi
Technology
announced.

"Sanmen 1"
grid and ha

Related Stories

- China's Taishan 1 reactor connected to grid
- Chinese AP1000s pass commissioning milestones
- Fuel loading under way at Chinese AP1000
- Hot testing of Sanmen 2 AP1000 completed

WNA Links

- Sanmen 1
- Advanced Nuclear Pov Reactors
- Nuclear Pov China

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More progress for China's Hualong One technology

2 February 2018

Print Email

The reactor pressure vessel has been installed at China's demonstration Hualong One nuclear reactor, Fuqing 5, under construction at in Fujian province.

China National Nuclear Corporation (CNNC) said Fuqing 5 is expected to start up and begin commercial operation in 2019 or 2020. Installation of the RPV marks the completion of the installation of the unit's main components, CNNC said.

The Hualong One reactor pressure vessel was designed by China Nuclear Power Research and Design Institute and manufactured by China First Heavy Machinery.

The three steam generators and pump casings were installed earlier in January. Two demonstration Hualong One units are being built at Fuqing 5&6. The Hualong One (HPR1000), an indigenous 1100MWe, three-loop pressurised water reactor, incorporates elements of CNNC's ACP1000 and China General Nuclear's (CGN's) reactor designs. Construction of two Hualong One units is also underway at CGN's Fangchenggang in Guangxi province. Those units, based on CGN's ACPR1000+ design, are also expected to start up in 2019 and 2020.

U.A.E. Completes First of Four Korean-Built Nuclear Reactors

By Bruce Stanley and Heesu Lee
March 26, 2018, 4:14 PM GMT+2 *Updated on March 27,*

- Barakah Unit 1 to load fuel in May: Korean energy ministry
- Reactor is Arab world's first; Saudis also want atomic plants

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Leningrad II-1 starts pilot operation

09 March 2018

Russia has today connected unit 1 of the Leningrad Phase II nuclear power plant to the grid and it has started producing its first power, state nuclear corporation Rosatom has announced. The VVER 1200 reactor was brought to the minimum controllable power level on 6 February.

Leningrad-II unit 1 (Image: Rosatom)

Chinese EPR connected

2 July 2018

Print Email

Unit 1 of China's Taishan nuclear plant in Guangdong province was connected to the on 29 June, becoming the world's first EPR to achieve grid connection and power generation, China General Nuclear International (CGN) and EDF Group announced. Taishan 1 is expected to enter commercial operation later this year.

Zheng Dongshan, CEO of CGN UK described the grid connection of the new Taishan 1 reactor as "a major step forward in China," but also noted the significance for the UK, where EPR technology will be used at both Hinkley Point C and Sizewell C.

"The fact that an EPR power station has been linked to the electricity network for the first time reinforces our strong confidence in this reactor technology and in the [Hinkley Point C] project as a whole," he said.

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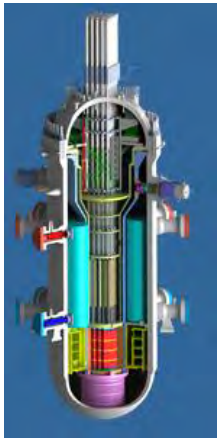
Small Modular Reactors,
more than a niche market?



Vendor	Country	Design	Type	Net capacity (MW)	In operation*	Under construction*
Babcock & Wilcox	United States	mPower	PWR	180	0	0
CNEA	Argentina	CAREM-25	PWR	25	0	1
CNEC	China	HTR-PM	HTR	210	0	Twin units
CNNC	China	ACP-100	PWR	100	0	0
KAERI	Korea	SMART	PWR	110	0	0
NuScale	United States	NuScale SMR	PWR	45	0	0
OKBM	Russia	KLT-40S	Floating PWR	2x35	0	Twin units (one barge)

*: As of 31 December 2014.

Design certification of US NuScale on-going at NRC

Fuel loading completed, testing reactor units at KLT-40s on-going

Global First Power 5MW microreactor licence application in Canada

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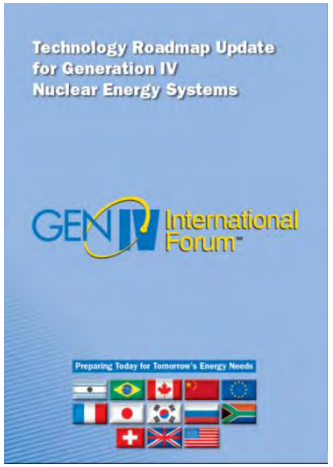
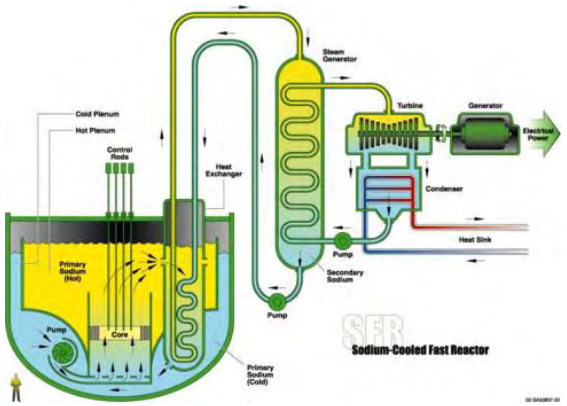
Generation IV technologies





6 designs developed in an international collaborative framework

- "Fast Reactors":
  - Sodium-cooled fast reactor (SFR)
  - Lead-cooled fast reactor (LFR)
  - Gas-cooled fast reactor (GFR)
- "Thermal Reactors":
  - Super-critical water-cooled reactor (SCWR)
  - Very high temperature reactor (VHTR)
- "Thermal/Fast Reactor":
  - Molten Salt Reactor (MSR)

Goals

- Sustainability
- Economics
- Safety and Reliability
- Proliferation Resistance & Physical Protection

At R&D level today (GIF). Prototypes of some of these technologies planned over the period 2030/2040. **Commercialisation beyond 2040**, alongside further evolutions of LWRs

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Reactor systems with "Gen IV technologies": in operation, under construction or at siting / license application stage

In operation
Under construction
At siting stage or license submission

- Lead Fast Reactor
- Sodium Fast Reactor
- High Temperature Reactor
- Molten Salt Reactor

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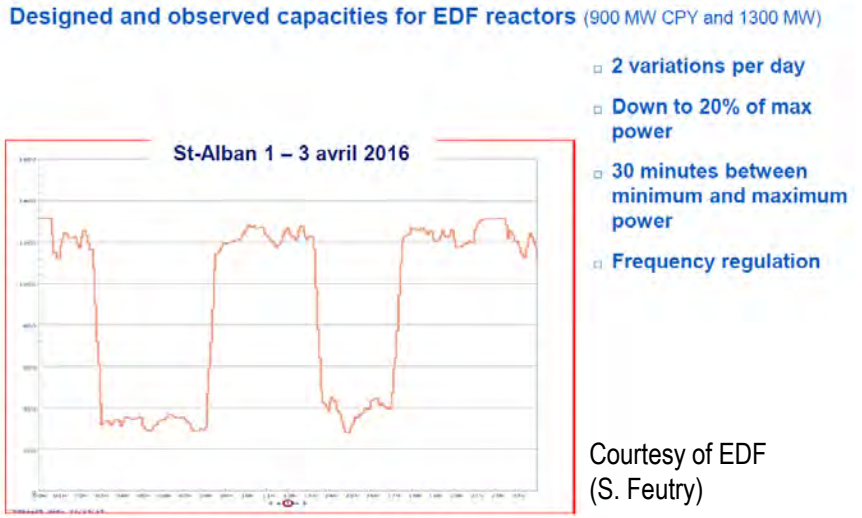
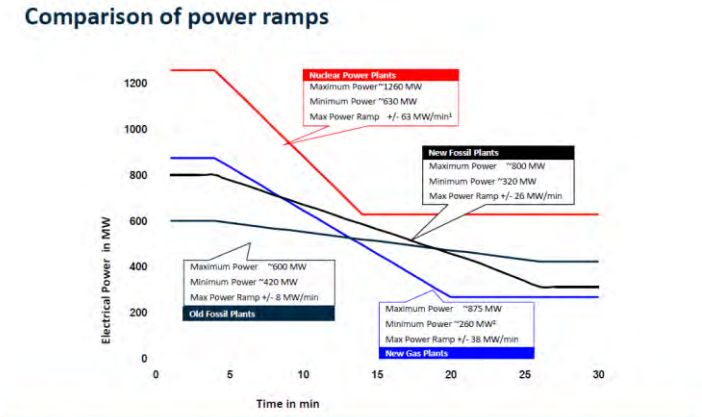
Flexibility: Role of Nuclear (1)

- IEA analyses show the need for flexibility of future generation systems including power plants, grids & energy storage.
- Gas often presented as “natural partner” of variable renewables. Gas is flexible but is *not* a low C source of power.
- Today’s **nuclear fleet already provides flexibility** (France, Germany, US too) “flexible operation”: load following, frequency response…



Courtesy of EDF (S. Feutry)



Nuclear Power Plants belong to the most flexible plants in the grid!

Courtesy of PreussenElektra (D. Janin)

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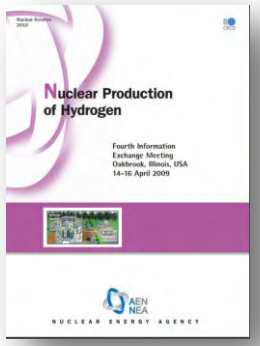
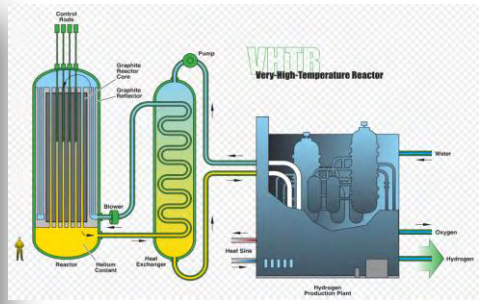
Flexibility: Role of Nuclear (2)

- Nuclear can contribute further to flexibility of energy systems:
  - Contribution to **energy storage**
    - Famous example of Swiss Hydro buying cheap nuclear electricity from France at night to pump water up, and sell hydro electricity during the day time (but this model challenged by current electricity market conditions)
  - Contribution to **non-electric applications** / decarbonise other sectors:
    - District heating: over 35 years of experience from Beznau NPP in Switzerland, supplying heat & hot water to local communities
    - Desalination: a very energy-intensive process which can use nuclear heat & electricity
    - Process heat for industry
    - Hydrogen production (fuel, storage)
  - **Hybrid Energy Systems**





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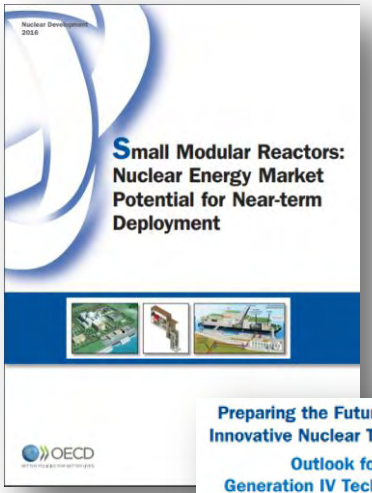
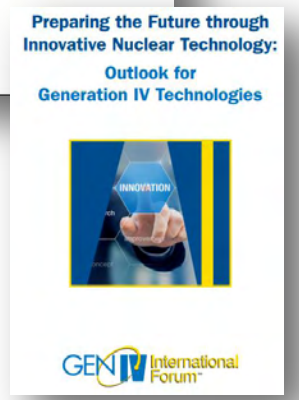
Innovations





- **Advanced reactors**
  - **Small Modular Reactors**:
    - Offer deployment flexibility (scalable, siting)
    - Offer increased operational flexibility
  - **Gen IV reactors** (including non LWR-cooled SMRs)
    - Fuel flexibility (from open to closed fuel cycle, U, Th)
    - High temperatures, higher efficiency
  - Targeting both electric and non-electric markets.
- Nuclear: **low C source of electricity AND heat**!!! (and few competitors (CCS, biomass)
- Flexibility key for future power & future energy systems
- **NICE Future initiative** important forum to discuss attributes of nuclear among other clean energy sources.

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Nuclear Innovation Clean Energy Future - NICE Future

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NUCLEAR INNOVATION: CLEAN ENERGY FUTURE (NICE FUTURE)

A CLEAN ENERGY MINISTERIAL INITIATIVE

Countries Launch a Nuclear Innovation Initiative under the Clean Energy Ministerial

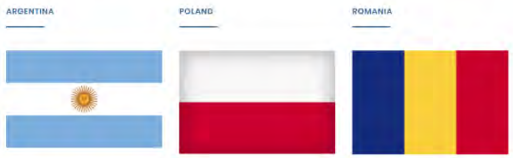
24 May 2018

- Technology evaluations of innovative energy systems and uses
- Engagement of policy makers and stakeholders in future energy choices
- Valuation, market structure, and ability to finance
- Communicating nuclear energy's role in clean, integrated energy systems

Photos courtesy of Third Way

PARTICIPATING COUNTRIES

PARTNERS



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Some take-aways

- Current fleet provides ~10% of the world's electricity, the 2nd largest source of low carbon electricity. Ageing fleet – LTO major issue in coming years
- Replacing the existing fleet and deploying new Nuclear Power Plants (NPPs) to produce 15-16% of global electricity will require major investments as well as stable and favourable policies, "good" products from industry, and public support
- Innovations are needed:
  - To reduce the costs of Gen III/III+ reactors
  - To ensure the success (costs, manufacturability, flexibility) of SMRs and Gen IV reactors
  - To demonstrate at industrial scale the use of nuclear energy for non-electric applications (process heat, hydrogen, desalination, etc)

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To find out more…

- NEA reports:
  - IEA/NEA Nuclear Technology Roadmap
  - Full costs of electricity provision
  - The costs of decarbonisation: system costs with high shares of nuclear and renewables
- Gen IV International Forum:
  - 4th Symposium (Oct 2018)
  - R&D Outlook to be published www.gen-4.org
- International Forum for Nuclear Energy Cooperation (IFNEC) www.ifnec.org
  - IFNEC/NICE Future conference on challenges and opportunities facing NE (Nov 2018)
  - Int. Summit on SMRs and Advanced Nuclear (Washington DC, 14-15 Nov 2019)

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Today's panel: "prospects for development of innovative technology"

- **Ms Marylin Kray**, Vice President, American Nuclear Society
- **Dr Gareth Headdock**, Science & Technology Director, UK NNL
- **Mr Petr Zelenov**, Head Int. Cooperation, JSC 'Science & Innovation', Russia
- **Mr Daisuke Matsuno**, Director Nuclear Energy Policy Planning Division, METI, Japan

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