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Nuclear Power's Contribution to Sustainable Development and Clean Energy Systems

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Wednesday 23 June

United Nations

HIGH-LEVEL DIALOGUE ON
ENERGY
UNITED NATIONS, NEW YORK, SEPTEMBER 2021

Webinar Details

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Agenda

Aliki van Heek, IAEA
Nuclear Energy's Contribution to a Net Zero World

Diane Cameron, OECD-NEA
Towards an Understanding of the Economics of Nuclear Energy in a Carbon-constrained Future

Stefano Monti, IAEA
Advanced Nuclear Technologies to Decarbonize the Entire Energy Sector

Henri Paillere, IAEA
Moderator

United Nations

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Nuclear Energy's Contribution to a Net Zero World

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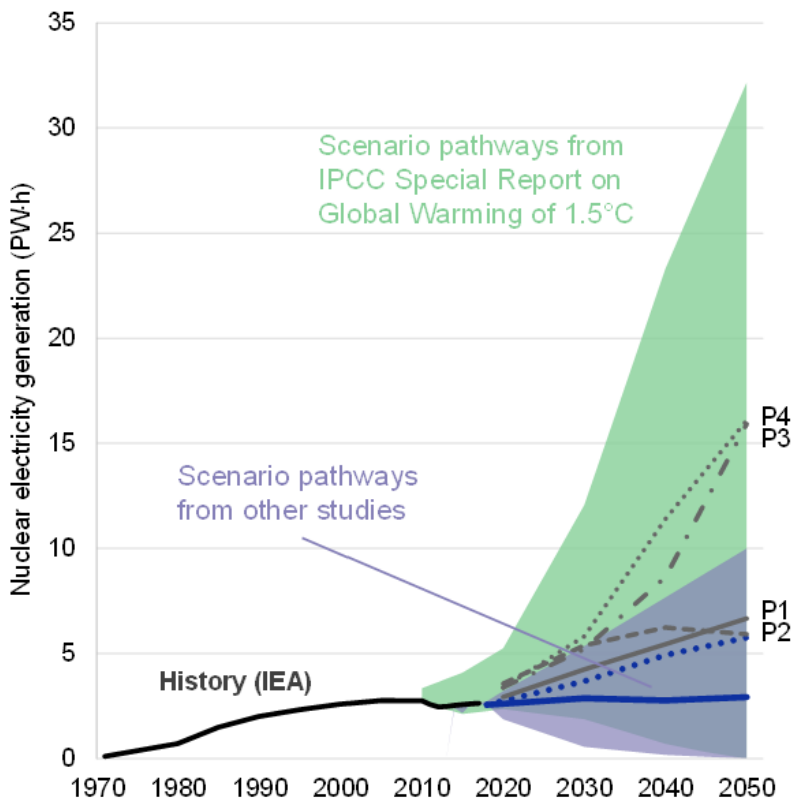
HLDE webinar Nuclear Power's Contribution to Sustainable Development and Clean Energy Systems
23 June 2021

Outline

- Role of NP in decarbonization scenarios
- Contribution of nuclear power to SDGs
- Nuclear investments, post-covid recovery
- Challenges

Role of NP in decarbonization scenarios

- 2018: IPCC report Global Warming of 1.5°C: all four "illustrative scenarios" include a significant increase of nuclear capacity
- 2021: IEA report Net Zero by 2050: nuclear energy will make a significant contribution to their Net Zero Emissions scenario, and will provide an essential foundation in the transition to a net-zero energy system.

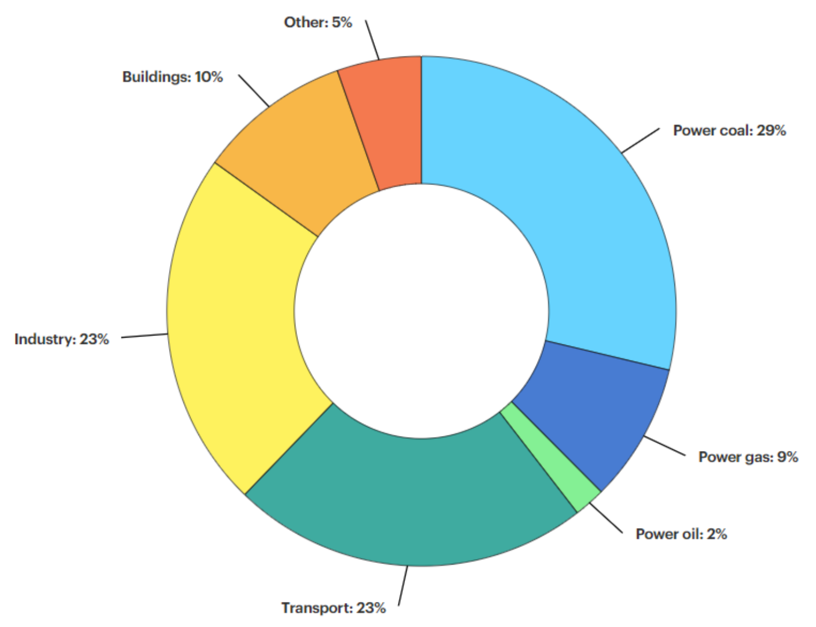


Climate Change and Nuclear Power 2020 | IAEA

Energy, Electricity and Nuclear Power Estimates for the Period up to 2050 | IAEA

Role of NP in low carbon energy supply

- Existing market: large scale electricity supply
- Near term additional potential:
  - Non-electric energy supply
  - Energy supply (electric and non-electric) with SMR



Global energy-related CO2 emissions by sector (Source: IEA, 2021)

IAEA

Contribution of nuclear power to SDGs

- Nuclear technology bears benefits for many SDGs, and nuclear power in particular contributes to SDGs on energy, economic growth and climate action.

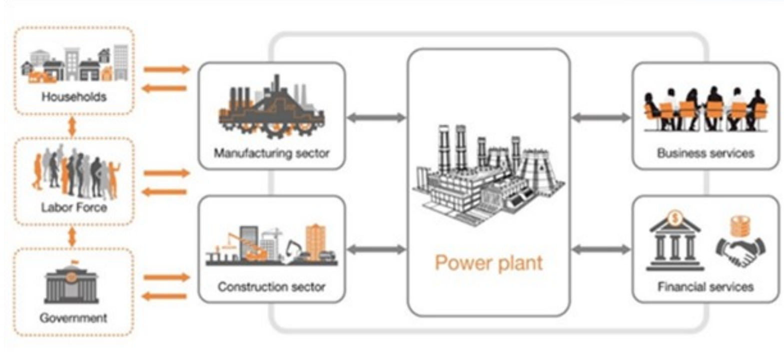
Nuclear energy investment for a sustainable post covid world

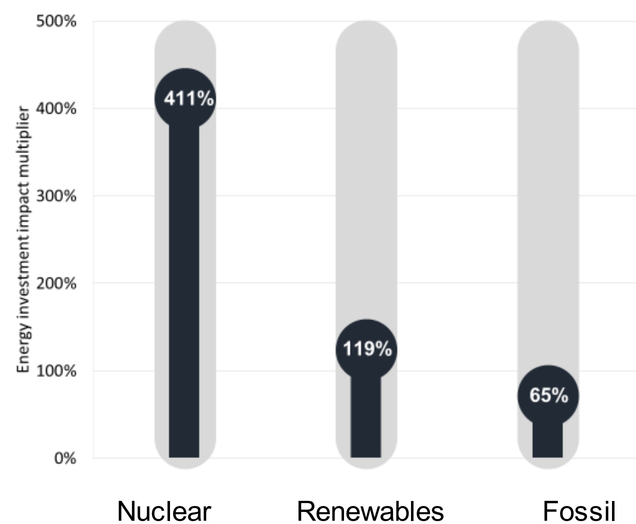
- In response to the COVID-19 crisis, national governments are developing and implementing investment-led recovery plans to stimulate economic activity.
- Increasing recognition for the need for these investments to deliver a sustainable recovery that brings the world closer to net zero greenhouse gas emissions.
- Investment in nuclear energy is well matched to respond to these multiple urgent needs by boosting economic activity and job creation both
  - in the short term — for example with "shovel ready" projects to extend the operating lifetimes of nuclear power plants,
  - and over the longer term with new-build projects, enhancing sustainable growth, development and industrialization.

Construction site of the Akkuyu Nuclear Power Plant in Turkey

Nuclear energy investment for a sustainable post Covid world

- Investment in nuclear power projects can stimulate economic activity and employment across many sectors, including construction, manufacturing and services
- IMF: investment in nuclear power generates a larger economic impact than investment in other forms of energy





Building Back Better: How Big Are Green Spending Multipliers? (imf.org)

Challenges for nuclear energy to contribute to a Net Zero World

- Operating nuclear fleet:
  - More than two thirds of operational reactors is over 30 years old.
  - Electricity produced from these older fully amortized reactors is among the cheapest sources of low-carbon power, **but**:
  - the competitiveness of these plants may be challenged by even cheaper fossil fuels or subsidized renewables.

- Additional nuclear capacity:
  - The current pace of reactor construction remains far slower than what is needed to achieve a net zero world.

- Many longer term national growth strategies feature nuclear power **and**
- around half of the low emission development strategies submitted under the Paris Agreement identify an important role for nuclear power, **but**:
- current market and policy environment may be unable to mobilize the required investment.

Enabling factors to support the contribution of nuclear energy to a Net Zero World

- Costs:
  - control newbuild costs through streamlined supply chains and modular construction
- Policy framework:
  - supporting plant lifetime extensions by improving the competitiveness of operating plants by measures to value and remunerate the contribution of existing plants to low carbon energy systems
  - accelerating the launch of new projects by more favorable policy framework to increase investor confidence and lower financing costs

Action for:

- nuclear industry
- govern-ments

transitions-to-low-carbon-electricity-systems-changing-course-in-a-post-pandemic-world.pdf (iaea.org)

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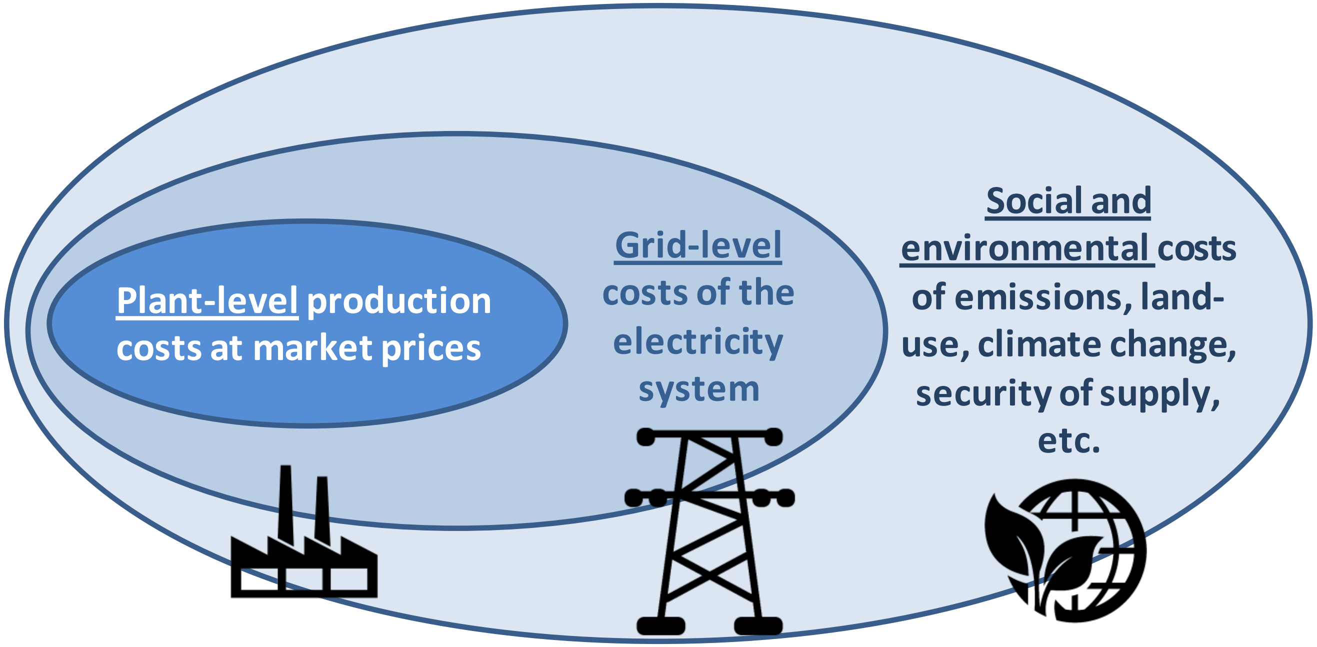
Thank you for your attention!

Towards an Understanding of the Economics of Nuclear Energy in a Carbon-constrained Future

Diane Cameron
Head of Division
Nuclear Technology Development and Economics
OECD Nuclear Energy Agency

High Level Dialogue on Energy
23 June 2021

The costs of electricity: from plant-level to system costs

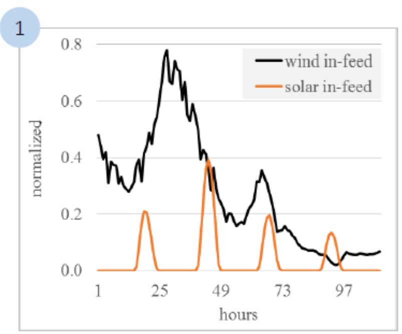


The actual cost of electricity should reflect not only plant-level **GENERATION** costs but also grid-level **SYSTEM** costs and **SOCIAL & ENVIRONMENTAL** costs

What do we mean by system costs?

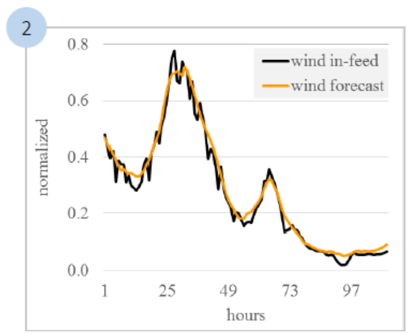
- Total system costs = plant-level generation costs + grid-level system costs
- System costs are mainly due to characteristics intrinsic to variable generation

Source: L. Hirth



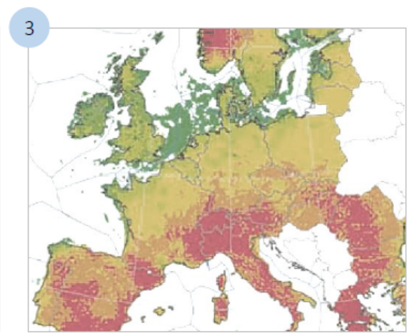
VREs are not always available

Profile costs (Changing mix)



VREs are difficult to predict

Balancing costs (Short-term variations)



Good VRE sites are distant from load centers

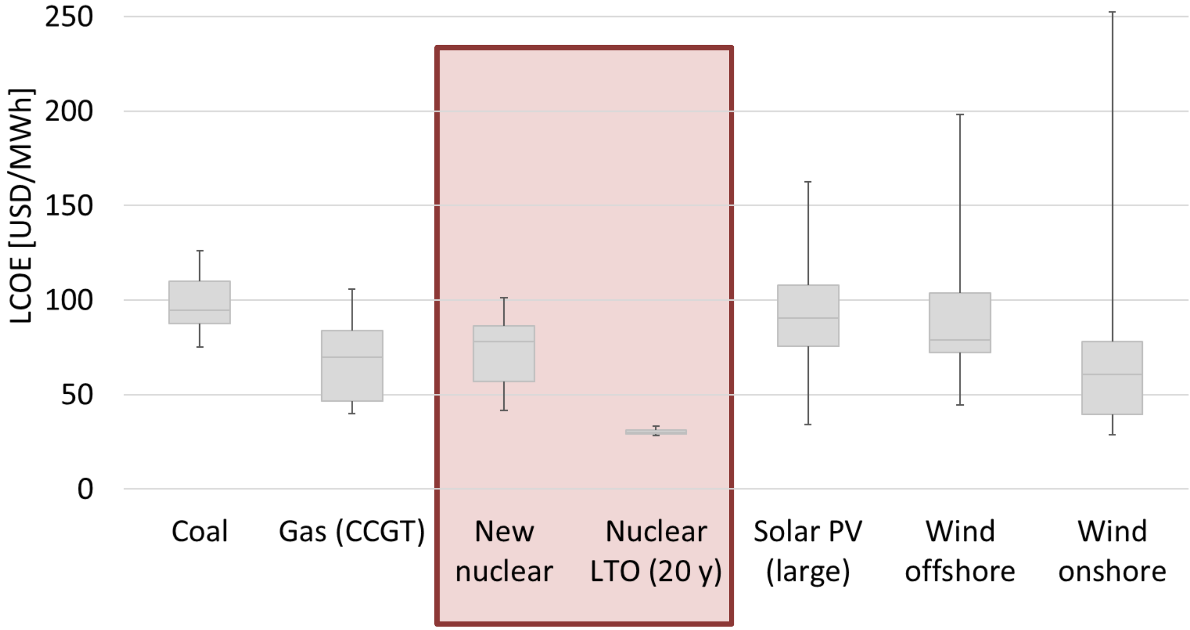
Transmission and distribution costs

System costs depend on:

- Local & regional factors and the existing mix
- VRE penetration and load profiles
- Flexibility resources (hydro, storage, interconnections)

Additional impacts on load factors of dispatchable generators and prices.

Nuclear power competitiveness
Key results from the IEA/NEA – Projected Cost of Electricity 2020

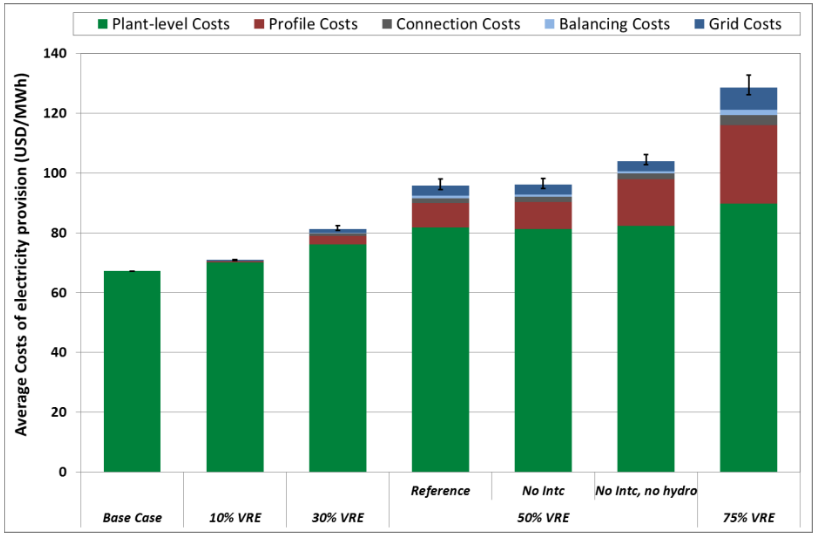


Source: IEA/NEA (2020) with cost of capital of 7% and CO2 price @ 30 USD/tCO2

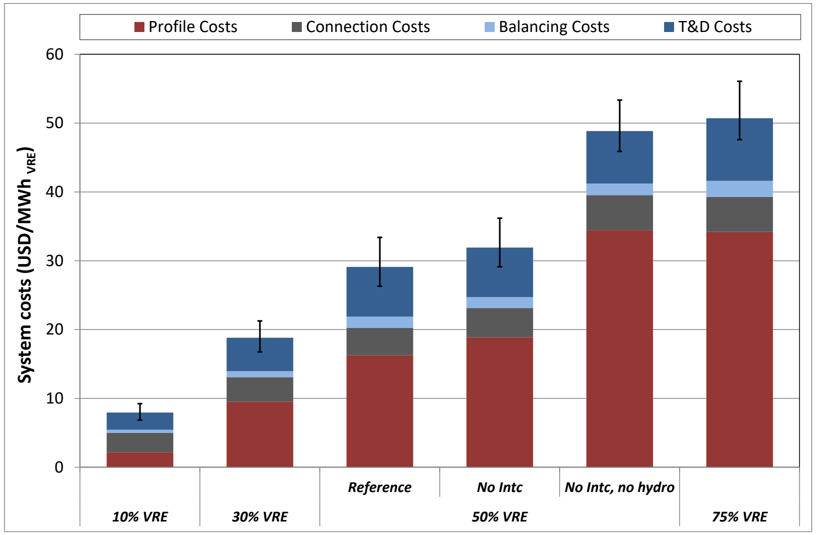
Nuclear LTO one of the most competitive solutions. Costs reductions expected for new nuclear that will improve competitiveness. **Policy framework critical** in both cases.

As variable renewables share increases system costs grow quickly

Total Costs

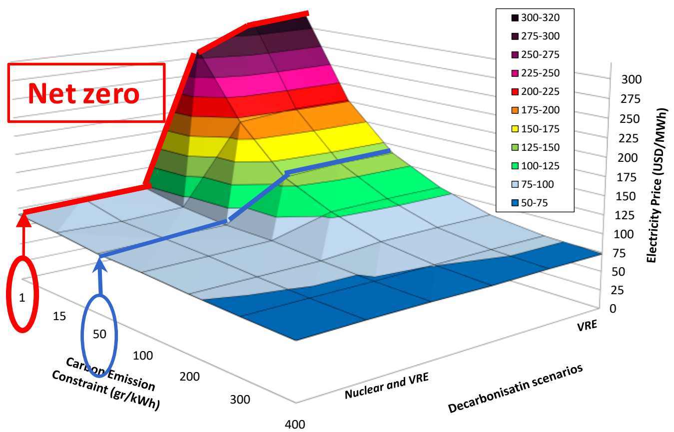


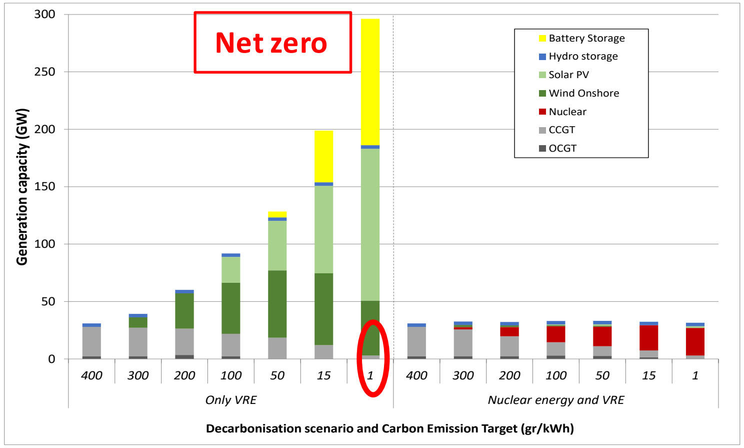
Breakdown of System Costs



System costs are significant and increase with VRE generation share
Profile costs are the dominant component

System Costs Are a Function of (1) Carbon Targets and (2) VRE Targets

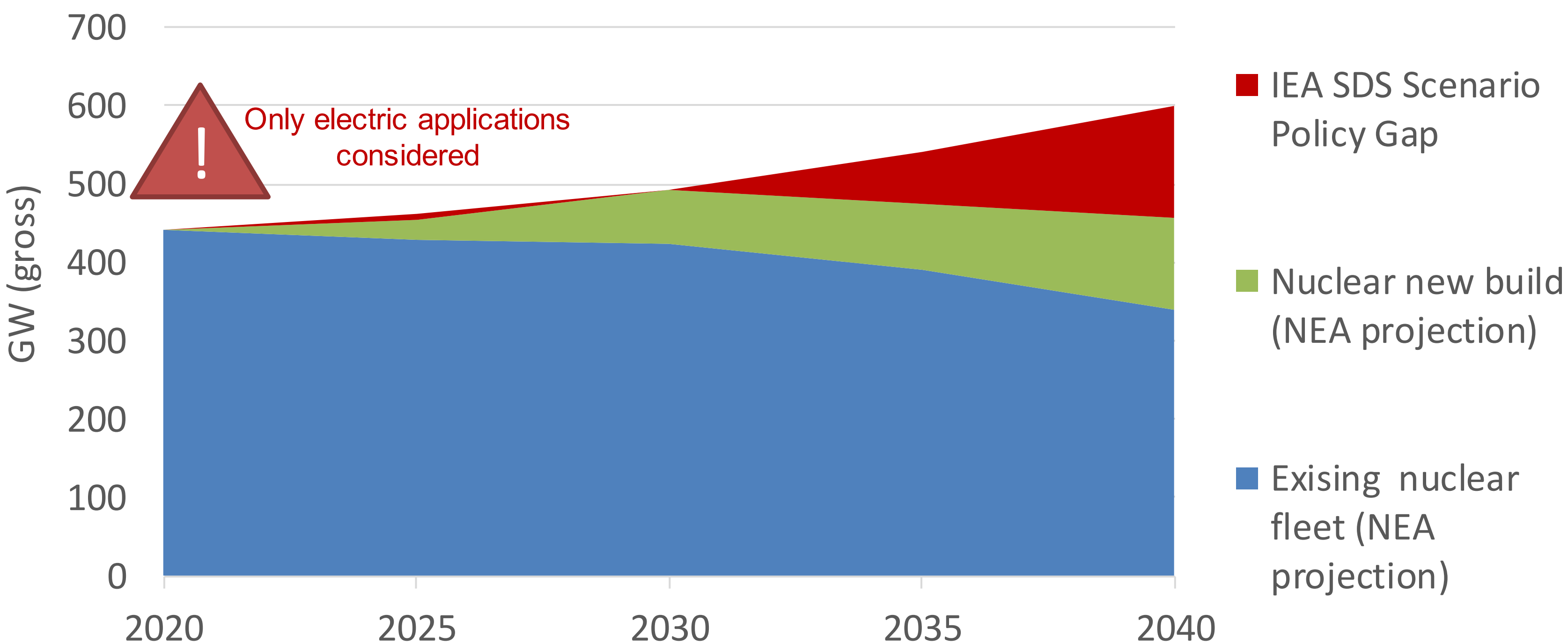




Source: N. Sepulveda, MIT

The cost of electricity increases with the stringency of the carbon constraint, especially in scenarios where only variable renewables are deployed.

Nuclear power outlook in IEA's *Tracking Clean Energy Progress 2020*



Meeting IEA SDS scenario requires to foster both **existing nuclear reactors** though long term operations and to **accelerate new-build** (Gen-III large reactors and SMRs)

Thank you

More information @ www.oecd-nea.org

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Nuclear Power's Contribution to Sustainable Development and Clean Energy Systems
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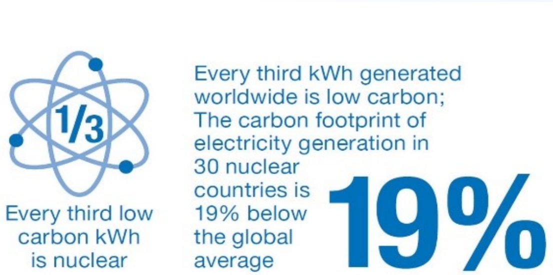
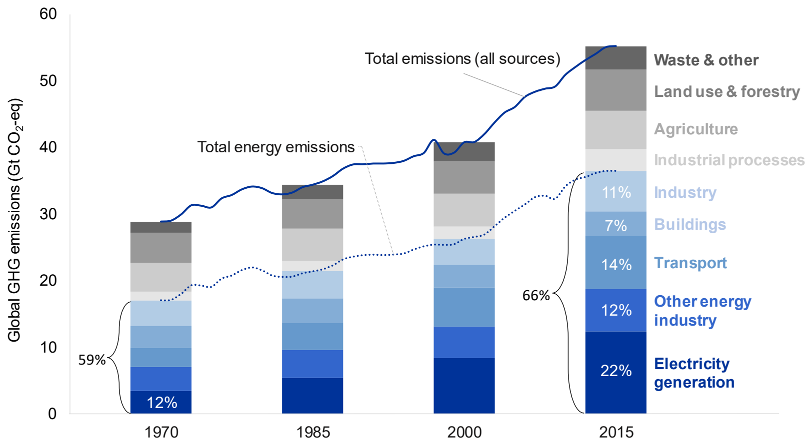
Advanced Nuclear Technologies to Decarbonize the Entire Energy Sector

Stefano Monti
Head of the Nuclear Power Technology Development Section
International Atomic Energy Agency

- The world is moving fast towards electrification….and NP already provides 1/3 of low carbon electricity



- But this is not sufficient:



There are "**hard to abate sectors**" that are hard to electrify: industry- steel, cement, heavy duty transport, …

- These sectors can be decarbonized with low carbon heat and hydrogen
- Nuclear Energy is the only low carbon energy source able to provide at industrial scale all the major energy vectors: *heat, electricity and hydrogen*
- Dispatchable
- ... and also in cogeneration mode

NPPs for district heating and water desalination

- **71 NPPs** – including a fast reactor - in the world already operated for non-electric applications
- **District Heating**: decades of experience, in Russia, Hungary, Switzerland, etc
- In June 2020, the new **Floating Nuclear Power Plant** Akademic Lomonosov, powered by two SMR units, provided 1st heat to Pevek district
- In November 2020, **Haiyang NPP** (AP1000) started delivering commercial district heating

Source: http://fnpp.info/

Source: IAEA PRIS (2020)

	Number of Reactors with NEA
TOTALS:	71
⊞ Desalination	10
⊞ District Heating	56
⊞ Process Heating	32

Haiyang begins commercial-scale district heat supply

20 November 2020

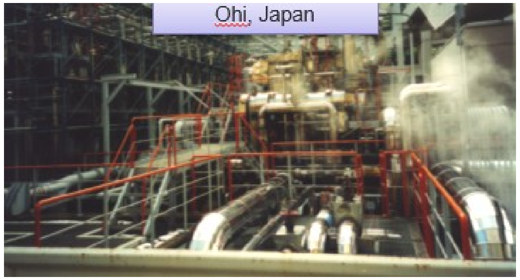
Share

China's Haiyang nuclear power plant in Shandong province has officially started providing district heat to the surrounding area. A trial of the project - the country's first commercial nuclear heating project - was carried out last winter, providing heat to 700,000 square metres of housing, including the plant's dormitory and some local residents.

A pipeline carrying heated water from the Haiyang plant (Image: SPIC)

Source: WNN

Nuclear desalination



Reactors: 10
Total reactor-years: >240

Desalination projects:

- **Japan:** desalination facilities coupled to PWRs (Genkai, Ohi, Takahama)
- **India:** hybrid demonstration plant at Madras PHWR
- **Pakistan:** thermal demonstration plant at KANUPP PHWR (CANDU)
- **Kazakhstan:** BN-350 fast reactor at Aktau (decomm) used for desalination

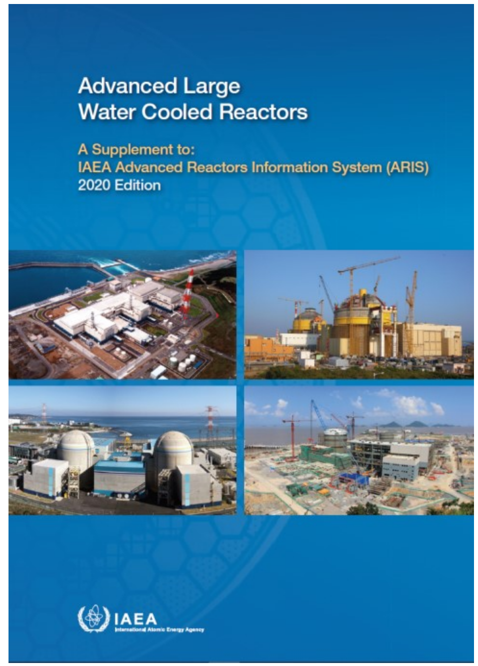
Advanced evolutionary NPPs for immediate deployment also for non-electric applications of nuclear power and able to operate in load following mode or integrated with renewables and energy storages

Canada	
EC6	740 MWe
ACR1000	1165 MWe

China	
HPR1000	1000 MWe
CAP1400	1400 MWe

France	
EPR	1630 MWe
ATMEA1	1200 MWe

Japan	
ABWR	1315 MWe
ATMEA1	1200 MWe
APWR	1700 MWe

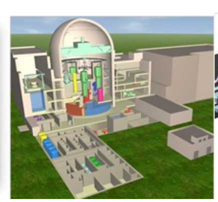
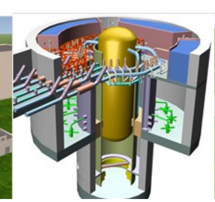


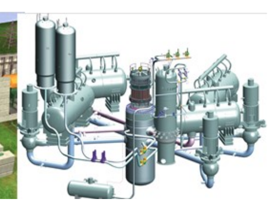
Republic of Korea	
APR1400	1416 MWe
OPR1000	993 MWe

Russian Federation	
VVER-1000	917 MWe
VVER-1200	1114 MWe
VVER-TOI	1175 MWe

United States of America	
ABWR	1315 MWe
AP1000	1117 MWe
ESBWR	1520 MWe

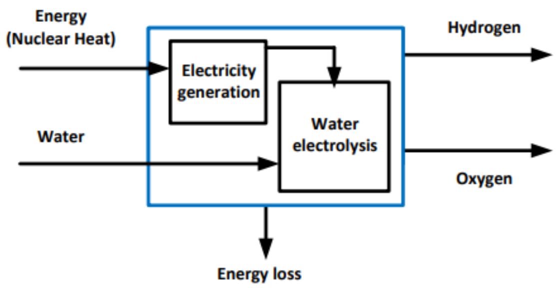


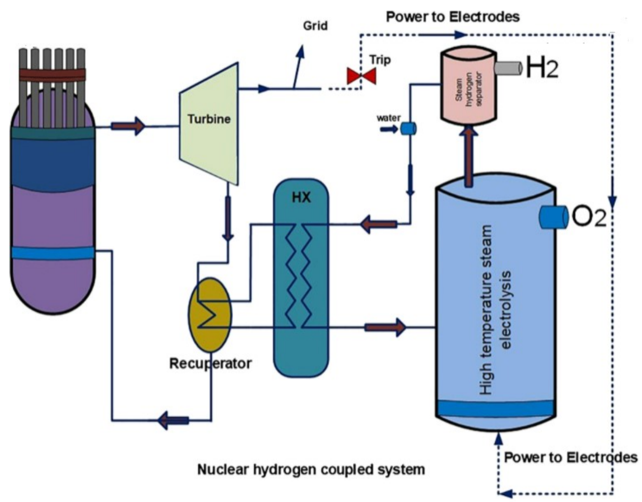


Using existing NPPs with electrolysers to produce hydrogen:

4 major projects funded by US DOE to advance flexible operation of LWRs with integrated H production systems (H2@Scale Initiative)	
FirstEnergy Solutions (FES)	demonstration project using a 2MW PEM electrolyser to be coupled with Davis Besse NPP, Ohio
Xcel Energy	1 MW HTSE coupled with the Prairie Island NPP
Arizona Public Service	study to evaluate the business potential of installing a reversible PEM electrolyser in Palo Verde NPP
Exelon	1 MW PEM electrolyser coupled with one of Exelon's BWR

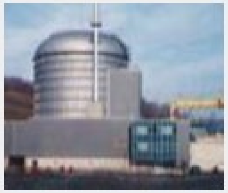


"These first-of-a-kind projects represent significant advances for improving the long-term economic competitiveness of the LWR industry. They will enable the production of commodities such as hydrogen in addition to electricity from commercial NPPs. These projects also accelerate the transition to a national hydrogen economy by contributing to the use of hydrogen as a storage medium for production of electricity, as a zero-emitting transportation fuel, or as a replacement for industrial processes that currently use carbon-emitting sources in hydrogen production."
Bruce Hallbert, director of DOE's LWR Sustainability Program



Process heat can be delivered by High Temperature Gas Reactors for which an extensive operating experience exists

Past Experience | Current test reactors

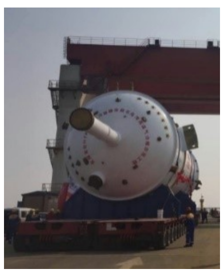
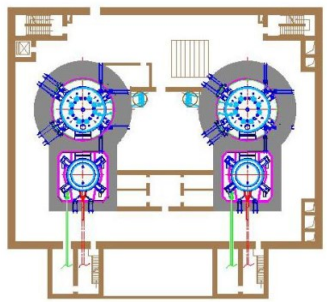
						
DRAGON	PB-1	AVR	FSR	THTR	HTTR	HTR-10
(1963-1976)	(1967-1974)	(1967-1988)	(1976-1989)	(1986-1989)	(since 1998)	(since 2000)
						

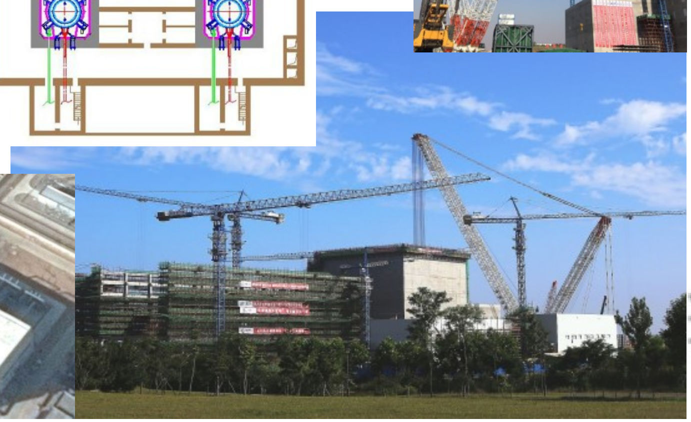
- Wealth of know-how available
- Mature technology ready for commercial deployment (in next decade) for temperatures up to ~850 ^{o}C

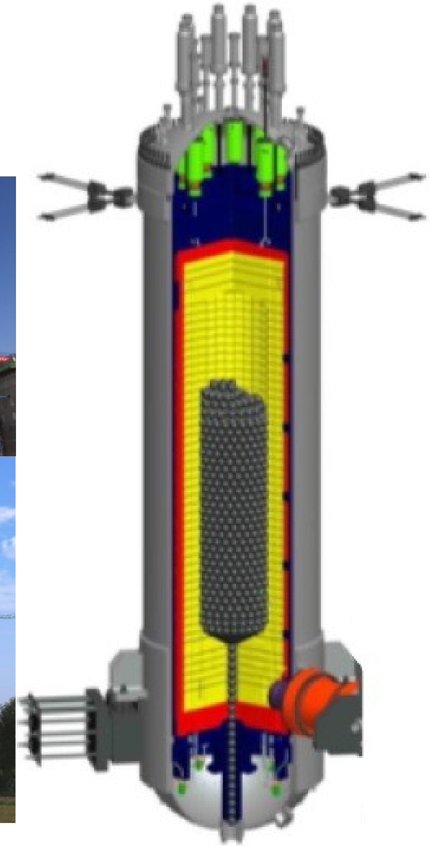
Advanced modular HTGRs: HTR-PM in China

HTR-PM construction of a commercial demonstration plant

- modular 2 x 250MWth
- operation in 2018
- Shidao Bay,
- Shandong province, China

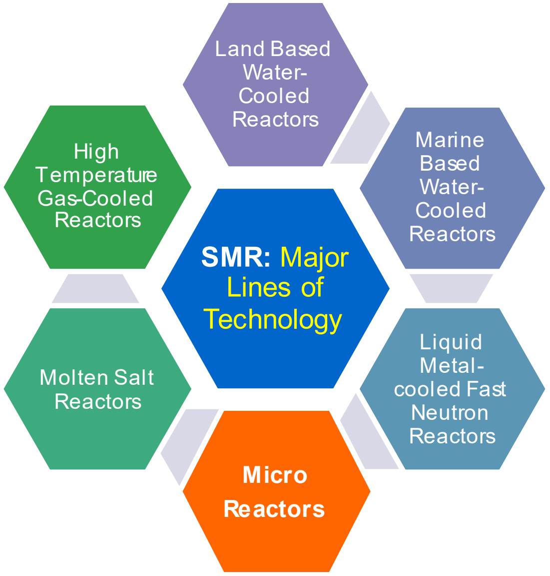


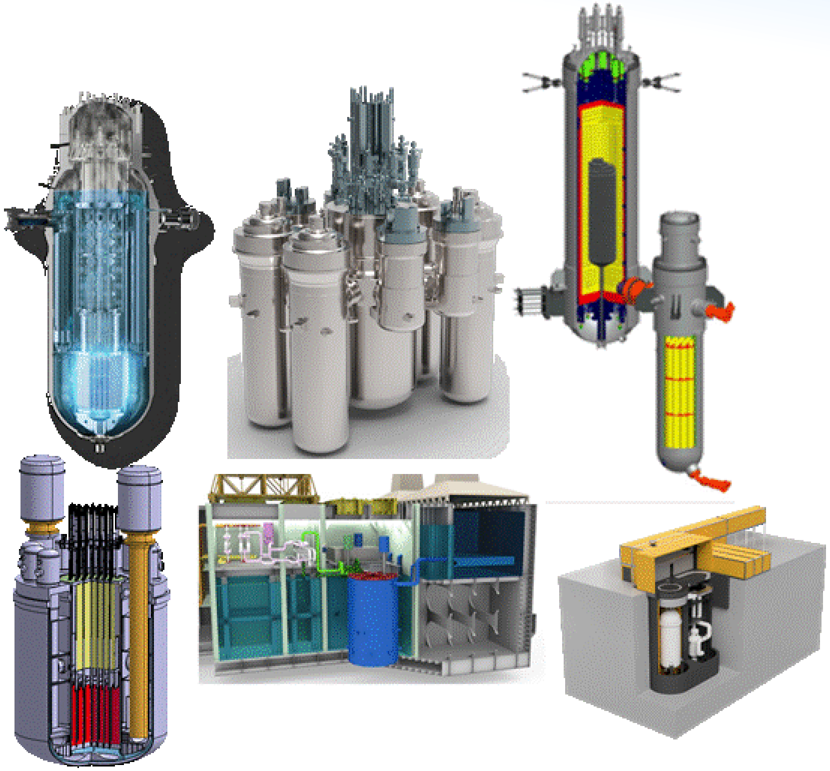


HTGRs - benefits

- Higher (↑20-50%) efficiency in electricity generation than conventional NNPs due to higher coolant outlet temperatures
- Potential to participate in the complete energy market with cogeneration and high temperature process heat application
  - ✓ Process steam for petro-chemical industry and future hydrogen production
  - ✓ Market potential substantial and larger than the electricity market
  - ✓ Allows flexibility of operation switching between electricity and process heat
- Significantly improved safety
  - ✓ Decay heat removal by natural means only, i.e. no meltdown
  - ✓ No large release - radioactivity contained in coated particle fuel
  - ✓ EPZ can be at the site boundary
- Position close to markets or heat users
  - ✓ Savings in transmission costs
- Can achieve higher fuel burnup (80-200 GWd/t)
  - ✓ Flexible fuel cycle and can burn plutonium very effectively

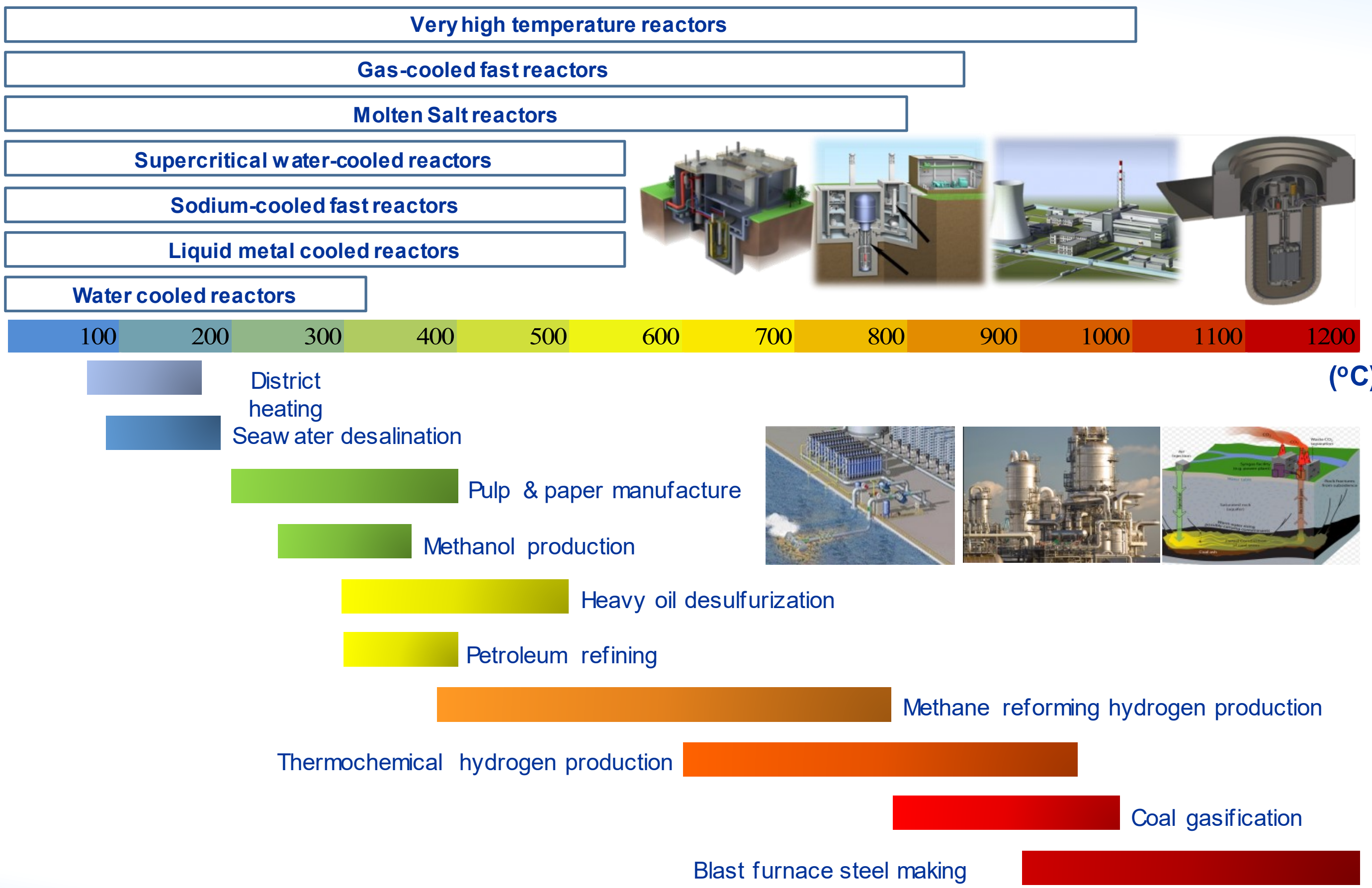
… not only SMR of HTGR type





Multipurpose applications of SMRs

Advanced Reactors for Non-Electric Applications



H2 production via thermochemical processes

- **Pure thermochemical cycles** (driven by thermal energy only):

  Sulphur-Iodine cycle (Japan, USA, China)

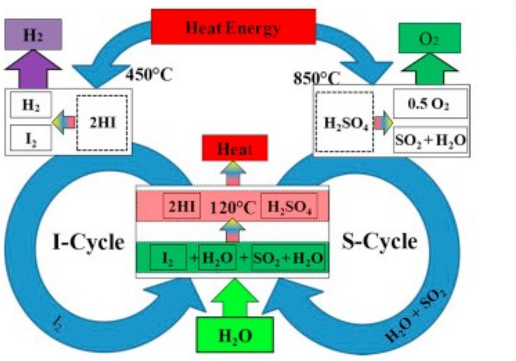
- **Hybrid thermochemical cycles** (driven by thermal at ~500C and one other form of energy such as electricity or photons):

  Hybrid Sulphur

  Copper-Chlorine cycle

  Magnesium-Chlorine

- High and very high temperature reactors are good candidates for thermo-chemical and hybrid cycles for nuclear hydrogen production



$$H_2SO_{4(aq)} \xrightarrow{heat(300-500^\circ C)} H_2O_{(g)} + SO_{3(g)}$$

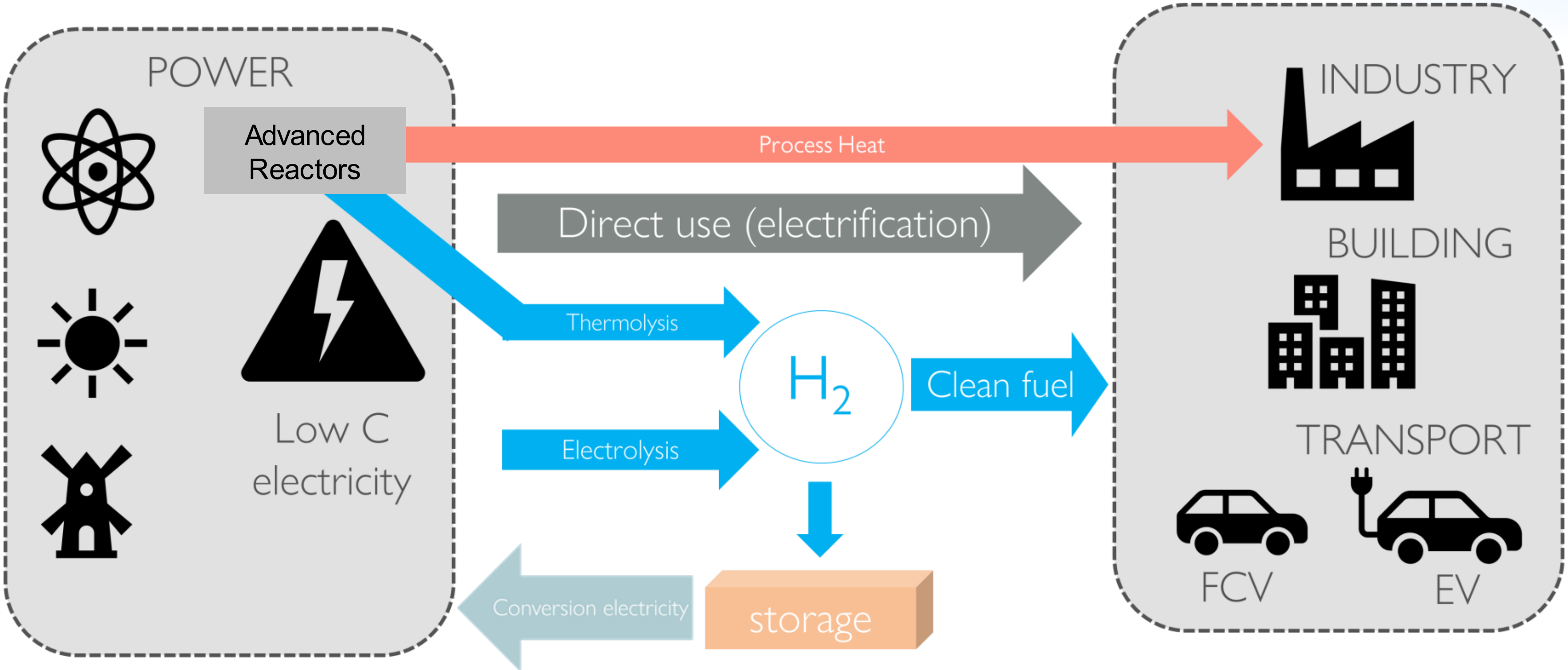
$$SO_{3(g)} \xrightarrow{heat(800-900^\circ C)} \frac{1}{2}O_{2(g)} + SO_{2(g)}$$

$$SO_{2(g)} + I_{2(g)} + 2H_2O_{(l)} \rightarrow 2HI_{(g)} + H_2SO_{4(aq)}$$

$$2HI_{(g)} \xrightarrow{heat(425-450^\circ C)} H_{2(g)} + I_{2(g)}$$

Coupling via Electricity, Heat and Hydrogen

NPPs: large Gen III reactors + Advanced reactors (incl. SMRs)



3 low-carbon energy vectors: electricity, heat, hydrogen

Take-aways

- Meeting the objectives of the Paris Agreement requires huge efforts - massive decarbonization is necessary
- IEA recently proposed a “path” to net zero – massive amounts of renewables, but also nuclear, and hydrogen
- Nuclear has a key role to play, complementing renewables – for electricity system decarbonization
- Contribution of nuclear to decarbonize the hard to abate sectors (heat, hydrogen) could be even more important, provided governments and industry accelerate innovation in advanced reactors incl. Small Modular Reactors
- Advanced reactors & SMRs have common challenges: standardization, harmonization of regulatory framework, competitiveness with other clean energy sources
- Of paramount importance:
  - to bridge the gap between reactor developers and end-users
  - Rapidly increase TRL and LRL: need to accelerate demonstration and dramatically reduce time to market
- IAEA is engaged to support Member States in all aspects of advanced reactors development and deployment

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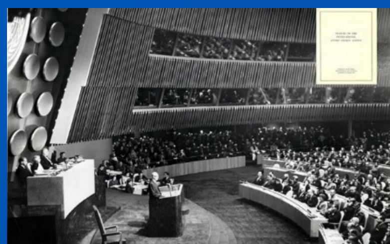
8 December 1953


1 to 23 October 1957


11 December 1957


1959


10 December 2005

1958 to 1979


23 August 1979

Atoms for peace and Development…

Thank you for your attention!

Contact:
Stefano MONTI
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Q&A

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Thank you for your attention. This webinar has now ended.

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