Small Modular Nuclear for the Chemical Industry: Cracking Atoms to Make Molecules

A Special Report

NexantECA

June 2024

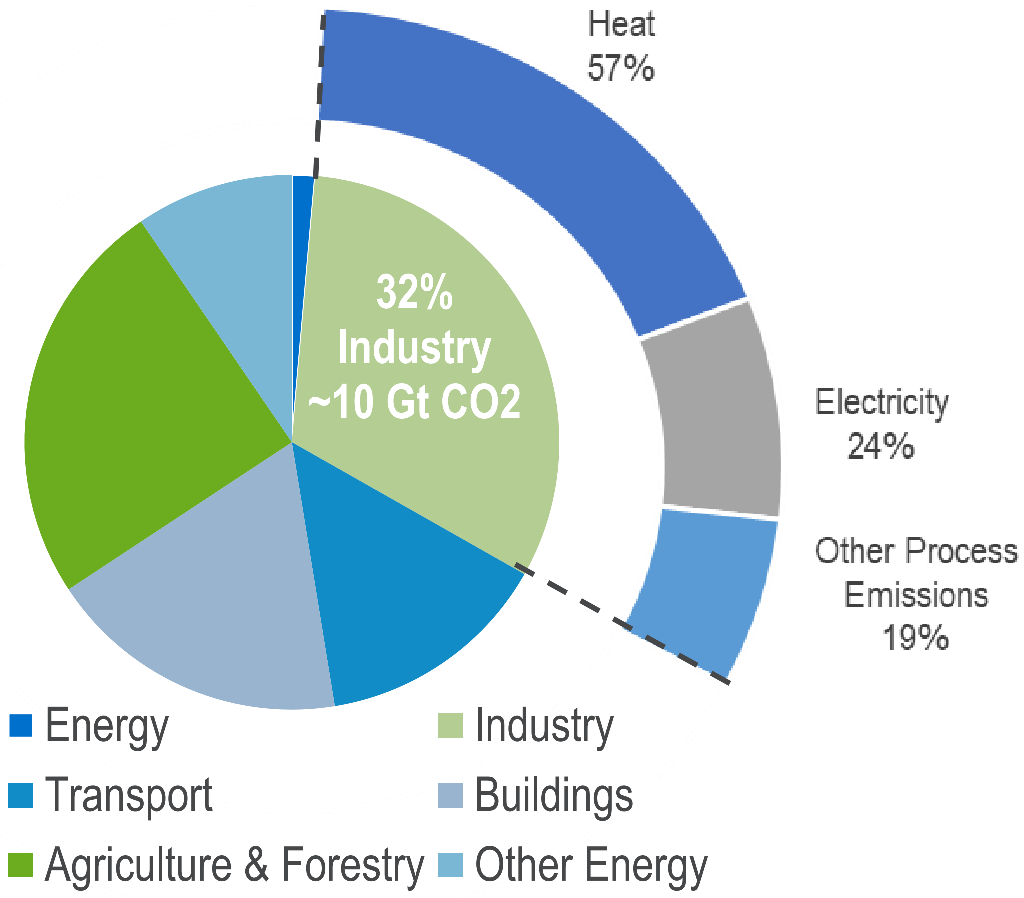
The net zero transition for industry will require shifting all process heat and electricity needs to low/zero carbon alternatives by 2050

Nuclear is a low carbon option for both heat and power

Key Advantages:

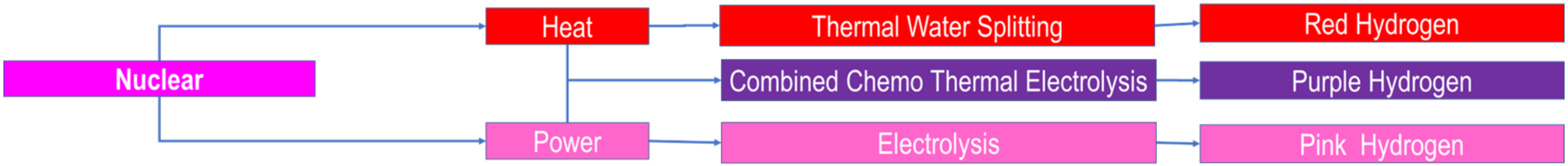
- Baseline generation for high reliability
- Able to address both electric power and process heat needs
- Well-established Low Lifecycle CO_2 Emissions
- Low land footprint
- Zero air pollution at point of use

Annual Global GHG Emissions by End-Use



Sources:
IEA World Emissions Dataset, 2021
IPCC AR5 Working Group 3 Report (2014)

Nuclear energy also offers a low-CI lifeline to the growing need for green H_2 – without the transmission-constrained geography of conventional renewable power

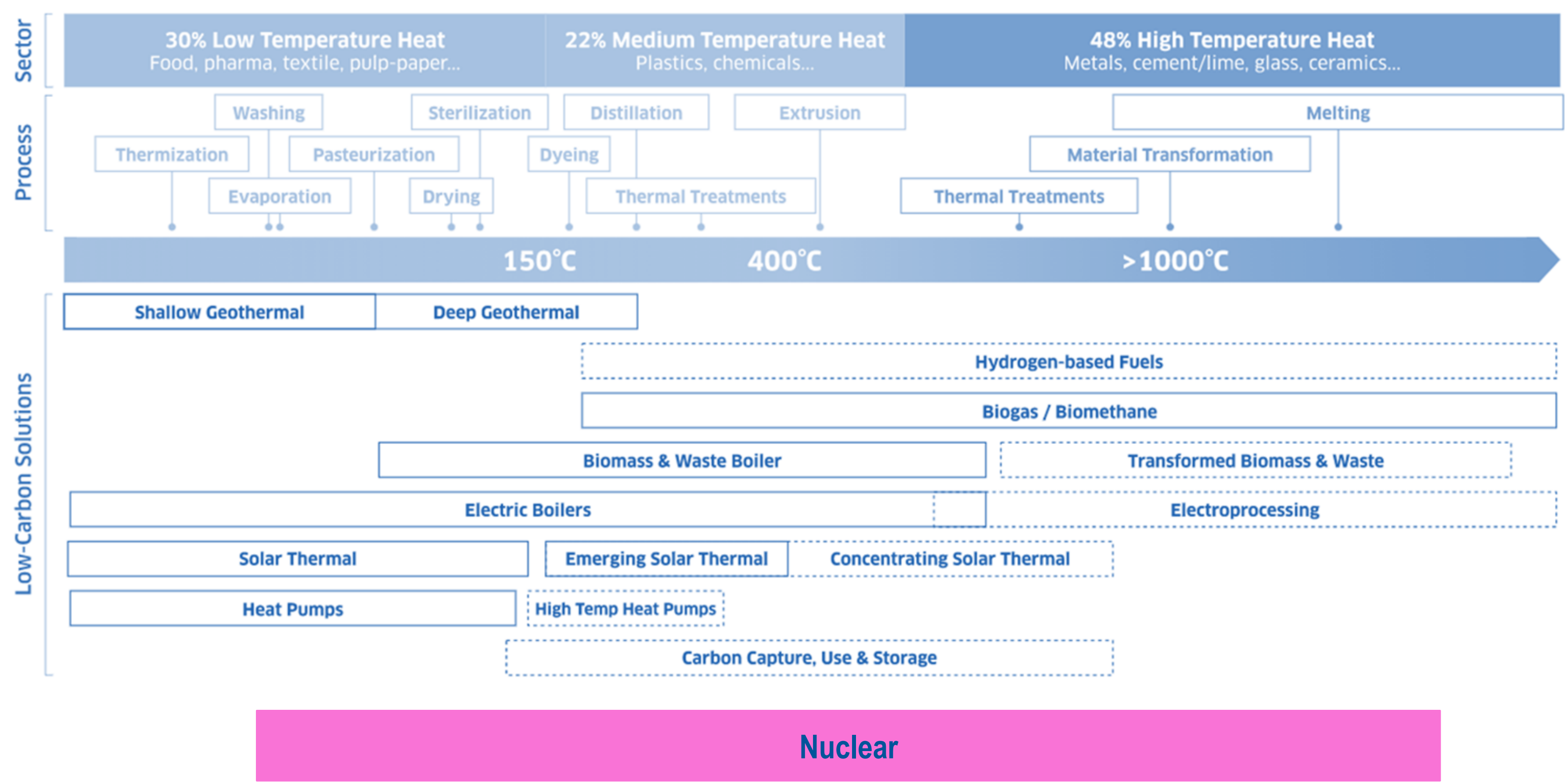


Nuclear Technologies Allow Access to Proven and Innovative Clean Hydrogen Processes

- Low-CI nuclear power is fungible; all conventional water electrolysis processes can be used with nuclear to make “pink hydrogen”
- Nuclear is ideal for emerging high-temperature solid oxide electrolysis (for both H_2 and CO), which features much greater efficiency than the current standard but requires clean heat sources
- Nuclear thermolysis processes (e.g., Sulfur-Iodine cycle) for hydrogen become viable with Gen IV high temperature reactors
- Combined water electrolysis methods (e.g., Westinghouse Cycle) can take advantage of abundant thermal energy and greatly reduced electricity consumption in Gen IV high temperature reactors

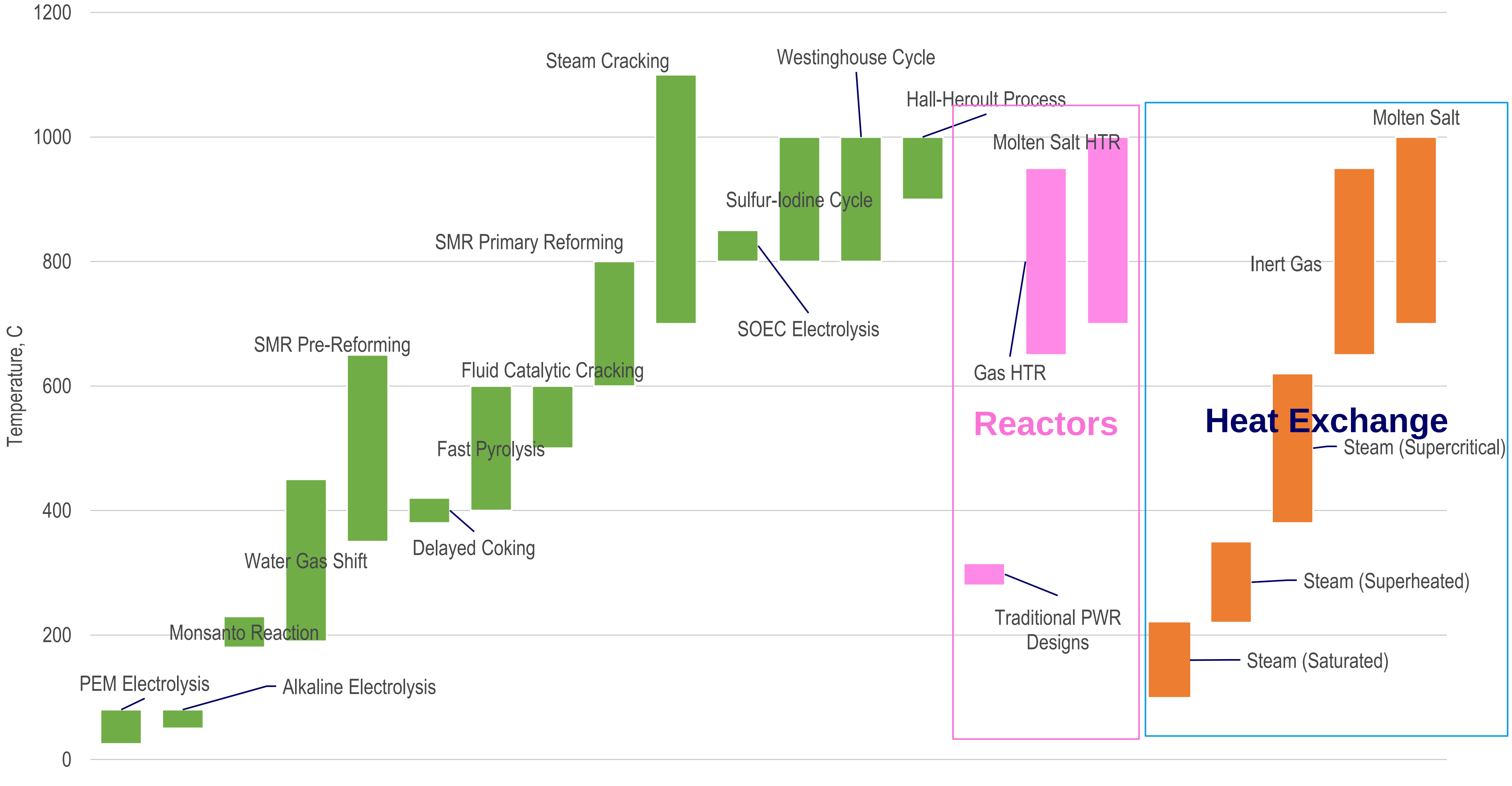
Nuclear is a proven option for providing high grade thermal energy without electricity as an intermediate

- The green transition means that the cost of high-grade thermal energy may no longer be cheaper than electricity due to a paucity of low/zero carbon options
- When compared against precombustion carbon capture, solar thermal, and electrical heating options, thermal power becomes significantly more expensive relative to electricity than previously
- This provides a niche for nuclear power…



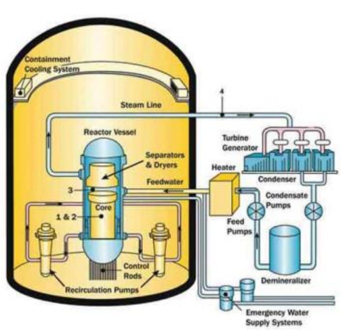
Nuclear power can provide for process thermal energy needs but not all reactors or heat transfer mechanisms can work

Process Technology Applications Require Newer High-Temperature Reactor Designs and Exotic Heat Exchange Media

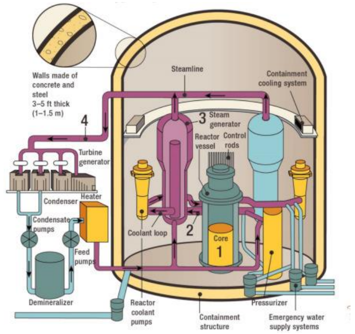


New generations of small, modular nuclear reactor (SMR) designs promise low-cost deployment packages in the range of hundreds of megawatts potentially suited for individual facilities

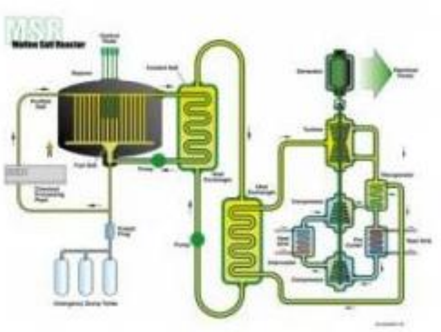
Design Types of Major Nuclear SMRs



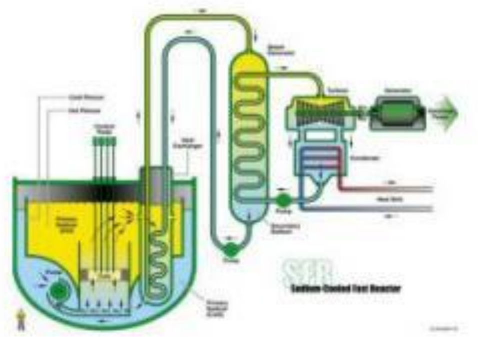
Boiling Water Reactor (BWR)



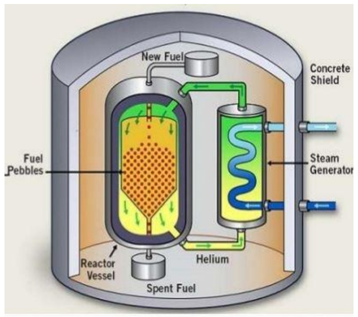
Pressurized Water Reactor (PWR)



Molten Salt Reactor (MSR)

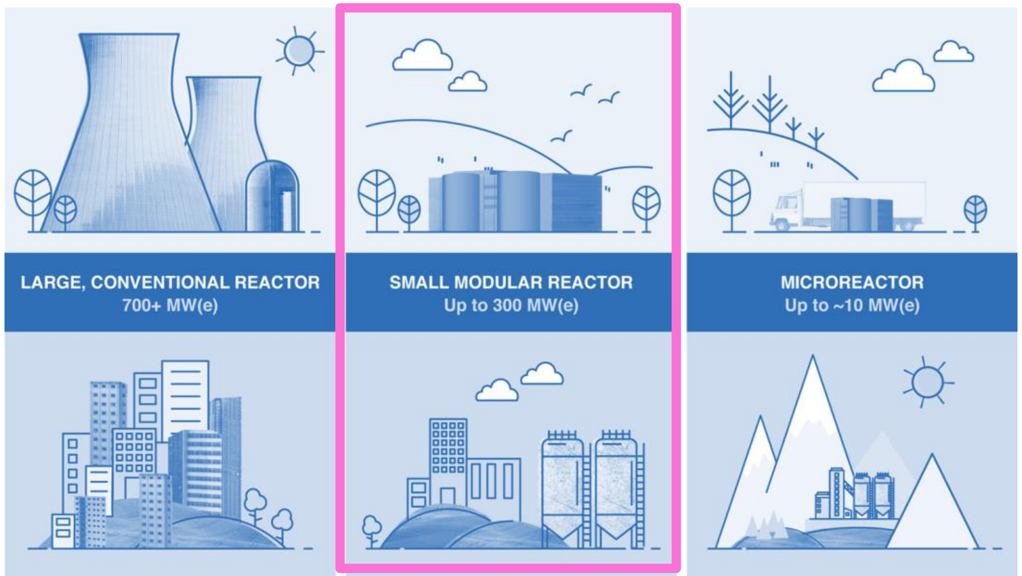


Sodium Fast Neutron Reactor



High Temperature Gas-Cooled Reactor (HGTR)

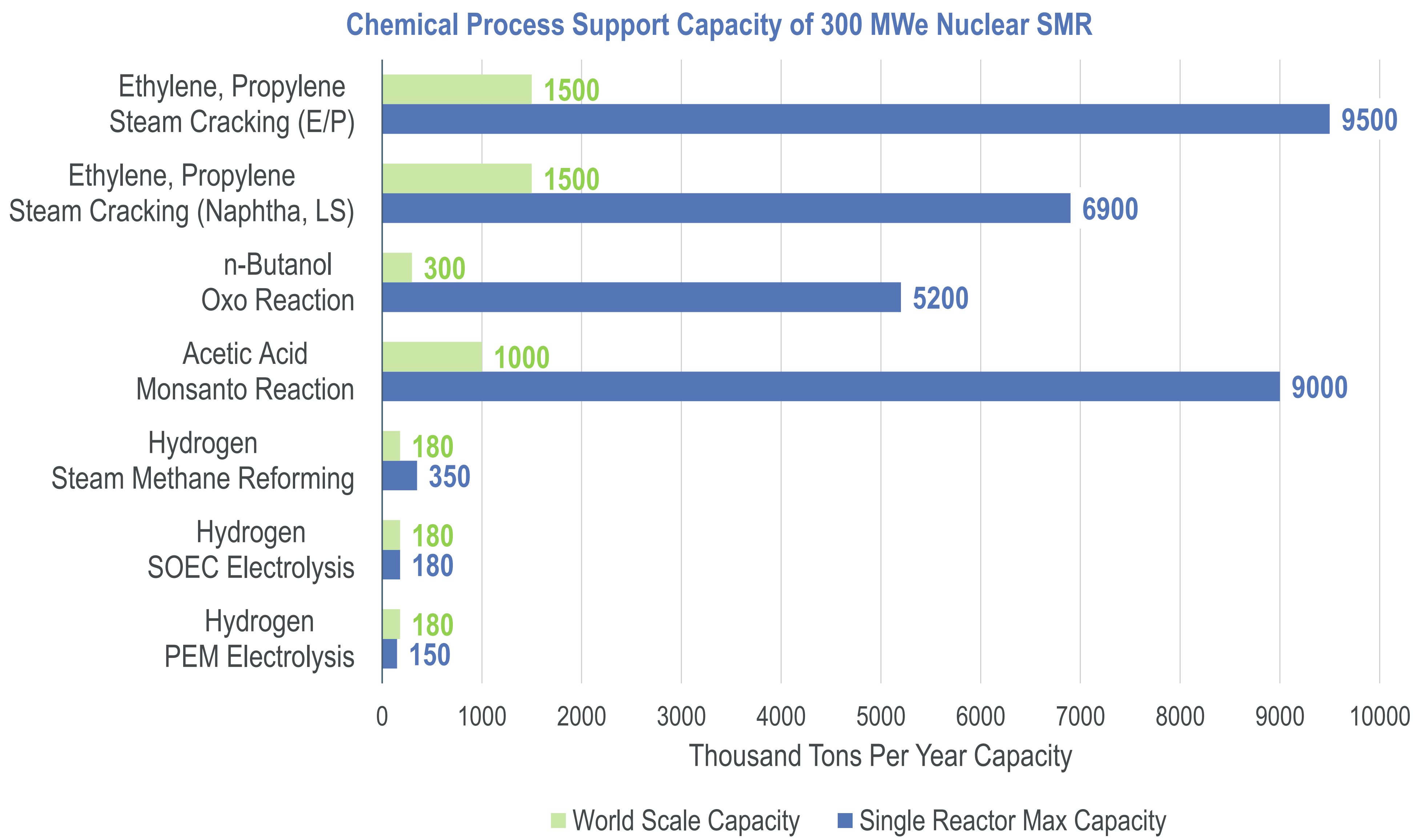
Scale of Reactors



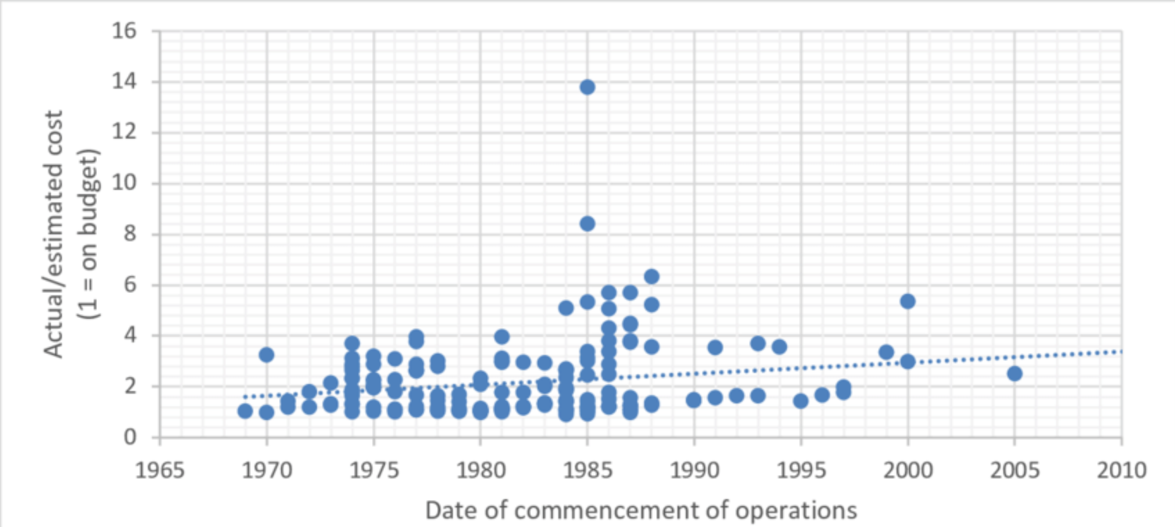
Some Risk Remains...

- Few current worldwide deployments
- Cost reductions in serial production not proven
- Poor track record of Gen III and Gen III+ reactor deployment due to cost overruns

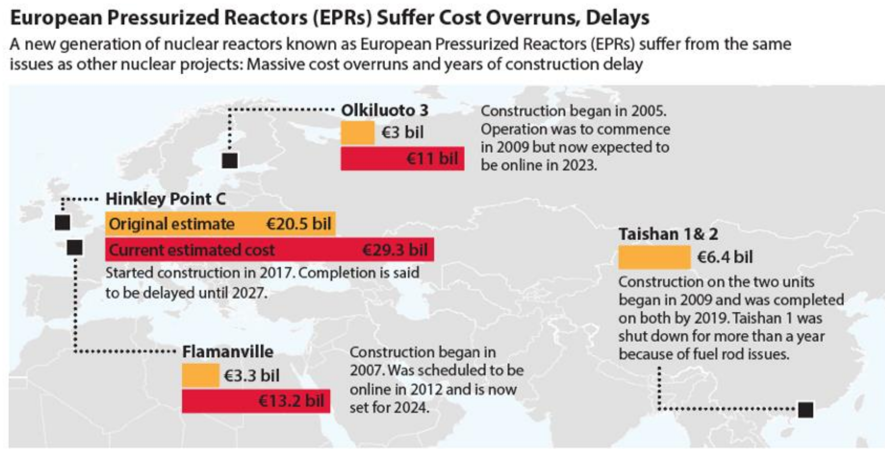
However, modular reactor designs are fixed in scale, and may be more suited to large manufacturing complexes rather than standalone plants



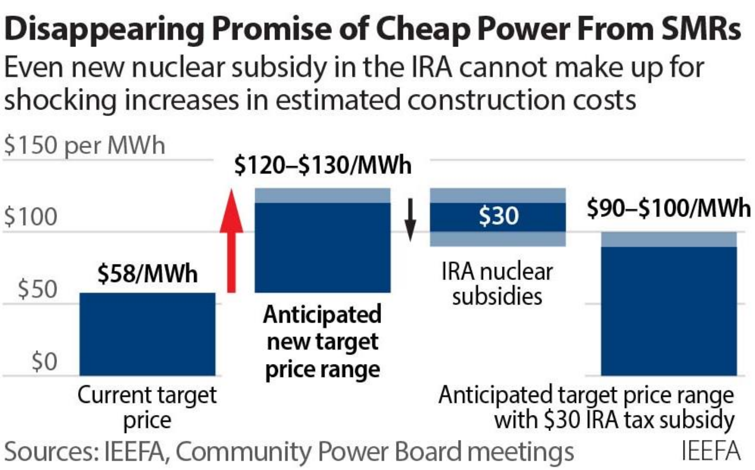
A key question for the process industries is cost – over the past 50 years, nuclear has had a very poor record of capital cost overruns for deployment and SMRs threaten the same



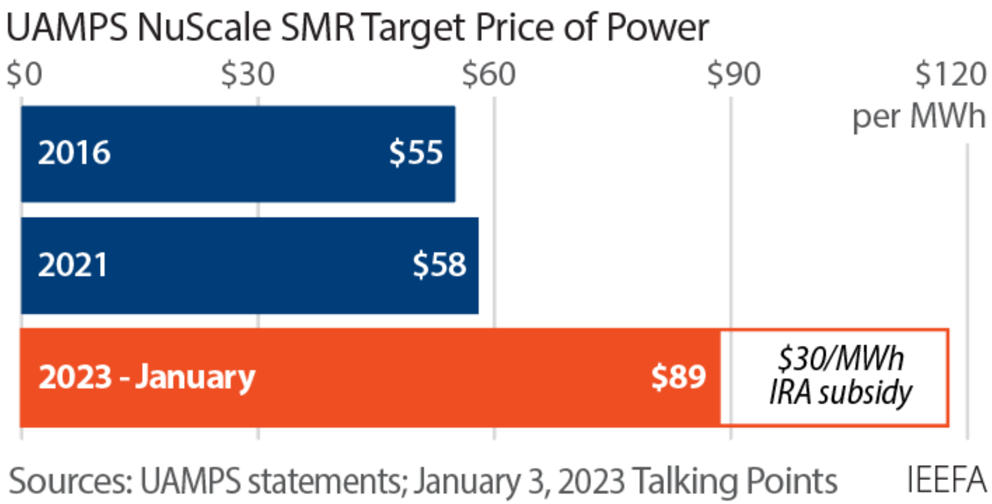
Buzier, A., Flyvbjerg, B., et al. "Quantiative Cost and Schedule Risk Analysis of Nuclear Waste Storage", SSRN Electronic Journal, 2018



Source: https://ieefa.org/resources/european-pressurized-reactors-eprs-next-generation-design-suffers-old-problems



Source: https://energypost.eu/small-modular-reactor-cost-overruns-the-same-old-problems-haunt-new-nuclear-in-utah/



Source: https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor

NexantECA's special report aims to answer key questions about small modular nuclear in the chemical industry

NexantECA will explore the compatibility of major electric and thermal energy using processes with nuclear reactors:

- What process adaptations are needed
- What reactor designs are available, their deployment history, and their compatibility with thermal energy needs
- How operational factors with nuclear reactors and major processes align or conflict

The study will also focus on key economic questions:

- What technology risks are associated with deploying nuclear SMRs in the process industries?
- What are manufacturers cost claims and what would the implications be in major electric and thermal energy-intensive processes?
- What are the sources of the capital cost escalation seen in recent deployment of nuclear reactors, and which factors apply to the chemical and fuel industries?
- What are manufacturers' claims of capital cost reduction over the course of serial deployment, and can these claims be corroborated?

NexantECA has approached this report in our capacity as techno-economic and cost engineering experts, rather than as nuclear engineers. As such we will not critically comment on the safety, efficacy, or deep regulatory aspects of nuclear SMRs in this report

NexantECA's detailed nuclear SMR developer coverage includes credible technology offerings nearing commercialization by 2034, including all those in development with chemical companies

Technology Name	Single Module Capacity (MWe)	Installation Capacity	Type	Developer
NuScale Voygr	77	460, up to 925	Pressurized Water Reactor	NuScale
SMR-300	150	300	Pressurized Water Reactor	Holtec (SMR, LLC)
AP-300	300	300	Pressurized Water Reactor	Westinghouse
Rolls Royce SMR	470	470	Pressurized Water Reactor	Rolls Royce SMR LLC
BWRX-300	300	300	Boiling Water Reactor	GE Hitachi
Xe-100	80	320	High Temperature Gas-cooled	X-Energy
HTR-PM	105	650	Sodium Fast Neutron	CNNC-Tsinghua

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USA

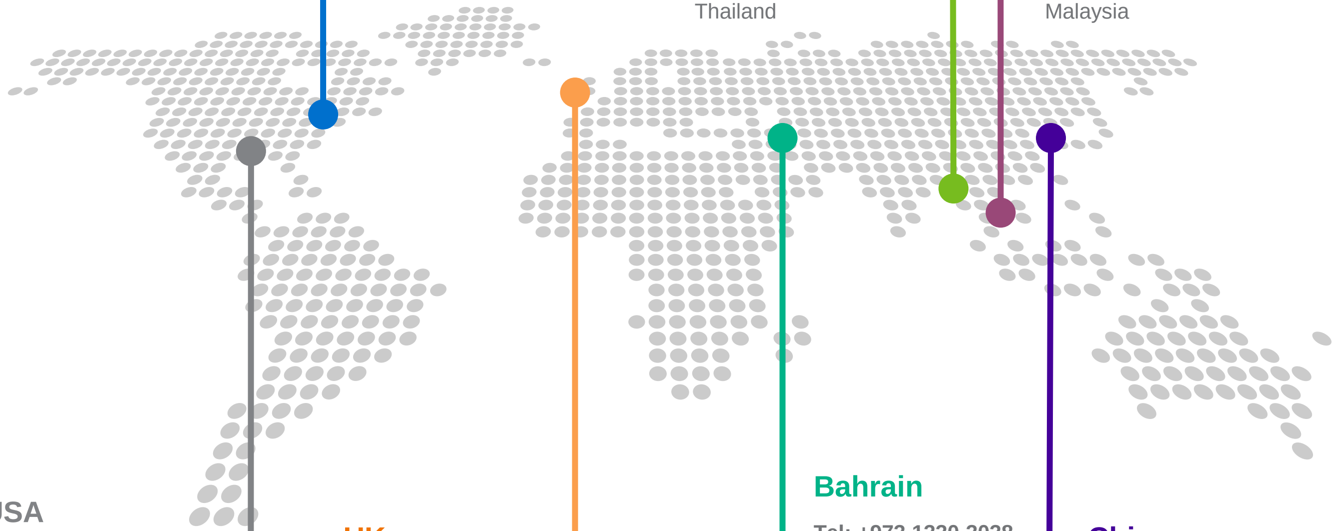
Tel: +1 914 609 0300
44 S Broadway
5th Floor, White Plains
NY 10601-4425
USA

Thailand

Tel: +662 793 4600
22nd Floor, Rasa Tower I
555 Phahonyothin Road
Kwaeng Chatuchak
Khet Chatuchak
Bangkok 10900
Thailand

Malaysia

Tel: +60 322 98 7212
Level 28
The Gardens South Tower
Mid Valley City
Lingkaran Syed Putra
Kuala Lumpur 59200
Malaysia



USA

Tel: +1 832 462 7176
609 Main Street, Floor 25
c/o WeWork
Houston
Texas 77002
USA

UK

Tel: +44 20 7950 1600
110 Cannon Street
London
EC4N 6EU
United Kingdom

Bahrain

Tel: +973 1330 3038
Level 49, Suite 4902
West Tower
Bahrain Financial
Harbour
PO Box 60686
Bahrain

China

Tel: +86 21 6050 1119
Room 02-15, 2F Block 1
58 Yao Yuan Road
Pudong, Shanghai, 200126
China

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