TECHNOLOGY FACTSHEET

NUCLEAR ENERGY: GENERATION-IV NUCLEAR REACTORS FOR HYDROGEN PRODUCTION

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Sector	Hydrogen supply
ETS / Non-ETS	ETS
Type of Technology	Nuclear energy
Description	Generation-IV nuclear power plants represent a set of advanced reactor designs that are currently going through extensive research for commercial applications. Generation-IV nuclear energy systems include the nuclear reactor, its energy conversion systems and necessary fuel-cycle technologies. The Generation IV International Forum (GIF) selected six systems as generation-IV technologies: gas-cooled fast reactor (GFR), lead-cooled fast reactor (LFR), molten salt reactor (MSR), sodium-cooled fast reactor (SFR), supercritical-water-cooled reactor (SCWR) and very high-temperature reactor (VHTR) (NEA, 2014). According to IAEA (2013), the VHTR system is considered the prime candidate for large scale hydrogen production. The VHTR is a graphite-moderated, helium-cooled reactor with thermal neutron spectrum. It can be used for heat applications such as process heat for hydrogen production - the heat application process is generally coupled with the reactor through an intermediate heat exchanger. The VHTR can produce hydrogen by using thermochemical processes, combined thermochemical and electrolysis, high temperature steam electrolysis, or from heat, water and natural gas by applying the steam reformer technology (NEA, 2014).
TRL level 2020	TRL 5
	The start of the deployment of all generation-IV reactors is not foreseen before 2030. Over the past decade, R&D funding has not been equivalent for the different generation-IV systems and the degree of technical progress has not been uniform. Therefore by 2020, some of these technologies will still be situated in between the 'viability' and 'performance' phases, whereas basic concepts are being tested under relevant conditions and engineering-scale processes are optimised under prototypical conditions, respectively. By that time, none of them would have reached the 'demonstration' phase, whereas a detailed design is completed and licensing, construction and operation of the system are carried out with the aim of bringing it to the commercial deployment stage. In particular, heating of chemical reactors by helium is a departure from current industrial practice and needs specific R&D and demonstration. The viability of using nuclear process heat to produce hydrogen needs further study. Any contamination of the product will have to be avoided. Development of heat exchangers, coolant gas ducts and valves will be necessary for isolation of the nuclear island from the production facilities (NEA, 2014).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MW		850								
			300			-			1,500		
Potential	Global	MW	Current			2030			2050		
			-			Unlimited			Unlimited		
			-	–	-	-	–	-	-	–	-
Market share	Electricity production in OECD Europe	%	25			N/A			N/A		
			25	–	25	-	–	-	-	–	-

Capacity utlization factor		0.90
Full-load running hours per year		8,000.00
Unit of Activity	PJ/year	
Technical lifetime (years)		60.00
Progress ratio		0.90
Hourly profile	No	
Explanation	The main reference of capacity represents the rounded average plant capacity (MWe) from leading advanced reactor companies that are currently pursuing commercialization (EIRP, 2017). The potential for the generation-IV technology is regarded as unlimited and the market share value of 25% is attributed to the current share of nuclear energy from electricity production within OECD EU (including less advanced technologies i.e. generation-III) (NEA, 2015). The capacity utilization, lifetime and full-load running hours are based on the specifications for JAEA's VHTR for hydrogen production 'GTHTR300C' (IAEA, 2013). In terms of progress ratio, according to Lang, P. A. (2017), "if both the pre-1970s learning rates and the Linear or Accelerating deployment rates had continued, OCC in 2015 could have been around 2 to 10% of actual", whereas OCC refers to Overnight Construction Costs.	

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MW	N/A			2.76			2.76		
		-	–	-	1.50	–	4.27	1.50	–	4.27
Other costs per year	mln. € / MW	N/A			N/A			N/A		
		-	–	-	-	–	-	-	–	-
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	N/A			0.12			0.12		
		-	–	-	0.08	–	0.18	0.08	–	0.18
Variable costs per year	mln. € / MW	N/A			-			-		
		-	–	-	*Min*	–	*Max*	*Min*	–	*Max*

Costs explanation	Costs are specified from 2030 onwards as the start of the deployment of all generation-IV reactors is not foreseen before 2030 (NEA, 2015). The main reference on costs is based on a recent study from EIRP (2017) where costs are estimated for Advanced Nuclear Plants (on a NOAK or Nth-of-a-kind basis i.e. mature widely-deployed systems) using the GIF plant cost accounting framework. In the study, costs are estimated on average as $3,782/kW (used for main reference) with a minimum of $2,053/kW and a maximum of $5,855/kW. Capital costs consist of direct construction costs, indirect services costs, owner's costs and supplementary costs (EIRP, 2017). Pre-construction costs and financing costs have been deducted from the total capital costs, resulting on $3,063/kW as main reference. Fixed operational costs include O&M costs that represent ~74% of the total operating costs that are $21/MWh on average, and $14/MWh as minimum and $14/MWh as maximum (EIRP, 2017).

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:*	PJ	N/A			-1.00			-1.00		
	Hydrogen		-	–	-	-1.00	–	-1.00	-1.00	–	-1.00
	Uranium	PJ	N/A			2.00			2.00		
			-	–	-	2.00	–	2.44	2.00	–	2.44
		PJ	N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-
		PJ	N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-

Energy in- and Outputs explanation	Energy in- and outputs are specified from 2030 onwards as the start of the deployment of all generation-IV reactors is not foreseen before 2030 (NEA, 2015). The main reference for energy in- and outputs is based on JAEA's VHTR for hydrogen and electricity cogeneration 'GTHTR300C' (IAEA, 2013) with a hydrogen production of 120 tonnes/day (World Nuclear Association, 2017) and hydrogen conversion efficiency of 50% (IAEA, 2013). A report from the IAEA/ARIS (2011) gives a hydrogen conversion efficiency of 41% for the same technology and hydrogen production of 126 tonnes/day.

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS)

	Substance	Unit	Current			2030			2050		
Emissions			N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-
			N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-
			N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-
			N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-

Emissions explanation	The process of nuclear fission does not produce any CO2 or other greenhouse gas emissions (OECD, 2015), therefore nuclear power plants do not emit any greenhouse gas emissions directly during operation.

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