TECHNOLOGY FACTSHEET

NUCLEAR ENERGY: GENERATION-III NUCLEAR REACTORS

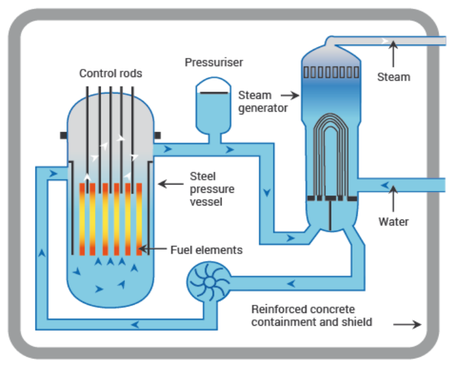
Date of factsheet	26-7-2018
Author	Silvana Gamboa Palacios
Sector	Electricity generation
ETS / Non-ETS	ETS
Type of Technology	Nuclear energy

Description

A nuclear reactor produces and controls the release of energy from splitting the atoms of certain elements. Then, the energy released in the nuclear power reactor is used as heat to make steam to generate electricity. Most nuclear reactors use enriched uranium as a nuclear fuel.

The most common nuclear reactor design is the pressurised water reactor (PWR), which has water under pressure at over 300°C in its primary cooling/heat transfer circuit and generates steam in a secondary circuit. The boiling water reactor (BWR) design however, makes steam in the primary circuit above the reactor core, at similar temperatures and pressure. Both types use water as both coolant and moderator, to slow neutrons (World Nuclear Association, 2018).

A Pressurized Water Reactor (PWR)



Source: World Nuclear Association (2018)

TRL level 2020

TRL 9

Most of the anticipated growth in nuclear capacity in the coming decades will come with the deployment of large generation-III reactors (in the range 1 000-1 700 MW unit size), either PWRs or BWRs. Generation-III reactors have enhanced safety features and higher efficiency, as well as improved fuel economy in comparison with generation-II reactors (NEA, 2015).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MW		1,600								
			500			-			3,300		
Potential		MW	Current			2030			2050		
			Unlimited			Unlimited			Unlimited		
			-	–	-	-	–	-	-	–	-
Market share	OECD Europe	%	25			N/A			N/A		
			25	–	25	-	–	-	-	–	-
Capacity utlization factor	0.92										
Full-load running hours per year	8,000										
Unit of Activity	PJ/year										
Technical lifetime (years)	60.00										
Progress ratio	0.90										
Hourly profile	No										

Explanation

The main capacity refers to the EPR (European Pressurised Water Reactor) AREVA design with 1,650 MWe net capacity (AREVA, 2012). The EPR is designed to achieve 92% availability averaged over the entire 60 years of its operation lifetime (IET, 2017). IEA/NEA (2015) states a capacity factor of 85% for a nuclear power plant.

The potential for the generation-III 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 (NEA, 2015). A progress ratio of 90% is stated as 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 related to Overnight Construction Costs.

COSTS

Year of Euro: 2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MW	4.37			4.12			3.77		
		3.51	–	7.10	3.51	–	7.10	3.51	–	7.10
Other costs per year	€ / MWh	9.07			9.07			9.07		
		5.29	–	9.07	5.29	–	9.07	5.29	–	9.07
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	0.09			0.08			0.06		
		0.05	–	0.16	0.05	–	0.16	0.05	–	0.16
Variable costs per year	€ / MWh	2.51			2.51			2.51		
		2.51	–	11.44	2.51	–	11.44	2.51	–	11.44

Costs explanation

The main source is based on a study from the JRC (2014) whereas costs are projected for 2010-2050. The CAPEX estimate of (€2013)4,350/kWe includes the following costs: civil and structural costs, major equipment costs, balance of plant costs, electrical and I&C supply and installation, project indirect costs, development costs and interconnection costs (JRC, 2014). The costs data is complemented with a study from the (MIT, 2018) whereas a nuclear nominal cost that concerns an 'nth-of-a-kind' (NOAK) nuclear power plant is estimated as (€2018)$5,500/kW overnight construction cost (OCC) without interest during construction.

For the high-end value, OCC are estimated up to (€2018)$8,140/kW (MIT, 2018). For the low-end value, the European Commission carried out a study on the "Synthesis on the economics of nuclear energy" based on a sample of 137 data points collected from 28 different sources from 2007 to 2012 (D'haeseleer, W.D., 2013). Here, the total investment costs at the lower-end are (€2012)3,400/kW and refer to OCC of a generation-III nuclear plant deployed in a country for the first time but that is already operational somewhere else (i.e. FOAK or First-of-a-Kind). Overnight constructions costs include: civil and structural costs, mechanical equipment supply and installation, electrical instrumentation and control, project indirect costs, owners costs and a provision for contingency. Operational costs include O&M costs. Other costs represent the fuel costs. According to IEA/NEA (2015), decommissioning costs are estimated to be 15% of the OCC.

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Electricity	PJ	-1.00			-1.00			-1.00		
			-1.00	–	-1.00	-1.00	–	-1.00	-1.00	–	-1.00
	Uranium	PJ	1.59			1.59			1.59		
			1.49	–	2.86	1.49	–	2.86	1.49	–	2.86
		PJ	N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-
		PJ	N/A			N/A			N/A		
			-	–	-	-	–	-	-	–	-

Energy in- and Outputs explanation

The thermal efficiency is the ratio of gross MWe to thermal MW, this relates to the difference in temperature between the steam from the reactor and the cooling water. It is often 33-37% for generation-III nuclear power reactors (World Nuclear Association, 2018).

The thermal efficiency of the EPR AREVA design is 37% (AREVA, 2017) and it is used for the main reference. From 2030 onwards, an improvement in efficiency to 38% of generation-III is estimated (JRC, 2014).

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.

REFERENCES AND SOURCES

AREVA (2017). The EPR reactor: the reference for New Build. Link: http://us.areva.com/home/liblocal/docs/Solutions/supplier/NewEPRReactorBrochure2012.pdf

JRC (2014). Energy Technology Reference Indicator (ETRI) projections for 2010-2050. Joint Research Centre of the European Commission.

MIT (2018). The Future of Nuclear Energy in a Carbon-Constrained World.

D'haeseleer, W.D. (2013). Synthesis on the Economics of Nuclear Energy. European Commission.

IEA, NEA (2015). Projected Costs of Generating Electricity.

IET (2017). Nuclear Reactor Types. The Institution of Engineering and Technology (IET).

NEA (2015). Technology Roadmap - Nuclear Energy.

OECD (2015). Nuclear Energy: Combating climate change. NEA.

Peter A. Lang (2017). Nuclear Power Learning and Deployment Rates; Disruption and Global Benefits Forgone.

World Nuclear Association, 2018. Nuclear Power Reactors. Link: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/nuclear-power-reactors.aspx

World Nuclear Association, 2018. The economics of nuclear power. Link: www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx