**TECHNOLOGY FACTSHEET**

ECN › TNO innovation for life

# NUCLEAR ENERGY: GENERATION-IV NUCLEAR REACTORS FOR ELECTRICITY AND HYDROGEN PRODUCTION

| | |
|---|---|
| Date of factsheet | 3-8-2018 |
| Author | Silvana Gamboa Palacios |
| Sector | Electricity generation |
| | 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.<br><br>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 equitable 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 |
| Unit of Activity | PJ/year |
| Technical lifetime (years) | 60.00 |
| Progress ratio | 0.90 |
| Hourly profile | |
| 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).<br><br>The capacity utilization, lifetime and full-load running hours are based on the specifications for JAEA's VHTR for hydrogen and electricity cogeneration '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 related to Overnight Construction Costs. |

## COSTS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year of Euro | 2015 | | | | | | | | |
| | Euro per Functional Unit | Current | | | 2030 | | | 2050 | |
| Investment costs | mln. € / MW | N/A | | | N/A | | | N/A | | |
| | | - | – | - | - | – | - | - | – | - |
| Other costs per year | mln. € / MW | N/A | | | N/A | | | N/A | | |
| | | - | – | - | - | – | - | - | – | - |
| Fixed operational costs per year (excl. fuel costs) | mln. € / MW | N/A | | | N/A | | | N/A | | |
| | | - | – | - | - | – | - | - | – | - |
| Variable costs per year | mln. € / MW | N/A | | | N/A | | | N/A | | |
| | | - | – | - | - | – | - | - | – | - |
| Costs explanation | All costs are specified under the technology factsheet for generation-IV nuclear reactors for hydrogen production. | | | | | | | | |

## ENERGY IN- AND OUTPUTS

| | Energy carrier | Unit | Current | | | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy carriers (per unit of main output) | *Main output:* Electricity | PJ | N/A | | | -1.00 | | | -1.00 | | |
| | | | - | – | - | -1.00 | – | -1.00 | -1.00 | – | -1.00 |
| | Hydrogen | PJ | N/A | | | -0.36 | | | -0.36 | | |
| | | | - | – | - | -0.46 | – | -0.36 | -0.46 | – | -0.36 |
| | Uranium | PJ | N/A | | | 2.71 | | | 2.71 | | |
| | | | - | – | - | 2.26 | – | 3.10 | 2.26 | – | 3.10 |
| | | 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).<br><br>The main reference for energy in- and outputs is based on JAEA's VHTR for hydrogen and electricity cogeneration 'GTHTR300C' (IAEA, 2013) with a net output of 202 MWe and an average amount of hydrogen of 24,000 Nm3/hr, a thermal efficiency of 50%. A report from the IAEA/ARIS (2011) shows a thermal efficiency of 47% for the same technology with a net output of 174 MWe and 0,64 million m3/day of hydrogen. |

## 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


EIRP (2017). What will advanced nuclear power plants cost? A Standardized Cost Analysis of Advanced Nuclear Technologies in Commercial Development. Energy Options Network.

IAEA (2013). Hydrogen Production Using Nuclear Energy. IAEA Nuclear Energy Series. No. NP-T-4.2

IAEA/ARIS (2011). Status report 101 - Gas Turbine High Temperature Reactor (GTHTR300C). Advanced Reactors Information System (ARIS). Link: https://aris.iaea.org/sites/overview.html

NEA (2014). Technology Roadmap Update for Generation IV Nuclear Energy Systems.

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 (WNA), 2017. Nuclear process heat for industry. Link: http://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-process-heat-for-industry.aspx