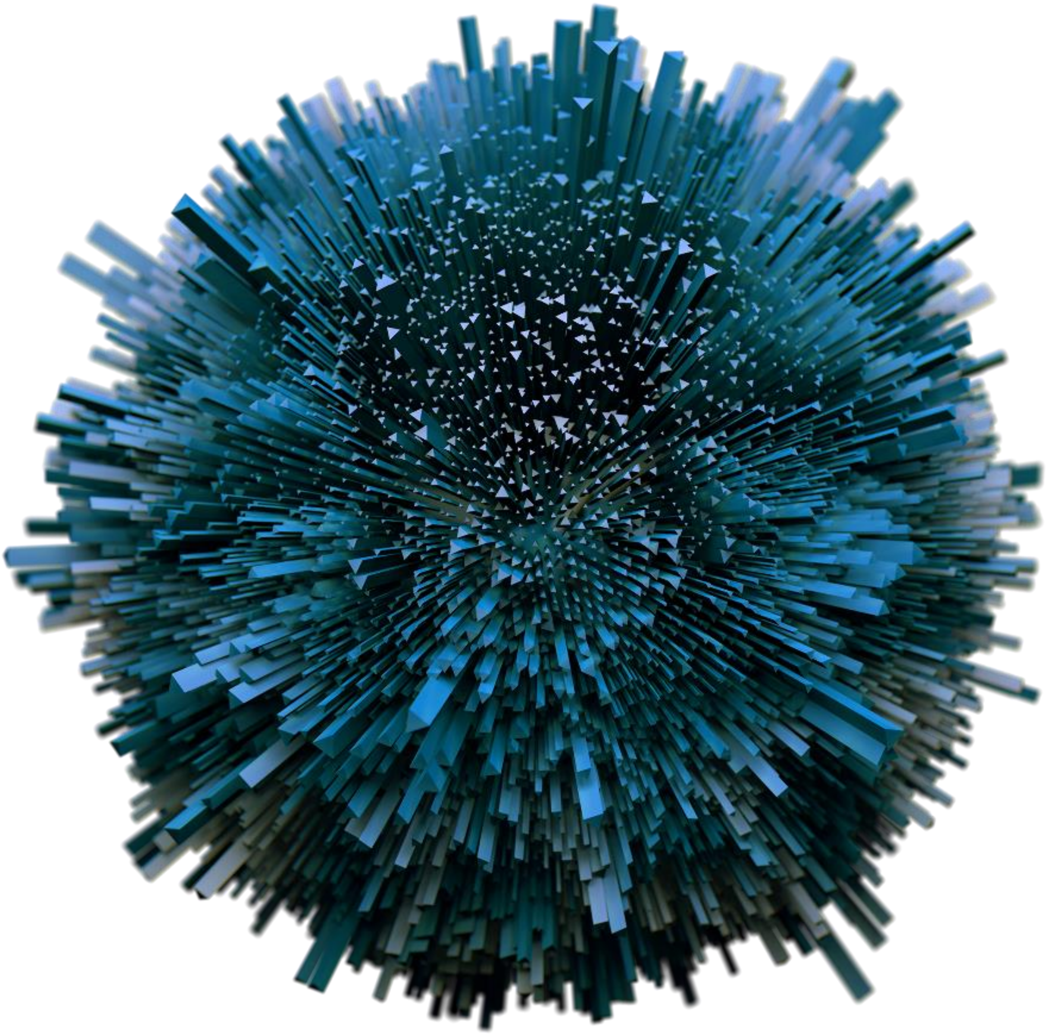

Economic and Social Impact Report

FORATOM

25 April 2019

Content

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List of acronyms

Bn.	Billion
CAPEX	Capital expenditure
CCS	Carbon Capture and Storage
CIT	Corporate income tax
GDP	Gross Domestic Product
GW	Gigawatt
EC	European Commission
EU	European Union
EUR	Euro
EURATOM	European Atomic Energy Community
FORATOM	European Atomic Forum
IAEA	International Atomic Energy Agency
ISL	In situ leach mining
ISCO	International Standard Classification of Occupations
LTO	Long term operation
Mil.	Million
MOX	Mixed oxide
MW	Megawatt
MWe	Megawatt electrical
OPEX	Operating expenditures
PINC	Nuclear Illustrative Programme
PIT	Personal income tax
Ppm	Parts per million
Pu	Plutonium
TWh	Terawatt hour
U	Uranium
VAT	Value added tax

The socio-economic impact evaluation of the Nuclear Industry on the European Union has been carried out using the CGE methodology (Computed General Equilibrium) and Deloitte´s approaches, which evaluate the direct and indirect effects of the nuclear industry in the EU economy.

I. Executive Summary

Objectives and acknowledgements

For more than 60 years already, nuclear energy has been a reliable source of electricity in the European countries. In 1957, the *Euratom Treaty* established the *European Atomic Energy Community (Euratom)* and since then, the nuclear industry has had a significant contribution to the Union's economic growth, enhancing security of supply on the continent. Nowadays, as the commitment for a climate-neutral economy by 2050 is one of the key policy objectives of the Union, the contribution of nuclear power could become an indispensable prerequisite for achieving the ambitious low-carbon targets. Thus, nuclear energy is considered[1] one of the key instruments for a sustainable, competitive and secure energy system in 2050, as set out in the EU's *Energy Roadmap 2050.*

The aim of the present study is to analyse the contribution of the nuclear power sector to the overall economy of the European Union. It will assess current economic and social benefits generated directly through the nuclear industry and effects resulting from the nuclear sector's economic activities throughout the European Union. The analysis was conducted to show both the current impact of the industry and provide a measurable outlook on its future benefits in 2050. The areas of the EU economy analysed in the impact assessment are impact on GDP, job creation, including highly skilled jobs, disposable household income, public revenues and trade balance.

The methodological fundament of the present study is the Computable General Equilibrium (CGE) Model. This quantitative tool simulates the macroeconomic linkages within the European Union or any selected geographic region and measures the impacts in several areas of the economy. The results of the modelling exercise are particularly useful in examining the total effects of an economic activity or of a change in the level of that activity. The assessment is divided into 2 impact dimensions, namely direct and indirect dimensions. The **direct dimension** translates into effects generated directly through operators of nuclear power plants and the supply chain affiliated to the nuclear industry, including raw material suppliers, fabricators, sub-component suppliers, original equipment manufacturers, system integrators and technology vendors. The **indirect dimension** comprises 2 layers: firstly, the effects created through economic activities between the nuclear sector and suppliers from other industries, and secondly, effects created in the EU economy through the expenses of nuclear industry employees and suppliers' employees.

The starting point for the quantitative impact assessment is a nuclear capacity of 118 GW with a share in electricity production of 25% in 2019. To understand how nuclear energy can help Europe reach its 2050 low-carbon targets, a high nuclear capacity scenario of 150 GW will be considered, maintaining a constant 24% share of nuclear in the electricity production until 2050. For comparison, a Low Scenario of 36 GW and a Medium Scenario of 103 GW will be analysed. All three scenarios are the result of a thorough examination conducted by FTI

[1] European Commission 2018b.

Consulting LLP in 2018, commissioned by FORATOM[2], and do not take into consideration future expenditure on decommissioning of nuclear power plants. The High Scenario combines the long-term operation of existing nuclear power plants, new projects currently under construction or in the planning stage, as well as additional new projects. Moreover, the assumption for both scenarios is that the EU will have decarbonized its economy by up to 95% (compared to 1990 levels), with electricity demand rising to more than 4,100 TWh (from 3,100 TWh currently) due to increased electrification.

Table 1 – Evolution of the nuclear capacities and share of electricity production in the scenarios

Applied nuclear scenarios	Capacity [GW]	Share of total [%]	Period**
Current	**118**	**25%**	**2019**
Low Scenario**	**36**	**5%**	**2020 - 2050**
Medium Scenario**	**103**	**16%**	**2020 - 2050**
High Scenario**	**150**	**24%**	**2020 - 2050**

**In a Scenario likely to happen (Low Scenario), most of the existing plants will close without further extensions and new plants projects will fail to materialize.*
***Presented capacities are for 2050.*
Source: FTI-CL Energy 2018

The study is aimed at estimating the overall economic and social benefits associated with the nuclear power industry in the European Union. The objectives of the study are as follows:

- ✓ Calculate the overall **current** and **potential economic benefits** that the nuclear power industry has on **employment** and the creation of **highly skilled jobs**[3], **state revenues** and **economic growth** (impact on GDP) within the European Union;
- ✓ Assess the economic effects generated **directly** by the operators of nuclear power plants and the nuclear supply chain, as well as **indirect impacts**, measured through "ripple" effects generated in other economic sectors and as a result of employees' expenses that lead to additional growth across the entire EU economy[4];
- ✓ Present the economic impact of the **current footprint of the industry** and compare the two **nuclear capacity evolution scenarios** with the **Low Scenario**;
- ✓ Provide a detailed insight about the **direct** and **indirect impact** deriving from nuclear industry activities, analysing all **28 EU countries** separately, whether with or without nuclear energy generation capacities;
- ✓ Provide an **objective**, **hard-fact based instrument** to support with rational arguments any potential discussions or debates undertaken

[2] FTI-CL Energy 2018.
[3] In this study, highly skilled labor is defined as being equal to Levels 1 (Managers) and 2 (Professionals) of the ILO International Standard Classification of Occupations (ISCO).
[4] The **indirect impact** dimension consists of both indirect and "induced" effects, unlike in the Input-Output-Methodology, which is frequently used to assess impacts of an entity or sector on a national economy.

by various EU decision-makers concerning the future of the nuclear power sector.

Moreover, the study provides a general overview and certain insights into the industry context, background information and key facts on the specifics of nuclear power generation and its supply chain. The period covered in this report is 2019-2050. A detailed description of the methodology for the impact assessment and the underlying assumptions of the results are presented in the Appendix of this document.

Key findings

A high nuclear power capacity of 150 GW would entail widespread economic benefits throughout the EU, sustaining more than one million new jobs and hundreds of billions of Euro in additional GDP growth, tax revenues and household income. The table below presents a summary of the current and future economic benefits. The first column indicates the present situation of the EU nuclear industry as of 2019, with an installed capacity of 118 GW. The Low Scenario indicates the economic effects deriving from a low nuclear setting in the future, with 36 GW installed capacity by 2050. The Medium Scenario assumes 103 GW nuclear capacity by 2050, whereas in a High Scenario, 150 GW nuclear capacity would be installed by 2050. The table below provides the current and potential outcomes of the analysed scenarios.

In the future, the nuclear industry could sustain **more than 1.3 million jobs** each year throughout the period in the EU

Table 2 - Summary of scenarios and economic benefits in 2019 and throughout the period 2020 - 2050

Annual economic benefits*	2019	2020 - 2050		
		LOW	MEDIUM	HIGH
Impact on GDP [bn. EUR]	507.4	281.8	483.6	**575.9**
Disposable household income [bn. EUR]	383.1	212.8	309.7	**490.9**
Public revenues [bn. EUR]	124.2	69.0	98.2	**110.2**
Trade balance [bn. EUR]	18.1	8.7	20.8	**33.5**
Total jobs [no. of jobs/year]	1,129,900	650,400	1,000,600	**1,321,600**
Highly skilled jobs [no. of jobs/year]	531,900	297,400	454,800	**595,600**

**Includes direct and indirect impact, as resulted from applying the CGE (Computable General Equilibrium) methodology, described in the Appendix – figures represent yearly average for the analysed period.*
Source: Deloitte analysis

Currently, the nuclear sector contributes with an impact on EU's GDP amounting to 507.4 billion Euro per year and generates yearly public revenues of about 124 billion Euro. Moreover, due to the nuclear sector, more than 1.1 million jobs are sustained each year throughout the period for European citizens, out of which nearly 600,000 highly skilled professionals work in the nuclear industry and its supply chain. In 2019, the disposable household income materialized due to the nuclear industry amounts to 383.1 billion Euro, whereas the EU trade balance showed a surplus of 18.1 billion Euro due to the sector.

The deployment of the High Scenario would entail a **significant increase of EU GDP** by annually **294.1 billion Euro**, summing up to an additional impact of almost **9 trillion Euro** over the entire period of analysis

In the High Scenario, 1.3 million jobs would be sustained each year throughout the period on the EU labour force market (EU 28), out of which 595,600 would represent highly skilled employees. In the period 2020 – 2050, the sector would significantly contribute to the EU's economic growth, generating on an annual basis an impact on GDP of 576 billion Euro, an additional tax revenue of 110.2 billion Euro, a disposable household income of 490.9 billion Euro, as well as an EU trade balance surplus of 33.5 billion Euro.

The incremental economic benefits arising from the deployment of a High Scenario with an installed capacity of 150 GW in comparison to the Low Scenario would be widespread. For instance, through the deployment of the High Scenario, the nuclear industry would account for a yearly incremental impact of 294.1 billion Euro in the EU GDP. In other words, the overall incremental impact of the High Scenario on EU GDP would rise to 8.8 trillion Euro throughout the timespan 2020-2050.

The table below presents a summary of the incremental impacts (annual average) of the High and Medium Scenario, compared to the Low Scenario.

Table 3 - Summary of annual incremental benefits in Medium and High Scenario, compared to Low Scenario

Annual incremental benefits* compared to Low Scenario	**2020 - 2050**	
	MEDIUM	**HIGH**
Impact on GDP [bn. EUR]	201.8	**294.1**
Disposable household income [bn. EUR]	96.9	**278.1**
Public revenues [bn. EUR]	29.2	**41.2**
Trade balance [bn. EUR]	21.1	**24.8**
Total jobs [average no. of jobs/year]	350,200	**671,200**
Highly skilled jobs [average no. of jobs/year]	157,300	**298,100**

**Figures represent the annual incremental benefits, including both direct and indirect impact for Medium and High Scenario, compared to Low Scenario for the analysed period 2020-2050.*

Source: Deloitte calculations

The differences between the Medium and High Scenarios should be assessed considering the multiplication factor derived from the increased installed energy capacity for baseload generation and the timing of commissioning new capacities[5]. Consequently, the High Scenario improves the electricity price available to EU industries, enhancing goods manufacturing (including nuclear supply chain) efficiency, job creation and disposable household income.

II. The EU Nuclear Power Industry – State of play and future opportunities

Overview of the nuclear industry in the European Union

A part of the European Union member states will rely on nuclear energy to generate part of their electricity for the decades to come. In 2017, electricity from nuclear amounted to 25.6% of the EU power production.[6] The countries which plan to keep or develop nuclear energy as part of their energy mix stress the positive impact on energy security, competitiveness and clean electricity targets.

The EU has the most advanced legally binding and enforceable regional framework for nuclear safety in the world and, despite diverging views among Member States on nuclear generated electricity, there is a shared recognition of the need to ensure the highest possible standards for the safe and responsible use of nuclear power and to protect citizens from radiation.

The safety standards for nuclear power plants in the EU are formalized in the national action plans of the EU member states and the European Commission monitors the implementation of those plans through the European Nuclear Safety Regulators Group.[7] The Nuclear Safety Directive from 2009 and its amendment from 2014 build the legal framework for nuclear security in the EU, being considered as the world's most advanced legally binding framework in this field, as it sets an ambitious EU-wide objective of reducing the risk of accidents and avoiding large radioactive releases.[8]

[5] There are differences between scenarios related to when the new capacities are commissioned (some reactors in the high scenario are expected to be connected to the grid faster compared to the medium scenario capacities evolution)
[6] Eurostat.
[7] European Commission 2017a.
[8] Ibid.

Nuclear power plants in the EU

In 2019, there are 126 nuclear power reactors in operation in 14 Member States, with a total estimated capacity of 118 GW by 2020 and an average age close to 30 years. In France, Finland, Slovakia and Great Britain, six reactors are currently under construction[9], while some EU countries plan to build new plants until 2050. Germany will phase out nuclear until 2022, with 10 out of 17 reactors already being shut down today, while newcomers like Poland are planning to introduce nuclear power in their electricity mix.

Altogether, there are 11 nuclear reactors currently in the process of decommissioning in the EU. Except Germany, all EU member states with nuclear capacities are currently either analysing the potential long term operation (LTO) of the existing fleet or planning to build new projects.

Moreover, Great Britain has recently announced its intention to close all coal-fired power plants by 2025 and to substitute the gap mainly with new gas and nuclear power plants.

On the other hand, countries currently without nuclear capacities are Austria, Cyprus, Denmark, Estonia, Greece, Croatia[10], Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Poland and Portugal. In Poland, 3 reactors are forecasted to be connected to the grid in 2029. Other Eastern and Central European member states, such as Bulgaria, the Czech Republic and Romania, are planning the extension of their nuclear power capacities in the late 2020s and 2030s.

The current landscape of nuclear power generation reactors in the European Union is presented in the table below.

Table 4 - Landscape of nuclear reactors in the EU in the high scenario

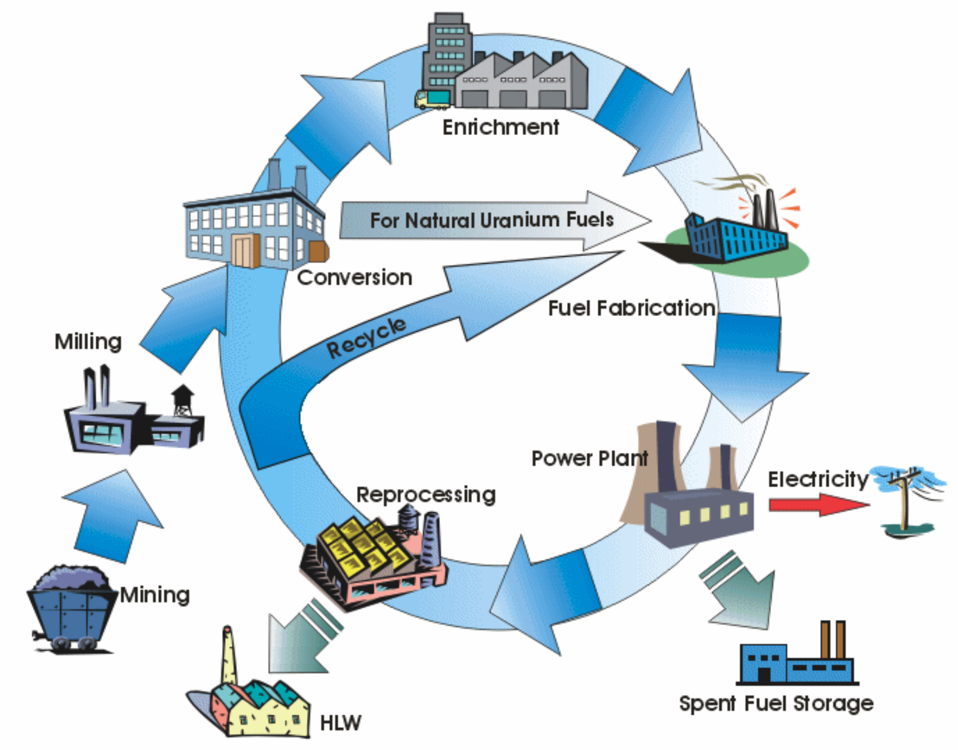
High scenario landscape of nuclear reactors in the EU	
In operation today*	126
Under construction today*	5
Expected to be decommissioned until 2050	11
Planned and envisaged until 2050	99
In operation in 2050	**122**

Note: Situation as of 2018
Source: FTI-CL Energy 2018, European Commission 2017a

[9] IAEA 2019.
[10] The NEK (Nuklearna Elektrarna Krško) reactor in Slovenia is owned in equal shares by the Slovenian and Croatian legal successors of the power plant founders. Thus, impact figures are higher for Croatia compared to other countries without nuclear capacities.

Nuclear fuel cycle[11]

Figure 1 - Nuclear fuel cycle



Source: M. Mohapatra and B.S. Tomar, 2013

Uranium is a slightly radioactive metal that occurs throughout the Earth's crust. It is about 500 times more abundant than gold and about as common as tin. It is, for example, found in concentrations of about four parts per million (ppm) in granite, which makes up 60% of the Earth's crust. In fertilizers, uranium concentration can be as high as 400 ppm (0.04%), and some coal deposits contain uranium at concentrations greater than 100 ppm (0.01%). There are a number of areas around the world where the concentration of uranium in the ground is sufficiently high that extraction of it for use as nuclear fuel is economically feasible. Such concentrations are called ores.

Uranium mining

Both excavation and in situ techniques are used to recover uranium ore. Excavation may be underground and open pit mining. In general, open pit mining is used where deposits are close to the surface and underground mining is used for deep deposits, typically greater than 120 m deep. Open pit mines require large holes on the surface, larger than the size of the ore deposit, since the walls of the pit must be sloped to prevent collapse. Underground mines have relatively small surface disturbance and the quantity of material that must be removed to access the ore is considerably less than in the case of an open pit mine.

An increasing proportion of the world's uranium now comes from in situ leach (ISL) mining, where oxygenated groundwater is circulated through a very

[11] World Nuclear Association 2017.

porous orebody to dissolve the uranium oxide and bring it to the surface. ISL may be with slightly acid or with alkaline solutions to keep the uranium in solution. The uranium oxide is then recovered from the solution as in a conventional mill. The decision as to which mining method to use for a particular deposit is governed by the nature of the orebody, safety and economic considerations.

Uranium milling

Milling, which is generally carried out close to a uranium mine, extracts the uranium from the ore (or ISL leachate). Most mining facilities include a mill, although where mines are close together, one mill may process the ore from several mines. Milling produces a uranium oxide concentrate which is shipped from the mill. It is sometimes referred to as 'yellowcake' and generally contains more than 80% uranium. The original ore may contain as little as 0.1% uranium, or even less. U3O8 is the uranium product which is sold. About 200 tones is required to keep a large (1000 MWe) nuclear power reactor generating electricity for one year. Such milling operations is quite complex[12], involving crushing, screening, agglomeration, stacking and heap leaching, uranium recovery and purification by solvent extraction, ammonium diuranate precipitation and calcination. Depending on the amount of recoverable ore, such mills can operate for 2 or more decades, generates hundreds of direct jobs and additional five folds indirect jobs during this period. That is why is often welcomed by local communities and authorities[13]

Conversion and enrichment

The uranium oxide product of a uranium mill is not directly usable as a fuel for a nuclear reactor and additional processing is required. Only 0.7% of natural uranium is 'fissile', or capable of undergoing fission, the process by which energy is produced in a nuclear reactor. The form, or isotope, of uranium which is fissile is the uranium-235 (U-235) isotope. The remainder is uranium-238 (U-238)[14]. For most kinds of reactor, the concentration of the fissile uranium-235 isotope needs to be increased – typically to between 3.5% and 5% U-235. Isotope separation is a physical process to concentrate ('enrich') one isotope relative to others. The heavy water type reactors from Cernavoda power-plant in Romania do not require uranium to be enriched.

Fuel fabrication

Reactor fuel is generally in the form of ceramic pellets. These are formed from pressed uranium oxide (UO_2) which is sintered (baked) at a high temperature (over 1400°C). The pellets are then encased in metal tubes to form fuel rods, which are arranged into a fuel assembly ready for introduction into a reactor. Some 27 tons of fresh enriched fuel is required each year by a 1000 MWe reactor.

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[12] https://www.mining-technology.com/projects/salamanca-uranium-project/
[13] https://www.berkeleyenergia.com/more-than-a-thousand-from-local-community-sign-petition-in-support-of-the-salamanca-project/
[14] U-238 is fissionable in fast neutron reactors, which are likely to be in wide use by mid-century.

Power generation and burn-up

Several hundred fuel assemblies make up the core of a reactor. In the reactor core the U-235 isotope fissions or splits, producing a lot of heat in a continuous process called a chain reaction. The process depends on the presence of a moderator such as water or graphite, and is fully controlled.

As in fossil-fuel burning electricity generating plants, the heat is used to produce steam to drive a turbine and an electric generator, in a 1000 MWe unit providing over 8 billion kilowatt hours (8 TWh) of electricity in one year. To maintain efficient reactor performance, about one-third of the spent fuel is removed every year or 18 months, to be replaced with fresh fuel.[15]

Typically, some 44 million kilowatt-hours of electricity are generated from one tone of natural uranium. The production of this amount of electrical power from fossil fuels would require the burning of over 20,000 tons of black coal or 8.5 million cubic meters of gas.

Used fuel

With time, the concentration of fission fragments and heavy elements will increase to the point where it is no longer practical to continue to use the fuel, though much potential remains in it. After 18-36 months the used fuel is removed from the reactor. The amount of energy that is produced from a fuel assembly varies with the type of reactor and the policy of the reactor operator.

When removed from a reactor, the fuel will be emitting both radiation, principally from the fission fragments, and heat. It is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. In the ponds the water shields the radiation and absorbs the heat, which is removed by circulating the water to external heat exchangers. Used fuel is held in such pools for several months and sometimes many years. It may be transferred to naturally-ventilated dry storage on site after about five years. Depending on policies in particular countries, some used fuel may be transferred to central storage facilities. Ultimately, used fuel must either be reprocessed in order to recycle most of it, or prepared for permanent disposal. The longer it is stored, the easier it is to handle, due to decay of radioactivity.

Currently, there are two alternatives for used fuel:

a) reprocessing to recover and recycle the usable portion of it;
b) long-term storage and final disposal without reprocessing.

Reprocessing

Used fuel still contains about 96% of its original uranium, of which the fissionable U-235 content has been reduced to less than a quarter of the initial value

Reprocessing separates uranium and plutonium from waste products (and from the fuel assembly cladding) by chopping up the fuel rods and dissolving

[15] In the USA, about 85% of reactors have an 18-month fuel cycle, a few have 24-month ones. In Asia, over 80% have 18-month cycles, the remaining ones 12-month cycles. In Europe, over 60% have 12-month cycles, while the rest has 18-month ones.

them in acid to separate the various materials. It enables recycling of the uranium and plutonium into fresh fuel, and produces a significantly reduced amount of waste (compared with treating all used fuel as waste).

Uranium and plutonium recycling

The uranium recovered from reprocessing, which typically contains a slightly higher concentration of U-235 than occurs in nature, can be reused as fuel after conversion and enrichment. The plutonium can be directly made into mixed oxide (MOX) fuel, in which uranium and plutonium oxides are combined. In reactors that use MOX fuel, plutonium substitutes for the U-235 in normal uranium oxide fuel. Increasingly, today's used fuel is being seen as a future resource rather than a waste.

Wastes

Wastes from the nuclear fuel cycle are categorized as high-, medium- or low-level wastes by the amount of radiation that they emit. These wastes come from a number of sources and include:

a) low-level waste produced at all stages of the fuel cycle;
b) intermediate-level waste produced during reactor operation and by reprocessing;
c) high-level waste, which is waste containing the highly-radioactive fission products separated in reprocessing, and in many countries, the used fuel itself. Separated high-level wastes also contain long-lived transuranic elements.

After reprocessing, the liquid high-level waste can be calcined (heated strongly) to produce a dry powder which is incorporated into borosilicate (Pyrex) glass to immobilize it. The glass is then poured into stainless steel canisters, each holding 400 kg of glass. A year's waste from a 1,000 MWe reactor is contained in five tonnes of such glass, or about 12 canisters 1.3 metres high and 0.4 metres in diameter. These can readily be transported and stored, with appropriate shielding.

Used fuel and separated wastes: final disposal

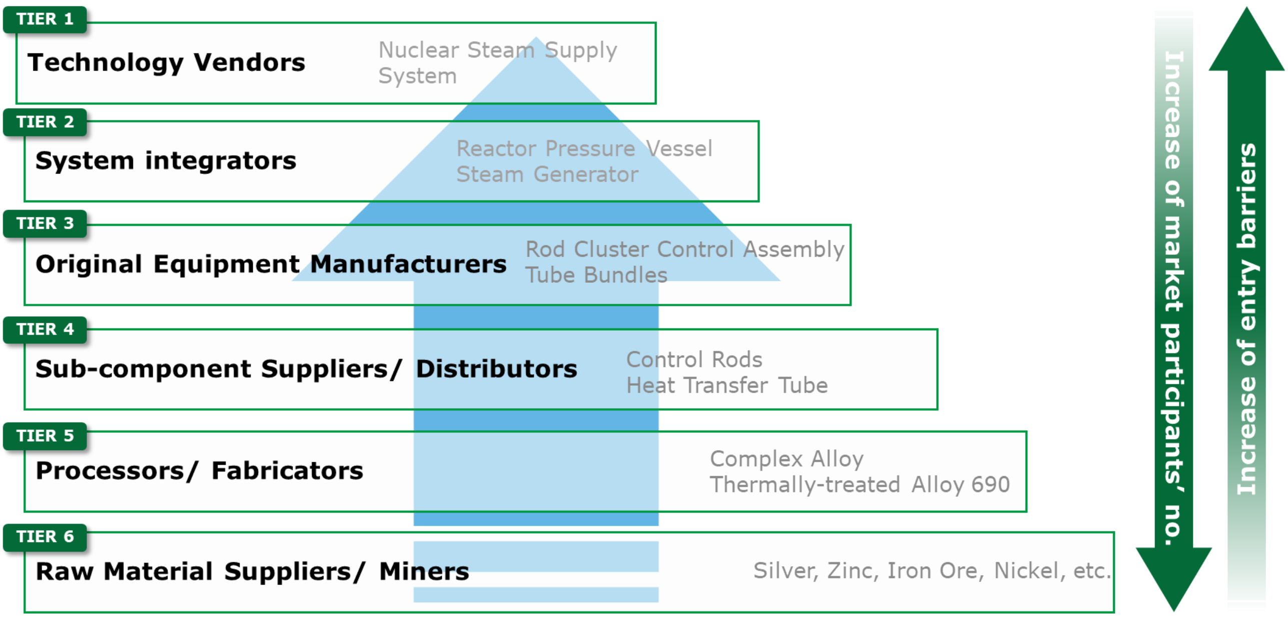
At the present time, there are no disposal facilities (as opposed to storage facilities) in operation in which used fuel, not destined for reprocessing, and the waste from reprocessing, can be placed. In either case the material is in a solid, stable waste form. Although technical issues related to disposal are straightforward, there is currently no pressing technical need to establish such facilities, as the total volume of such wastes is relatively small. Further, the longer it is stored the easier it is to handle, due to the progressive decrease of radioactivity. There is also a reluctance to dispose of used fuel because it represents a significant energy resource which could be reprocessed at a later date to allow recycling of the uranium and plutonium. A number of countries are carrying out studies to determine the optimum approach to the disposal of used fuel and wastes from reprocessing. The general consensus favours its placement into deep geological repositories, about 500 meters down. Examples of such repositories under discussion are the "Onkalo spent nuclear fuel repository" in Finland and the UK Government's program for a "Geological

Disposal Facility". This facilities will create jobs to, but their impact was not taken into consideration in the present study.

Nuclear supply chain[16]

The sourcing of nuclear energy consists of one of the most complex supply chains in the world. It typically consists of 6 tiers, each being under strict government guidelines and regulations from international and national sources. Starting from the beginning of the process cycle, these are raw material suppliers, fabricators, sub-component suppliers, original equipment manufacturers, system integrators and technology vendors.

Figure 2 - Nuclear Supply Chain



Source: World Nuclear Association 2014

Particularities of the nuclear supply chain often refer to an increased degree of quality standards. Throughout the whole supply chain, exceptional quality standards are required from 'nuclear-grade' components, which are higher than normal 'industrial or commercial grade'. Moreover, sector-specific performance and safety testing are required for the goods offered by suppliers, which raises two challenges concerning preparedness and capability to deliver at such high standards. Secondly, suppliers are confronted with the profitability challenge, which is a natural consequence of increased quality standards and derives from the first two challenges.

Obtaining U and Pu for civilian uses

Uranium (U) is the basic fuel of nuclear energy, while Plutonium (Pu) is a man-made element, formed in a nuclear reactor through neutron capture. About one third of the energy in a light water reactor comes from the fission of Pu-239. This is the main isotope of value recovered from reprocessing used fuel.

[16] Sitler, Andrea L. 2010.

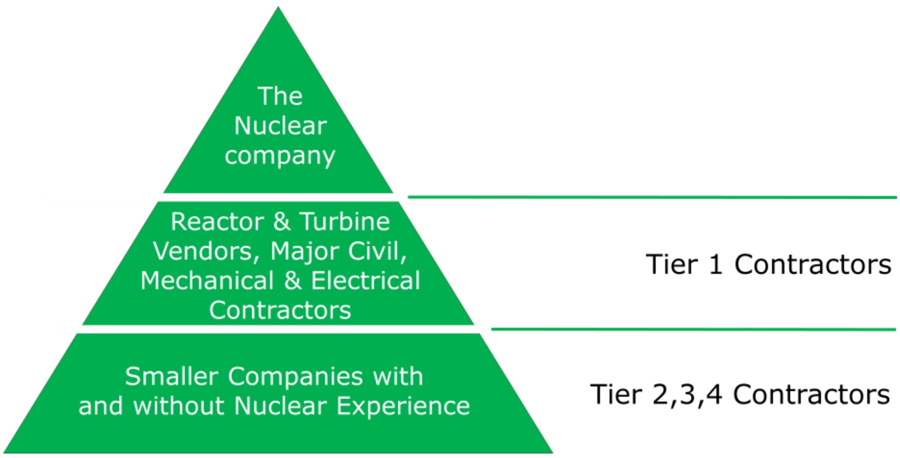
As is the case with uranium, plutonium can also be recovered from spent fuel and recycled to create fresh reactor fuel.

Delivery of Radioactive Material to power plants

Pu and U are transported to the generation facilities under strict government and global guidelines. International shipping standards are enforced in the packaging, transport and markings of said shipments. Enriched Uranium arrives at nuclear power sites in containers that are weighed to comply with the requirements of the *International Atomic Energy Agency (IAEA*), of the *European Atomic Energy Community* (*Euratom*) and of *Euratom Supply Agency (ESA)*. Deliveries to customers are made in containers that are transported in a licensed protective casing, referred to as casks, meeting international shipping standards.

Vendors

Figure 3 – A typical procurement pyramid



Source: Nuclear Industry Association 2013

The market opportunities associated with the development of reactors at can be split into:

- Civil Works
- Nuclear Steam Supply System
- Mechanical Systems – nuclear and non-nuclear
- Electrical Systems – nuclear and non-nuclear
- Turbine

Civil Works

The three main civil packages are:

- **Earthworks**: involves preparation of the site prior to main civil works, including site clearance and excavation, sea wall construction and elements of the temporary site infrastructure. It is expected to last approximately one year.
- **Marine and Tunneling Works**
- **Main Civil Works**

There are other civil/ building packages covering Ancillary Buildings and Associated Developments (including, accommodation campuses, park and ride facilities, highway and wharf improvement works, mostly outside the nuclear site).[17]

Nuclear Steam Supply System

The main components/ services performed in this category are comprised of **lead forging for the reactor vessel**, **steam generators** and **loop pipework** (primary circuit Class 1 components).

Secondary services are also needed, such as:

- Transportation, lifting and mechanical installation of major equipment and pipework;
- Supply, prefabrication and installation of small bore ancillary pipework around the reactor vessel / steam generator;
- Provision of structural steel restraints and pipework supports;
- Welding services;
- Non-destructing testing services.[18]

Mechanical Systems – nuclear and non-nuclear

The nuclear company might break down the supply and installation of the main mechanical equipment into a series of discrete packages. Some of these are for equipment design, while the manufacturing packages might be only for equipment such as pumps, valves, compressors, tanks, pressure vessels, heat exchangers, chillers etc. Companies which are not large enough to directly supply this equipment to the nuclear company need to contact manufacturers of the respective type of equipment and position themselves to provide subassemblies or support services associated with these contracts.

There are several mechanical installation packages, such as:

- Balance of Nuclear Island Mechanical Equipment;
- Balance of Plant Mechanical Equipment;
- Nuclear HVAC Plant Installation;
- Non-Nuclear HVAC Plant Installation;
- Waste Treatment Packages.[19]

Electrical Systems – nuclear and non-nuclear

The electrical contracts can be split into at least five major packages. These are:

- Construction Electrical Supplies (provision of the site electrical infrastructure to facilitate power for the construction activities);
- IEG Scope (general electrical erection);
- Small Power and Lighting (design, procurement, prefabrication, installation and commissioning);
- Fire and Hydrogen Detection (design, procurement, prefabrication, installation and commissioning);

[17] Nuclear Industry Association 2013
[18] Nuclear Industry Association 2013
[19] Nuclear Industry Association 2013

- IT and Communications Infrastructure (design, procurement, prefabrication, installation and commissioning);
- Ancillary Buildings' Works (design, procurement, prefabrication, installation and commissioning).[20]

Turbine

The companies supply their own proprietary turbine, but sometimes release enquiries into the market for packages such as:

- Main Steam and Feed Water Pipework Systems;
- Turbine Auxiliary Pipework;
- Moisture Separator Re-Heater and Deaerator Vessels;
- Feed Heaters;
- Assorted Vessels and Tanks.

Smaller companies may find a role as selected subcontractors for the provision of sub-assemblies, provision of niche site installation services or niche services such as non-destructing testing.[21]

Recycling Technologies

Recycling allows 30% more energy to be extracted from the original uranium and leads to a great reduction for wastes to be disposed of. Overall, the closed fuel cycle cost is assessed as comparable with that for direct disposal of used fuel, and preserves a resource that may become more valuable in the future.

Decommissioning of Plants and Transportation of Radioactive Waste

During their life cycle, plants are required to set up a fund that will cover the costs of decommissioning. The decommission process can take 20 or more years.

Plant decommissioning is a multi-step process. This entails the removal and disposal of radioactive components and materials such as the reactor and associated piping and the clean-up of radioactive or hazardous contamination that may remain in the buildings and on the site. Radioactive materials must be handled in a fashion to reduce risk. The entire facility is sealed off to allow the grounds to return to a radiation safe zone. The energy generation room is sealed for a pre-determined time after the rods are removed. Hot rods from working plants are not immediately shipped upon decommission. Instead, there is a long-term process taken to further reduce the risk of contamination during transit.

Transport of Nuclear Waste

Risk reduction methods entail rods being placed in water pools to cool for at least 5 years before being transported to their first intermediate storage facility where they will remain for another 30 to 100 years. During this stay, radiation levels will reduce significantly. Spent fuel rods are transported via rail and truck. They must be transported in cement casks manufactured specifically for this purpose.

[20] Nuclear Industry Association 2013
[21] Nuclear Industry Association 2013

Please consult Figure 1 for an overview over the goods that are offered by every tier of the supply chain.

Nuclear reactor technologies and generations

As a well-established large-scale zero-carbon technology in power generation, nuclear energy has the potential to play a decisive role in realizing the EU's ambitious low-carbon targets for 2050.

The importance of long-term operations (LTO) is expected to increase in the coming years, as by 2030, the majority of nuclear reactors would be operating beyond their original design life. Long-term operations are likely to represent the majority of nuclear investments in the short to medium term. The main recitals for LTO are linked to electricity market conditions, but have to take in consideration social and political factors, as well. Today, the operational lifetime extension of certain nuclear power reactors has already been approved in some EU Member States (e.g. Hungary and the Czech Republic). Such decisions are subject to a strict and comprehensive safety review by the competent independent national regulator, and highest safety standards have to be implemented.

In Table 4, installed capacity figures for existing, LTO and new nuclear reactors are shown for the short, medium and long term.

Table 5 - Installed nuclear capacity for the period 2020 - 2050, High Scenario

Installed nuclear capacity for High Scenario [MW]				
	2020	**2030**	**2040**	**2050**
Existing	107,674	20,901	8,666	0
LTO	6,280	79,373	81,176	20,356
New	4,142	28,251	58,079	129,981
Total	**118,096**	**128,525**	**147,921**	**150,337**

Source: FTI-CL Energy 2018

Main nuclear reactor designs[22]

Currently the most used nuclear reactor design worldwide is the **pressurized water reactor (PWR)**, with notable exceptions being Japan and Canada. It has water at over 300°C under pressure in its primary cooling/ heat transfer circuit, and generates steam in a secondary circuit. PWRs are one of three types of **light water reactor (LWR)**, the other types being **boiling water reactors (BWRs)** and **supercritical water reactors (SCWRs)**. Russia's

[22] World Nuclear Association 2018.

VVER reactors are similar to U.S. PWRs (please see the footnote)[23]. France operates many PWRs to generate the bulk of its electricity.

The **boiling water reactor (BWR)** produces steam in only one circuit above the reactor core, but at slightly lower temperatures and pressure compared to the PWR. Both types use water as both coolant and moderator, to slow neutrons. Since water normally boils at 100°C, they have robust steel pressure vessels or tubes to enable the higher operating temperature.

Advanced gas-cooled reactors (AGR) use graphite as a moderator, carbon dioxide as primary coolant and uranium oxide pellets as fuel. The carbon dioxide circulates through the core, reaching 650°C and then past steam generator tubes outside it, but still inside the concrete and steel pressure vessel (hence 'integral' design). Control rods penetrate the moderator and a secondary shutdown system involves injecting nitrogen to the coolant.

The **pressurized heavy water reactor (PHWR)** design has been developed since the 1950s in Canada and is widely known as the **CANDU**. PHWRs generally use natural uranium oxide as fuel, hence it needs a more efficient moderator, in this case heavy water (D_2O). The PHWR produces more energy per kilogram of mined uranium than other designs, but also produces a much larger amount of used fuel per unit output. CANDU reactors can accept a variety of fuels.[24]

For a comprehensive list of existing nuclear units throughout the European Union, please consult the set of assumptions in the Appendix.

Main nuclear reactor generations

Currently, the majority of reactors are considered 2nd Generation reactor systems, as the vast majority of the 1st Generation systems were retired some time ago. There are only a few 3rd Generation reactors in operation as of 2014 and they are considered developments of the second generation with enhanced safety. Thus, there is no clear distinction between the 2nd and the 3rd Generation.

Small modular reactors (SMRs) have several design features that differentiate them from other sources of power generation. In contrast to large nuclear or fossil-fuel generating facilities that typically have electricity output in excess of 700 MW(e), SMRs are relatively small, producing less than 300 MW(e). While globally there exist a number of designs and operating reactors that fall into the size range of SMRs, they lack the other characteristics associated with SMR design.[25]

Micro Nuclear Reactors (MNRs) are a distinct class of small reactor systems, typically of under 30MW electricity and 100MW thermal output, which could

[23] The water-water energetic reactor (WWER) represents a series of pressurized water reactor designs originally developed in the Soviet Union, and now Russia. VVER were originally developed before the 1970s, and have been continually updated. Power output ranges from 70 to 1200 MWe, with designs of up to 1700 MWe in development.
[24] A table with all the Operating and New European power plants can be found in the Appendix, in the Set of assumptions
[25] IAEA TECDOC SERIES 2018.

occupy distinct and different market niches, in comparison to larger Small Modular Reactors (SMR's).[26]

Concerning the 4th Generation, an international cooperation framework is sharing R&D to develop six nuclear reactor technologies (or seven, considering the two variants of Molten Salt Reactor) for demonstration between 2020 and 2030. Four of them are fast neutron reactors. All of these operate at higher temperatures than today's reactors. In particular, four are designated for hydrogen production.[27]

All six systems represent advances in sustainability, economics, safety, reliability and proliferation-resistance. **Europe is pushing ahead with two of the fast reactor designs:**

1. As a first alternative technology, the lead-cooled fast reactor (ALFRED) with the construction of an experimental reactor to demonstrate the technology, in another European country willing to host this program, and supported by a lead-bismuth irradiation facility project in Belgium (MYRRHA);
2. As a second alternative technology, the gas-cooled fast reactor (ALLEGRO), also requiring the construction of technology demonstrator in a European country. [28]

Nuclear research in Europe[29]

The nuclear research in Europe encompasses multiple layers of local and centralized initiatives and programs. While various companies and organisations trigger and support local or regional R&D plans, the centralized plans are usually funded through EU multiannual framework programmes. Case in point, the Euratom Research and Training Programme complements, but remains separate from Horizon Europe (the EU framework programme for research and innovation) and from ITER (the International Thermonuclear Experimental Reactor).

The Euratom Research and Training Programme for the period **2021-2025** will have an envelope of 1.68 bn. EUR in current prices. The distribution of the amount referred shall be:

- ✓ 43% for fusion research and development;
- ✓ 25% for nuclear fission, safety and radiation protection;
- ✓ 32% for direct actions undertaken by the Joint Research Centre.[30]

For the 2021-2027 period, ITER, the international fusion energy project **will have a budget, allocated separately, of 6.1 billion EUR**, to build and operate a reactor with the purpose of testing the feasibility of fusion as an energy source.[31]

[26] Nuvia 2016.
[27] World Nuclear Association 2018.
[28] ESNII 2010.
[29] European Parliament 2019a.
[30] European Parliament 2019b.
[31] European Commission 2018a.

The amount dedicated to the Euratom programme for the 2014-2018 period was EUR 1,608 million, divided among programmes in three specific research areas:

- Indirect actions in fusion energy research – 728 mil. EUR

  EU is a founding member and main financial partner of ITER, an international nuclear fusion research and engineering project, which is currently building the world's largest experimental nuclear fusion reactor in Cadarache, France. A Joint Undertaking for ITER and the Development of Fusion Energy has been established in order to promote scientific research and technological development in the field of fusion (Council Decision 2007/198/Euratom). Its members are Euratom (represented by the Commission), the EU Member States and certain third countries which have concluded cooperation agreements with Euratom.

- Nuclear fission and radiation protection – 315 mil. EUR

  In 2007, in order to better coordinate research and development in the field of nuclear fission energy, as well as for demonstration and deployment, the Sustainable Nuclear Energy Technology Platform was established.

- Direct actions undertaken by the Commission's Joint Research Centre (JRC) – 559 mil. EUR

  JRC collaborates closely in key policy areas with the other European Commission Directorates-General (DGs), delivering on priority topics and its existing long-term obligations (i.e. as specified in existing EU legislation and contracts).

  Unlike the other Directorates-General of the Commission, the JRC manages scientific infrastructures and nuclear facilities. Given the geographic spread of its sites and the technical nature of its work, the JRC policy is to place local decision-making responsibility with the operational services.[32]

[32] European Commission 2018a.

III. Current contribution of the Nuclear Power Industry to the EU economy

The impact assessment takes into consideration the current nuclear energy production throughout the entire European Union and is quantified in billion Euro. Individual assessments for each country are to be found in the Appendix.

The primary object of this study consists of analysing the indicators **employment, state revenues, gross domestic product and disposable household income,** which can be measures of the direct and indirect impact that the nuclear energy industry has on the EU economy. For more details related to what direct and indirect impact imply, please consult the methodological notes section presented in the Appendix.

The results show that the nuclear industry has a significant impact on affiliated industries and the EU economy as a whole. The present chapter provides a detailed view on the current impact, while the future impact with a horizon of 30 years is presented in Chapter IV.

The overall figures for current impact are presented in the following figure.

In 2019, the nuclear industry sustains more than **1.1 million jobs** in the EU economy and has an impact in GDP of more than **half a trillion Euro**

Figure 4 – Overview of the current impact of the nuclear industry

2019 IMPACT

507.4 bn. EUR	in **EU GDP** generated by nuclear sector, equal to a 3 – 3.5% share of 2019 EU GDP
1,129,900	average **number of jobs sustained** by the nuclear sector
47%	of the total number of **jobs in the nuclear industry are highly skilled**, equaling a number of **531,900**
383.1 bn. EUR	**disposable household incomes** due to the activities of the EU nuclear industry
124.2 bn. EUR	**public revenues generated through tax payments** due to the nuclear sector
1,092.3 bn. EUR	**Investments** undertaken in the EU due to nuclear industry
18.1 bn. EUR	**trade surplus** within EU due to the nuclear sector

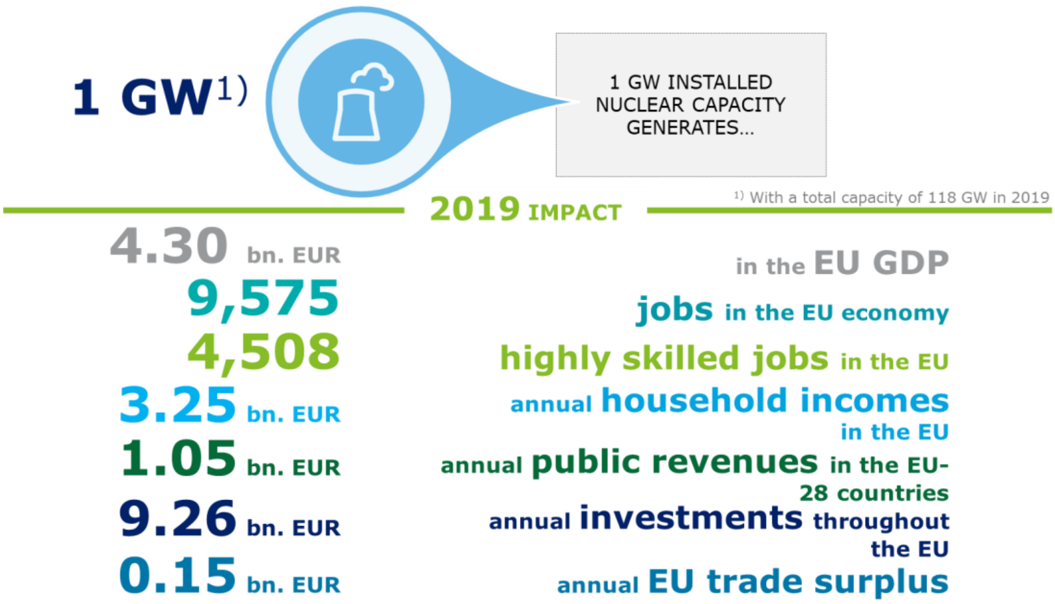
Source: Deloitte calculations

The results of the current impact assessment show that in 2019, the nuclear industry sustains **1,129,900 full-time jobs**, generates **124.2 bn. Euro state revenues**, **383.1 billion Euro in household income**, **507.4 billion Euro in the EU GDP, 1,092.3 billion Euro volume of investment and 18.1 billion Euro trade surplus** in the EU economy.

Another approach to exemplify the economic benefits arising from the activities of the EU nuclear industry is to show the impact of 1 GW installed nuclear capacity on the economy. According to that, every GW of installed nuclear capacity in the European Union generates 9.26 billion Euro annual investments in the whole EU economy, 4.30 billion Euro impact on the EU GDP, 3.25 billion Euro of household incomes for EU citizen employed directly or indirectly through the nuclear industry, 1.05 billion public revenues and an EU trade surplus of 0.15 billion Euro in 2019. What is more, every GW installed nuclear capacity sustains 9,575 direct and indirect jobs and provides 4,508 highly skilled jobs on the EU labour force market in 2019.

Every GW installed nuclear capacity **generates 4.3 billion Euro** in the EU GDP in 2019

Figure 5 - Impact of 1 GW installed nuclear capacity on the EU economy, 2019



Source: Deloitte calculation

Impact on GDP

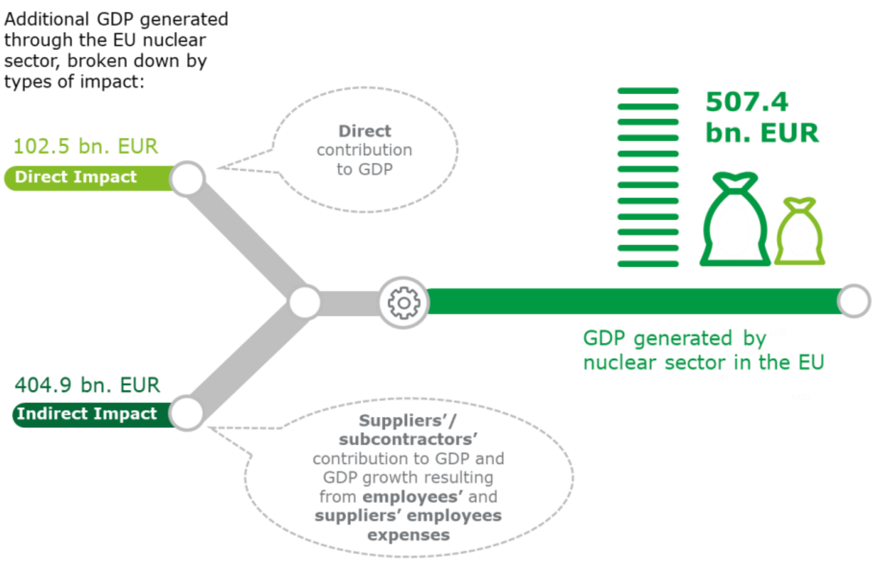
Macroeconomic indicators such as GDP provide valuable insights regarding the share that an industry has in the economy of the European Union.

The **direct impact** comprises of the activities directly associated to nuclear power generation and amounts to **102.5 billion Euro**. The **indirect impact** reaches **404.9 billion Euro** and is generated through suppliers in the nuclear supply chain the expenses of the industry's direct employees, as well as the expenses of the suppliers' employees in the EU economy. Finally, the overall impact of the nuclear sector on the European GDP totals **507.4 billion Euro** in 2019, more than a **half trillion Euro,** translating into **3 – 3.5 %** of the EU GDP.

The current impact in the EU GDP amounts to **half a trillion Euro**

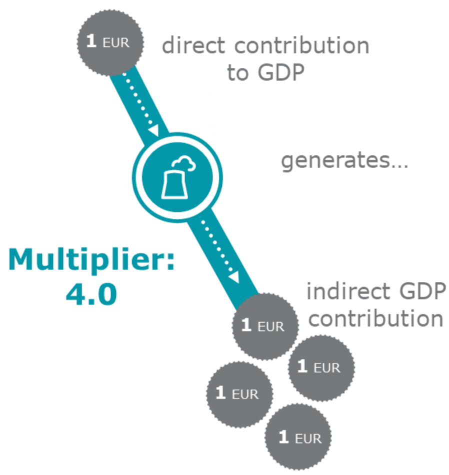
The figure presented below captures the effects of the nuclear industry on the current EU GDP.

Figure 6 - Impact on EU GDP, 2019



Source: Deloitte calculations

Figure 7 - GDP Multiplier, 2019



The multiplier effect is an intuitive indicator to assess the overall effects deriving from nuclear industry. As shown in the figure on the left, **every Euro** of direct impact in GDP created by the nuclear industry generates an indirect impact of **4 Euro** and an overall impact of **5 Euro** in the GDP of the European Union.

Source: Deloitte calculations

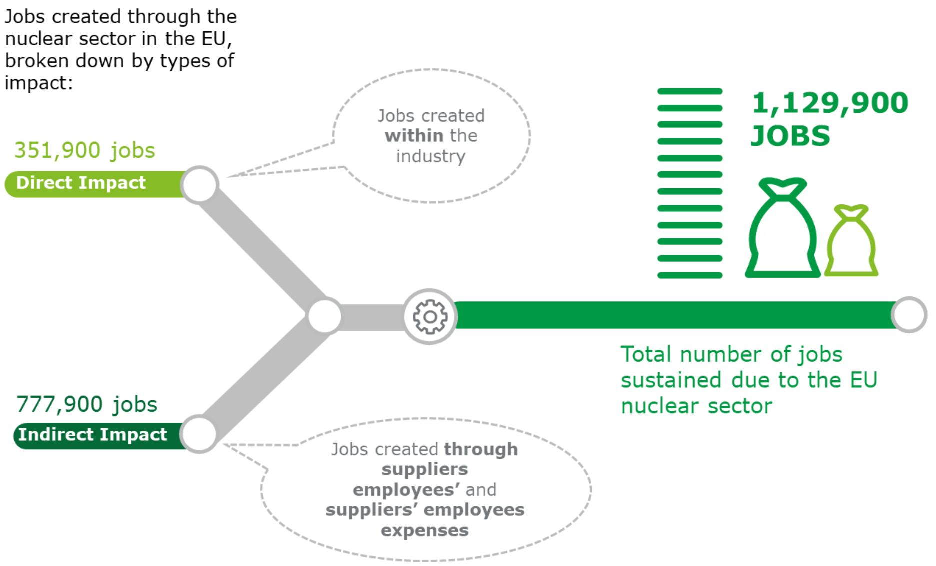
Today, **every Euro** of direct impact of the nuclear industry on the EU GDP will generate a total of **5 Euro** in the GDP

Impact on employment

The assessment for the impact of today's nuclear industry on the labour force markets shows that every year, **351,900 jobs** will be **sustained directly** through the industry's performance. These direct jobs **indirectly sustain** other **777,900 jobs** offered and sustained on average by the suppliers every year. What is more, the indirect impact includes job created through the expenditures of both the industries' employees and suppliers' employees in other economic sectors. Overall, the nuclear industry accounts for more than **1.1 million jobs**, or, to put it differently, through the nuclear industry's economic activities, **1,129,800 jobs are currently sustained on the European labour force market.** Please consult the figure below for an overview of current impact on employment.

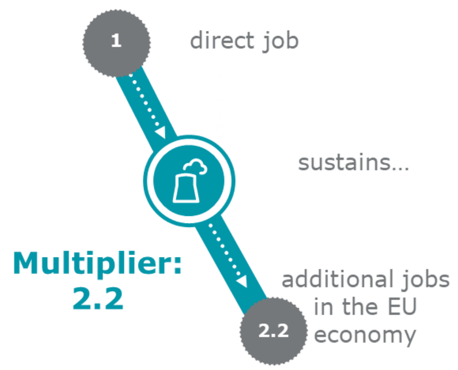
In 2019, the nuclear industry sustains **more than 1.1 million jobs** throughout the European Union, out of which **more than half a million** are staffed **with highly skilled professionals**

Figure 8 - Impact on employment, 2019



Source: Deloitte calculations

Figure 9 – Jobs multiplier, 2019



Every direct job in the nuclear industry generates **2.2 indirect jobs throughout the EU labour force market** in the present. Altogether, 1 job in the nuclear industry sustains a total of **3.2 jobs** in the EU.

Source: Deloitte calculations

Highly skilled professionals

Figure 10 - Highly skilled jobs, 2015 - 2020

Source: Deloitte calculations

Today, **47%** of the labour force **directly or indirectly employed by the nuclear sector** in the EU is **highly skilled**

In other words, approximately **1 out of 2 employees** in the nuclear industry in the European Union are highly skilled today, representing a remarkable **share of 47%**. In the electricity sector, the average share of highly skilled employees is considerably lower and currently varies between 25% and 36%.[33]

Employment during the nuclear lifetime phases

Compared to other sectors, the nuclear industry is considered a labour-intensive energy generation technology.[34] The nuclear life cycle can be separated into three major phases: construction, operation and decommissioning. The construction phase takes approximately 10 years, whereas the operation phase is considered to last around 50 years. Decommissioning is expected to be completed after 10 years.[35] During the three phases, both labour intensity and types of supplied labour differ significantly.[36] Main activities during the construction phase are to be divided in field craft labour and field non-manual labour. Field craft labour is the largest component of the construction workforce, 70% to 75% of the field work force are employed to realize the conventional nuclear plant construction. The field craft labour category comprises civil, electrical, mechanical, piping and instrumentation personnel used during the installation and start-up of the units. On the other hand, the field non-manual labour is the smaller part of the construction workforce and accounts for approximately 25% to 30%. The non-manual labour force comprises of field management, field supervision, field engineers, quality assurance/quality control, environmental-safety and health and administrative/clerical staff.[37]

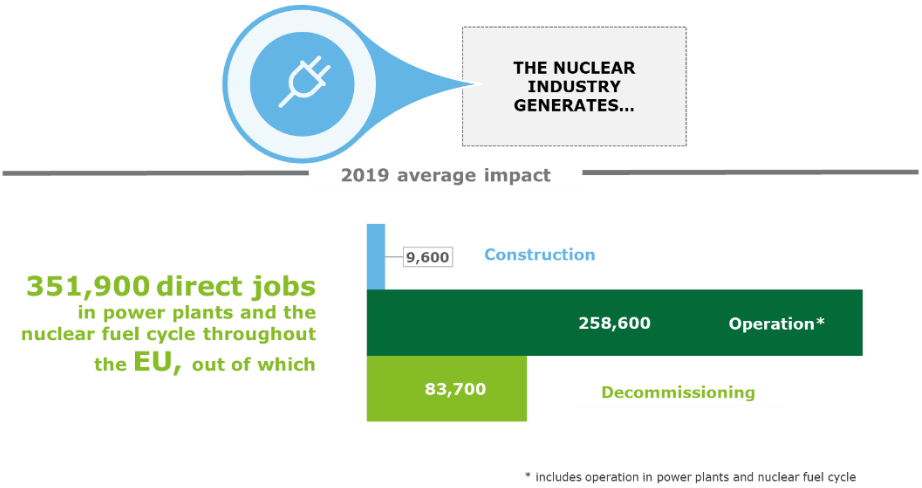
During operation phase, job activities are mainly in the following categories: engineering, materials and services, operations, maintenance, support services, training and management.[38]

[33] Eurostat, *Employment by occupation and economic activity* table.
[34] Please consult the last subchapter of chapter IV for a comparison with wind and hydro sectors.
[35] OECD 2018.
[36] Ibid.
[37] Ibid.
[38] Ibid.

Decommissioning phase implies project management and engineering activities that range from site restoration, (environmental) remediation services and waste management services.[39]

Please consult the figure below for an overview over the impact on employment during the three lifetime phases of the nuclear power industry.

Figure 11 – Direct impact on employment during three nuclear lifetime phases, 2019



Source: Deloitte calculations

Impact on disposable household income

Disposable household income is the amount of money that households have available for spending and saving after income taxes have been accounted for. Disposable income is often monitored as one of the key economic indicators and used to gauge the overall state of the economy.

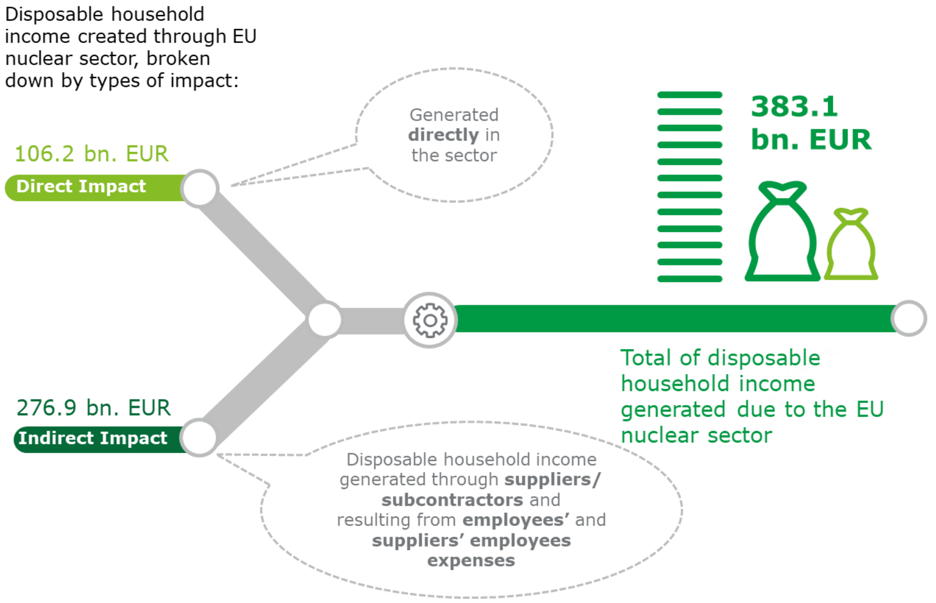
Today, the nuclear industry generates an annual disposable household income of **383.1 billion Euro**. The direct impact represents the disposable household income of employees directly working in nuclear power plants and amounts to **106.2 billion Euro** throughout the period. The indirect impact translates both into the incomes of employees throughout the nuclear supply chain and the incomes of the industry's direct employees' and the suppliers' employees. The indirect impact of the nuclear sector in EU household incomes amounts to **276.9 billion Euro**.

The figure presented below captures the impact of the industry on disposable household incomes throughout the European Union.

In 2019, the nuclear industry accounts for a **total of 383.1 billion Euro disposable household income** in the European Union

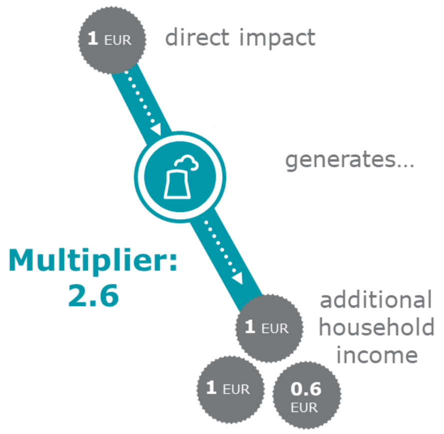
[39] Ibid.

Figure 12 - Impact on disposable household income, 2019



Source: Deloitte calculations

Figure 13 - Disposable household multiplier, 2019



Every Euro generated as direct impact of the EU nuclear sector generates an indirect impact of **2.6 Euro** and a total of **3.6 Euro** in disposable income among European households today.

Source: Deloitte calculations

With every Euro generated in household incomes, the nuclear industry generates a total of **3.6 Euro of household income** in the EU

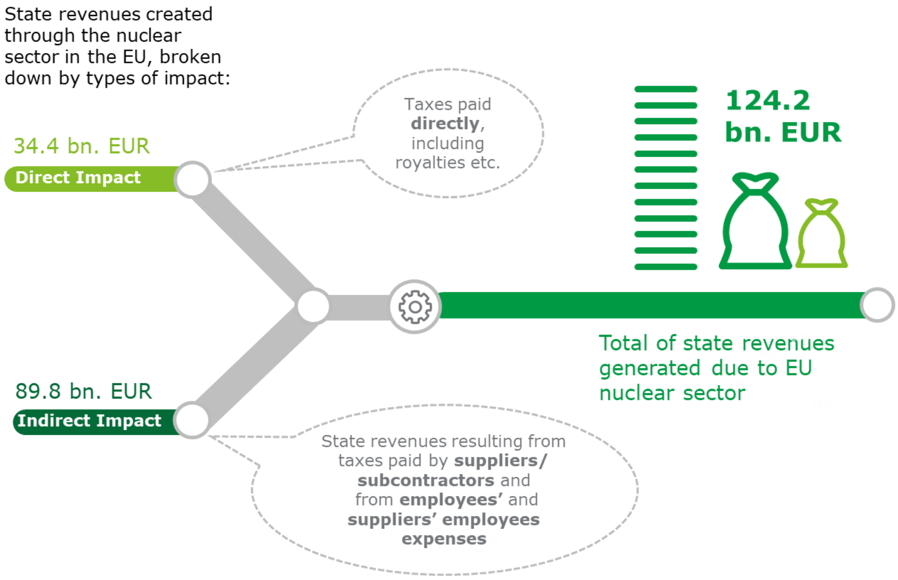
Impact on public revenues

Taxes deriving from the EU nuclear sector activity significantly contribute to the national budgets of EU member states. For the current period, total impact on public revenues generated through the nuclear industry amount to reach **124.2 billion Euro**, indirect taxes (VAT, excise duty, etc.) and PIT accounting for the greatest share of tax contributions.

The current **direct impact** that the nuclear industry has on state revenues through tax contributions amounts to **34.4 billion Euro,** whereas the **indirect** impact amounts to **89.8 billion Euro**, primarily resulting from PIT[40], CIT[41] and VAT[42]. Additionally, the effects on the economy through the expenditures of the operators' and suppliers' employees are included in the indirect impact.

The nuclear industry currently generates a **total of 124.2 billion Euro public revenues** per year in the European Union

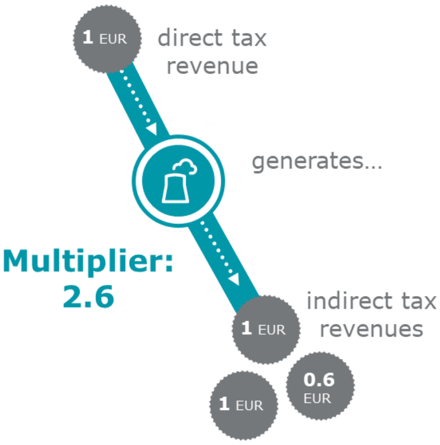
Figure 14 - Impact on EU public revenues, 2019



Source: Deloitte calculations

40 Personal income tax
41 Corporate income tax
42 Value added tax

Figure 15 - Public revenues multiplier, 2019



Source: Deloitte calculations

Every Euro payed directly by the nuclear industry through tax payments generates indirect tax revenues of **2.6 Euro** and a total of **3.6 Euro** public revenues throughout the EU.

Every Euro paid for taxes from the nuclear industry generates state revenues of **3.6 Euro** in the European Union

Impact on trade balance

Trade balance expresses **the difference between the value of the exports and the imports from/in a country/region**. In this case, a negative trade balance would indicate that the country/region is net importer of goods and services (with imports higher than exports), therefore having a **trade deficit**, while a positive value of the indicator indicates that the country/region is a net exporter of goods and services (with exports therefore being higher than imports), therefore having a **trade surplus**.

Currently, the nuclear sector generates an annual trade surplus of **18.1 bn. Euro in the EU**. This represents total impact, therefore includes both direct and indirect impact.

Currently, the sector generates a trade surplus of **18.1 bn. Euro** per year in the EU

Imports resulted from the nuclear activity are represented by all the products and services required for the building and operation of the nuclear power plants, but also acquisition of other goods/services resulted in an indirect manner (e.g. additional purchases of imported consumption products, resulting from increase in wages or additional salaries paid by the nuclear sector).

Exports resulted from the nuclear activity are represented by the sales of electricity generated by the nuclear industry, but also by the indirect exports (e.g. increase of exports of manufacturing industry due to lower electricity prices).

Current nuclear industry impact on the 28 EU-countries' economies

Member states with nuclear power generation

Currently, there are 14 EU countries with nuclear power generation. These countries are Belgium, Bulgaria, the Czech Republic, Germany, Spain, Finland, France, Great Britain, Hungary, the Netherlands, Romania, Sweden, Slovenia and the Slovak Republic. The impact of nuclear power generation in these countries derives from both direct contributions of the sector, such as contribution to GDP growth, job creation and paid taxes, and indirect effects, deriving from the suppliers and employees' contributions that sustain the domestic economies. Details on the impact of the nuclear industry on the national economies of EU member states with nuclear capacities are published in the Appendix.

Today, there are **14 countries with nuclear capacities** in the European Union

Member states without nuclear power generation

Concerning the 14 EU countries without current nuclear power generation (Austria, Cyprus, Denmark, Estonia, Greece, Croatia, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Poland and Portugal), there is a recordable impact - both direct and indirect - deriving from nuclear power generation, as well. Thus, the industry still has positive economic effects on these countries. This is due to the interconnectedness of the national economies and labour force markets. More precisely, countries without nuclear capacities still have qualified workforce and subcontractors providing expertise and technologies for the nuclear industries in neighbouring member states, which generates both direct and indirect effects in the domestic economy and labour force markets of the non-nuclear countries. Please consult the Appendix for detailed impact figures of the nuclear industry on EU member states without nuclear power generation.

Even though a country has no installed nuclear capacity, positive effects still exist due to cross-border economic activities

IV. The Contribution of the Nuclear Power Industry to the European Union's 2050 Vision

For a thorough understanding of the future benefits the nuclear industry could have on the future EU economy, the present study applied two capacity scenarios for installed nuclear energy for the period 2020-2050.[43] As previously mentioned, these scenarios are:

- High Scenario with **150 GW** installed nuclear capacity by 2050
- Medium Scenario with **103 GW** installed nuclear capacity by 2050

The following pages introduce and detail the future benefits of the high nuclear capacity scenario. For more information about the medium capacity scenario, please consult subchapter "Economic effects in the medium capacity scenario". Moreover, a comparative analysis is provided in the subchapter "Contribution to a sustainable economic growth in the EU – Assessment of future scenarios". For more details on disaggregated impact results, please consult the Appendix. There you will find detailed information on future economic benefits generated by the nuclear industry in the 28 member states of the Union.

Economic benefits in the high capacity scenario

The figure shown below depicts the overall outcomes of the impact assessment for the High Scenario. Its deployment would **sustain positive effects throughout all analysed areas**: GDP growth, employment, public revenues and household incomes. Detailed figures for each of the selected indicators are to be found on the following pages of this chapter.

[43] FTI-CL Energy 2018.

Figure 16 - Overview of the additional economic effects in the High Scenario, 2020 - 2050

2020 → 2050

576.0 bn. EUR — in **EU GDP** generated annually by nuclear sector, equal to a 1.5 - 2% share of EU GDP

1,321,600 — average number of **jobs** sustained each year throughout the period by the nuclear sector

45% — of the total number of jobs in the nuclear sector will be **highly skilled**, equaling a number of 595,600

490.9 bn. EUR — average disposable **household income** per year due to the activities of the nuclear sector

110.2 bn. EUR — average **state revenues** generated annually through tax payments deriving from the European nuclear sector

33.5 bn. EUR — average **trade surplus** generated annually within the European nuclear sector

Source: Deloitte calculations

The cumulated impact of the nuclear industry on **the EU GDP** would amount to **17.3 trillion Euro** until 2050

The results of the impact assessment for the High Scenario show that the nuclear industry will **sustain 1,321,600 full-time jobs** throughout the period, will **generate 110.2 bn. Euro of additional cumulated state revenues, 490.9 bn. Euro in household income, 576.0 bn. Euro of cumulated additional GDP and 33.5 bn. EUR trade surplus** over the analysed period (2020-2050).

In the future, the nuclear industry could sustain **1.3 million jobs** for Europeans every year, generating total of **576.0 billion Euro in EU GDP** annually and **490.9 billion Euro** annual **household income** throughout the EU

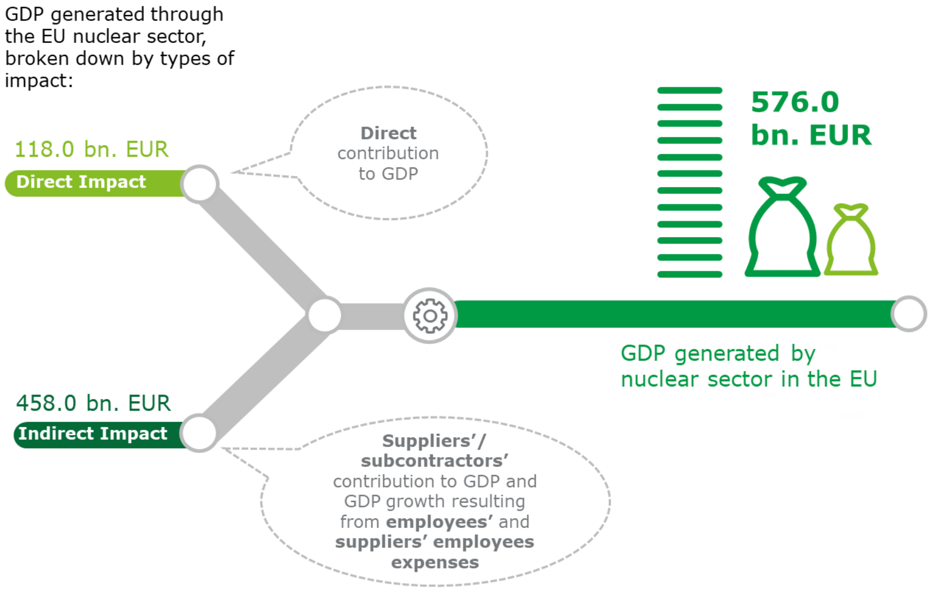
Impact on EU GDP

GDP as a macroeconomic indicator can provide insights regarding the share of the nuclear industry on future economic growth in the European Union.

The **direct impact** can be calculated through the activities associated directly to the nuclear power generation and will reach **118 billion Euro**, whereas the **indirect impact** will amount to **458 billion Euro**, generated through suppliers and subcontractors that are engaged by the nuclear industry. Additionally, the indirect impact contains the expenses of the industry's direct employees, as well as the expenses of the suppliers' employees in the EU economy. Finally, the cumulated impact of the nuclear sector on the European GDP will amount to **576 billion Euro per year**, more than half a trillion Euro by 2050. This will represent a share of 1.5 – 2 % in the projected GDP by 2050.

The figure presented below captures the effects on the EU GDP, occurring due to the nuclear industry activities, for the period 2020 - 2050.

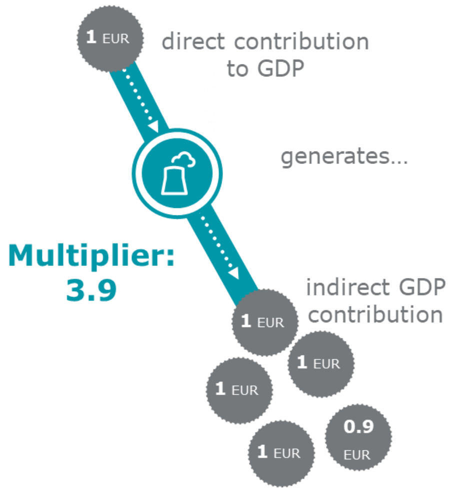
Figure 17 -Impact of the nuclear industry on the EU GDP, 2020 - 2050



Source: Deloitte calculations

The overall **yearly** impact of the nuclear industry on **EU GDP** will amount to **half a trillion Euro**

Figure 18 - Multiplier GDP, 2020 - 2050



Source: Deloitte calculations

As presented in the figure on the left, the multiplier for **1 Euro** of direct impact on GDP due to the nuclear sector is 3.9, translating into the generation of **3.9 Euro** indirect and **4.9 Euro** total impact on the EU GDP.

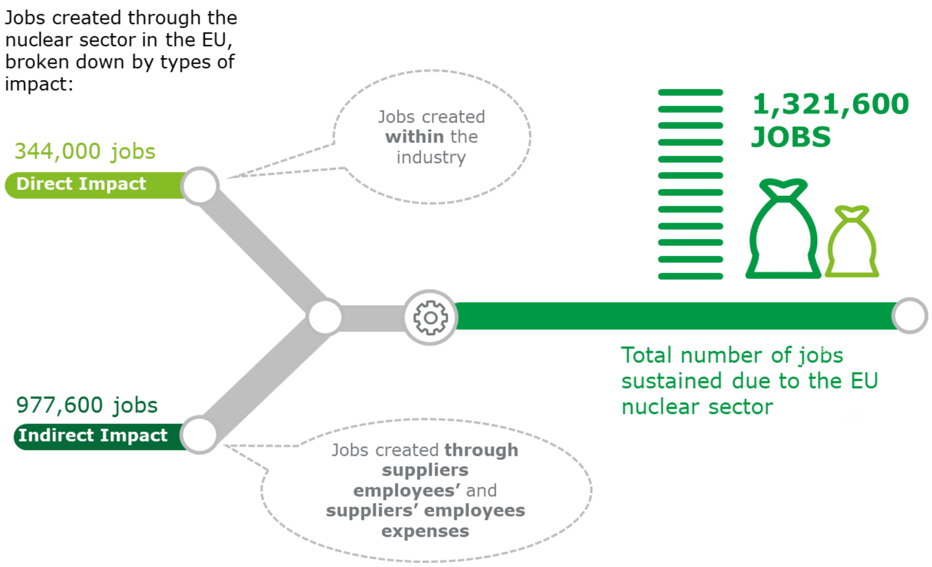
Every Euro of direct impact of the nuclear industry on the EU GDP will generate a total of **4.9 Euro in EU GDP**

Impact on employment

The estimates indicate that between 2020 and 2050, **344,000 jobs** will be **sustained directly** through the nuclear industry every year. These direct jobs will **indirectly sustain** other **977,600 jobs** offered by the suppliers. Moreover, the indirect impact figure includes job created through the expenditures of both the industries' employees and suppliers' employees in diverse economic sectors. Overall, the nuclear industry will account annually for more than one million jobs, or more precisely, **1,321,600 jobs** on the European labour force market, by 2050.

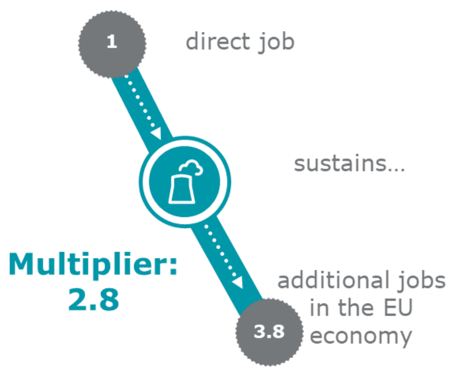
In the period 2020 -2050, the nuclear industry could account for **more than 1.3 million jobs annually** on the EU labour force market

Figure 19 - Impact of the nuclear industry on the EU labour market, 2020 - 2050



Source: Deloitte calculations

Figure 20 - Jobs Multiplier, 2020 - 2050



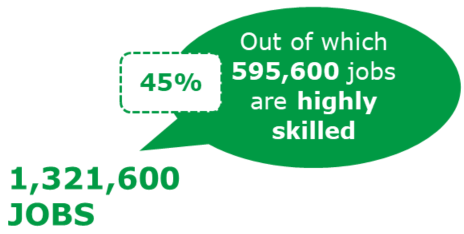
Every job directly generated in the nuclear industry would sustain **2.8 indirect jobs**, totalling **3.8 jobs** on the EU labour force market.

In the future, every **job generated directly** in the nuclear industry will **sustain nearly 4 jobs** in the European Union

Source: Deloitte calculations

Highly skilled professionals

Figure 21 - Highly skilled jobs, 2020 - 2050



Source: Deloitte calculations

In the future, **45%** of the nuclear labour force will be **highly skilled** in the EU

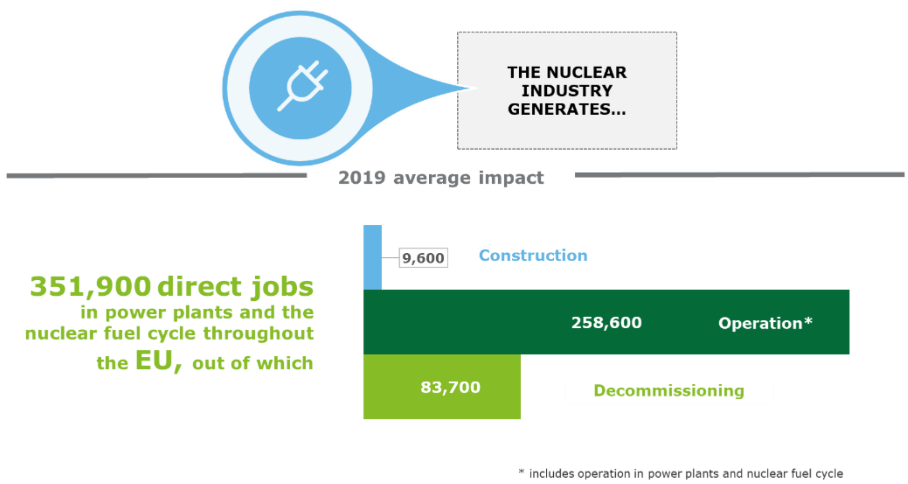
Out of a total of **1,321,600 jobs** that are sustained every year throughout the period by the nuclear sector, the share of highly skilled jobs will amount to **595,600**.

In other words, more than **half a million of well-paid jobs** will be sustained annually by the nuclear industry throughout the European Union. This means that approximately **1 out of 2 employees** working directly or indirectly in the nuclear industry will be highly skilled, representing a **share of 45%** throughout the period. Compared to the current situation, the share of highly skilled professionals decreased by 2 percentage points, mainly due to the expected increase of employment during construction phase, which requires less qualified labour force compared to operation phase.

Employment during the nuclear lifetime phases

The figure below shows the different impact figures for High Scenario on employment throughout the three lifetime phases of the nuclear power industry. In the High Scenario, 155,800 jobs will be sustained annually in the operation phase in the European Union throughout the period. Moreover, during the next 30 years, 143,400 jobs will be sustained on average every year through construction works in nuclear power plants.

Figure 22 - Impact on employment during nuclear lifetime phases, 2020 - 2050



Source: Deloitte calculations

Impact on disposable household incomes in the EU

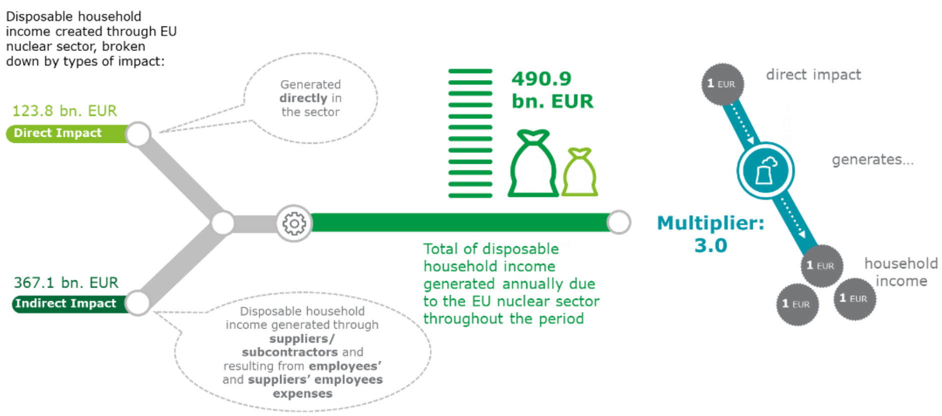
For the future period, the nuclear industry would generate on average an annual disposable household of **490.9 billion Euro** in the period 2020-2050.

The direct impact created by the nuclear industry will amount to **123.8 billion Euro** throughout the period. The indirect impact translates both into the incomes of employees throughout the nuclear supply chain and the incomes of the industry's direct employees' and the suppliers' employees and will total **367.1 billion Euro**.

The figure presented below shows the impact of the industry on disposable household incomes throughout the European Union.

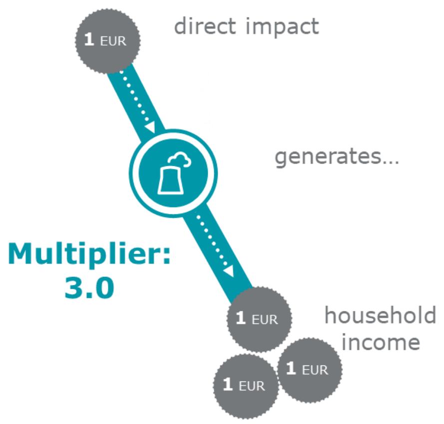
In the future, disposable household incomes in the EU will amount to **nearly half a trillion Euro annually** due to the nuclear industry activities

Figure 23 - Impact on disposable household income, 2020 - 2050



Source: Deloitte calculations

Figure 24 - Household income multiplier, 2020 - 2050



1 Euro of direct impact generated due to the nuclear industry will create **3 Euro** of disposable household income throughout the EU, translating into a total impact of **4 Euro**.

By 2050, **every** Euro of household income **generated** due to the nuclear industry will sustain overall **4 Euro** of household income throughout the EU

Source: Deloitte calculations

Impact on public revenues

Taxes deriving from the EU nuclear sector activity will significantly contribute to the national budgets of EU member states. For the period 2020–2050, total impact on public revenues generated through the nuclear industry will reach **110.2 billion Euro** every year.

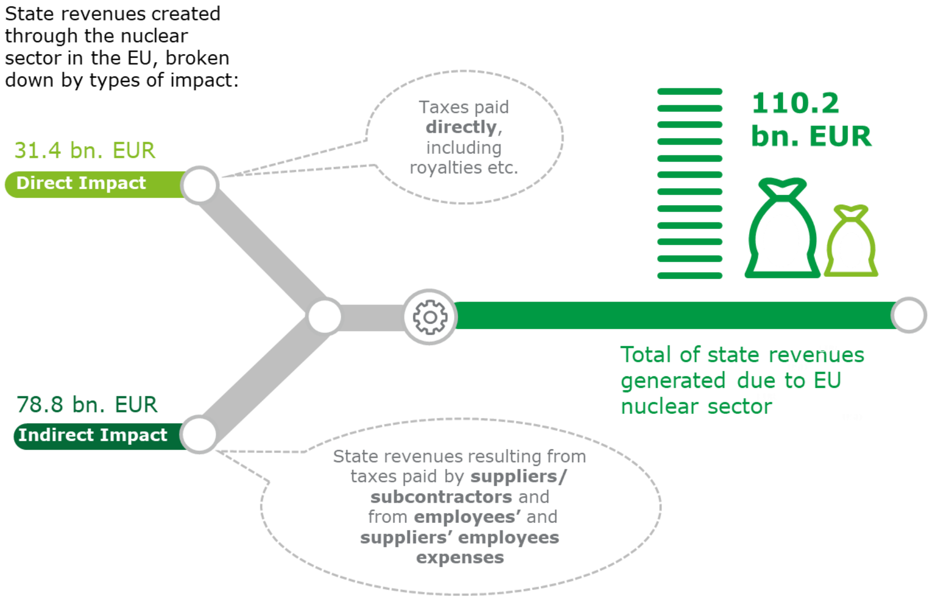
Tax contributions represent a direct support regarding state expenditures and facilitate budget tasks like development of infrastructure, education and health care.

The additional output, created jobs and higher wages that the nuclear industry generates will translate into higher tax collections and subsequently into an increase of public revenues.

The direct impact that the nuclear industry has on state revenues through tax contributions will amount to **31.4 billion Euro.** These contributions mainly consist of VAT, PIT and CIT paid by the nuclear power plant operators. **The indirect** impact will amount to **78.8 billion Euro.** Additionally, the effects on the economy through the expenditures of the operators' and suppliers' employees, predominantly consisting of VAT are included in the indirect impact mentioned above.

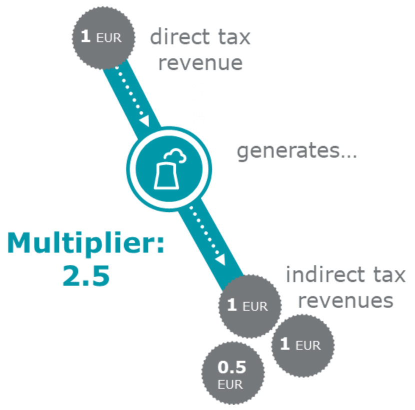
For the period 2020-2050, **the yearly average of state revenues** deriving from the nuclear industry would **cover about 80% of the 2019 budget of the European Union**

Figure 25 - Impact on public revenues, 2020 - 2050



Source: Deloitte calculations

Figure 26 - Public revenues multiplier, 2020 - 2050



1 Euro direct tax payment in the European nuclear industry will account for **2.5 Euro** indirect tax payments, resulting in overall **3.5 Euro** pubic revenues.

Source: Deloitte calculations

By 2050, **every Euro** of taxes paid from the nuclear industry will generate **additional public revenues of 2.5 Euro**

By 2050, the trade balance surplus of the nuclear industry will amount to **33.5 bn. Euro** annually

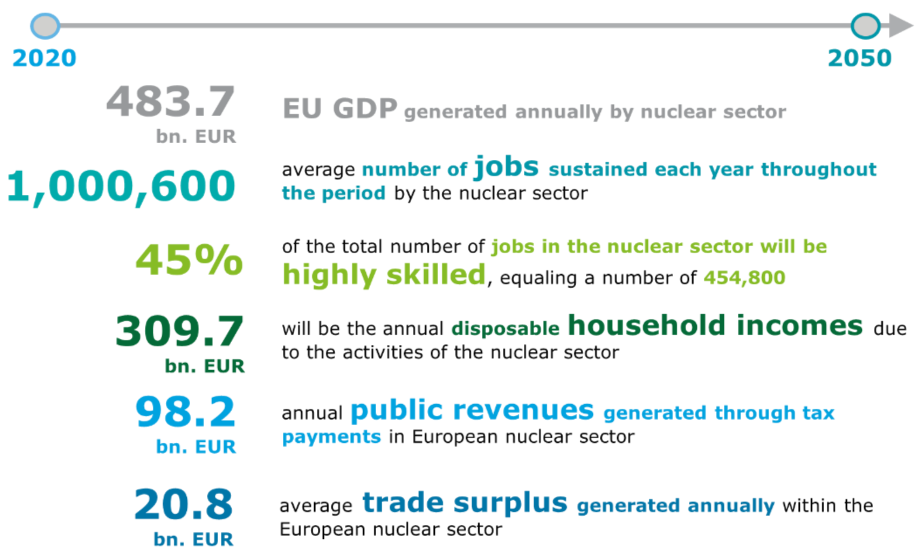
Impact on trade balance

The nuclear sector will have significant impact on the trade balance of EU. In this regard, for the period 2020–2050, annual average trade balance surplus generated through the nuclear industry will reach on average **33.5 billion Euro** in the High Scenario. This represents total impact, including both direct and indirect impact.

Economic effects in the medium capacity scenario

The figure below depicts the economic benefits of the impact assessment for the Medium Scenario. Its deployment would generate 483.7 billion Euro in the EU GDP, would sustain annually 1,000,600 jobs on average, out of which 454,800 would be highly skilled, and could generate 98.2 billion Euro public revenues and 309.7 billion Euro disposable household incomes, respectively.

Figure 27 - Economic effects in the Medium Scenario, 2020 - 2050



Source: Deloitte calculations

Contribution to a sustainable economic growth in the EU – Impact comparison for two future scenarios

The Scenario likely to happen (Low Scenario) scenario indicates the economic effects deriving from a low nuclear setting in the future, with 36 GW installed capacity by 2050. The Low Scenario serves as a reference point for the impact assessment. The **deployment of the high nuclear capacity scenario would lead to the amplification of positive effects** and benefits in all of the analysed impact areas throughout the period 2020 - 2050. Compared to Medium Scenario, the indicators GDP, job creation and household incomes would see a significant increase in the High Scenario.

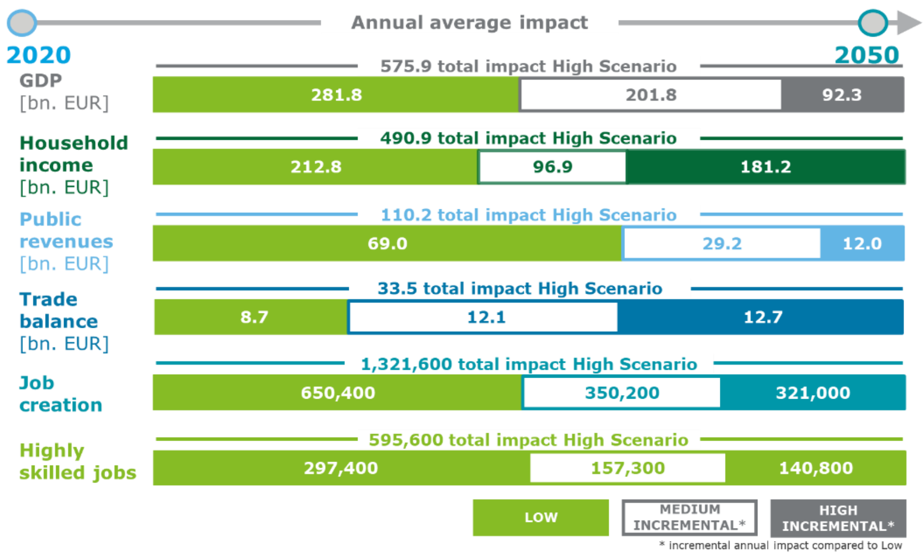
Compared to the Medium Scenario, the impact on employment would see an **increase by 321,000 jobs every year**, with **140,800 highly skilled jobs** sustained annually, if the high capacity scenario will be deployed**.** What is more, GDP contribution of the nuclear industry would amount to **additional 92.3 billion Euro annually**, while household incomes of Europeans would even rise by annually **181.2 billion Euro** throughout the period.

Compared to Low Scenario, future benefits of the High Scenario are even more decisive. More details on the incremental impacts of high and Medium Scenario are provided on the following pages.

The figure below depicts the summary of economic benefits of both medium and High Scenario, emphasizing the annual incremental impact that these scenarios would have throughout the period 2020 – 2050, compared to the Low Scenario.

Compared to Medium Scenario, the deployment of the **high nuclear capacity scenario** would lead to the **amplification of positive effects** throughout the EU

Figure 28 – Low Scenario and incremental impact of Medium and High Scenario, 2020 – 2050



Source: Deloitte calculations

In the High Scenario, **321,000 additional jobs** would be sustained every year, compared to Medium Scenario

Impact on GDP

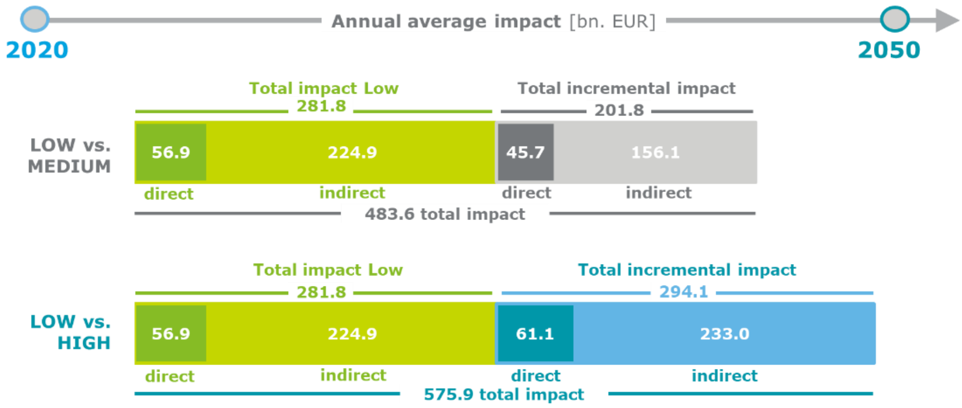
Comparing High and Medium to the Low Scenario, additional economic benefits will be substantial in the future.

The deployment of the High Scenario would generate an annual incremental impact of **294.1 billion Euro** throughout the period, dividing into an additional direct impact of 61.1 billion Euro and indirect impact of 233 billion Euro, compared to Low Scenario. This yearly incremental impact would translate into an **overall incremental impact of nearly 9 trillion Euro on the EU GDP** generated due to the deployment of the High Scenario throughout the period, being added to Low Scenario. Overall, the High Scenario would account for a cumulated impact of no less **than 17.3 trillion Euro** during the upcoming 30 years.

On the other hand, the deployment of the Medium Scenario would lead to a reduction of GDP impact by 92.3 billion Euro every year. For the whole period, this would translate into a total reduction of 2.8 trillion Euro in the EU GDP.

The deployment of the **High Scenario** would entail an overall incremental impact on GDP of nearly **9 trillion Euro** during the next 30 years

Figure 29 – GDP impact, Low, High and Medium Scenario, 2020 - 2050



Source: Deloitte calculations

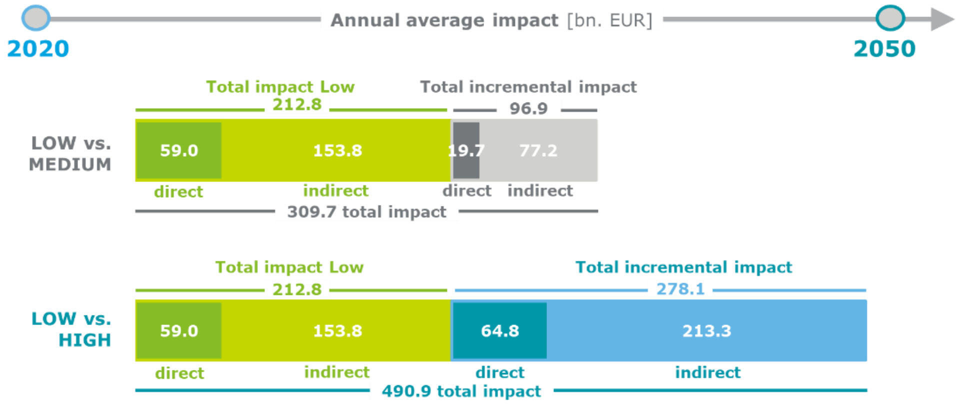
Impact on disposable household income

In the High Scenario, EU household incomes would increase by **278.1 billion Euro** on an annual basis, compared to Low Scenario. The direct incremental impact will amount to 64.8 billion Euro, whereas the additional indirect impact will be 213.3 billion Euro every year. To put it differently, the resulting **incremental impact would rise to a total of 8.3 trillion Euro** over the time span of the upcoming 30 years, being added to Low Scenario. Subsequently, the total impact of the nuclear industry on European household incomes would reach a cumulated amount of **14.7 trillion** Euro over the period 2020 – 2050.

In contrast, the deployment of the Medium Scenario would involve a significant increase of future household incomes. An annual shortfall of 181.2 billion Euro would result in a total impact reduction of 5.4 trillion Euro over the period.

Due to the nuclear industry, the incremental impact on EU household incomes would rise by **overall 8.3 trillion Euro** throughout the period

Figure 30 – Impact on disposable household income, Low, High and Medium Scenario, 2020 – 2050



Source: Deloitte calculations

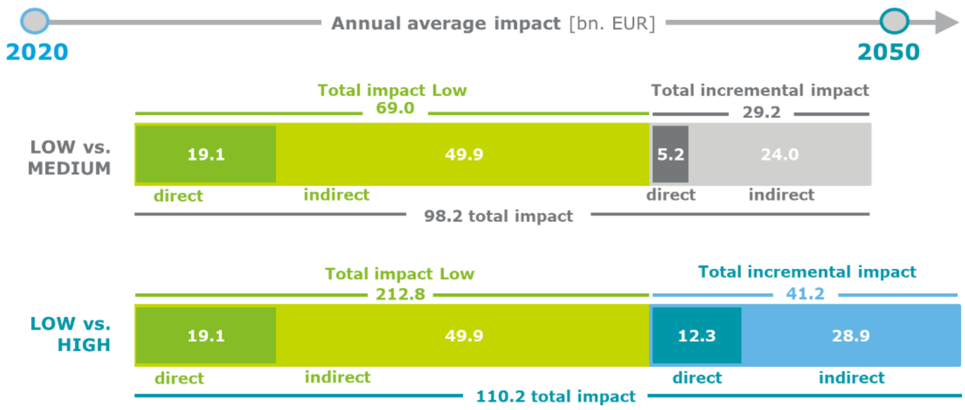
Impact on public revenues

As the figure below shows, the deployment of the High Scenario with a nuclear capacity of 150 GW would entail an additional annual impact of **41.2 billion Euro** on public revenues in the EU, divided into 12.3 billion Euro direct and 28.9 billion Euro indirect impact on annual public revenues, compared to Low Scenario. This results in an incremental impact of **more than 1.2 trillion Euro** or a cumulated impact of **3.3 trillion Euro public revenues** in the EU member states in the course of the upcoming 30 years.

In the high scenario, the incremental impact on EU public revenues would rise to **overall 41.2 billion Euro** every year

On the other hand, in the Medium Scenario, the incremental impact would shrink by 12 billion Euro every year, totalling a reduction of 360 billion Euro in state revenues throughout the analysed period.

Figure 31 - Impact on public revenues, Low, High and Medium Scenario, 2020 – 2050



Source: Deloitte calculations

Impact on employment

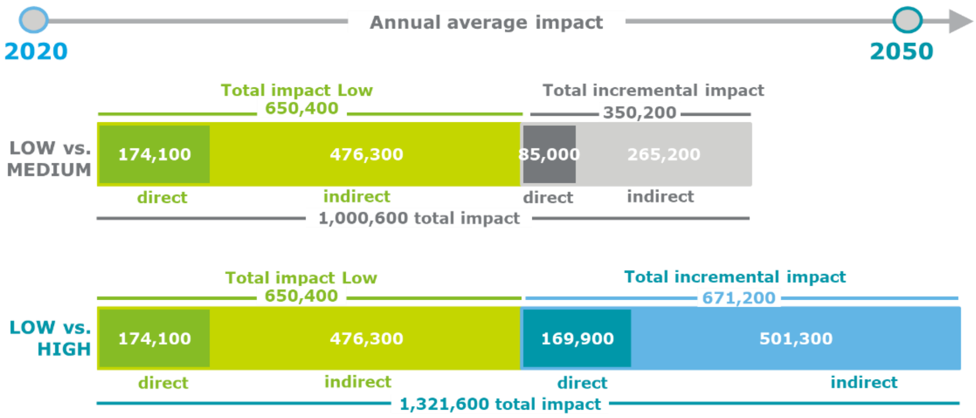
The nuclear industry could have a substantial contribution to the creation and security of jobs. Through the deployment of the High Scenario, the industry could sustain an additional number of 169,900 direct and 501,300 indirect employees every year, compared to Low Scenario. This translates into an annual contribution to the labour force market amounting to **671,200 jobs**. Subsequently, the cumulated incremental impact on employment is substantial: Throughout the period, the nuclear industry could sustain a number of more than **20 million additional direct and indirect jobs** in the in the High Scenario, being added to a Business as usual situation.

Overall, a cumulated number of **39.6 million jobs** would be sustained by the nuclear industry throughout the period, if the High Scenario will be deployed.

On the contrary, employment figures would see a significant decline in the Medium Scenario, shrinking by 321,000 jobs per year or cumulated 9.6 million jobs compared to High Scenario throughout the period 2020 - 2050.

The nuclear industry could account for **overall 39.6 million jobs** during the upcoming 30 years

Figure 32 - Impact on employment, Low, High and Medium Scenario, 2020 – 2050



Source: Deloitte calculations

Impact on highly skilled jobs

As the present study has shown, the nuclear industry has a remarkable share of highly skilled employees.

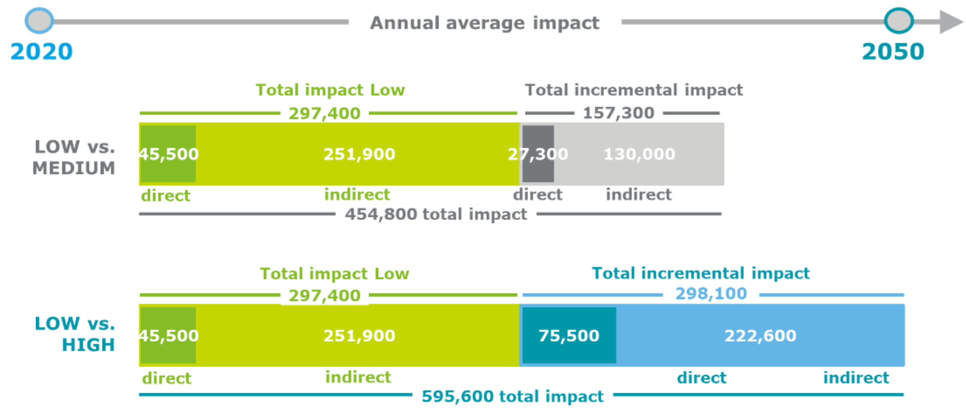
In the future period, the deployment of the High Scenario would lead to an annual incremental impact of **298,100 highly skilled jobs** in the EU economy, compared to Low Scenario. In other words, during the next 30 years, the nuclear industry would generate or sustain additional **9 million jobs for highly skilled professionals** throughout the EU, if the High Scenario will be deployed.

The cumulated impact for High Scenario would amount to no less than **17.9 million** highly skilled jobs throughout the EU during the upcoming 30 years.

On the other hand, the deployment of the Medium Scenario would involve a decline by more than 4.2 million highly skilled jobs until 2050.

In the next 30 years, **overall 18 million highly skilled professionals** could be employed by the nuclear industry

Figure 33 - Impact on highly skilled employment, Low, High and Medium Scenario, 2020 – 2050



Source: Deloitte calculations

Impact on trade balance

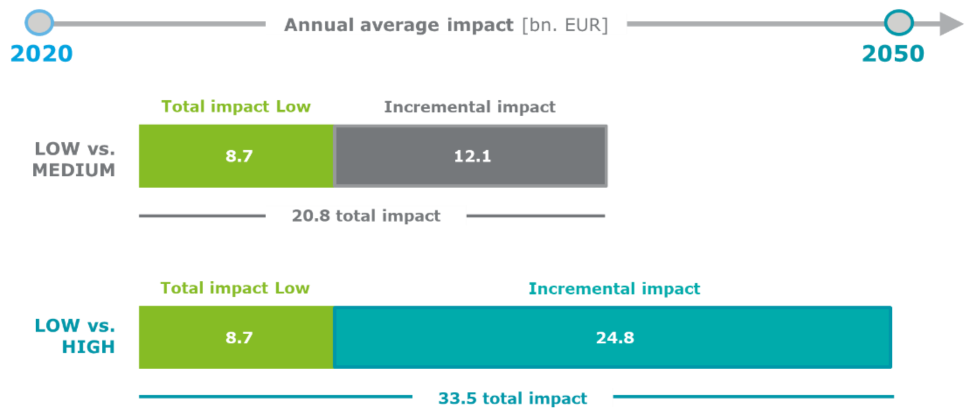
Additional installed nuclear capacities within EU will also generate significantly additional trade surplus, re-enforcing the importance of the nuclear sector in the overall EU economy.

As the figure below shows, the deployment of the High Scenario with a nuclear capacity of 150 GW would trigger an additional annual impact of **24.8 billion Euro** on trade surplus in the EU, compared to Low Scenario. This results in a total incremental impact of **744 billion Euro,** or an overall cumulated impact of **1 trillion Euro** trade surplus in the EU during the upcoming 30 years.

On the other hand, in the Medium Scenario, the incremental impact would shrink by 12.7 billion Euro every year, totalling a reduction of 381 billion Euro throughout the analysed period (2020-2050).

Due to the nuclear industry, the trade surplus of the EU could raise by **1 trillion Euro** during the upcoming 30 years

Figure 34 - Impact on trade balance, Low, High and Medium Scenario, 2020 – 2050



Source: Deloitte calculations

Impact comparison of labour-intensive energy sectors

For a benchmarking purpose, the impact analysis has been extended with comparisons between two other sectors of the energy industry that provide a significant number of jobs in the national economies. The expectation was that the present study will have the same order of magnitude with other impact studies, for indicators like installed capacity [GW], employment [jobs/ year] and total impact on GDP [bn. EUR].

The chosen energy sectors were wind and hydro energy. Being also energy sources with low carbon footprint, it made the comparison even more relevant.

The results confirmed the hypothesis, proving that our methodology has consistent results with various other methodologies (for example input-output model).

Based on this comparison, another conclusion can be drawn: **the nuclear sector provides more jobs per installed GW and has a larger impact on the GDP than the other two clean energy sectors.**

The European Wind Energy Association presents in its 2017 study "Local impact, global leadership", that in 2030, the 400 GW installed in wind will sustain **716,600 jobs**. The total impact on GDP will be up to **116.5 bn. Euro**.[44]

The International Hydropower Association published a study in 2015, covering both the EU-28 countries and the whole European continent. According to it, in 2030, the total installed capacity will be 263 GW, sustaining annually **127,000 jobs** and having a total annual impact of **52 bn. Euro** on GDP.[45]

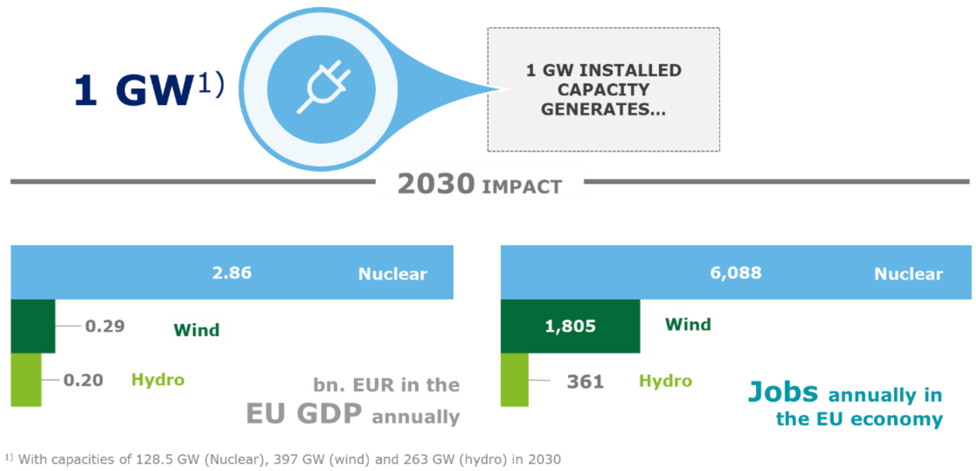
The present study shows that the EU nuclear sector will have a net installed power of 128.5 GW in 2030 (growing to 150.3 GW by 2050), an average of **1,321,000 direct and indirect jobs** generated or sustained annually by 2030 and an annual impact on GDP of **575.9 bn. Euro**.

Compared to the wind and hydro sectors, nuclear will accounts for a higher impact on both EU GDP and job creation. When broken down into 1 GW of installed capacity, the scale of economic effects the nuclear industry would have in the EU becomes even more distinct. In 2030, 1 GW of installed nuclear capacity would generate a yearly impact of 2.9 billion Euro on EU GDP, whereas the wind industry would merely account for 0.3 billion Euro annually. This implies that the impact of the nuclear industry on EU GDP will be about **10 times higher** than the impact of the EU wind industry. Additionally, the effects on employment would be even more beneficial. By 2030, 1 GW of installed nuclear capacity would translate into 6,088 jobs sustained annually on the EU labour market. Accordingly, the nuclear industry's impact on job creation would be more than **thrice as large** compared to the wind sector's impact. Compared to the hydro sector, numbers are even more impressive: the impact of nuclear on job creation would be about **17 times higher** than the impact of the EU hydro industry. Please consult the figure below for an overview of the economic effects of the nuclear, wind and hydro sectors by 2030.

In the High Scenario, the impact of the nuclear industry on job creation in the EU will be **three times higher** than the impact of the EU wind sector and even **17 times higher** than the impact of the hydro sector by 2030

[44] European Wind Energy Association 2017.
[45] International Hydropower Association 2015.

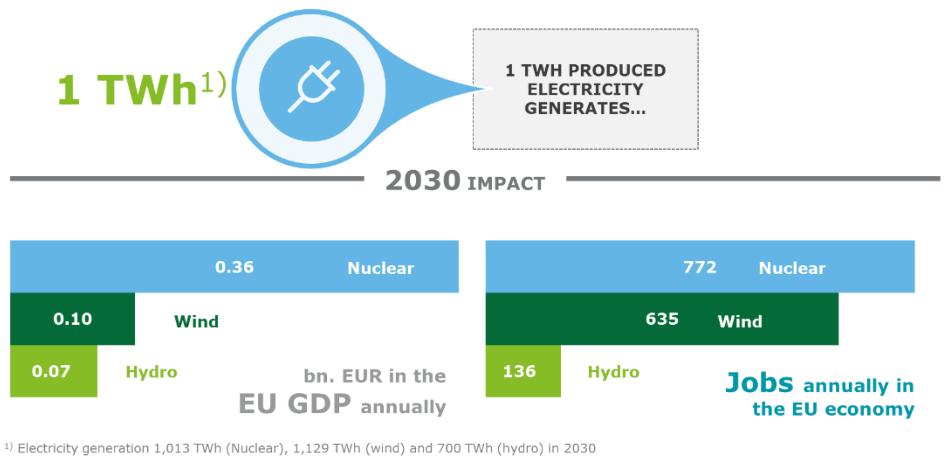
Figure 35 - Impact of 1 GW installed capacity on EU GDP and employment, nuclear, wind and hydro, 2030



Source: Deloitte analysis

An alternative approach of comparing energy sectors would be to assess the impact of one TWh produced electricity on the economy. Please consult the the figure below to see the impact of one TWh produced energy on the EU GDP and employment by 2030.

Figure 36 - Impact of 1 TWh produced electricty on EU GDP and employment, nuclear, wind and hydro, 2030



Source: Deloitte analysis

The impact of the energy sector on the EU economy in different future scenarios

Another benchmark relevant for the current report could be considered the results from a study conducted in 2013 for the European Commission concerning the employment effects of energy roadmap 2050 alternatives[46]. The latter analyses six development scenarios for the EU 2050 energy landscape, as presented in the table below.

Table 6 - Outline of the six scenarios from the study conducted in 2013 for the European Commission concerning the employment effects of energy roadmap 2050 alternatives

Scenario code	EU policy	Description
BA	Current policies	Baseline scenario considers only the policies and measures adopted until March 2010. This scenario implies the achievement of 2020 targets in terms of RES and GHG emissions through energy efficiency measures in residential, transport and services sectors.
S1	Higher energy efficiency	This scenario implies energy efficiency measures such as standards for household appliances, new buildings and electricity generation.
S2	Diversified supply technologies	This scenario foresees no support measures for energy efficiency and RES. Also, there are no constraints for nuclear and CCS.
S3	High RES	This scenario implies additional measures for achieving a high overall RES share and higher use of renewable sources in power generation.
S4	Delayed CCS	This scenario is similar to S2, but implies constraints for CCS. Assumptions for nuclear energy are similar to the ones from S1 and S2.
S5	Low nuclear	This scenario is similar to S2, but implies constraints for nuclear energy. Assumptions for CCS are similar to the ones from S1 and S2.

Source: Employment Effects of selected scenarios from the Energy roadmap 2050 (2013), Deloitte remake

The table below presents the results of this study, illustrating the differences between the six scenarios. These results show that for the scenarios with higher nuclear (S2 and S4), the contribution of the energy sector to the overall EU economy will be, in general, higher compared to the scenario with higher RES (S3). This states once more the importance of the nuclear technology in the future energy system of the EU.

[46] European Commission 2013.

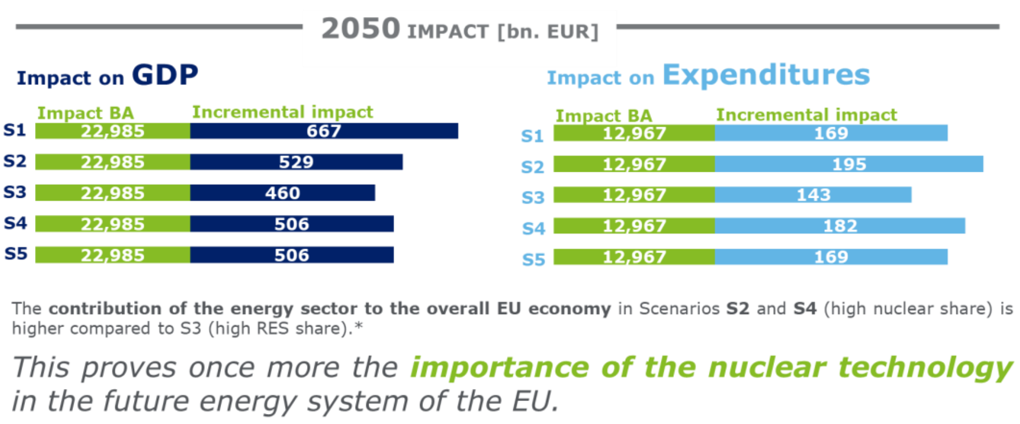
Table 7 – Macroeconomic results of the six scenarios from the study conducted in 2013 for the European Commission concerning the employment effects of energy roadmap 2050 alternatives

		Impact 2050				
	BA	**S1**	**S2**	**S3**	**S4**	**S5**
	bn. EUR 2005	*% difference from BA*	*% difference from BA*	*% difference from BA*	*% difference from BA*	*% difference from BA*
GDP	22,985	2.9%	2.3%	2.0%	2.2%	2.2%
Consumer expenditure	12,967	1.3%	1.5%	1.1%	1.4%	1.3%
Investment	5,357	7.4%	4.0%	3.4%	4.0%	3.8%
Exports (extra-EU)	4,432	0.4%	0.4%	0.2%	0.3%	0.2%
Imports (extra-EU)	4,258	0.5%	0.0%	0.6%	-0.1%	-0.2%

Source: Employment Effects of selected scenarios from the Energy roadmap 2050 (2013), Deloitte remake

To put it differently, the impact of the energy sector on EU GDP is expected to be bigger in the 2 Scenarios with high nuclear capacities than in the Scenario with a high share of energy from renewable sources. In Scenario S2, the energy sector is expected to account for a total impact of 23.514 trillion Euro in EU GDP in 2050, whereas Scenario S3 would generate an impact of 23.445 trillion Euro. The difference is no less than an additional impact of 69 billion Euro that could be generated in the EU economy, if the S2 scenario was deployed. Likewise, the total impact on expenditures and investments would increase by 52 billion Euro and 32 billion Euro, respectively, if S3 would come to pass by 2050. Figure 36 shows the different incremental increase in impact for the six scenarios analyzed in the abovementioned study

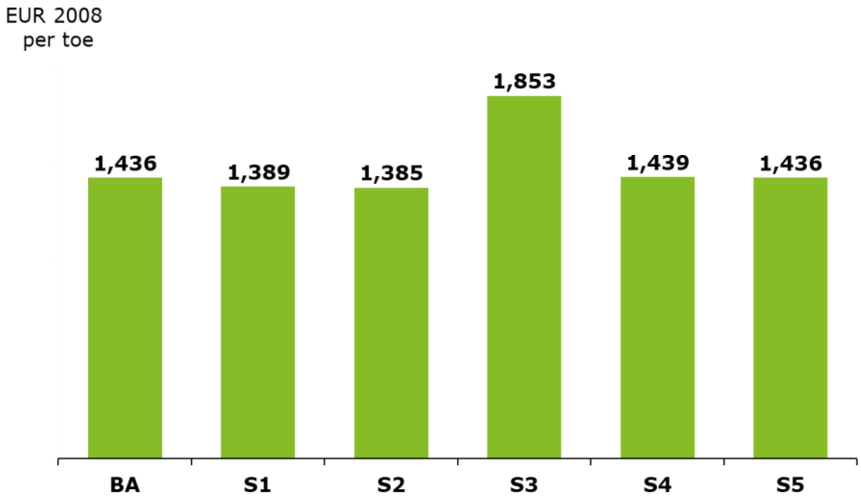
Figure 37 - Total impact on GDP, expenditures and investment in the six Scenarios by 2050, EC study 2013



Source: European Commission 2013, Deloitte remake

Moreover, the same study identifies differences in the electricity prices (retail). S3, the Scenario with a high share of RES, would imply the higher electricity price compared to S2 or S4 with a high share in nuclear power generation, reflecting the higher generation costs required for RES technologies.

Figure 38 – Electricity prices differences between the six scenarios from the study conducted in 2013 for the European Commission concerning the employment effects of energy roadmap 2050 alternatives



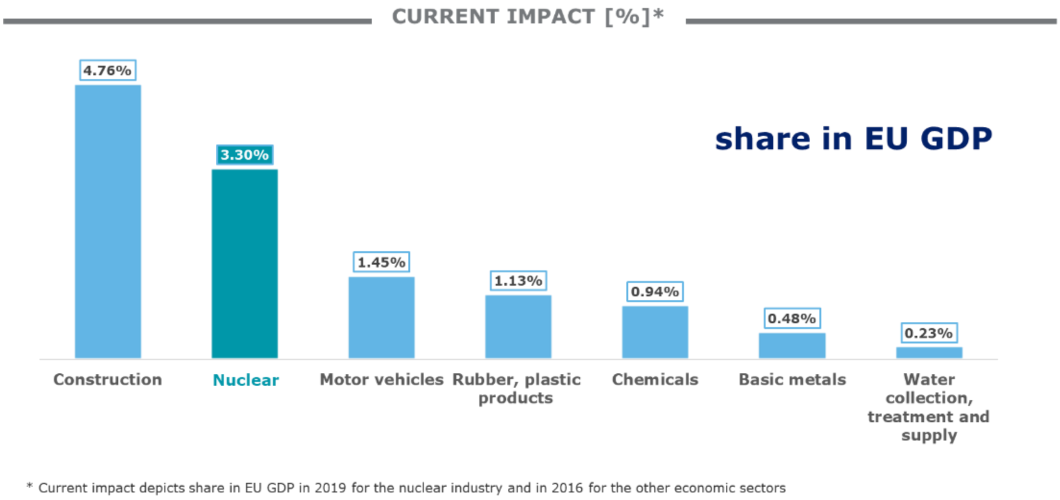
Source: Employment Effects of selected scenarios from the Energy roadmap 2050 (2013), Deloitte remake

Benchmark with other economic sectors

The nuclear industry accounted for a share of 3.30% in the 2019 EU GDP, totalling 507.4 billion Euro. Compared to other sectors, the share is significant. For example, 4.76% of the total value of goods and services produced in the EU in 2016 derived from the activities of the construction sector, whereas the motor vehicles industry accounted for a share of 1.45% in EU GDP in 2016.[47]

[47] European Wind Energy Association 2017.

Figure 39 - Benchmark economic sectors, current share in EU GDP



Source: European Wind Energy Association 2017, Deloitte calculations

V. Closing remarks

How could the impact of the nuclear industry on the EU economy evolve until 2050, and which of the capacity scenarios would help establish a sustainable growth of the EU economy until 2050?

The primary objective of the present study was to analyse the contribution of the nuclear sector to the overall economy of the European Union. The study outlined the current economic and social benefits throughout the European Union and gave a measurable outlook on future benefits in the upcoming 30 years based on a comprehensive methodology – Computable General Equilibrium (CGE).

Moreover, the study provides a detailed examination and comparison of the different future capacity scenarios. Impact results indicate that the deployment of a High Scenario with a nuclear capacity of 150 GW would enable the nuclear industry to continue having a significant contribution to the European economy and beyond.

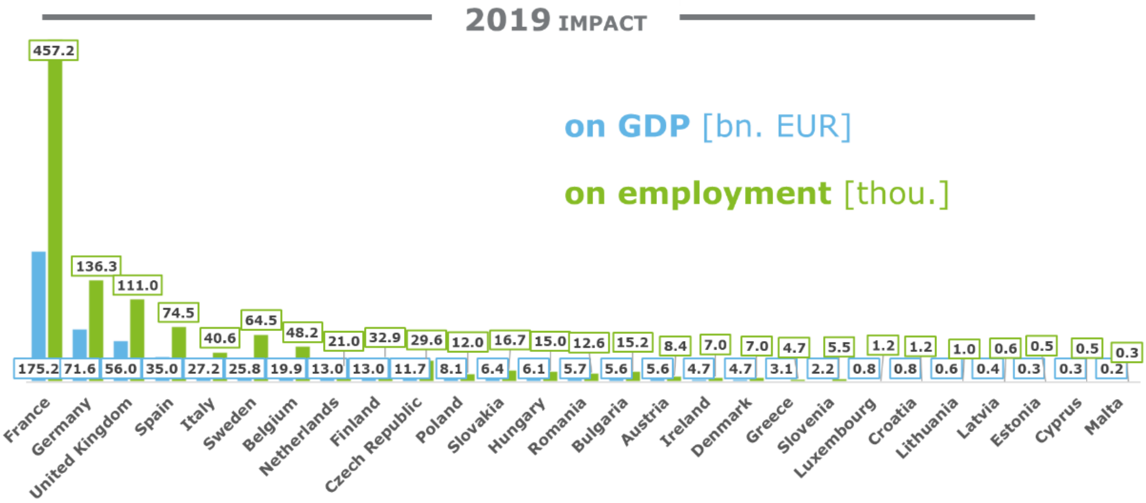
Secondly, the study pleads for a successive transition from the current state of play (118 GW installed nuclear capacity in the EU) towards the deployment of a 150 GW capacity by 2050. The effects presented in this study are manifold and involve a thorough reconciliation to ensure alignment with EU objectives and policies. As one of the objectives of this study was to provide measurability of future benefits generated by the EU nuclear industry in the period 2020 - 2050, decision makers now have at their disposal a reliable forecast of benefits that would derive from the deployment of a 150 GW nuclear power capacity throughout the European Union.

Appendix

Disaggregated impact assessment

For a detailed view on the current contribution of the nuclear industry on the economy of the 28 member states of the European Union, please consult the figure below. Moreover, please consider the following two subchapters for a slit on countries with and without nuclear capacities, as well.

Figure 40 - Impact on GDP and employment in the EU-28 countries



Source: Deloitte calculations

Countries with current nuclear capacities

The table below shows the current impact of the nuclear power sector on GDP, employment, state revenues and disposable household income in the national economies of the 14 EU-28 member states with nuclear power capacities.

Table 8 - Impact in EU-28 countries with nuclear capacities, 2019

	Employment	GDP[48] [bn. EUR]	Household income [bn. EUR]	Public revenues [bn. EUR]
Belgium	48,200	19.9	14.7	5.5
Bulgaria	15,200	5.6	4.0	1.8
Czech Republic	29,600	11.7	8.6	3.4
Germany	136,300	71.6	55.7	13.9
Spain	74.500	35.0	26.7	8.0
France	457,200	175.2	127.7	53.3

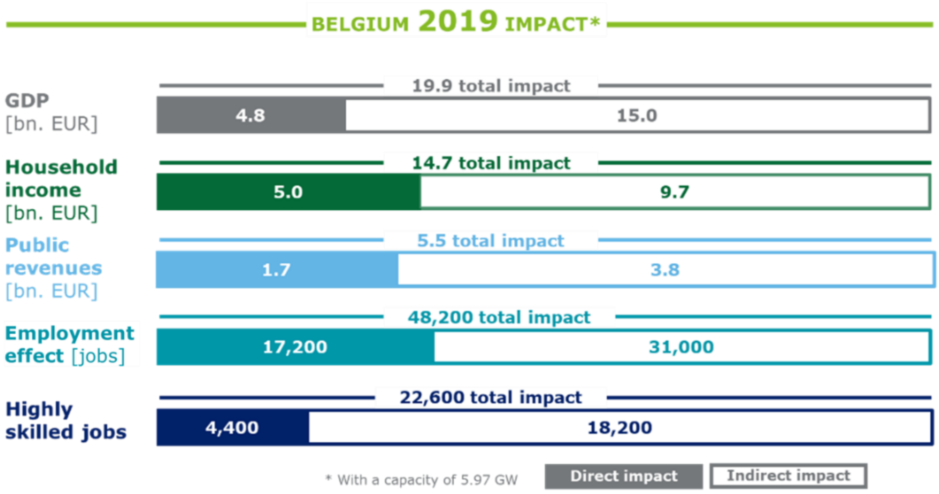
[48] The direct impact on GDP can be equated with the annual turnover of the nuclear industry.

	Employment	GDP[48] [bn. EUR]	Household income [bn. EUR]	Public revenues [bn. EUR]
Hungary	15,000	6.1	4.5	1.7
Netherlands	21,000	13.0	10.4	1.9
Romania	12,600	5.7	4.3	1.4
Slovenia	5,500	2.2	1.6	0.6
Slovakia	16,700	6.4	4.7	1.9
Finland	32,900	13.0	9.5	3.8
Sweden	64,500	25.8	19.0	7.4
United Kingdom	111,000	56.0	43.2	11.6

Source: Deloitte calculations

The following figures show the disaggregated results of the current impact of the nuclear industry in the EU-28 member states with nuclear power capacities. The figures include the split between direct and indirect impact[49] for the selected indicators impact on GDP, employment, disposable household income and state revenues.

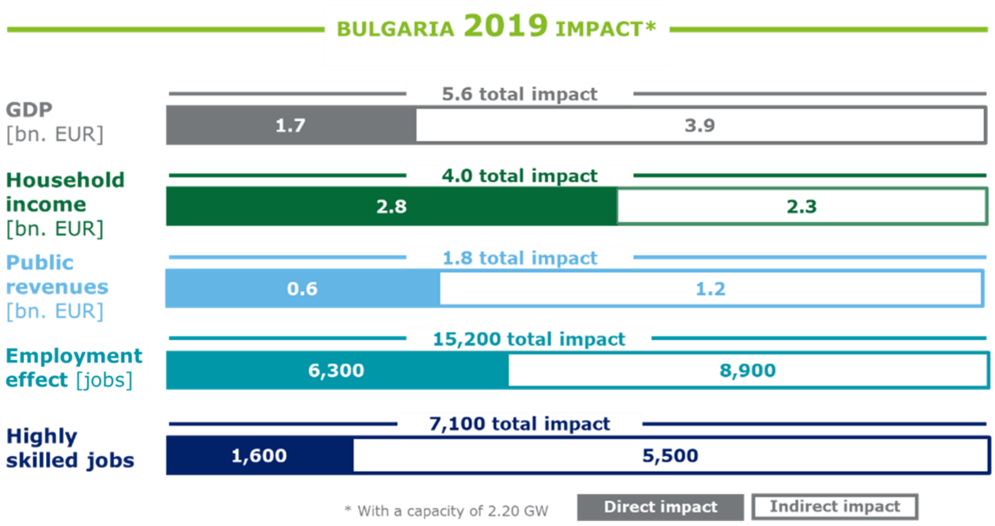
Figure 41 - Belgium: Direct, indirect and total impact, 2019



Source: Deloitte calculations

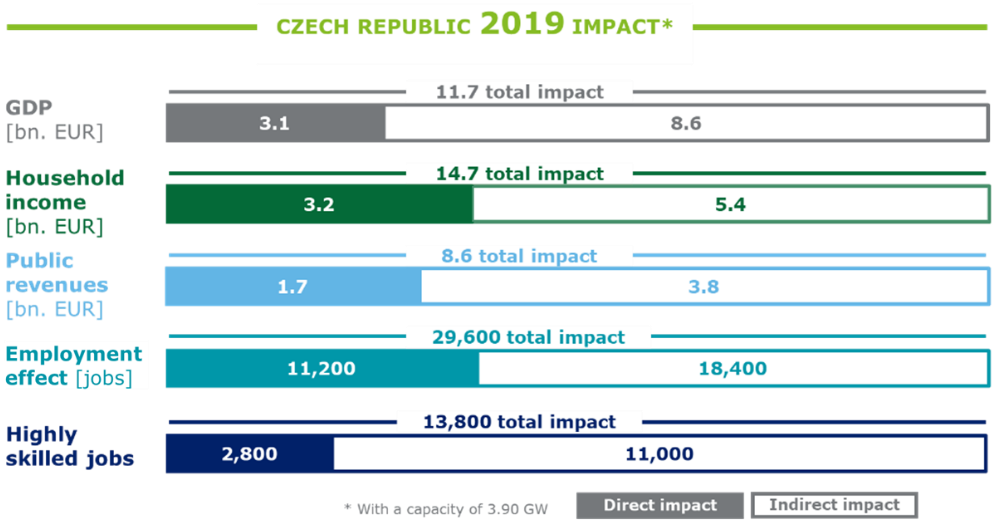
[49] Impact figures are rounded to one decimal.

Figure 42 - Bulgaria: Direct, indirect and total impact, 2019



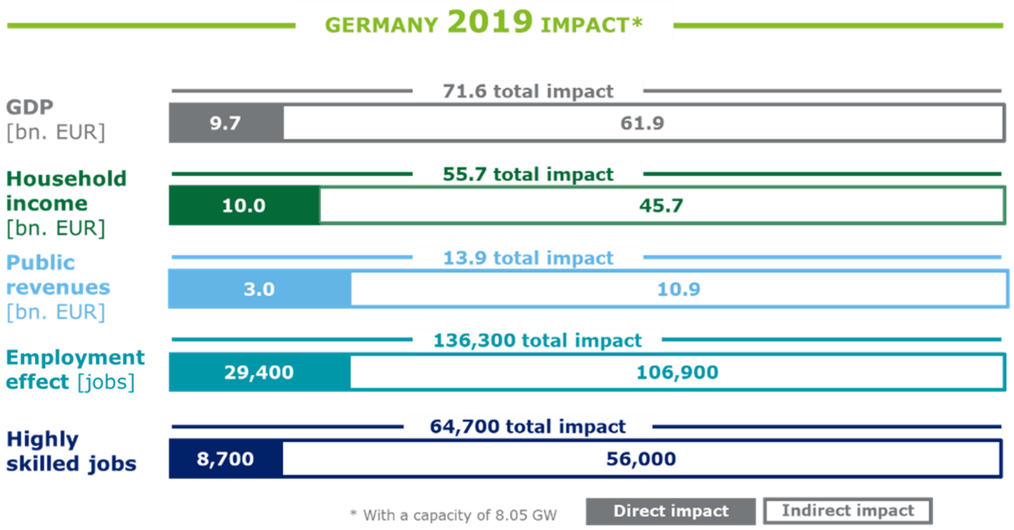
Source: Deloitte calculations

Figure 43 - Czech Republic: Direct, indirect and total impact, 2019



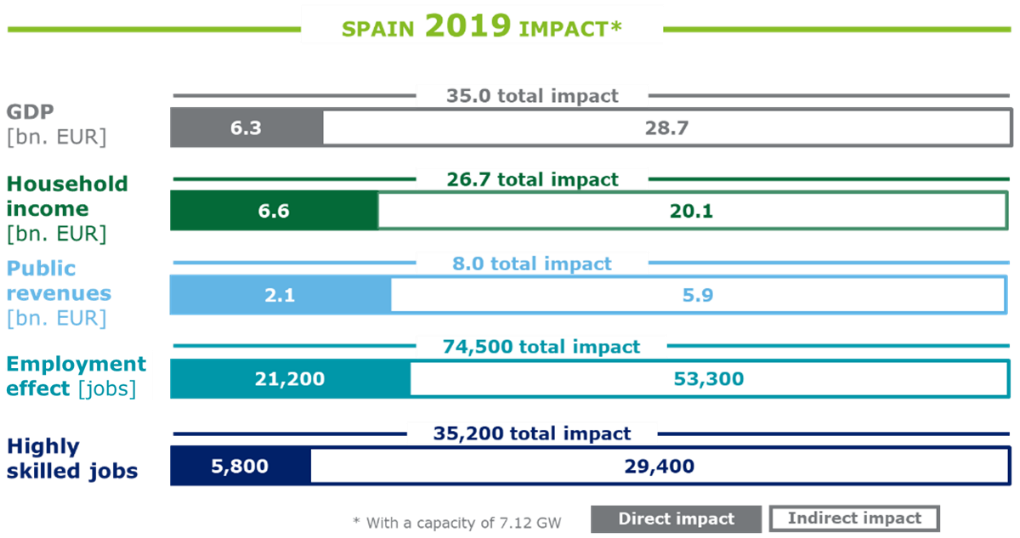
Source: Deloitte calculations

Figure 44 - Germany: Direct, indirect and total impact, 2019



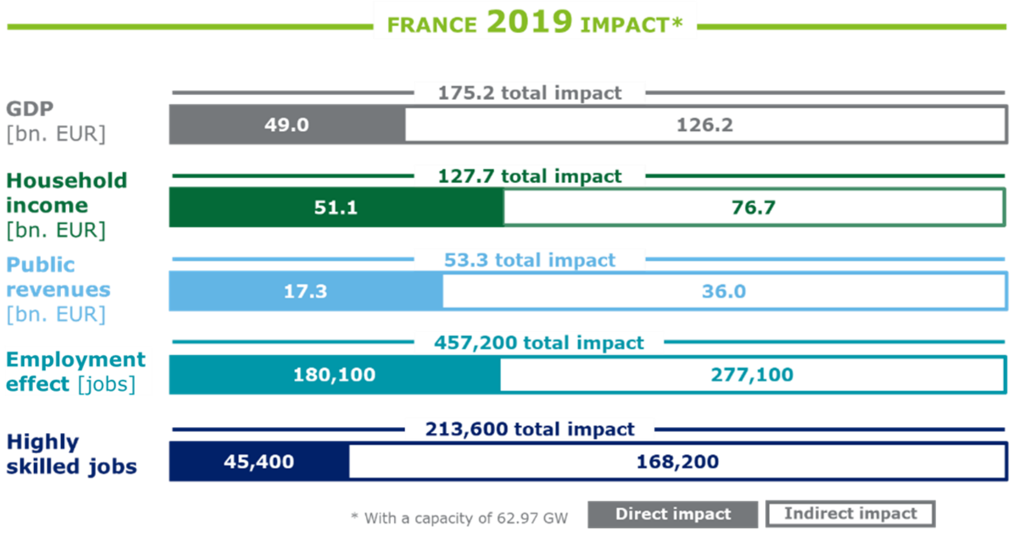
Source: Deloitte calculations

Figure 45 - Spain: Direct, indirect and total impact, 2019



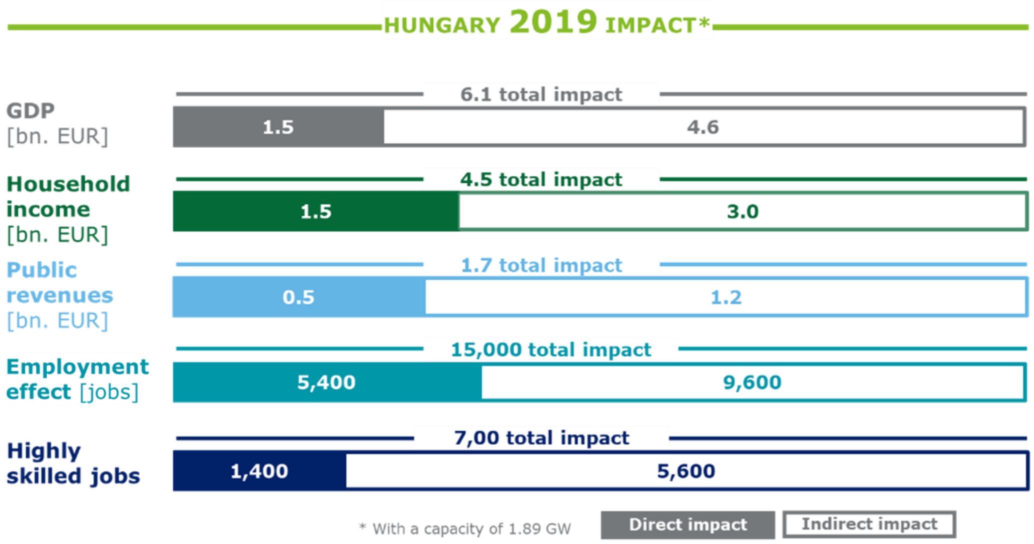
Source: Deloitte calculations

Figure 46 – France: Direct, indirect and total impact, 2019



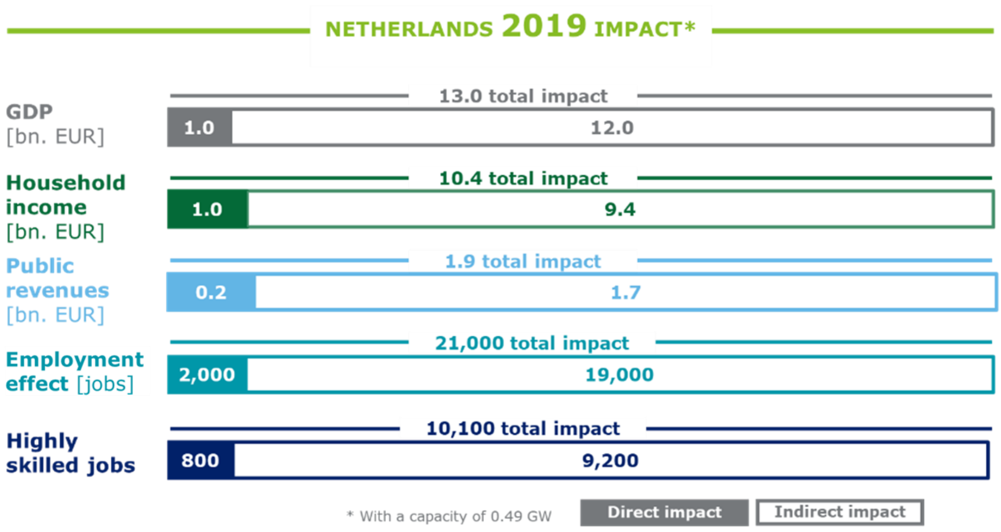
Source: Deloitte calculations

Figure 47 - Hungary: Direct, indirect and total impact, 2019



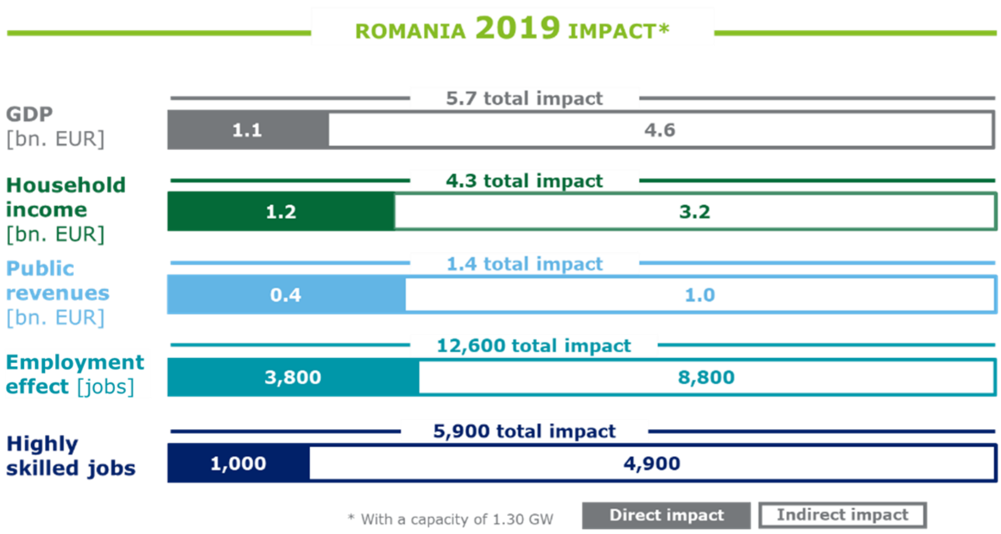
Source: Deloitte calculations

Figure 48 - Netherlands: Direct, indirect and total impact, 2019



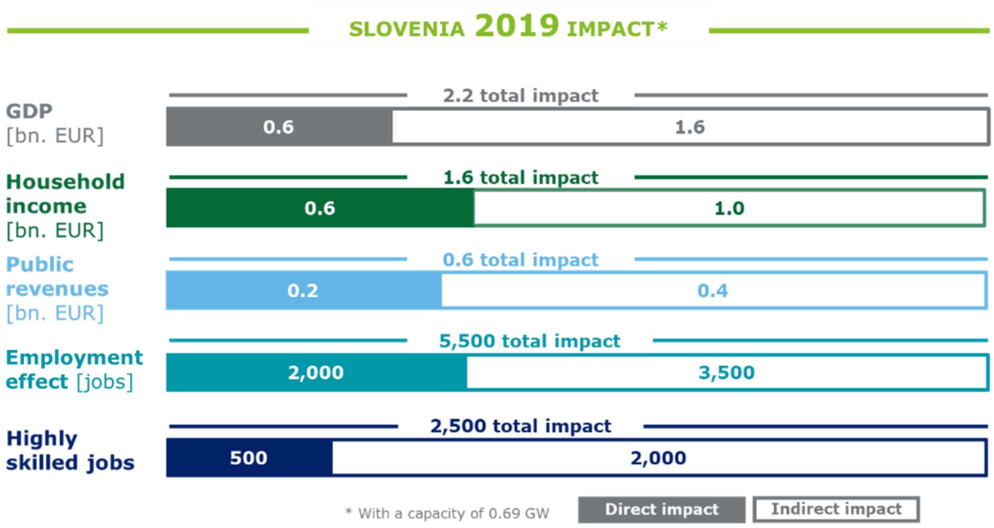
Source: Deloitte calculations

Figure 49 - Romania: Direct, indirect and total impact, 2019



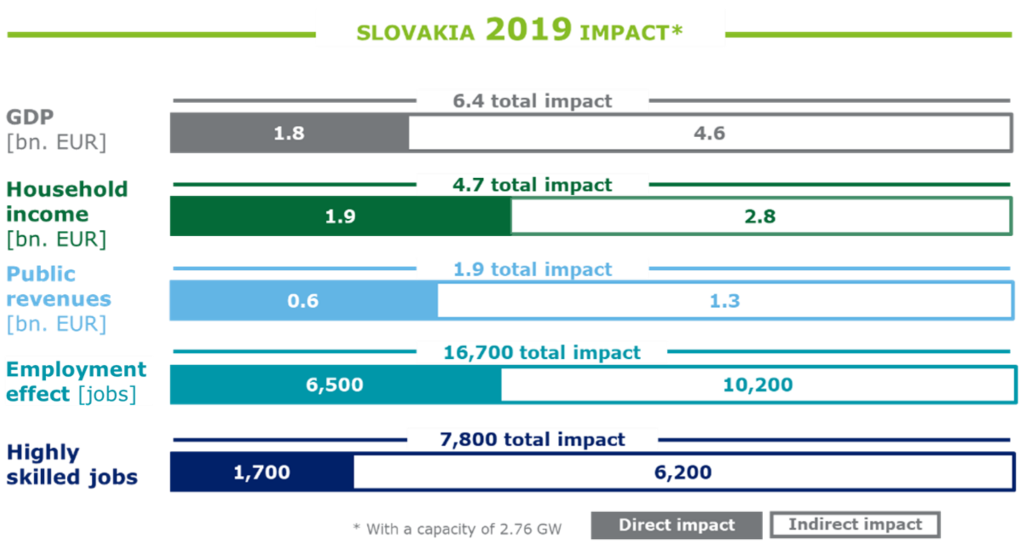
Source: Deloitte calculations

Figure 50 - Slovenia: Direct, indirect and total impact, 2019



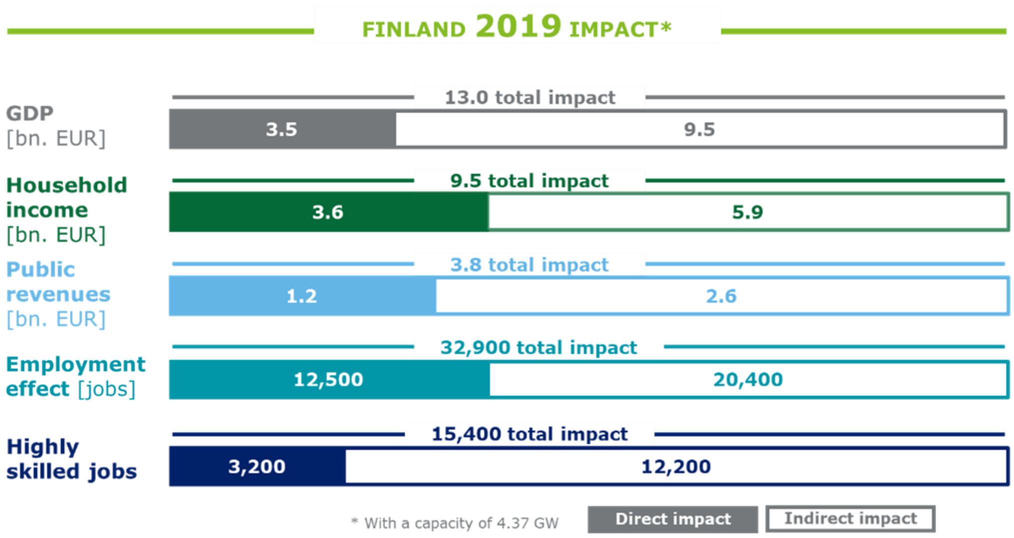
Source: Deloitte calculations

Figure 51 - Slovakia: Direct, indirect and total impact, 2019



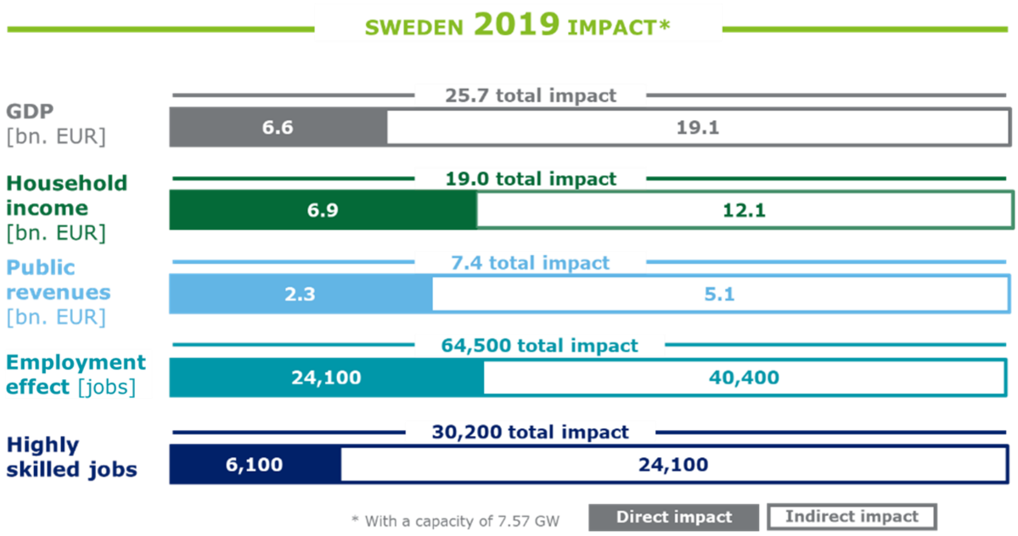
Source: Deloitte calculations

Figure 52 - Finland: Direct, indirect and total impact, 2019



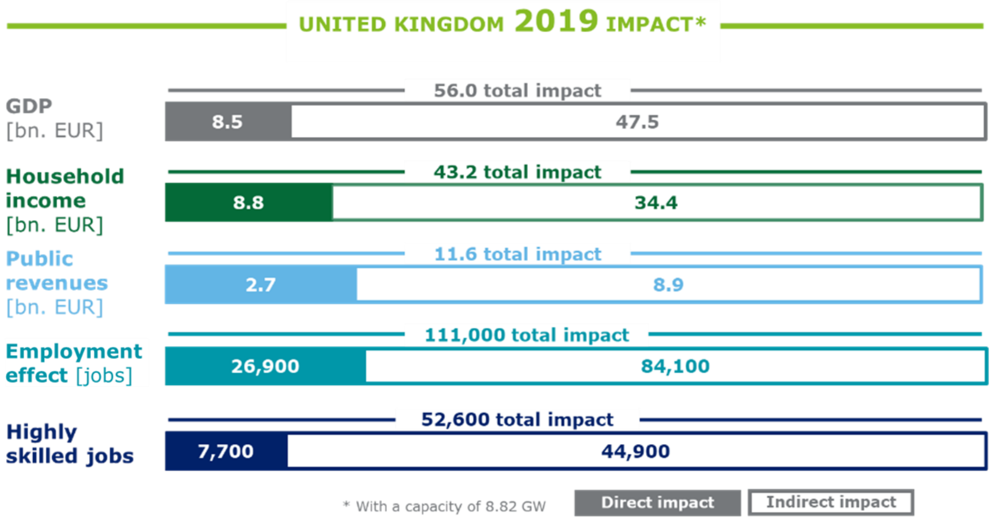
Source: Deloitte calculations

Figure 53 - Sweden: Direct, indirect and total impact, 2019



Source: Deloitte calculations

Figure 54 - United Kingdom: Direct, indirect and total impact, 2019



Source: Deloitte calculations

Countries without current nuclear capacities

Even though 14 of the EU-28 member states currently do not have installed nuclear power capacities, there is still an observable footprint of the industry in the economies of those countries. Cross border cooperation and migration of employees lead to an impact on national GDP, employment, disposable household incomes and state revenues, both due to direct and indirect effects.[50] The table below shows the current overall impact of the nuclear power sector on GDP, employment, household incomes, and public revenues in the EU-28 countries without nuclear power capacities. Moreover, please consult Figures 51 and 52 for more information on direct and indirect impacts in the analysed impact areas.

Table 9 - Impact in EU-28 countries without nuclear capacities, 2019

	Employment	GDP[51] [bn. EUR]	Household income [bn. EUR]	Public revenues [bn. EUR]
Denmark	7,000	4.7	3.8	0.6
Estonia	500	0.3	0.3	0.0
Greece	4,700	3.1	2.5	0.4
Croatia	1,200	0.8	0.7	0.1
Ireland	7,000	4.7	3.8	0.6
Italy	40,600	27.2	21.9	3.6
Cyprus	500	0.3	0.3	0.0
Latvia	600	0.4	0.3	0.1
Lithuania	1,000	0.6	0.5	0.1
Luxembourg	1,200	0.8	0.7	0.1
Malta	300	0.2	0.1	0.0
Austria	8,400	5.6	4.5	0.7
Poland	12,000	8.1	6.5	1.1
Portugal	4,600	3.1	2.5	0.4

Source: Deloitte calculations

[50] Impact figures are rounded to one decimal.
[51] The direct impact on GDP can be equated with the annual turnover of the nuclear industry.

Figure 55 - Direct and indirect impact on GDP and household income, countries without nuclear capacities, 2019

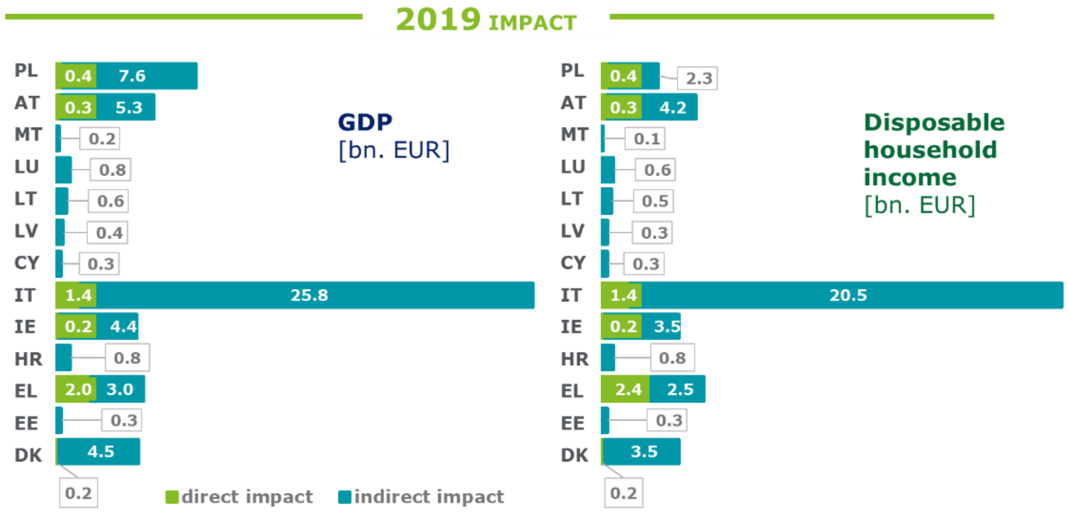
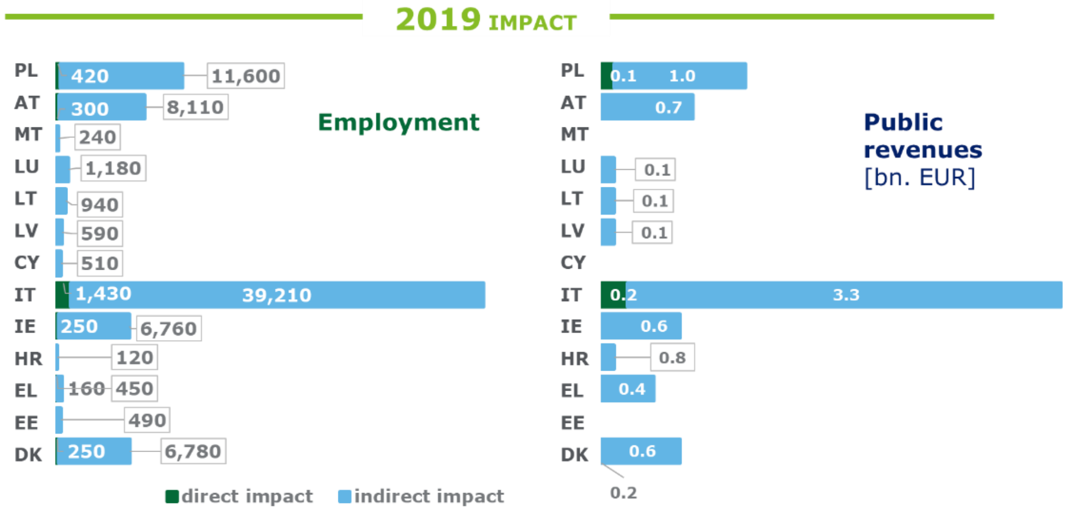


Figure 56 - Direct and indirect impact on Employment and public revenues in countries without nuclear capacities, 2019



Set of assumptions

- GDP growth projections used in this study are provided in the table below for every EU-28 country and reflect the annual national GDP evolution;
- Decommissioning costs for nuclear power plants are not included in the impact assessment;
- Current and future nuclear capacities for every EU-28 country can be consulted in Table 8;
- EU Employment numbers will increase from 4.7 million in 2020 to 5.1 million in 2050;
- The structure of the labour market (skilled vs. unskilled workers) was calibrated using the Eurostat data on employment by ISCO skill level;
- The source of the input-output structure of the CGE model is the WIOD database;
- The impact of expenditures required for building the nuclear capacities in all scenarios (e.g. CAPEX) was calculated based on the available data from the FTI-CL Energy study;
- The energy demand will gradually increase from 3,115.7 TWh in 2020 to 4,072.3 TWh in 2050;
- Concerning the impact on public revenues, all taxes collected in the EU are included in the model, with a constant structure over the projection period;
- The highest share have - in a descending order - indirect taxes (VAT, excise duty, etc.), PIT, and CIT;
- Average electricity prices will see a soft increase from 150 EUR/MWh in 2020 to 159 EUR/MWh in 2050;[52]
- Exchange rates for non-EUR-countries are assumed to be constant over the projection period.

GDP growth

Table 10 - GDP growth in the 28 EU member states

GDP growth [%]	2016	2020	2025	2030	2035	2040	2045	2050
Belgium	1.3	1.4	1.2	1.4	1.5	1.6	1.8	1.7
Bulgaria	2.9	2.2	1.7	1.5	1.2	1.1	1.0	0.9
Czech Republic	2.2	1.9	1.6	1.8	1.4	1.1	1.1	1.1
Denmark	1.2	1.6	1.7	1.6	1.6	1.6	1.8	1.8
Germany	1.8	1.4	0.8	1.0	1.0	1.2	1.3	1.1
Estonia	2.3	2.4	1.7	1.7	1.5	1.4	1.3	1.1
Ireland	5.0	3.3	1.7	1.8	1.8	1.6	1.5	1.5
Greece	-1.4	-0.3	0.6	0.5	0.7	0.8	1.2	1.1
Spain	0.4	0.8	1.3	1.3	1.0	1.0	1.3	1.8
France	1.1	1.1	1.2	1.2	1.4	1.7	1.9	1.9
Croatia	1.1	1.0	0.6	1.0	1.3	1.6	1.9	1.6
Italy	-0.3	0.5	0.6	0.3	0.3	0.5	1.1	1.3
Cyprus	0.3	1.1	2.0	1.1	1.3	1.6	1.9	1.7

52 European Commission 2017b.

GDP growth [%]	2016	2020	2025	2030	2035	2040	2045	2050
Latvia	1.4	4.2	3.3	2.7	1.6	1.7	1.2	0.9
Lithuania	2.1	1.7	0.6	0.5	0.6	1.0	1.1	0.9
Luxembourg	3.0	3.8	3.1	2.5	2.3	2.1	2.0	1.8
Hungary	1.9	1.9	2.4	2.1	1.6	1.2	1.3	1.5
Malta	6.1	4.2	3.8	3.2	2.5	2.0	1.5	1.2
Netherlands	1.3	1.4	1.2	1.1	1.2	1.5	1.8	1.8
Austria	1.4	1.7	1.7	1.5	1.7	1.7	1.5	1.3
Poland	2.7	2.6	2.1	1.9	1.5	1.2	0.9	0.7
Portugal	0.4	0.8	1.2	1.0	0.8	0.8	0.9	0.9
Romania	3.5	3.4	2.8	2.1	1.3	1.3	1.2	1.3
Slovenia	1.0	2.1	1.9	1.6	1.5	1.3	1.2	1.2
Slovakia	2.4	2.8	2.9	2.8	2.2	1.8	1.2	1.2
Finland	0.4	0.7	0.7	1.1	1.3	1.5	1.6	1.5
Sweden	2.7	1.9	2.0	1.9	2.0	2.0	2.0	1.8
United Kingdom	1.5	1.6	1.7	1.8	1.8	1.8	1.9	1.8

Source: European Commission 2017b

Nuclear capacities

Table 11 - Nuclear capacities in the 28 EU member states

Nuclear capacities in 2019 [MW]	
Total	**118,096**
Belgium	5,967
Bulgaria	2,200
Czech Republic	3,904
Denmark	0
Germany	8,052
Estonia	0
Ireland	0
Greece	0
Spain	7,121
France	62,970
Croatia	0
Italy	0
Cyprus	0
Latvia	0
Lithuania	0
Luxembourg	0
Hungary	1,889
Malta	0

Nuclear capacities in 2019 [MW]	
Netherlands	485
Austria	0
Poland	0
Portugal	0
Romania	1,300
Slovenia	696
Slovakia	2,758
Finland	4,369
Sweden	7,569
United Kingdom	8,816

Source: FTI-CL Energy 2018

Nuclear reactors

Table 12 - Nuclear reactors in the 28 EU member states

Nuclear reactors currently in operation	
Total	**126**
Belgium	7
Bulgaria	2
Czech Republic	6
Denmark	0
Germany	7
Estonia	0
Ireland	0
Greece	0
Spain	7
France	58
Croatia	0
Italy	0
Cyprus	0
Latvia	0
Lithuania	0
Luxembourg	0
Hungary	4
Malta	0
Netherlands	1
Austria	0
Poland	0
Portugal	0
Romania	2
Slovenia	1

Nuclear reactors currently in operation	
Slovakia	4
Finland	4
Sweden	8
United Kingdom	15

Source: IAEA PRIS Power Reactor Information System

Methodological notes

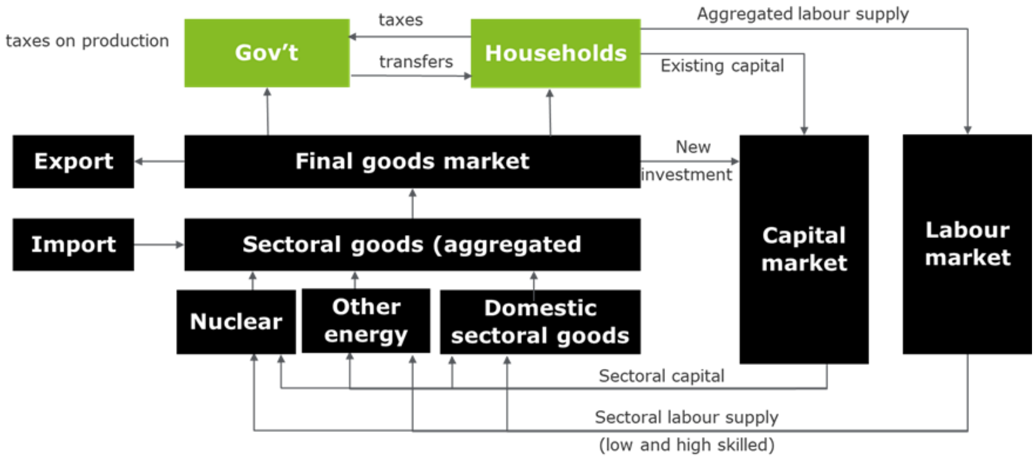
The present study was elaborated based on the Computable General Equilibrium (CGE) Model. This quantitative tool simulates the macroeconomic linkages within a selected geographic region and measures the impacts in several areas of the economy. The results of the modelling exercise are particularly useful in examining the total effects of an economic activity or of a change in the level of that activity.

The model used to illustrate the impact of the nuclear sector on the EU economy is a slightly modified version of the CGE Model. This model is recursively dynamic - that means that effects of policies are introduced in the dynamic context and the effects of actions introduced in one period will affect the economy in the following periods, as well. The model has a 5-year time resolution. The basic structure of the model is similar to that used in the standard General Equilibrium Modelling - the main building block of the model are production firms where goods are produced. The main difference to the standard setting is an extensively developed energy sector – baseload and peak demand are treated differently. Moreover, there are five energy subsectors in the model – nuclear, solar, wind, other non-renewables and other renewables.

Goods are produced by production firms and traded on a competitive market – hence firms act as a price taker. Domestically produced goods are linked with imported goods using the Armington aggregator to compose final goods. There are four kinds of composites – export goods, investment goods (used by companies to build their capital), consumption goods which give utility to the consumers and public goods consumed by the government and financed through taxes. The government collects taxes, buys public goods and invests in public infrastructure. The decision of how to divide income from taxes is discretionary – therefore the government does not optimize to increase social welfare. Consumers supply labour and receive wages and capital income (as they are owners of firms and capital). Their utility stems from consumption and leisure. Labour is traded on the competitive labour market in two segments – skilled and unskilled labour. In this study, skilled labour is defined as being equal to Levels 1 (Managers) and 2 (Professionals) of the International Standard Classification of Occupations (ISCO)[53]. Additionally, the study analyses the share of highly skilled labour force employed directly by the nuclear industry and indirectly throughout the supply chain and in other economic sectors, based on EUROSTAT employment data and empiric analysis of publicly available data from EU member states.

[53] ILO 2012.

Figure 57 - CGE Model Scheme



Source: Deloitte analysis

The main questions for the underlying analysis were:

i) How much spending does the nuclear industry bring to the European Union?
ii) How many jobs does the nuclear industry support in the EU?
iii) How much income is generated for households through the EU nuclear industry?
iv) How much tax revenue is generated by the EU nuclear industry?

These questions translate into four main indicators that were calculated:

Impact on GDP

- **Direct impact:** Impact of nuclear power plants operators' and nuclear supply chain activities on EU GDP

- **Indirect impact**: Secondary ("ripple") effects deriving from the nuclear industry generating subsequent "waves" of economic activity and additional contribution in EU GDP from other economic sectors, deriving from expenses of direct employees and employees in other economic sectors.

Impact on job creation

- **Direct impact:** Direct employment in nuclear power plants and the nuclear supply chain

- **Indirect impact:** Employment deriving from the nuclear industry activities, including both employees in other affiliated economic sectors and additional employment in the economy, resulting from expenses of direct employees and employees in other economic sectors.

Impact on disposable household income

- **Direct impact:** Disposable household income deriving from the activities of nuclear power plant operators and nuclear supply chain

- **Indirect impact**: Disposable household income of both suppliers' employees and income within other sectors of the EU economy, generated through expenses of direct employees and employees in other economic sectors.

Impact on public revenues

- **Direct impact:** State revenues generated **directly** due to tax payments from the nuclear power plant operators and nuclear supply chain

- **Indirect impact**: State revenues generated through both suppliers' tax payments and payments in other economic sectors, generated through expenses of direct employees and employees in other economic sectors.

Concerning the impact calculation for the 28 EU member states, overall results have been disaggregated using EUROSTAT data on GDP and installed nuclear power capacity figures provided in the FTI-CL Energy study. For countries without nuclear capacities, direct and indirect impacts are considerably low and mainly a result of cross border exchange of labour force.

Compared to the Input-Output model, the CGE impact assessment that has been applied in the present study provides more precise modelling results. Thus, diverging methodological approaches could lead to different results if comparing several impact assessments that have been commissioned on the national level. Moreover, results deriving from the CGE Model should be compared with results of Input-Output-Model impact assessments only after taking into consideration the different approach for depicting impact dimensions, since CGE Model incorporates induced impact in the indirect impact dimension. Subsequently, unlike the Input-Output-Model, the present study shows indirect impacts to reflect and differentiate benefits arising for non-nuclear related industries and the EU economy as a whole, as a result of the economic activities of the nuclear industry. With other words, like the Input-Output-methodology, the CGE Model depicts the induced impact as an integral part of the indirect impact dimension, showing the economic effects deriving from expenses of both nuclear sector and non-nuclear suppliers' employees.

Compared to the Input-Output Model, CGE Methodology has the following features and benefits:

- Limited supply of production factors and intermediate inputs are given. Therefore, if the demand for a given factor is higher than the price, the demand for this factor will increase in other branches as well;
- Substitution possibilities in production technology make it possible to use labour instead of capital or materials, if labour is considered abundant;
- The energy sector modelling is more precise due to the disaggregation into baseload and peak production
- More detailed modelling in terms of government and "revenue recycling". E.g. if tax revenues increase (due to the nuclear sector development), than government can increase social transfers.

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