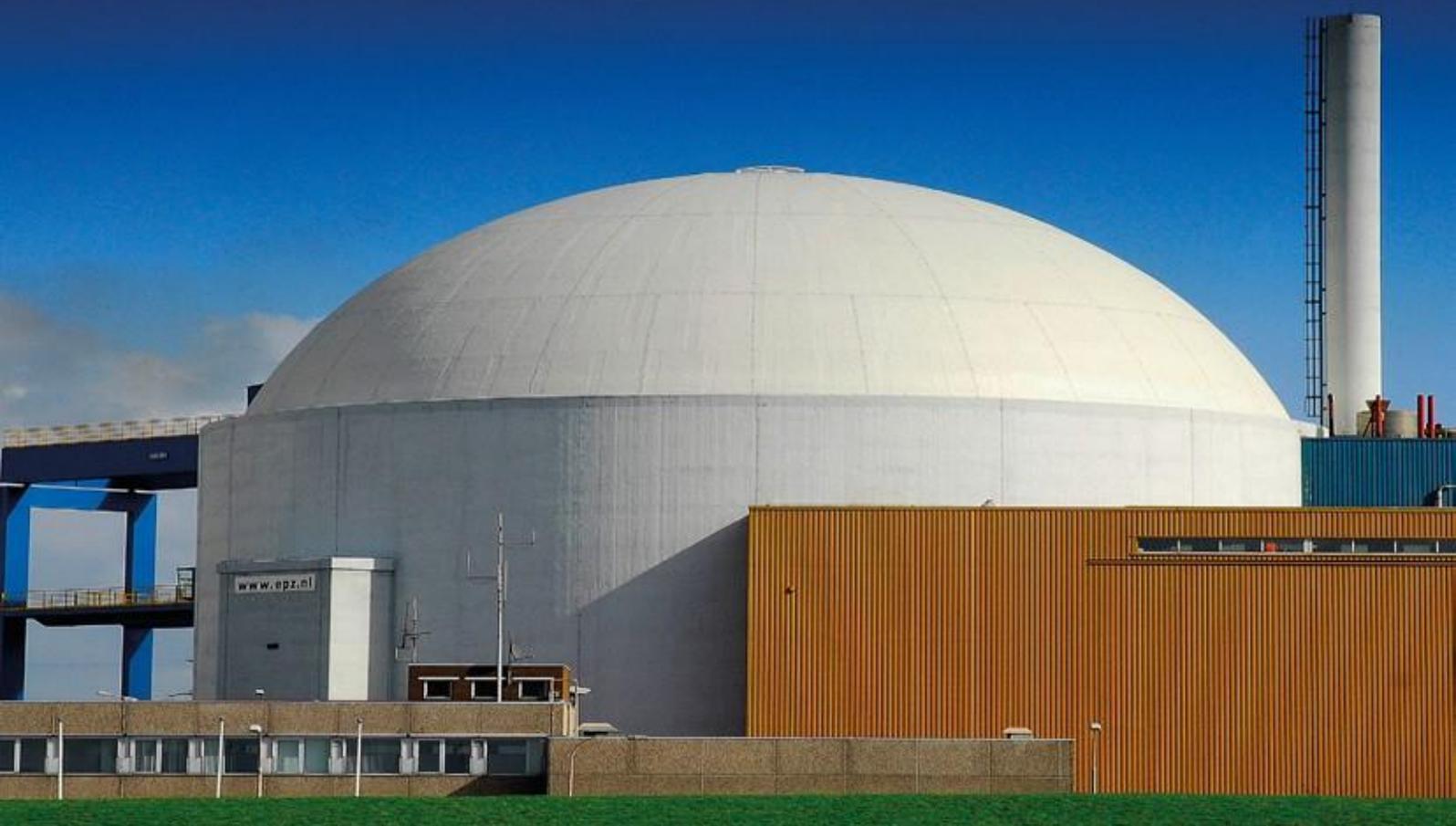




# The role of the Dutch State in the business case for nuclear energy

Recommendations and background information



# Acknowledgements

## The role of the Dutch State in the business case for nuclear energy

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*The e-Lise Foundation is a non-governmental organization with no financial ties to the nuclear industry. e-Lise wants to increase the chances of new nuclear power stations being built. It does this for the sake of improving the world's prosperity and living environment.*

[www.e-lise.nl](http://www.e-lise.nl)



## Glossary of terms

SDE	Stimulering Duurzame Energie	Sustainable Energy Stimulus
Atomausstieg	Kernuitstap	Atom Exit
EZK,	Ministerie van Economische Zaken en Klimaat	Ministry of Economic Affairs and Climate
I&W	Ministerie van Infrastructuur en Waterstaat	Ministry of Infrastructure and Water Management
ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming	Nuclear Safety and Radiation Protection Authority
RES	Regionale Energie Strategy	Regional Energy Strategy
NVS	Nederlandse Vereniging voor Stralingshygiëne	Dutch Association for Radiation Hygiene
RID	Reactor Institute Delft	Delft Reactor Institute
RIVM	Rijksinstituut voor Volksgezondheid en Milieu	National Institute for Public Health and Environment
AWTI	Adviesraad voor wetenschap, technologie en innovatie	Advisory Council for Science, Technology and Innovation
EPR		European Pressurized Reactor
O&M		Operations & Management
SMR		Small Modular Reactor
ETS		European Trading Scheme
IAEA		International Atomic Energy Agency
NGO		Non-Governmental Organization
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	Dutch Organization for Applied Scientific Research
VOBK	Handreiking voor een veilig ontwerp en het veilig bedrijven van kernreactoren	Guide for the safe design and operation of nuclear reactors
PFAS		Per- and polyfluoroalkyl substances
COVRA	Centrale Organisatie voor Radioactief Afval	Central Radioactive Waste Storage

# Foreword

By committing to the Paris Agreement, the Netherlands must reduce its CO<sub>2</sub> emissions by 49% to possibly 55% compared to 1990.<sup>1</sup> In the end, these emissions must be reduced to zero. Various technologies are available for the energy production that emit little to no CO<sub>2</sub> such as: wind, solar, geothermal energy, hydropower, and nuclear energy.

Dutch laws, regulations, and national strategy still lack a concrete vision on nuclear energy. In fact, in the past nuclear energy has been shunned or excluded from the discussion. Fortunately, the House of Representatives has asked the government for a market consultation.<sup>2</sup> Knowledge of the possibilities of nuclear energy in the Netherlands is still insufficient but we hope that this whitepaper and the outcome of the market consultation will change this.

The e-Lise Foundation is an NGO that wants to increase political, social, and economic support for nuclear energy, based on the knowledge that nuclear energy should play a key role in achieving CO<sub>2</sub> reductions and a fair distribution of wealth and growth in the Netherlands, as well as developing countries.

Nuclear energy is sustainable. It is in practical terms an infinite source of energy because uranium and thorium are virtually inexhaustible. Like wind turbines and solar panels, nuclear power plants do not emit greenhouse gases during power production. Some renewable sources necessary for the transition, such as wind and solar, are now benefiting from government support. Nuclear energy deserves the same support.

So, we have decided to participate in the market consultation. In this white paper we explain what steps the Dutch government must take to support energy companies that want to use nuclear energy. In the annexes we provide insight into the reasons why these steps should be taken.

1 [www.nu.nl/economie/6096017/europa-schroeft-klimaatdoelen-op-55-procent-minder-co2-uitstoot-in-2030.html](http://www.nu.nl/economie/6096017/europa-schroeft-klimaatdoelen-op-55-procent-minder-co2-uitstoot-in-2030.html)

2 The Dijkhoff resolution:  
<https://www.tweedekamer.nl/kamerstukken/detail?id=2020Z16571&did=2020D35893>

# What should the government do to encourage the construction of new nuclear power stations?

## 1 Offer guarantees against political fluctuations

Energy companies and suppliers from megawatt to gigawatt-scale power plants are reluctant to embark on large and long-term projects, as governments have shown themselves to be unreliable in the past. Examples are the Atomausstieg in Germany, the nuclear exit in Belgium and the biomass failure as well as the situation around the Eemshaven power plant in the Netherlands. Recent nuclear power plant projects in France, Finland and Britain have been hampered by a stacking of government-enforced changes in preparation and construction. The government itself thus poses an unacceptable high risk to these commercial ventures. By designing a long-term vision including a state guarantee or state participation, the government can become a reliable partner again.

## 2 Create new forms of government funding mechanisms to ensure low-interest loans for new nuclear builds

An overstretched electricity market with unplanned overproduction leads to marginal and even negative electricity prices. It is therefore important that new medium to large-scale power plants which do not receive price guarantees or which do not have quotas are financed in a new way. Interest rates are to a significant extent decisive for the cost of electricity production of new plants. These low interest rates are possible if the government is the financing provider (i.e. issues guarantees), or if a form of financing is chosen such as RAB (Regulated Asset Based financing model). We propose that EZK, I&W, ANVS, energy companies and potential reactor partners work together to mitigate these costs as much as possible.

## 3 Perform a macroeconomic cost-benefit analysis of nuclear energy

We believe that the Dutch government can make a commitment at a relatively low cost by financing a large part of the initially needed capital. Since the government is 'in the same boat' as the private operator, the latter can be sure that the government does not change its mind halfway through. From a social point of view, such a commitment is desirable because of the CO<sub>2</sub> reduction that, especially in later years will bring a great deal of prosperity.

## 4 Work together with energy companies and vendors to achieve a more balanced cost structure

Research for the UK government by LucidCatalyst shows large differences in capex (capital expenditure) for identical power stations in Western and non-Western countries. An important difference is the interest rate which we discussed under point 2. Other cost aspects also show major discrepancies between Western and non-Western reactors. The research establishes a relationship between a negative government influence and higher costs. We propose that EZK, I&W, ANVS, energy companies and potential reactor partners work together to mitigate these costs as much as possible.

## 5 Identify national and international opportunities for cooperation, leading to serial production in reactor technology

As with wind turbines and solar panels, nuclear reactors can be progressively cheaper through serial production. To stimulate this process, promising reactor designs must be identified. To this end, cooperation can be carried out with countries and energy companies. The willingness to use the same reactor designs can be a strong lever in the rapid decarbonisation of our economies.

## **6 Enable provinces and RES regions to jointly develop nuclear power plants to achieve their RES objectives**

Nuclear power plants can produce large amounts of heat and electricity, more than enough for one RES region. That is why we propose that RES regions should be able to jointly implement nuclear power stations to achieve their common carbon reduction and clean energy production objectives

## **7 Encourage energy companies to replace their fossil and/or biomass plants with nuclear power plants**

Existing power plants have a connection to the high-voltage grid and the provision of cooling facilities. This infrastructure is valuable and can be redeployed. We propose encouraging energy companies to convert existing fossil and biomass plants into nuclear power plants.

## **8 Encourage research into the use of nuclear energy for non-electrical processes**

Nuclear energy can play a significant role in decarbonising the chemical industry and steel production. Utilization of nuclear heat can help in the transition to a fossil-free future. It is also ideally suited to produce hydrogen and clean drinking water.

## **9 Leverage compatibility of the Dutch licensing framework with efficient commissioning of innovative reactor systems**

Internationally and within the Netherlands, concerns have often been expressed as to whether the 'admission framework', i.e. the regulations and the supervisory authorities, are designed to allow innovative reactor systems. Research shows that, especially in the Netherlands, it is not the regulation that hinders innovation.

## **10 Raise the level of nuclear knowledge in the government**

In the last 10 years, radiation and education institutes such as the Dutch Association for Radiation Protection (NVS), the Reactor Institute in Delft (RID), the Health Council, the ANVS and the RIVM have signaled that nuclear education and research have been seriously underperforming. Just recently, the Advisory Council for Science, Technology, and Innovation (AWTI) wrote an urgent letter about this

## **11 Bring peace of mind to radiation-protection policy**

In the nuclear sector, two issues play a major role: radiation protection and continuous improvement. Underlying these issues is a third principle: LNT, which stands for Linear No Threshold. In this section we briefly explain how these issues are related and affect the nuclear industry.

## **12 Bring peace of mind to society – proactively take up the discussion about waste storage**

As the broader social conversation about nuclear energy becomes serious, politicians should start talking about the usefulness and necessity of achieving a long-term storage solution for radioactive waste. Such a conversation is already being discussed by the Rathenau Institute; they are preparing a report on which several authors of this white paper have given input.

## **13 Ensure that nuclear energy is considered sustainable in the EU Taxonomy**

One of the barriers for nuclear energy is financing. One factor that determines this within the EU is the way in which nuclear energy will be included in the European Taxonomy. We call for nuclear power stations of the current generation, which show that they recycle their waste, to also be eligible for sustainable financing. As a result, although their fuel costs will increase slightly, their financing costs will decrease.

**E**-lise

ANNEX



# 1

## Offer guarantees against political fluctuations

Energy companies and suppliers from megawatt to gigawatt-scale power plants are reluctant to embark on large and long-term projects, as governments have shown themselves to be unreliable in the past. Examples are the Atomausstieg in Germany, the nuclear exit in Belgium and the biomass failure as well as the situation around the Eemshaven power plant in the Netherlands. Recent nuclear power plant projects in France, Finland and Britain have been hampered by a stacking of government-enforced changes in preparation and construction. The government itself thus poses an unacceptable high risk to these commercial ventures. By designing a long-term vision including a state guarantee or state participation, the government can become a reliable partner again.

There are examples showing why people are reluctant to invest in large-scale energy facilities that require a long-term commitment, including from the government.

For example, there is the damage claim by the owner of the Eemshaven power station because they built it and put it into operation after having received several indications from the Dutch government that the plant was needed, and now they must close it again. There is the stalled process around the biomass plant in Diemen. More generally, there is the failure around the use of biomass for energy generation in the Netherlands thanks to a 180 degree turn from subsidizing biomass to wanting to eliminate it by the government. The Dutch government indicated for years that new coal<sup>3</sup>—and biomass—plants were necessary to ensure security of electricity supply to Dutch customers. The government did this—among other things—by making subsidies (SDE+) available for biomass co-use and biomass in coal-fired power stations.<sup>4,5</sup> Now it appears that these measures were premature, and that relatively new coal & biomass-fired power stations must close prematurely. The operators (RWE) are now filing lawsuits against the Dutch government.

We see a similar pattern in Germany where Vattenfall had to close three nuclear power plants prematurely.<sup>6</sup> In 2011, the Merkel Government decided to force the premature closure of the remaining nuclear power plants, leading to a loss of profits and lawsuits.<sup>7</sup> A settlement between the companies and the German government has been reached recently. Now, Germany must pay them 2.4 billion Euro in damages.<sup>8</sup>

There are similar problems at the Dutch Pallas reactor project. The Dutch government bears responsibility for the emergence of an unnecessarily complicated situation. On one hand, the government determined that the High Flux Reactor was aging and needed to be replaced.<sup>9</sup> On the other hand, the government doesn't want to provide sufficient guarantees to enable the financing of the Pallas reactor. This causes a lot of uncertainty, and it is questionable whether the Pallas project will continue.<sup>10</sup>

Finally, we want to highlight that the increasing costs of the ongoing European Pressurized Reactor (EPR) construction projects in Europe has damaged confidence.

<sup>3</sup> Quote: "in the past, the Dutch government has designated the ports of the Maasvlakte near Rotterdam and the Eemshaven in Groningen as locations for new plants, due to the presence of ports for the import of fuel and the availability of sufficient cooling water. RWE accepted the invitation of the Dutch government and has built a state-of-the-art coal-fired power station in the Eemshaven with a capacity of 1,560 MW, which was commissioned in 2015." - [www.group.rwe.nl-NL/ons-portfolio/onze-vestigingen/kolencentrale-eemshaven](http://www.group.rwe.nl-NL/ons-portfolio/onze-vestigingen/kolencentrale-eemshaven)

<sup>4</sup> Citaat [2012]: "One of the cheapest renewable energy options in the Netherlands is to add and use biomass in coal-fired power plants. The government therefore wants to make the updating and re-use of biomass in coal-fired power stations mandatory in the coming years." - [web.archive.org/web/20120321170628/http://www.rijksarchief.nl/onderwerpen/duurzame-energie/bio-energie](http://www.rijksarchief.nl/web/20120321170628/http://www.rijksarchief.nl/onderwerpen/duurzame-energie/bio-energie)

<sup>5</sup> Quote [2014]: "Co-operation and co-use of biomass in coal-fired power stations will be supported in the SDE+ 2015, according to the Parliamentary Letter of 11 November 2014, in which the Minister of Economic Affairs announced the plans for the SDE+ 2015." - [zoek.officielebekendmakingen.nl/blg-456169.pdf](http://zoek.officielebekendmakingen.nl/blg-456169.pdf)

[group.vattenfall.com/what-we-do/our-energy-sources/nuclear-power](http://group.vattenfall.com/what-we-do/our-energy-sources/nuclear-power)

<sup>7</sup> [www.world-nuclear-news.org/C-Vattenfall-sues-Germany-over-phase-out-policy-16101401.html](http://www.world-nuclear-news.org/C-Vattenfall-sues-Germany-over-phase-out-policy-16101401.html)

<sup>8</sup> [nos.nl/artikel/2371323-duitsland-compenseert-energiebedrijven-voor-vervroegd-sluiten-kerncentrales.html](http://nos.nl/artikel/2371323-duitsland-compenseert-energiebedrijven-voor-vervroegd-sluiten-kerncentrales.html)

<sup>9</sup> [www.rijksoverheid.nl/documenten/kamerstukken/2020/12/09/kamerbrief-over-stand-van-zaken-pallas-reactor](http://www.rijksoverheid.nl/documenten/kamerstukken/2020/12/09/kamerbrief-over-stand-van-zaken-pallas-reactor)

<sup>10</sup> [www.rijksoverheid.nl/documenten/kamerstukken/2021/03/11/voorzieningszekerheid-van-medische-isotopen](http://www.rijksoverheid.nl/documenten/kamerstukken/2021/03/11/voorzieningszekerheid-van-medische-isotopen)

These projects involved a complex confluence of circumstances. A study conducted by the Massachusetts Institute of Technology (MIT)<sup>11</sup> shows that the government played a crucial role in continuously increasing costs. Consider, for instance, the major design changes demanded by governments, while construction was already underway. This led to large-scale technical and financial reconsiderations.<sup>12</sup>

A prerequisite for bringing new nuclear power plants online is a government that ensures that the operational life of a new power plant is at least equal to the initially estimated service life. The alternative—to ensure that the operator has other financial guarantees against swinging policies—is conceivable but socially suboptimal.

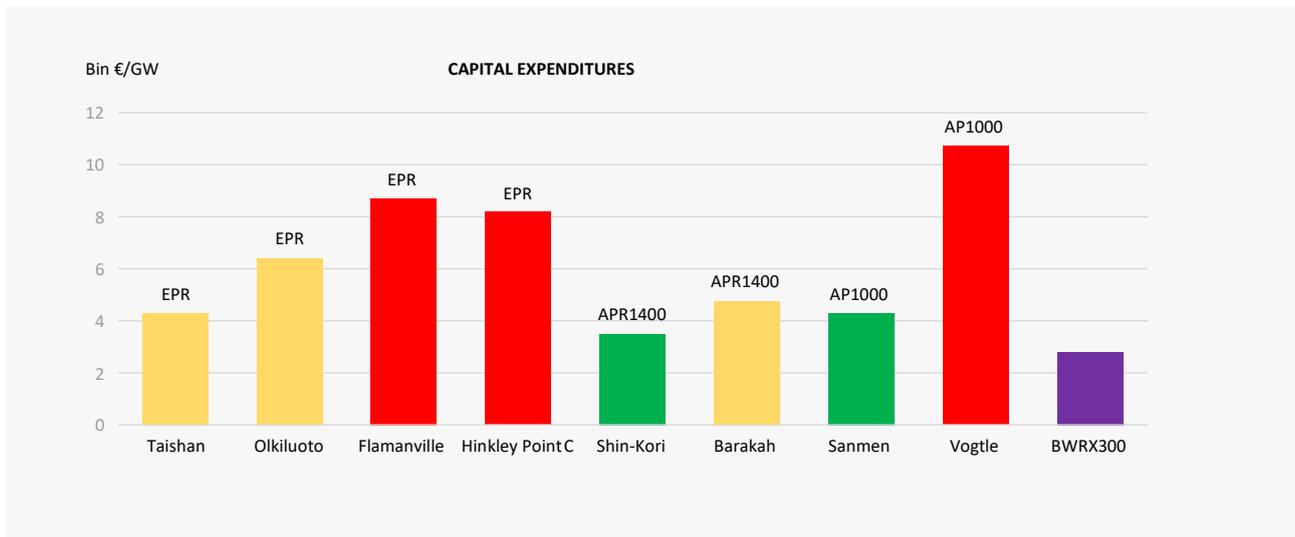
<sup>11</sup> [energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world](https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world)

<sup>12</sup> [www.world-nuclear-news.org/Articles/Stuk-requests-more-details-on-EPR-systems](https://www.world-nuclear-news.org/Articles/Stuk-requests-more-details-on-EPR-systems)

# 2

## Create new forms of government funding mechanisms to ensure low-interest loans for new nuclear builds

An overstretched electricity market with unplanned overproduction leads to marginal and even negative electricity prices. It is therefore important that new medium to large-scale power plants which do not receive price guarantees or do not have quotas are financed in a new way. Interest rates are to a significant extent decisive for the cost of electricity production of new plants. These low interest rates are possible if the government is the financing provider—(i.e. issues guarantees), or if a form of financing is chosen such as RAB (Regulated Asset Based financing model). We propose that EZK, I&W, ANVS, energy companies and potential reactor partners work together to mitigate these costs as much as possible.

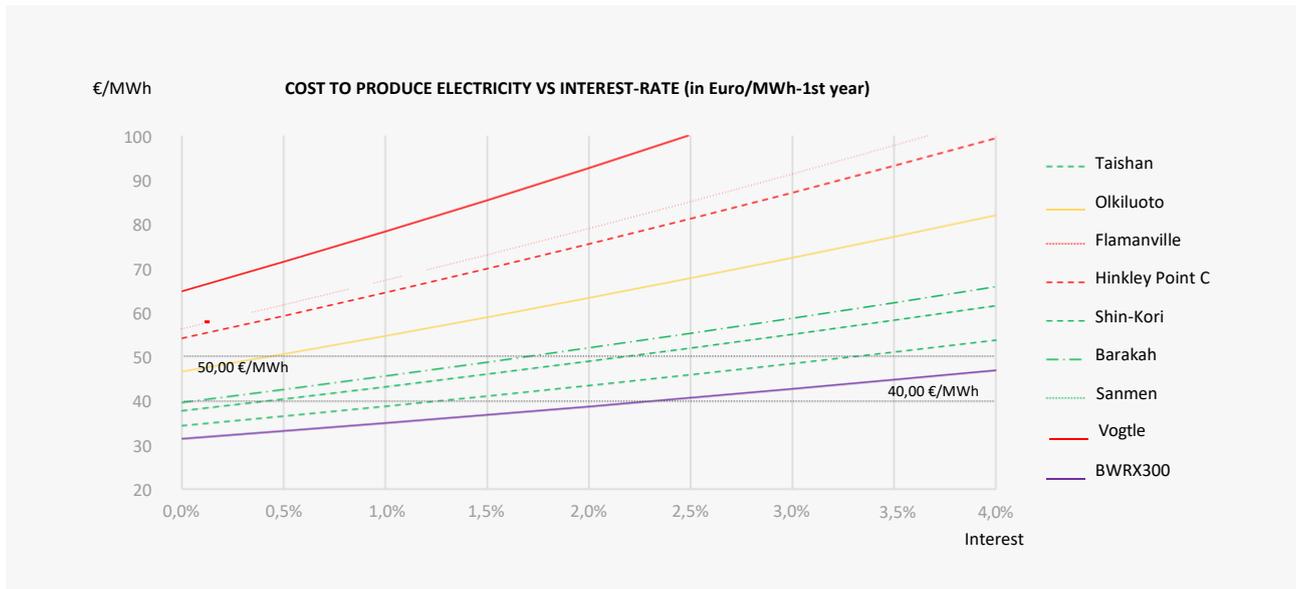


The business case for new nuclear power plants can be significantly improved if the government considers new ways of financing. If a power plant is financed with a loan that must be repaid in 30 years, the loan and interest payments alone constitute a sizable portion of the production costs of electricity and heat-energy. For instance, with an interest rate of 8%, the financing burden in the first operational year is over 63% of the cost to produce electricity, but if we use an interest rate of 0%, the burden decreases to 30% of the initial cost to produce electricity, resulting in a lower consumer price for electricity.

We performed a bandwidth analysis to determine under which circumstances a nuclear power plant can be operated cheaply in the Netherlands. First, we considered the full construction costs of existing foreign Generation III+ nuclear construction projects.

Linking these figures to a wide range of financing rates, we get the graph<sup>13</sup> on the next page:

<sup>13</sup> Production costs: fuel 5€/MWh, Fixed O&M 99€/kW, Variable O&M 2,1€/MWh



Based on this bandwidth analysis, we found that a nuclear power plant can be brought online with a first-year electricity cost of 40 to 50€/MWh in the Netherlands. 40 €/MWh is attainable with a CAPEX of 2800 €/kW and a financial interest rate of approximately 2.3%. Considering an existing APR1400 with CAPEX of 4700€/kW (Barakah) we see a possible first-year-cost between 40 and 50€/MWh at a financing rate between 0 and 2.1%, while an EPR (Olkiluoto) remains below 50 €/MWh at a CAPEX of 6400€/kW and a financing interest rate of 0.5%. This suggests that new nuclear reactors can be built in the Netherlands at an affordable level, but also helps keep consumer costs low.

We specifically take non-Asian examples for the APR1400 and EPR. There are cheaper precedents, as the graph indicates, but these can only be found in Asia. (More on this later)

The bandwidth analysis shows that there is room for better business cases in the Netherlands, made possible by, for instance, SMR technology (e.g. based on GE-Hitachi BWRX300).

Considering financing for other forms of energy such as wind and solar, we see interest rates at such low levels that—when applied to nuclear—can lead to a similarly profitable business case.

However, it is unclear whether new nuclear power stations can count on the same treatment. To ensure a low interest rate, we propose the following options:

1. The government finances the nuclear power station with a low-interest loan and sells the plant on completion;
2. The government guarantees the financing of the power plant and thus ensures a low-interest loan;
3. The government and energy companies examine the RAB funding methodology applied in Britain to energy infrastructure, possibly including, future nuclear power stations<sup>14</sup>.

The construction of new nuclear power plants takes some time, but then leads to drastic CO2 reductions for at least 60 years and offers unparalleled security of supply for the Dutch electricity and energy consumer. That is why we believe that it is justifiable to be *first mover*<sup>15</sup> as a government, thereby creating momentum and sharply decreasing construction costs and associated reductions in electricity costs, thus creating positive spinoff effects in other countries.

<sup>14</sup> [www.gov.uk/government/consultations/regulated-asset-base-rab-model-for-nuclear](http://www.gov.uk/government/consultations/regulated-asset-base-rab-model-for-nuclear)

<sup>15</sup> Together with industrial partners, utilities and vendors

# 3

## Perform a macroeconomic cost-benefit analysis of nuclear energy.

We believe that the Dutch government can make a commitment at a relatively low cost by financing a large part of the initially needed capital. Since the government is 'in the same boat' as the private operator, the latter can be sure that the government does not change its mind halfway through. From a social point of view, such a commitment is desirable because of the CO<sub>2</sub> reduction that, especially in later years will bring a great deal of prosperity.

Nuclear energy when considered from a financial/economic point of view is characterized by high initial costs (capital intensive) and a long operational lifespan (we account for 60 years) with constant energy production at very low marginal costs. Given the long project & build-time required, each private company will demand a clear commitment from the government. Usually, this commitment is difficult to make concrete, or (in the case of guaranteed prices) it is awfully expensive for society. That's why many studies conclude that nuclear energy comes at high costs.

We believe that the Dutch government can build trust by showing a clear commitment—at a reasonably low cost—by financing a large part of the initially needed capital for a new nuclear power plant. Since the government then shares the same risk as the private operator, the latter can be sure that the government does not change its mind halfway. From a societal point of view, such a commitment is desirable because of the CO<sub>2</sub> reduction that—especially in later years—will bring a lot of prosperity. After all, in the short term (10 years) we can still

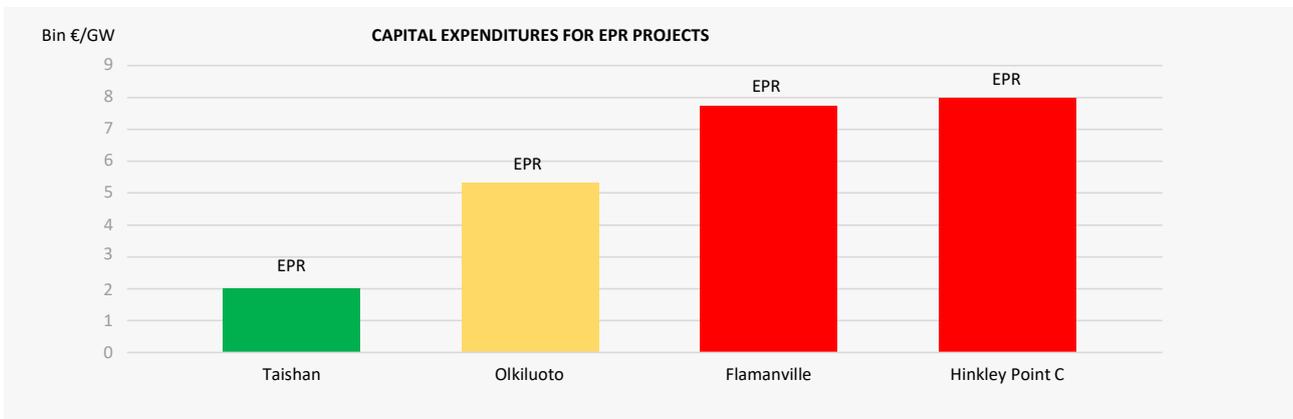
make large (efficient) steps with wind and solar energy, but in the medium term a technology is needed that can deliver energy constantly and reliably. The price for CO<sub>2</sub> emissions of the 'next best alternative' (e.g. natural gas) will eventually be so high that the long-term yields (in tons of CO<sub>2</sub> equivalent) more than make up for the initial investment in nuclear due to the high social return.

Dr. Rogier Potter van Loon analyzed the costs of this loan for the government—in an article yet to be published—and quantified the social benefits. This leads to a positive business case for Dutch society, with a social return of 9.3% over a period of 65 years. Expressed in terms of today's CO<sub>2</sub> prices, this implies a subsidy of (only) 5€ per ton (well below the ETS and SDE++ price). Finally, a sensitivity analysis shows that the business case remains (very) positive even with changing assumptions and parameters.

# 4

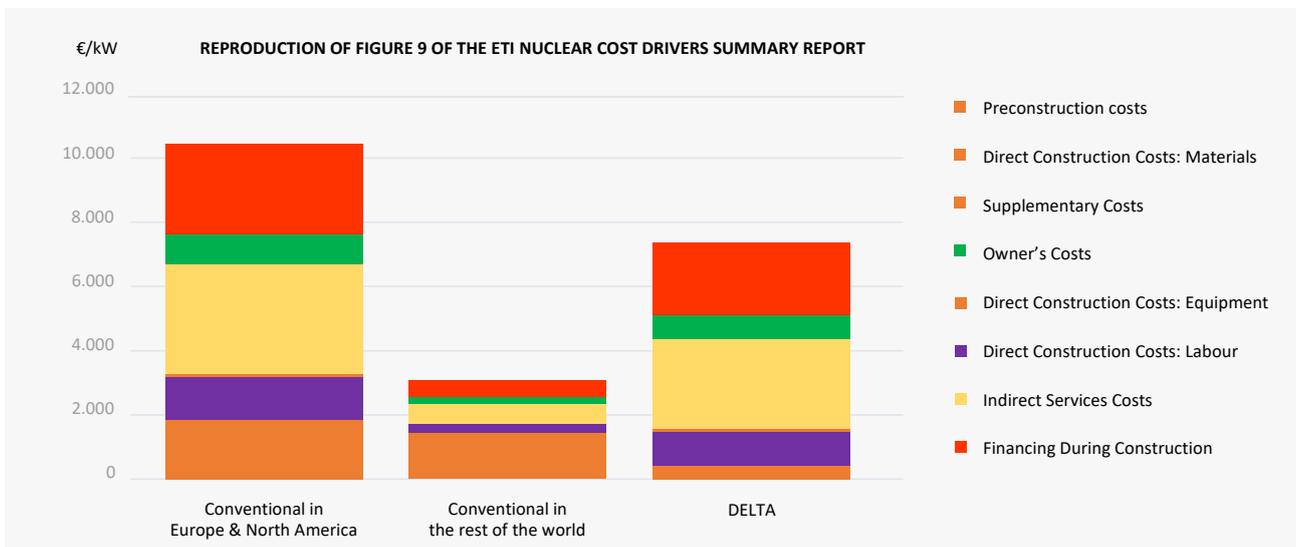
## Work together with energy companies and vendors to achieve a more balanced cost-structure

Research for the UK government by LucidCatalyst shows large differences in capex (capital expenditure) for identical power stations in Western and non-Western countries. An important difference is the interest rate which we discussed under point 2. Other cost aspects also show major discrepancies between Western and non-Western reactors. The research establishes a relationship between a negative government influence and higher costs. We propose that EZK, I&W, ANVS, energy companies and potential reactor partners work together to mitigate these costs as much as possible.



Considering the capital expenditures of Western and non-Western reactors, we see great differences. Consider for instance, the differences between EPR projects in Finland, France, Great Britain and two units of the same reactor type in China. We believe that this skewed growth can be corrected by multilateral cooperation between the government, energy companies and vendors.

A representative of the CNNC (China National Nuclear Corporation) showed—at the IAEA international conference on climate change and the role of nuclear power in 2019—that China has started to build more efficiently by gaining experience and structuring the nuclear construction industry on efficiency. For example, the work has been divided into civil works, installation, hoisting, and concrete works.<sup>17</sup>



<sup>16</sup> [eprints.whiterose.ac.uk/165805](https://eprints.whiterose.ac.uk/165805)

<sup>17</sup> [en.cnncc.com.cn/2019-11/22/c\\_447346.htm](http://en.cnncc.com.cn/2019-11/22/c_447346.htm)

On the previous page we see a reproduction of Figure 9 from the ETI Nuclear Cost Drivers Summary Report.<sup>18</sup> This graph shows a "genre" comparison between similar light water reactors built in Europe & North America (EU&NA) and in the rest of the world (ROW). The right column (DELTA) is our own addition to the graph from the ETI report and it shows the differences between EU&NA and ROW columns. There are significant cost reduction opportunities in the following rubrics: "Financing During Construction", "Owner's Costs", "Indirect Services Costs" and "Direct Construction Costs: Labor".

As you can clearly see, there is a lot of headway to be made in all four rubrics. particularly, the government has a role to play in financing the nuclear power plant; in (internationally) harmonizing the licensing framework and by making optimal use of serialized production & manufacturing of components (Indirect Services Costs).

<sup>18</sup> [www.eti.co.uk/library/the-eti-nuclear-cost-drivers-project-summary-report](http://www.eti.co.uk/library/the-eti-nuclear-cost-drivers-project-summary-report)

# 5

## Identify national and international opportunities for cooperation, leading to serial production in reactor technology

As with wind turbines and solar panels, nuclear reactors can be progressively cheaper through serial production. To stimulate this process, promising reactor designs must be identified. To this end, cooperation can be carried out with countries and energy companies. The willingness to use the same reactor designs can be a strong lever in the rapid decarbonisation of our economies.

The structural support that the government has given to solar and wind generation has significantly reduced the investment risk for these technologies. This long-term involvement also successfully reduced costs thanks to the accumulation of experience, process improvement, serial production and serial implementation of new models. The government can now opt to enact the same evolution in nuclear energy. Vendors already lay the foundation for this by betting on models that can be built serially. The Dutch government could start by enabling the licensing for serialized reactor construction. The existing Dutch laws and regulations are equipped for this: for example, it already enables 'risk informed' and 'graded' working methods – although new practical experience is a prerequisite. Both are applicable to reactor safety (e.g. adapted safety measures) and reactor protection (e.g. custom Design Base Threats). A contribution from Dutch nuclear agencies to internationally agreed (IAEA) codes and standards of reactor designs and the acceptance of licenses (Module Design Certifications) can promote international harmonization, analogous to industries such as aviation. This includes an Airbus-like approach, in which an entire power station is supplied as a product and assembled on-site from components that were manufactured in dedicated factories.

If the Netherlands were successful in implementing this strategy, many new standardized nuclear power stations could be built smoothly in the Netherlands and its neighboring countries, making it easier to meet our obligations under the Paris Agreement—unlike a strategy in which nuclear energy remains excluded.

It is advisable to pay special attention to reactor types such as SMRs because they are smaller in size and fully standardized and therefore ideally suited to build in series. Some SMRs are available that cost less than one billion Euro and are competitive with the current gas plants (even without CO2 pricing).<sup>19,20</sup>

<sup>19</sup> GE-Hitachi BWRx300: [nuclear.gewater.com/build-a-plant/products/nuclear-power-plants-overview/bwr-x-300](https://nuclear.gewater.com/build-a-plant/products/nuclear-power-plants-overview/bwr-x-300)

<sup>20</sup> Open100 cost estimate: [analytics.zoho.com/open-view/230281900000010557/289737b7abeae16ee37e96f2ef455aa8](https://analytics.zoho.com/open-view/230281900000010557/289737b7abeae16ee37e96f2ef455aa8)

There is sufficient existing transmission and cooling capacity in the Netherlands for many dozens of such SMRs (at least 15 Gigawatts).<sup>21</sup> This is sufficient potential to initiate serial production of reactor and power plant components and the serial construction of nuclear power stations.

Experience shows that simply building more reactors does not guarantee enabling the benefits of serial production. In the United States, for example, successive reactors often became more expensive, not less. This was partly due to a lack of focus on standardization—even with plants of the same global design, changes in the design were made again and again during the execution. As a result, the technical complexity increased, as did the complexity of project management.<sup>22</sup> By opting for a pre-standardized and simpler product, which can be replicated repeatedly, and by focusing strongly on standardization in project management, these pitfalls can be avoided.

Within Europe, the possible deployment of SMRs is proactively pursued in Great Britain, Poland, Estonia, the Czech Republic, Romania, Finland, Sweden and Ireland.<sup>23</sup> This multilateral cooperation led to, among other things, a large-scale exploration of the technological maturity of many SMR concepts.<sup>24</sup> As a follow-up several companies and NGOs have signed the Tallinn Declaration.<sup>25</sup>

<sup>21</sup> *We have mapped out the existing fossil production capacity. Coal and gas plants need cooling, and already attached to the current grid infrastructure. Replacing "fossil" in those places with nuclear energy therefore does not escalate costs for the grid operators.*

<sup>22</sup> *Quote: "Studies of cost escalation in mega-projects more broadly have found that nuclear power plant projects exhibit greater and more frequent cost overruns and delays compared to other electricity generation infrastructure, which has been linked to reduced modularity and more complex project governance compared to other technologies."*

<sup>23</sup> [www.bbc.com/news/science-environment-54703204](https://www.bbc.com/news/science-environment-54703204)

<sup>24</sup> [tractebel-engie.com/en/tractebel-s-vision-on-small-modular-reactors](https://tractebel-engie.com/en/tractebel-s-vision-on-small-modular-reactors)

<sup>25</sup> [www.e-lise.nl/post/stichting-e-lise-ondertekent-verklaring-van-tallinn](https://www.e-lise.nl/post/stichting-e-lise-ondertekent-verklaring-van-tallinn)

# 6

## Enable provinces and RES regions to jointly develop nuclear power plants to achieve their RES objectives

Nuclear power plants can produce large amounts of heat and electricity, more than enough for one RES region. That is why we propose that RES regions should be able to jointly implement nuclear power stations to achieve their common carbon reduction and clean energy production objectives.

In the ongoing implementation of the RES (Regional Energy Strategy) we notice that mainly wind and solar energy were considered—but these were not the only technologies available. During the discussions at the *Climate Tables*, under the leadership of Ed Nijpels, it was quickly (and prematurely) decided that it would be impossible for new nuclear reactors to come online before 2030. These rulings were made 11 years before 2030. However, we see that the nominal construction time for a nuclear power plant in the world is around six years. The nuclear power plant at Borssele was built within five years. The expected construction period of new serial produced SMRs are between two and four years.<sup>26,27,28,29</sup>

Meanwhile, it is questionable whether the RES regions will be able to find sufficient support to achieve the required capacity for wind and solar. It was recently announced that the current RES, if the approved projects are carried out, is successful. But after RES 1, RES 2, 3, 4 and 5 may be possible, and the task ahead will not become any easier for the regions in any case. It remains to be seen whether the approved RES-1 plans are feasible. It is also possible that the current "bids" cannot be fulfilled.

A critical look into RES regions shows that there is an uneven playing field. Not everyone has access to the same resources. For instance, we see large differences in the availability of sufficient wind. A coastal province has more wind resources than provinces that are further inland. Also, due to a lack of support for onshore wind, many regions increasingly prefer solar panels—despite the higher costs, vast space requirements, and the high burden it puts on the grid-operator in terms of required grid-expansions and other overhead costs.

To offer the RES regions an alternative, we propose enabling them to join forces on larger sustainable projects—for example, offshore wind, but also nuclear energy projects. They can then contribute to their RES objectives in proportion to the CO<sub>2</sub>-free electricity and heat generated. In a pilot study, we found that more than thirteen locations in eleven provinces in the Netherlands are suitable for the construction of SMRs, which (under optimal conditions) can supply their first electricity before 2030. However, we propose giving RES regions a or two-year grace period to eventually meet their obligations, should there be a delay in the realization of SMRs due to unforeseen government and regulatory pressure.

<sup>26</sup> Quote from David Sledzik of GE Hitachi: "For our first of a kind we are looking at 30 months, for our Nth of a kind we are looking at 24 months."

<sup>27</sup> Quote from Scott Rasmussen of NuScale: "For a 12-module plant, our construction-cycle is estimated to be 36 months."

<sup>28</sup> Quote from Mark Mitchell of USNC: "The on-site activity will be completed in a manner of months."

<sup>29</sup> Statements were made at a Conference organized by Fermi Energia: [youtu.be/nMwdelu7Sjc](https://youtu.be/nMwdelu7Sjc)

# 7

## Encourage energy companies to replace their fossil and/or biomass plants with nuclear power plants

Existing power plants have a connection to the high-voltage grid and the provision of cooling facilities. This infrastructure is valuable and can be redeployed. We propose encouraging energy companies to convert existing fossil and biomass plants into nuclear power plants.

A preliminary exploration tells us that there are about 13 locations with power plants—that generate energy and electricity by burning coal and biomass or natural gas—in the Netherlands. Some of these plants may be able to run on alternative fuels such as hydrogen or synthetic hydrocarbons in the future, but most of them will still need to be replaced. We expect that these plants will eventually become unprofitable due to an increasing CO<sub>2</sub> price and this will make the operators decide to decommission these plants; we also expect that this will compromise the security of electricity and/or heat energy supply.

The good news is that most plants are ideally suited to be replaced with SMRs—initially, because most of these plants have a capacity lower than 1000 megawatt. Looking at the existing plants, the average capacity is around 1400 megawatt. Nine locations are suitable for at least two 300 megawatt SMRs each.

Here are some important reasons for looking specifically at the replacement of existing plants: the plant is already in use (or has been); there are therefore precedents of successful environmental impact reports and permits on the physical site; the site has one or more connections to the high-voltage grid; the site is accessible to all necessary equipment and components; and cooling facilities and cooling water are available.

It is essential that connections to the high-voltage grid and cooling facilities are available. This prevents new high-voltage lines from having to be drawn to a place, along inhabited areas. The fact that a permit has been issued at this power station to generate energy is also important. This sets a precedent for a new license. We therefore propose that policies should be put in place to encourage operators to replace the current power stations with nuclear power stations, using existing energy infrastructure as much as possible.

# 8

## The government encourages research into the use of nuclear energy for non-electrical processes

Nuclear energy can play a significant role in decarbonising the chemical industry and steel production. Utilization of nuclear heat can help in the transition to a fossil-free future. It is also ideally suited to produce hydrogen and clean drinking water.

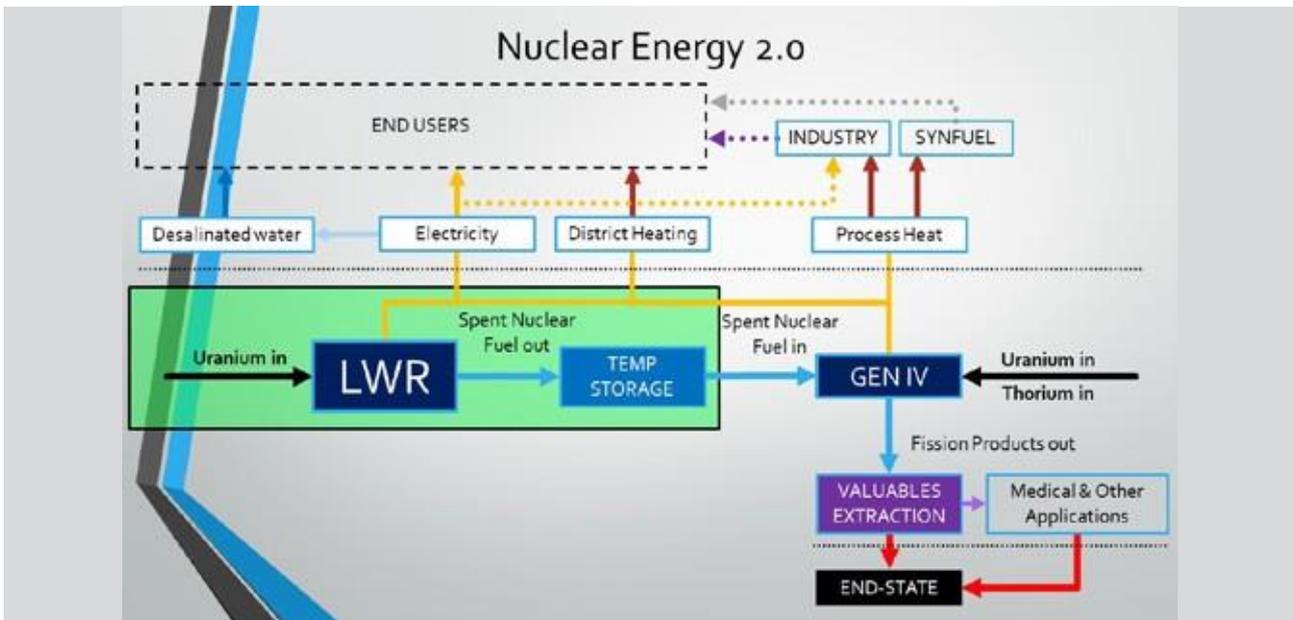
The annual primary energy consumption of the Netherlands is expected to be around 2750 petajoules by 2030 (approximately 750 TWh).<sup>30</sup> TNO's TRANSFORM model calculates for 40 GW of renewable energy in 2030 and more than 140 GW by 2050.<sup>31</sup> This results in 140 TWh in 2030 and 490 TWh in 2050 while using a hypothetical capacity factor of 40%.

It is important to note that the TRANSFORM model considers large-scale behavioral change in terms of energy consumption in the Netherlands.

It is uncertain whether these models are actually feasible. Dutch society may not be willing to make such sacrifices. It is therefore doubtful whether with wind and sun (even with high penetration of wind & sun as described in TRANSFORM-like scenarios) we manage to fully decarbonize the Dutch economy. This was the reason for the e-Lise Foundation to develop its 'Nuclear Energy 2.0' vision.

In this vision we show that it is possible to develop a cradle-to-cradle strategy for nuclear energy. Different types of nuclear reactors are used for different applications.

This includes the production of hydrogen, synthetic fuels, clean drinking water, urban heat, industrial heat, steel production and large-scale chemistry. To make these processes CO<sub>2</sub>-free, we propose that the Dutch government ask research institutes such as TNO to investigate and ultimately apply the possibilities of [high-temperature] reactors for non-electrical processes in collaboration with market players. This can open a new path to large-scale CO<sub>2</sub> reductions and the preservation of fundamental basic industries in the Netherlands and Europe.



<sup>30</sup> [www.pbl.nl/sites/default/files/downloads/pbl-2020-klimaat-en-energieverkenning2020-3995.pdf](http://www.pbl.nl/sites/default/files/downloads/pbl-2020-klimaat-en-energieverkenning2020-3995.pdf)

<sup>31</sup> [publications.tno.nl/publication/34636734/bgfjkg/TNO-2020-P10338.pdf](http://publications.tno.nl/publication/34636734/bgfjkg/TNO-2020-P10338.pdf)

# 9

## Leverage compatibility of the Dutch licensing framework with efficient commissioning of innovative reactor systems

Internationally and within the Netherlands, concerns have often been expressed as to whether the 'admission framework', i.e. the regulations and the supervisory authorities, are designed to allow innovative reactor systems. Research shows that, especially in the Netherlands, it is not the regulation that hinders innovation.

Research by Tjerk Kuipers, nuclear safety specialist at the Ministry of Defense, shows that Dutch regulations seem to meet basic requirements of flexibility and efficiency.<sup>32</sup> However, some risk factors for the licensing process itself should be addressed, the lack of capacity and practical experience in both public departments and the regulator, which can lead to delays and/or substantial cost increases. Plus needlessly slow processes are not conducive to public support.

Here are our recommendations that can contribute to an efficient and smooth licensing process, which meets the international safety requirements set for nuclear power generation installations.

**Streamline licensing.** If a reactor system in the country of origin has successfully passed through all licensing-stages, it offers confidence to license the system in other countries as well. In practice it works well if the supervisor of the host country 'walks along' during the licensing procedure or is informed by the regulator of the country of origin.

**Licensing based on Module Design Certification.** Module Design Certification (MDC) would be a beneficial factor for the international acceptance of SMRs. It is a cost-effective approach in which reactor certification is separated from site approval. Have the ANVS offer international expertise to the IAEA to facilitate this and allow it to participate in reactor validation processes. This way, these methods and knowledge can be deployed in the Netherlands to have the licensing included in legislation, with the aim of implementing and accepting foreign or internationally agreed (IAEA) codes and standards of reactor designs.

**Further shape a 'risk-informed' and 'graded approach'.** A gradual approach ('grading') involves applying certain preconditions proportionately, depending on the potential risk to the environment. In the authorization process of large research reactors (several tens of megawatts thermally), the gradual approach may show that the prerequisites set for the power reactors apply accordingly. It is also possible that several prerequisites do not apply to certain reactors. Our recommendation would be to add an annex to the VOBK (Safe Design and Safe Companies of Nuclear Reactors) guide on how to apply the gradual approach to SMRs, other low-power reactors, nuclear barges, etc. or a more general annex on this topic.

<sup>32</sup> Tjerk P. Kuipers, Developing nuclear security related legislative guarantees in licensing mobile Small Modular Reactors (Master thesis, T.U. Braunschweig, Augustus 2020) - [doi.org/10.25933/opus4-2662](https://doi.org/10.25933/opus4-2662)

# 10

## Raise the level about nuclear knowledge in the government

In the last 10 years, radiation and education institutes such as the Dutch Association for Radiation Protection (NVS), the Reactor Institute in Delft (RID), the Health Council, the ANVS and the RIVM have signaled that nuclear education and research have been seriously underperforming. Just recently, the Advisory Council for Science, Technology, and Innovation (AWTI) wrote an urgent letter about this.<sup>33</sup>

Many people think that if the Netherlands would stop using nuclear energy, expertise on nuclear engineering and radiation protection would no longer be needed. Nothing could be less true. Many sectors are dealing with radiation and radioactivity. Think of the application of radioactive substances in hospitals (for diagnosis and therapy) and industry (assessment of welding or measurement of asphalt thickness in road construction). In addition, the presence of such materials plays a role in dwellings (natural radioactivity in building materials and in the soil), the safety of mining operation, geothermal energy, the gypsum/cement/phosphate industry, and other applications.

In 2020, a report<sup>34</sup> was commissioned by the ANVS, drawn up by a committee that included André van der Zande (former DG RIVM), Carolien Leijen (chair of the NVS, the professional association of radiation protection experts) and Bert Wolterbeek (director of the reactor institute Delft). This committee noted that in the Netherlands, knowledge in the fields of nuclear engineering, safety, and that of radiation protection, has withered down to a critical point. Causes are shrunk budgets, disbanded departments, retirement, and the fact highly skilled people have moved abroad. The question is whether this message has been heard by policymakers

In 2020, for example, attempts were made within EZK to decrease the subsidy for research into nuclear engineering and radiation protection by 50%—cut it in half.

Almost every ministry or inspection body has something to do with radiation protection or nuclear safety and technology. However, the government does not seem very concerned about the fact that knowledge and research on these subjects is eroding. This has two main causes:

1. The fact that it is a 'small' subject in most ministries, with at most two policy officials dealing with these subjects on a part-time basis. Often, these officials also must cover many other topics.
2. The fact that nuclear knowledge deficits in ministerial departments leads to having difficulty formulating the right questions to the technical knowledge institutes.

To maintain the current level of knowledge and expertise, an investment of many millions of Euros is needed. We therefore recommend that the Dutch government reserves a budget for this in the short term.

<sup>33</sup> [www.awti.nl/documenten/adviezen/2021/02/17/advies-rijk-aan-kennis](http://www.awti.nl/documenten/adviezen/2021/02/17/advies-rijk-aan-kennis)

<sup>34</sup> [www.autoriteitnvs.nl/documenten/rapporten/2020/06/11/naar-een-agenda-en-platform-nucleaire-technologie-en-straling](http://www.autoriteitnvs.nl/documenten/rapporten/2020/06/11/naar-een-agenda-en-platform-nucleaire-technologie-en-straling)

# 11

## Bring peace of mind to radiation-protection policy

In the nuclear sector, two issues play a major role: radiation protection and continuous improvement. Underlying these issues is a third principle: LNT, which stands for Linear No Threshold. In this section we briefly explain how these issues are related and affect the nuclear industry.

Radiation protection is based on the following principles: Justification, Optimization and Dose Limits.

Justification is about whether you can apply radiation in society at all (ethically). Our rules are clear about this: the generation of energy by nuclear fission is justified.

Next, it is important to optimize radiation exposure. The word ALARA (As Low as Reasonably Achievable) is often used in this context. Socio-economic factors must be considered. Many people confuse ALARA with 'as low as possible', but it is precisely by taking socio-economic factors into account that an optimal level of exposure is created, where lowering exposure even further makes no sense, and is not desirable.

The dose limits are there to protect the population (1 mSv per year) and employees (20 mSv per year) from a high radiation dose caused by licensed activities. These values have been established internationally. Exceeding those limits is equivalent to a violation of the law.

Are ALARA and Linear No Threshold (LNT) a recipe for continuous improvement?

In the nuclear industry, the principle of continuous improvement (according to Plan-Do-Check-Act) is also of great importance, especially in the field of reliability and safety.

Whereas ALARA is wrongly seen by many people as a 'race to zero millisievert', continuous improvement is wrongly seen as a 'race to the top'. The PDCA cycle applied to business operations (efficiency in production) has a built in brake: the costs of efficiency must outweigh the additional yields. But safety can always be improved and—in the eyes of many people—is 'unaffordable', so one loses sight of the fact that even what is 'safe' is tied to socio-economic factors. Safety should also be based on an optimization principle, sometimes referred to as SAHARA (Safety as High as Reasonably Achievable).

The LNT hypothesis states that radiation creates a chance of cancer, and that this chance increases linearly with the dose: twice as much dose, twice as likely. According to LNT, there is no threshold where the probability becomes zero. So even the tiniest amount of radiation could technically lead to death, LNT says.

In practice, the LNT & ALARA have resulted in a loss of proportionality within the safety requirements. Often there is a lack of optimization because the aim is to achieve the highest safety and lowest radiation dose (because of LNT), while socio-economic factors play too small a role in the process.

Moreover, this correlates with a broader trend in our society: increasingly rejecting any risk (see, for example, current issues such as the discussion around PFAS and those around Tata Steel), rather than seeking a compromise possible disadvantages for residents and more-than-likely benefits for the economy & society.

In the case of nuclear energy, the danger perceived by the public is much greater than the danger assessed by experts. This leads to stricter policies guided by an irrational population rather than evidence-based analysis.

Finally, setting standards takes several steps, including the use of models. Uncertainties throughout this process are conservatively estimated. This leads to 'stacking of conservatism' —in other words, the norm becomes much stricter than is necessary to achieve a desired level of protection.

This desired level of protection itself can also be questioned. Do the [safety] requirements imposed on the use of radiation and nuclear energy offer the same level of protection to the population as is required of other branches of industry? In other words, are the standards set for nuclear energy proportional to actual risk?

We therefore recommend that the government sets a standard that is optimized and acceptable.

# 12

## Bring peace of mind to society – proactively take up the discussion about waste storage

As the broader social conversation about nuclear energy becomes serious, politicians should start talking about the usefulness and necessity of achieving a long-term storage solution for radioactive waste. Such a conversation is already being discussed by the Rathenau Institute—they are preparing a report on which several authors of this white paper have given input.

In the summer of 2020, in their recommendations on the Rathenau Institute's draft report on 'Long-term storage of radioactive waste', members of the Advisory Council of the e-Lise Foundation expressed their support to start the decision-making process on the final storage of radioactive waste. After all, we already have nuclear waste. We see in surrounding countries that these considerations are complex and take a lot of time.

Broadly speaking, we see two possible routes:

1. The Netherlands stops using nuclear energy—in this case, participation in the Belgian nuclear waste repository would be the logical choice. It might even be possible to do this without signing new treaties by choosing a border location and connecting a Dutch corridor to a Belgian underground repository.
2. The Netherlands continues using nuclear energy, possibly in the form of Generation IV reactors. If this is the case, it makes sense to start thinking about a domestic final waste repository now. Developing such a waste repository requires knowledge and expertise, which is something the Dutch government has to invest in.

The discussion that the Rathenau Institute is shaping, could be a prelude to the broader social conversation about nuclear waste storage. The e-Lise Foundation wants to participate in this discussion and will start to organize webinars on nuclear waste. We believe that an objective comparison between waste streams of different energy sources will become an important factor leading to greater support for nuclear energy.

# 13

## Ensure that nuclear energy is considered sustainable in the EU Taxonomy

One of the most significant barriers for nuclear energy is financing. One factor that determines this within the EU is the way in which nuclear energy will be included in the European Taxonomy. We call for nuclear power stations of the current generation, which show that they recycle their waste, to also be eligible for sustainable financing. As a result, although their fuel costs will increase slightly, their financing costs will decrease.

The EU Taxonomy (Taxonomy) is a tool to help investors understand whether an economic activity is environmentally sustainable or not. It helps to inform choices that lead to a low-carbon economy. The taxonomy may deem nuclear energy unsustainable; we expect that the reality of nuclear waste might be used to block nuclear from being included as a sustainable investment. However, considering the waste produced per unit of energy, existing nuclear energy technology is one of the energy sources that produces the least amounts of waste. Also note that this waste can be recycled in reactors of future generations.<sup>35,36,37,38</sup>

This topic is now under discussion at the EC Joint Research Centre. We expect that the next generation of nuclear power plants, which have a closed fuel cycle, will be admitted within the taxonomy.<sup>39</sup> But even so, fuel from the contemporary nuclear power stations can already be recycled. For instance, Dutch used nuclear fuel is reprocessed in France at La Hague.<sup>40</sup> Whatever part of the uranium is left can be used in so-called waste-burning reactors.

Indeed, newer generations of reactors offer great benefits in terms of using the uranium resource efficiently, while also greatly reducing the amount of long-lived fission products. Several new reactor concepts, including the molten salt reactor (currently under development in the Netherlands), can run on more fuels than just uranium, it can also use thorium.<sup>41</sup>

Now, we store about 95% of the nuclear fuel after recycling for later use. This is what happens at the Borssele nuclear power plant for instance. The way of reprocessing and reusing spent fuel—as Borssele does—and the methods of intermediate storage of the residual products as organized at COVRA, receives worldwide praise. The Netherlands is already demonstrating a near-circular fuel cycle.

It is advisable to reclassify the  $U_3O_8$ —which is stored at COVRA—as fuel because it is usable in reactors with a fast spectrum.

Climate change requires us to set the right priorities. We do not have the luxury of excluding technologies based on ideological considerations. Because climate policy is an urgent matter, all low-carbon energy sources must be able to contribute, and all these low-carbon energy sources must be given their place in the final taxonomy on sustainable finance.

There is a real danger that nuclear energy will be excluded from the taxonomy—making it inaccessible to private financing from institutional investors, including the Dutch state, who would consider nuclear as sustainable. It is therefore of the utmost importance that the taxation of nuclear be based on scientific evidence. It must not be influenced by any political or ideological agenda. More than 100 scientists and environmentalists have therefore signed a letter to the European Commission (EC) calling for a timely and equitable assessment of nuclear energy in the taxonomy.<sup>42,43</sup>

<sup>35</sup> [www.orano.group/en/nuclear-expertise/from-exploration-to-recycling/world-leader-in-recycling-used-nuclear-fuels](http://www.orano.group/en/nuclear-expertise/from-exploration-to-recycling/world-leader-in-recycling-used-nuclear-fuels)

<sup>36</sup> [large.stanford.edu/courses/2017/ph241/wang2](http://large.stanford.edu/courses/2017/ph241/wang2)

<sup>37</sup> [nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/prism1](http://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/prism1)

<sup>38</sup> [www.wired.com/story/recycled-nuclear-waste-will-power-a-new-reactor](http://www.wired.com/story/recycled-nuclear-waste-will-power-a-new-reactor)

<sup>39</sup> [www.scientificamerican.com/article/how-long-will-global-uranium-deposits-last](http://www.scientificamerican.com/article/how-long-will-global-uranium-deposits-last)

<sup>40</sup> [www.orano.group/en/nuclear-expertise/orano's-sites-around-the-world/recycling-spent-fuel/la-hague/unique-expertise](http://www.orano.group/en/nuclear-expertise/orano's-sites-around-the-world/recycling-spent-fuel/la-hague/unique-expertise)

<sup>41</sup> [snetp.eu/2020/05/27/over-100-non-industrial-organisations-call-for-a-just-assessment-of-nuclear-energy-in-the-eu-taxonomy-of-sustainable-finance](http://snetp.eu/2020/05/27/over-100-non-industrial-organisations-call-for-a-just-assessment-of-nuclear-energy-in-the-eu-taxonomy-of-sustainable-finance)

<sup>42</sup> [snetp.eu/wp-content/uploads/2020/05/NGO-Civil-society-on-Taxonomy-2020.pdf](http://snetp.eu/wp-content/uploads/2020/05/NGO-Civil-society-on-Taxonomy-2020.pdf)