TNO innovation for life

Public trust and nuclear energy

Perspectives on trust dynamics in the context of nuclear energy

TNO Publiek / TNO 2024 R12655
December 2024

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Classification report	TNO Publiek
Title	TNO Publiek
Report text	TNO Publiek
Number of pages	84 (excl. front and back cover)
Number of appendices	3
Sponsor	Topsector Energie / Ministerie van KGG
Project name	KVE24 Publiek vertrouwen kernenergie
Project number	060.59911

Preface

This report, a joint effort of the organisations TNO and NRG PALLAS, aims to advance the insights into trust dynamics around nuclear energy in the Netherlands, and what these dynamics imply for adjacent policy making. Furthermore, it proposes how policy makers and practitioners active in public interaction around nuclear energy, can deal with trust dynamics through a continuous cycle of sensing, analysing, and interacting.

The structure of the report is designed to accommodate two ways of perusing the material:

1) The extended management summary that can be read stand-alone, highlights the main aspects of the research approach, outcomes, policy implications and directions for further research. It is also provided in Dutch.
2) The report as a whole elaborates on these aspects and explains the applied sources and considerations in further depth. For an even deeper dive into the applied methodology (i.e. modelling of a causal loop diagram), three appendices are added.

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Management summary

Nuclear energy has gained renewed attention caused by the growing efforts to transition the Dutch energy system to one that is sustainable, affordable and reliable. To strengthen the nuclear knowledge infrastructure, the “Applied Knowledge Programme Nuclear Energy 2024” of TNO and NRG PALLAS, supported and funded by the Dutch government, was therefore initiated at the beginning of 2024. The topic of this report, “Public Trust in Nuclear energy”, is one of the themes in this programme.

Public trust in nuclear energy develops dynamically; trust comes about through complex interactions between the features of nuclear energy, its supporting policies (e.g. for regional investments), communication and engagement activities of stakeholders, adjacent policy issues (e.g. for other energy technologies), and how citizens process these topics simultaneously. This report 1) advances the insights into trust dynamics and what these dynamics imply for policy making, and 2) proposes how policy makers and practitioners active in public interaction around nuclear energy, can deal with trust dynamics through sensing, analysing, and interacting. Results of both are summarised below, after a short description of the research approach.

Research approach

The research approach focuses on understanding the dynamic and complex nature of public trust in nuclear energy. Recognising that trust is influenced by various factors and is not static, this research employs a systems thinking perspective to capture what is currently observable (from other research and media) about the interconnectedness of factors and feedback loops influencing public trust in nuclear energy. A limitation of this approach is that nuclear energy policy and public trust are constantly evolving, affecting the dynamics of trust. Therefore, we emphasise the need for continuous sensing, analysing, and interacting to support adaptive policy making.

Insights into trust dynamics

Historical patterns

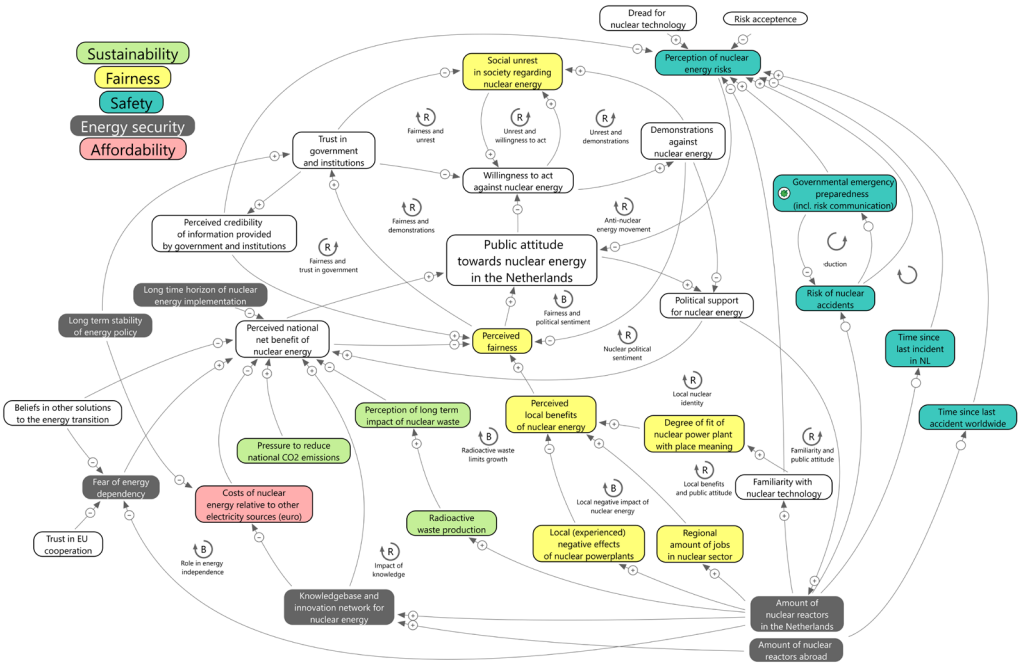
- Nuclear energy was far more prominent in the public discourse in the 1970s / 1980s than nowadays, with seemingly higher levels of concern, but also support. These public dialogues still shape today’s attitudes on trust. The nature of them has changed however: decades ago, the safety of operating a nuclear power plant, radioactive waste disposal, and the threat of a nuclear war were the most prominent concerns, next to the urgency for economic growth. Today, trust dynamics are more strongly shaped by perceptions of cost and climate change, while safety is important to a lesser degree. Also, in current discourse the advantages and disadvantages of nuclear energy are compared more to renewable energy technologies, such as wind and solar parks.

- Historical evidence shows that public discourse and trust in nuclear energy are highly variable. The particular dynamics of these changes are not yet properly

understood and need further research. For example: trust in nuclear energy may be (more so than, for instance, renewable energy) highly intertwined with political identity, shaped by the values that citizens hold, and tied to visions on what the energy system of the future should look like. What we can say however is that trends in trust seem to be cyclical and what has happened (e.g. a negative blow to trust resulting from a nuclear incident) is likely to happen again.

Current system dynamics

- A causal loop model was created to map the complexity of public trust in nuclear energy by examining the underlying causal structure. The causal structure is based on existing literature, supplemented with hypotheses from experts in the research team. Hence, the model needs further validation and empirical study and should be treated as an evolving model of public trust that displays potential relationships between variables.



Overview of the nuclear causal loop diagram

- The model's central variable is the public attitude towards nuclear energy in the Netherlands, which is directly influenced by:
  - Perception of nuclear energy risks (how society assesses potential dangers, including environmental, health, and safety risks);
  - Perceived net benefit (the public's understanding of the costs and gains from nuclear power, considering energy security, economic growth, and environmental sustainability); and
  - Perceived fairness (public judgment on the equity and justice of nuclear energy policies).

- The feedback loops in the model illustrate what public trust dynamics could take place over time and how policy makers may interact with these dynamics:

- The perception of nuclear energy risks may take more precedence in attitude formation over time, possibly due to nuclear incidents and the amplification of risks reported through the media. High trust in institutions (such as government), credible information reported by these institutions and fair decision-making procedures may dampen these amplification effects. Hence, policy makers should build trust and establish fair decision making and engagement procedures to foster the robustness of policy making to such external shocks.
- Trust, credibility, and fairness may also be used to dampen the societal unrest created by acts in favour of or against nuclear energy technology (e.g. demonstrations). If diverse societal groups are provided with opportunities to voice opinions surrounding nuclear energy, if their concerns are recognized and if local risks and costs are balanced by local benefits, perceived fairness will increase, fostering trust and the credibility of institutions and their communication in turn. Through such processes, conflict can be turned into constructive policy making.
- Trust, credibility, and fairness perceptions are highly interrelated and have been shaped over time through experiences with other topics and technologies. Policy makers should inform themselves (e.g. through social site characterization) about these experiences and how they may aid or hamper nuclear energy policies and projects in particular regions.
- The perceived net benefits of nuclear energy are likely to fluctuate, leading to variable public attitudes toward nuclear energy in turn. With increasing investments in nuclear power plants, the perceived attractiveness of additional nuclear energy capacity is likely to both be strengthened (through investments in the nuclear innovation network), as well as weakened (through meeting energy security requirements or through the accumulation of radioactive waste) over time. Geopolitical, technological, or demographic developments may also radically shift which of the key costs and benefits of nuclear energy take precedence in citizen's attitude formation, stressing the need to take long term impacts and effects on future generations into account in policy making.
- Similar strengthening and weaking effects may take place for communities near nuclear installations. Additional installations may shape local nuclear identities, foster a sense of familiarity, and create local benefits (strengthening local positive attitudes), but may also concentrate the perceived negative effects of these installations, such as construction activities, visual impact of new infrastructure and the liveability of the region (strengthening local negative attitudes). Because of their self-reinforcing effect, such concerns should be attended to carefully once they arise. Otherwise, these processes become difficult to manage due to the various interlocking effects between local effects, perceived fairness, trust, and attitude formation.

Public interaction

- People can interpret the same facts very differently, as they weigh the facts according to their own values and frames. Three of these dominant frames around nuclear energy are ecomodernism, energy justice, and lastly (becoming more prominent due to the current geopolitical tensions) the security frame. Awareness of dominant frames helps to understand why trust is shaped differently for different people.

- To align with best practices in citizen engagement, interaction activities should be guided by transparency, backed by data and supportive of public dialogue. These

activities should focus on relationship building and incorporating new insights gained throughout the interaction process. Only when these activities take on a dynamic character (e.g. by moving through iterative steps of sensing, analysing, and interacting) can constructive policy making occur.

- The trust in nuclear energy of the general public, and the trust in nuclear power plants of communities living near them, should be treated as distinct but interacting phenomena. These two types of trust develop through different dynamics (e.g. the proximity of the power plant location gives more prominence to liveability issues) that require separate sensing activities.

- Four key aspects of public trust that policy makers or community engagement managers should account for are:
  - Reflect on the presence of biases when interpreting the outcomes of sensing, analysing, and interacting.
  - Scrutinize data collection methods, not just results.
  - Design diverse interaction activities with low barriers to entry.
  - Appreciate the value of conflict and mistrust throughout interaction.

- Adaptive policy processes (continually sensing, analysing, and interacting, as explained below) may be more effective at dealing with trust dynamics than current practice. Throughout the life cycle of nuclear power plants (NPPs) there may be many opportunities for adaptivity, especially in the design of stakeholder engagement and participation procedures. However, there is a friction between such adaptivity and decision making around nuclear energy technology, where decisions may be 'locked-in' for decades due the nature of NPP's life cycles. A possible solution to this thorny problem may be to strengthen the robustness of policy making for changes in public trust dynamics. Such an approach to policy design would imply that the envisioned role of nuclear energy is specified for various alternative futures, not only those that fit the current narrative for the energy transition or for the economy of the future. Such an exercise should not be limited to professionals but should be opened for input by the general public. Doing such an exercise may help to strengthen the public and political support for decisions made on nuclear energy and may foster public trust by reinforcing the fairness of decision making.

Dealing with trust dynamics: Sensing, analysing, and interacting

To properly grasp this evolving complex theme, we advise policy makers to follow an iterative sequence of sensing, analysing, and interacting:

- Sensing, or monitoring, means keeping track of what is being perceived, stated, written, experienced, around the topic at hand. It involves having the right "radars" in place to notice current states ánd movements on a specific topic. As sensing activities in this project, we employed a literature scan, a case study of comparable technologies[1] (e.g. carbon capture and storage (CCS) and wind) and a media analysis. These sensing activities contribute to a better understanding of the (historical) patterns that have shaped public trust in nuclear energy.

[1] The case study will be reported separately; this report only contains a summary of the approach and results.

- **Analysing** is used to make sense of the data gathered in the former step. This can be done by adding the interpretative capacities of experts; by modelling techniques that place phenomena in relation to each other; or a combination. To analyse what was found in the literature scan, case study and media analysis, we applied complex system modelling to analyse how these findings relate to and influence each other. From the modelling exercise, the key dynamics that emerged were the interrelationship between public attitude on the one hand, and risk perceptions, trust in government, perceived fairness, and the long-term stability of energy policy on the other hand.

- **Interacting** is meant to interact with, and gather feedback from, the public using insights gained through sensing and analysing. We, as a research team, have not engaged in interaction activities throughout this study. Rather, we have identified considerations for interaction based on the insights from the various sensing and analysis methods we applied. Key elements for interacting are to establish a process of continuous public interaction, that is fed by transparent updates on the building process and the place of nuclear energy in the wider energy policy; to match the most prominent trust dynamics with the phases in the building process; and to involve citizens actively in dealing with perceived risks.

Finally, if it is decided to further develop this adaptive policy process, with sensing, analysing, and interacting activities, we propose a knowledge roadmap containing the following research lines:

1. Monitoring the dynamics of trust through, for example, establishing a recurring energy transition monitor for the wider energy system, developing new indicators and new indices for using historical survey data.
2. Exploring alternative scenarios and solutions for an energy system with varying degrees and types (e.g. SMR) of nuclear energy through, for example, futuring techniques (exploring possible future scenarios) and surveys.
3. Developing novel communication and information provision methods through, for example, serious gaming and citizen science
4. Developing novel stakeholder engagement and participation procedures through, for example, co-creation methods, such as group model building.

Developing policy guidance to include the insights from research lines 1 through 4 into training materials or tools for policy makers and guidance for structural changes to policy making on nuclear energy.

Dutch Summary

Kernenergie is opnieuw in de belangstelling gekomen door de toenemende inspanningen om het Nederlandse energiesysteem om te vormen naar een systeem dat duurzaam, betaalbaar en betrouwbaar is. Om de nucleaire kennisinfrastructuur te versterken is daarom begin 2024 het “Toegepast Kennisprogramma Kernenergie 2024” van TNO en NRG PALLAS gestart, ondersteund en gefinancierd door de Nederlandse overheid. Het onderwerp van dit rapport, “Publiek vertrouwen in kernenergie”, is een van de thema's in dit programma.

Publiek vertrouwen in kernenergie ontwikkelt zich dynamisch; vertrouwen ontstaat door complexe interacties tussen de kenmerken van kernenergie, het ondersteunende beleid (bijvoorbeeld investeringen in de regio), communicatie en betrokkenheid van belanghebbenden, aangrenzende beleidskwesties (zoals inspraakprocedures bij andere onderwerpen die overlopen in de percepties bij kernenergie), en hoe burgers deze onderwerpen tegelijkertijd verwerken. Dit rapport 1) vergroot de inzichten in vertrouwensdynamiek en wat deze dynamiek impliceert voor beleidsvorming, en 2) stelt voor hoe beleidsmakers en uitvoerders die actief zijn in publieke interactie rond kernenergie kunnen omgaan met vertrouwensdynamiek door detectie, analyse en interactie. De resultaten van beide worden hieronder samengevat, na een korte beschrijving van de onderzoeksaanpak.

Onderzoeksaanpak

De onderzoeksbenadering richt zich op het begrijpen van de dynamische en complexe aard van het publieke vertrouwen in kernenergie. Erkennend dat vertrouwen wordt beïnvloed door verschillende factoren en niet statisch is, maakt dit onderzoek gebruik van een systeemdenkenperspectief om vast te leggen wat momenteel waarneembaar is (uit ander onderzoek en media) over de onderlinge verbondenheid van factoren en terugkoppelingen die het publieke vertrouwen in kernenergie beïnvloeden. Een beperking van deze benadering is dat het kernenergiebeleid en het vertrouwen van het publiek voortdurend in beweging zijn, wat de dynamiek van het vertrouwen beïnvloedt. Daarom benadrukken we de noodzaak van voortdurende waarneming, analyse en interactie om adaptieve beleidsvorming te ondersteunen.

Inzichten in vertrouwensdynamiek

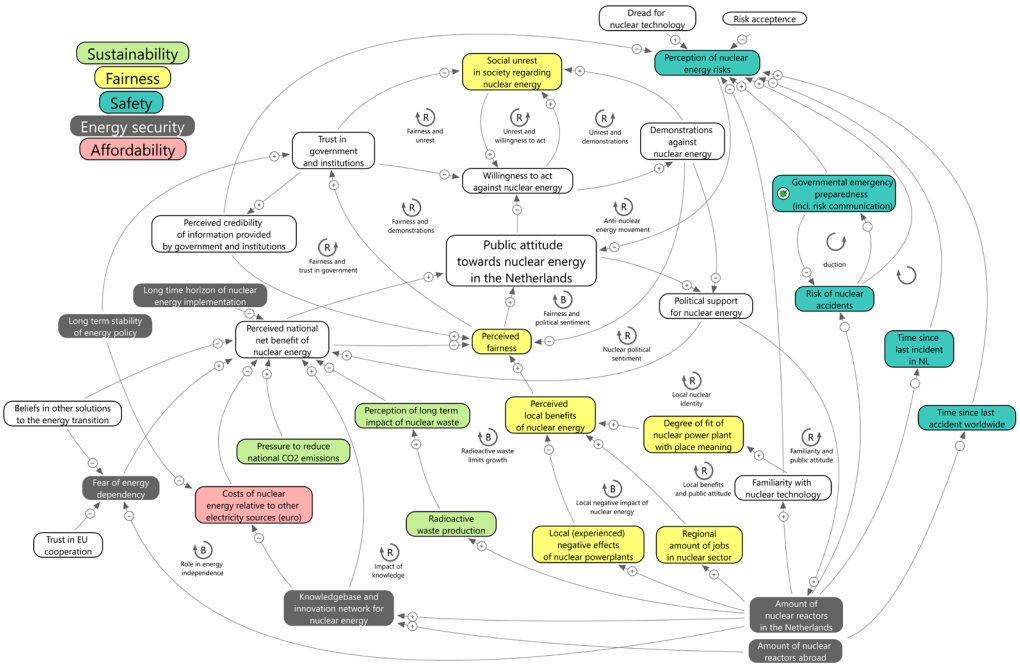
Historische patronen

- Kernenergie was in de jaren 1970 / 1980 veel prominenter aanwezig in het publieke debat dan tegenwoordig, met schijnbaar meer bezorgdheid, maar ook steun. Deze publieke dialogen bepalen nog steeds de huidige houding ten opzichte van vertrouwen. De aard ervan is echter veranderd: decennia geleden waren de veiligheid van het exploiteren van een kerncentrale, het opruimen van radioactief afval en de dreiging van een kernoorlog de meest prominente punten van zorg, naast de urgentie van economische groei. Tegenwoordig wordt de vertrouwensdynamiek sterker bepaald door percepties van kosten en klimaatverandering, terwijl veiligheid in mindere mate belangrijk is. In het huidige discours worden de voor- en nadelen van kernenergie ook meer vergeleken met hernieuwbare energietechnologieën, zoals wind- en zonneparken.

- Historisch bewijs toont aan dat het publieke discours en het vertrouwen in kernenergie zeer variabel zijn. De specifieke dynamiek van deze veranderingen is nog niet goed begrepen en vereist verder onderzoek. Bijvoorbeeld: vertrouwen in kernenergie kan (meer dan bijvoorbeeld hernieuwbare energie) sterk verweven zijn met politieke identiteit, gevormd door de waarden die burgers hebben, en verbonden zijn met visies op hoe het energiesysteem van de toekomst eruit zou moeten zien. Wat we echter kunnen zeggen, is dat trends in vertrouwen cyclisch lijken te zijn en dat wat is gebeurd (bijvoorbeeld een negatieve klap voor het vertrouwen als gevolg van een nucleair incident) waarschijnlijk opnieuw zal gebeuren.

Huidige systeemdynamiek

- Een causaal lusmodel is gemaakt om de complexiteit van het publieke vertrouwen in kernenergie in kaart te brengen door de onderliggende causale structuur te onderzoeken. De causale structuur is gebaseerd op bestaande literatuur, aangevuld met hypothesen van experts in het onderzoeksteam. Daarom heeft het model verdere validatie en empirisch onderzoek nodig en moet het worden behandeld als een evoluerend model van publiek vertrouwen dat potentiële relaties tussen variabelen weergeeft.



Overzicht van het nucleaire causale lusdiagram

- De centrale variabele van het model is de publieke houding ten opzichte van kernenergie in Nederland, die direct wordt beïnvloed door:
  - Perceptie van kernenergierisico's (hoe de samenleving potentiële gevaren beoordeelt, inclusief milieu-, gezondheids- en veiligheidsrisico's);
  - Waargenomen netto voordeel (het begrip van het publiek over de kosten en baten van kernenergie, rekening houdend met energiezekerheid, economische groei en milieuduurzaamheid); en
  - Waargenomen eerlijkheid (publieke beoordeling van de rechtvaardigheid en billijkheid van kernenergiebeleid).

- De feedbacklussen in het model illustreren welke dynamiek van publiek vertrouwen zich in de loop van de tijd zou kunnen voordoen en hoe beleidsmakers met deze dynamiek kunnen omgaan:
  - De perceptie van kernenergierisico's kan na verloop van tijd meer voorrang krijgen bij de vorming van attitudes, mogelijk als gevolg van nucleaire incidenten en de versterking van risico's die via de media worden gerapporteerd. Hoog vertrouwen in instellingen (zoals de overheid), geloofwaardige informatie die door deze instellingen wordt gerapporteerd en eerlijke besluitvormingsprocedures kunnen deze versterkingseffecten dempen. Daarom moeten beleidsmakers vertrouwen opbouwen en eerlijke besluitvormings- en betrokkenheidsprocedures vaststellen om de robuustheid van het beleid tegen dergelijke externe schokken te bevorderen.
  - Vertrouwen, geloofwaardigheid en eerlijkheid kunnen ook worden gebruikt om de maatschappelijke onrust te verminderen die wordt veroorzaakt door handelingen ten gunste van of tegen kernenergietechnologie (bijv. demonstraties). Als diverse maatschappelijke groepen de mogelijkheid krijgen om hun mening over kernenergie te uiten, als hun zorgen worden erkend en als lokale risico's en kosten worden gecompenseerd door lokale voordelen, zal de waargenomen eerlijkheid toenemen, wat op zijn beurt het vertrouwen en de geloofwaardigheid van instellingen en hun communicatie bevordert. Door dergelijke processen kan conflict worden omgezet in constructieve beleidsvorming.
  - Vertrouwen, geloofwaardigheid en percepties van eerlijkheid zijn sterk met elkaar verweven en zijn in de loop van de tijd gevormd door ervaringen met andere onderwerpen en technologieën. Beleidsmakers moeten zich informeren (bijv. door sociale sitekarakterisering) over deze ervaringen en hoe ze kernenergiebeleid en -projecten in specifieke regio's kunnen helpen of belemmeren.
  - De waargenomen netto voordelen van kernenergie zullen waarschijnlijk fluctueren, wat op zijn beurt leidt tot variabele publieke houdingen ten opzichte van kernenergie. Met toenemende investeringen in kerncentrales zal de waargenomen aantrekkelijkheid van extra kernenergiecapaciteit waarschijnlijk zowel worden versterkt (door investeringen in het nucleaire innovatienetwerk) als verzwakt (door het voldoen aan energiezekerheidseisen of door de accumulatie van radioactief afval) in de loop van de tijd. Geopolitieke, technologische of demografische ontwikkelingen kunnen ook radicaal verschuiven welke van de belangrijkste kosten en baten van kernenergie voorrang krijgen bij de vorming van de houding van burgers, wat de noodzaak benadrukt om bij beleidsvorming rekening te houden met de langetermijneffecten en effecten op toekomstige generaties.
  - Vergelijkbare versterkende en verzwakkende effecten kunnen optreden voor gemeenschappen in de buurt van nucleaire installaties. Extra installaties kunnen lokale nucleaire identiteiten vormen, een gevoel van vertrouwdheid bevorderen en lokale voordelen creëren (versterking van lokale positieve houdingen), maar kunnen ook de waargenomen negatieve effecten van deze installaties concentreren, zoals bouwactiviteiten, visuele impact van nieuwe infrastructuur en de leefbaarheid van de regio (versterking van lokale negatieve houdingen). Vanwege hun zelfversterkende effect moeten dergelijke zorgen zorgvuldig worden aangepakt zodra ze zich voordoen. Anders worden deze processen moeilijk te beheersen vanwege de verschillende onderling verbonden effecten tussen lokale effecten, waargenomen eerlijkheid, vertrouwen en houdingsvorming.

Publieke interactie

- Mensen kunnen dezelfde feiten heel verschillend interpreteren, omdat ze de feiten wegen volgens hun eigen waarden en kaders. Drie van deze dominante kaders rond kernenergie zijn ecomodernisme, energie rechtvaardigheid en ten slotte (steeds prominenter door de huidige geopolitieke spanningen) het veiligheidskader. Bewustzijn van dominante kaders helpt te begrijpen waarom vertrouwen voor verschillende mensen anders wordt gevormd.

- Om aan te sluiten bij best practices in burgerparticipatie, moeten interactieactiviteiten worden geleid door transparantie, ondersteund door gegevens en bevorderlijk voor publieke dialoog. Deze activiteiten moeten zich richten op het opbouwen van relaties en het integreren van nieuwe inzichten die tijdens het interactieproces worden verkregen. Alleen wanneer deze activiteiten een dynamisch karakter aannemen (bijv. door iteratieve stappen van waarnemen, analyseren en interactie te doorlopen) kan constructieve beleidsvorming plaatsvinden.

- Het vertrouwen in kernenergie van het algemene publiek en het vertrouwen in kerncentrales van gemeenschappen die in de buurt wonen, moeten worden behandeld als afzonderlijke maar onderling samenhangende fenomenen. Deze twee soorten vertrouwen ontwikkelen zich door verschillende dynamieken (bijv. de nabijheid van de locatie van de kerncentrale geeft meer nadruk aan leefbaarheidskwesties) die afzonderlijke waarnemingsactiviteiten vereisen.

- Vier belangrijke aspecten van publiek vertrouwen waarmee beleidsmakers of managers van gemeenschapsbetrokkenheid rekening moeten houden, zijn:
  - Reflecteer op de aanwezigheid van vooroordelen bij het interpreteren van de resultaten van waarnemen, analyseren en interacteren.
  - Onderzoek de methoden voor gegevensverzameling, niet alleen de resultaten.
  - Ontwerp diverse interactieactiviteiten met lage drempels voor deelname.
  - Waardeer de waarde van conflict en wantrouwen tijdens interactie.

- Adaptieve beleidsprocessen (voortdurend waarnemen, analyseren en interacteren, zoals hieronder uitgelegd) kunnen effectiever zijn in het omgaan met vertrouwensdynamiek dan de huidige praktijk. Gedurende de levenscyclus van kerncentrales (NPP's) kunnen er veel mogelijkheden zijn voor adaptiviteit, vooral bij het ontwerpen van procedures voor betrokkenheid en participatie van belanghebbenden. Er is echter een wrijving tussen dergelijke adaptiviteit en besluitvorming rond kernenergietechnologie, waarbij beslissingen mogelijk voor decennia worden 'vastgelegd' vanwege de aard van de levenscycli van NPP's. Een mogelijke oplossing voor dit lastige probleem kan zijn om de robuustheid van beleidsvorming voor veranderingen in de dynamiek van publiek vertrouwen te versterken. Een dergelijke benadering van beleidsontwerp zou impliceren dat de beoogde rol van kernenergie wordt gespecificeerd voor verschillende alternatieve toekomsten, niet alleen die passen bij het huidige narratief voor de energietransitie of voor de economie van de toekomst. Een dergelijke oefening zou niet beperkt moeten blijven tot professionals, maar zou open moeten staan voor input van het algemene publiek. Het uitvoeren van een dergelijke oefening kan helpen om de publieke en politieke steun voor beslissingen over kernenergie te versterken en kan het publieke vertrouwen bevorderen door de eerlijkheid van de besluitvorming te versterken.

Omgaan met vertrouwensdynamiek: Waarnemen, analyseren en interacteren

Om dit evoluerende complexe thema goed te begrijpen, adviseren we beleidsmakers om een iteratieve reeks van waarnemen, analyseren en interacteren te volgen:

- **Sensing**, of monitoren, betekent bijhouden wat wordt waargenomen, verklaard, geschreven, ervaren rond het betreffende onderwerp. Het houdt in dat de juiste "radars" aanwezig zijn om huidige toestanden en bewegingen over een specifiek onderwerp op te merken. Als waarnemingsactiviteiten in dit project hebben we een literatuurscan, een case study van vergelijkbare technologieën (bijv. koolstofafvang en -opslag (CCS) en wind) en een media-analyse uitgevoerd. Deze waarnemingsactiviteiten dragen bij aan een beter begrip van de (historische) patronen die het publieke vertrouwen in kernenergie hebben gevormd.

- **Analyseren** wordt gebruikt om de gegevens die in de vorige stap zijn verzameld te begrijpen. Dit kan worden gedaan door de interpretatieve capaciteiten van experts toe te voegen; door modelleringstechnieken die fenomenen in relatie tot elkaar plaatsen; of een combinatie. Om te analyseren wat werd gevonden in de literatuurscan, casestudy en media-analyse, hebben we complexe systeemmodellering toegepast om te analyseren hoe deze bevindingen zich tot elkaar verhouden en elkaar beïnvloeden. Uit de modelleringssessie kwamen de belangrijkste dynamieken naar voren, namelijk de onderlinge relatie tussen publieke houding enerzijds, en risicopercepties, vertrouwen in de overheid, waargenomen eerlijkheid en de langetermijnstabiliteit van het energiebeleid anderzijds.

- **Interactie** is bedoeld om te communiceren met en feedback te verzamelen van het publiek, gebruikmakend van inzichten verkregen door waarnemen en analyseren. Wij, als onderzoeksteam, hebben tijdens deze studie niet deelgenomen aan interactieactiviteiten. In plaats daarvan hebben we overwegingen voor interactie geïdentificeerd op basis van de inzichten uit de verschillende waarnemings- en analysemethoden die we hebben toegepast. Belangrijke elementen voor interactie zijn het opzetten van een proces van continue publieke interactie, gevoed door transparante updates over het bouwproces en de plaats van kernenergie in het bredere energiebeleid; het afstemmen van de meest prominente vertrouwensdynamiek op de fasen in het bouwproces; en het actief betrekken van burgers bij het omgaan met waargenomen risico's.

Ten slotte, als wordt besloten om dit adaptieve beleidsproces verder te ontwikkelen, met waarnemings-, analyse- en interactieactiviteiten, stellen we een kennisroutekaart voor met de volgende onderzoekslijnen:

1. Het monitoren van de dynamiek van vertrouwen door bijvoorbeeld het opzetten van een terugkerende energietransitiemonitor voor het bredere energiesysteem, het ontwikkelen van nieuwe indicatoren en nieuwe indices voor het gebruik van historische enquêtegegevens.
2. Het verkennen van alternatieve scenario's en oplossingen voor een energiesysteem met verschillende graden en typen (bijv. SMR) van kernenergie door bijvoorbeeld futuring technieken (het verkennen van mogelijke toekomstige scenario's) en enquêtes.
3. Het ontwikkelen van nieuwe communicatie- en informatievoorzieningsmethoden door bijvoorbeeld serious gaming en citizen science.
4. Het ontwikkelen van nieuwe procedures voor betrokkenheid en participatie van belanghebbenden door bijvoorbeeld co-creatiemethoden, zoals groepsmodelbouw.

5. Het ontwikkelen van beleidsrichtlijnen om de inzichten uit onderzoekslijnen 1 tot en met 4 op te nemen in trainingsmateriaal of hulpmiddelen voor beleidsmakers en richtlijnen voor structurele veranderingen in de beleidsvorming over kernenergie.

1 Introduction

1.1 Project background

Background

Nuclear energy has gained renewed attention caused by the growing efforts to transition the Dutch energy system to one that is sustainable, affordable and reliable. From a current marginal role in the entire energy mix, plans are now unfolding to scale this share of nuclear by means of at least two, possibly four, nuclear power plants[2].

The “Applied Knowledge Programme Nuclear Energy 2024” of TNO and NRG PALLAS, supported and funded by the Dutch government, was therefore initiated beginning of 2024 to strengthen the nuclear knowledge infrastructure. This report titled “Public Trust and Nuclear Energy” came forth from a key theme in this program, that emphasises the importance of understanding public opinions and trust for the accompanying policy-making process.

Nuclear energy as an energy technology has become more controversial in the Netherlands since the 1970s. Looking at the evolution of nuclear energy in the Netherlands, this is turbulent; from plans for large expansion in the 1970s, a public discussion in the mid-1980s and then a halt to expansion in the 1980s; to new plans for expansion from the 1990s onwards that did not materialize for a long time; and now, the aforementioned plans of the former and current government to expand nuclear generation capacity in the Netherlands with 2 to 4 reactors, from currently one. Meanwhile, some neighbouring countries have decided to either phase out or scale-up nuclear energy, and both internationally and in the Netherlands the possibilities of smaller modular reactors (SMR) are explored (this study will focus on the larger-scale nuclear power plants).

Research gap

Compared to the public protests in the Netherlands in the 1970s and 80s, the topic now seems to occupy the public mind to a lesser degree. One explanation for this points to changes in public sentiment; the public opinion about nuclear energy seems to be shifting towards more people with a positive opinion. A CBS study in 2023 pointed to a shift from 25% of the Dutch population in favour of increasing the share of nuclear energy in 2020, to 36% in 2023 (CBS, 2023). Almost half of the population is however reluctant or unsure, and the rest wants to maintain it as is (CBS, 2023). In light of these figures and the historic dynamics of public sentiment, the decision to proceed with plans to expand nuclear capacity could at some point face a louder public response. Moreover, public trust in nuclear energy cannot be seen in isolation, as other societal topics may have spill-over effects on the dynamics shaping trust, such as geopolitical tensions influencing the debate around energy policy. Current snapshots through studies of public sentiments around energy policy and/or nuclear energy hardly account for these connections. This research is thus aimed towards gaining a more thorough understanding of how public sentiment and trust in nuclear energy evolves, and the dynamics that shape it.

[2] https://nos.nl/artikel/2511577-tweede-kamer-wil-vier-grote-kerncentrales-in-plaats-van-twee

1.2 Scope and definitions

1.2.1 Scope

This research originated from a need to understand how public trust is shaped in these dynamic times for nuclear energy in the Netherlands. Via our approach of providing an objective methodology for obtaining and maintaining grip on the dynamics and making use of methodologies such as system modelling (all described in the following chapters), we believe we were able to bring several perspectives and serve a spectrum of alternatives for public interactions for the Ministry to employ.

There are a few disclaimers we would like to make in light of this research, which have been leading in the trajectory up to this report:

- We focus on trust, but acknowledge that distrust also deserves place in a healthy democracy where there is room for different voices and sentiments.
- Any view on trust, like ours, is shaped by context, timeframe, and methodology applied. We therefore emphasise the need for a continuous adaptive process of sensing, analysing and interacting to ensure translation to effective policy applications in practice.
- This research in no way is about changing attitudes and trust: it provides a view on trust dynamics and how these come about. We therefore focus more on analysing them, than on giving policy advice.

1.2.2 Definitions

Before the content can be understood well, it is important to be clear on definitions: what is trust? And how does trust differ from acceptance, for example? How we dealt with these concepts in this study is described in this paragraph.

Trust

Trust[3] is commonly defined as "*a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another*" (Rousseau et al., 1998, p. 395).[4] In this project, we primarily focus on **public trust**, or the trust **that the public has** in others. Several sub concepts of trust can be used to define *who* the public trusts[5]: 1) **Social trust: t**rust between people in general (see Schnabel et al., 2008); 2) **Political or institutional trust**: trust between citizens and political institutions (i.e., political trust) or institutions in general (i.e., institutional trust), such as banks, churches, universities, or judges; 3) **Technological trust: t**rust between a person and a technology. In the case of technological trust, trust is not assigned to another person, but to an inanimate object. As such, the definition of trust is different: "*an individual's willingness to be vulnerable to a technology based on person-specific expectations of the technology's predictability, reliability, and utility as moderated by the individual's predisposition to trust the technology*" (Lippert & Swiercz, 2005, p.341).

[3] The literature on citizen responses to energy technologies has primarily focused on trust, rather than skepticism or mistrust, which are separate concepts with distinct conceptual mechanisms (van Gessel et al., 2023).

[4] Other definitions also include a reference to monitoring and control, such as in the Integrated Model Of Trust (IMOT): "irrespective of the ability to monitor or control that other part" (Mayer, 1995)(p.712).

[5] Social and institutional trust are measured yearly by the Dutch Statistics Bureau (CBS), see and are a primary focus of the 'Sociaal en Cultureel Planbureau' (Representatie en vertrouwen | Sociaal en Cultureel Planbureau (scp.nl))

In the literature on energy technology, trust and acceptance, institutional trust is the primary focus. In this literature, trust is commonly divided into two[6] dimensions:

1. **Competence-based trust**. *"the extent to which responsible agents are perceived to have the relevant knowledge and expertise to implement and manage a (renewable) energy project."* (Liu et al., 2020)(p.2).
2. **Integrity-based trust.** *"the extent to which responsible agents are perceived to be honest and transparent about their activities, and are concerned with public interests."* (Liu et al., 2020 p.2).

Acceptance

A more dominant concept than trust in nuclear energy literature, is **acceptance,** which is defined as *"a favourable or positive response (including attitude, intention, behaviour and – where appropriate – use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)"* (Upham et al., 2015 p. 103). Acceptance can refer to various levels, objects and actors and is commonly subdivided into several dimensions.

Our project focuses on the public as the primary stakeholder and the concept of **public acceptance**, which is defined as *"the attitude or behavioural response to the implementation or adoption of a proposed technology held by the lay public of a given country, region or town."* (Upham et al., 2015 p. 105). **Local public acceptance** then refers to attitudes or behavioural responses to the implementation of specific infrastructure by communities at the local level.

Attitude

In the above definition an attitude is defined as an evaluative judgement (e.g. positive or negative) of an object – for example, a nuclear power plant or a nuclear energy policy. Because attitudes are defined consistently across studies, we use the concept of **public attitude –** rather than acceptance - to denote attitudes of the public in modelling trust dynamics (see chapter 4).

Energy justice

Energy justice refers to the *equitable distribution of both the benefits and burdens associated with energy production and consumption*. This equitable distribution is guided by three core tenets: recognition, which involves acknowledging the rights and needs of marginalized communities; distribution, focusing on the fair allocation of energy resources and services; and procedural justice, ensuring that all stakeholders have a voice in energy decision-making processes (Sovacool, 2014). Especially the last two deserve attention regarding governmental plans around nuclear energy, as the construction of extra plants come with great impacts and costs. Another principle, which is also relevant in the domain of nuclear energy, is intergenerational justice, which refers to ethical obligations we have towards future generations, particularly regarding the sustainability and environmental impacts of our actions today (RLI, 2022).

Use of these definitions in this report

The term 'acceptance' is still most commonly used in the literature on energy technologies, despite its issues: the concept may oversimplify complex interactions between the public and other stakeholders and may promote an instrumental focus of public engagement, centred on achieving a particular outcome with engagement (i.e. positive responses of citizens to the technology) (Batel, 2017). Many authors argue that research, policy, and public engagement practices should focus on other (process-based) concepts instead, such

[6] A third dimension 'benevolence' (the extent to which others are perceived to care about the person) is sometimes used as well (van Gessel et al., 2023), but (to the best of our knowledge) not in the context of energy technology acceptance. In the definition given above, the benevolence aspect seems to be subsumed under integrity-based trust.

as justice or trust. Keeping our scope wide, we have chosen to centre our research around the broader notion of trust and/or acceptance whenever relevant, as the field progresses towards finding a better alternative.

1.3 Reading guide

This report is structured as follows: in the next chapter (Chapter 2), our stepwise research approach is described which is shaped by the current evolution and complexity of the topic at hand. In the consequent chapters 3 (Sensing), 4 (Analysing) and 5 (Interacting) the results of these research steps are described. Chapter 6 describes policy implications the research team drafted based on this research. Following from this, the report concludes with a knowledge roadmap in chapter 7.

1.4 Research team

An invaluable feature of this research project is that it brought together two organisations with researchers who were not yet familiar with each other and their way of working, yet who together established a foundation of trust amongst the team, and, especially, a collective understanding of trust in nuclear energy. NRG PALLAS brought in nuclear expertise (e.g. on radiation and risk communication, decommissioning) with advanced analytical skills, whereas the TNO team contributed with expertise from social sciences, systems modelling, and the broader field of energy transition. The result of this cooperation lies before you. The team aspires that this cooperation serves as a basis for innovative joint research in the years to come.

2 Research approach

In this chapter, the steps of the research approach are outlined with their accompanying rationale.

It would be an illusion to assume that a current snapshot of public trust could give enough tools to decide on optimal policies and interactions with the public. Trust is a dynamic concept; as is policymaking around nuclear energy. Furthermore, any view on trust, like ours, is certainly shaped or even biased by context, timeframe of the research, and the methodology applied. From the onset, the team thus recognised that what is explicitly needed, is to get a grip on this evolving topic. We thus employed an approach that serves to get and sustain a degree of grip on the topic.

Trust in nuclear energy can be characterised as a topic embedded in a complex system, as it has several key features of complexity (Sterman, 2000). Interconnectedness is one of them, where multiple components interact and depend on each other, making changes in one part affect others unpredictably (for instance, fossil fuel prices affecting the cost perceptions of nuclear energy). Also, the relationship between cause and effect is not straightforward; minor changes can lead to significant impacts due to feedback loops, where components of the system reinforce one another or balance each other out. For example, politicians may suggest those policies for which they notice public support, but the public may also express support for policies just because their preferred politicians suggest them (Latré et al., 2019). Such a pattern may lead to a reinforcing feedback loop, where the root cause is difficult to spot.

Policy adaptability is therefore crucial, as complex systems can change and evolve over time in response to internal and external influences. This includes learning from past experiences and adapting to new conditions. Also, uncertainty, unpredictability, and diversity are inherent in complex systems. Adopting multiple perspectives, that portray this diversity and accommodate the uncertainty, are crucial for understanding and managing systemic phenomenon. Systems thinking allows for 'holistic, broad, long-term and dynamic view' of a problem situation, making it possible to redesign the underlying system and act in them more effectively (Sterman, 1994, p. 297).

For getting grip on this complexity, we loosely follow the steps proposed in the Cynefin framework (Snowden & Boone, 2007), which is a conceptual tool used to help decision-makers understand the nature of different situations and make appropriate choices depending on whether the context in which decisions are made is more clear-cut or complex. As complexity increases, there is more need to follow a cycle of making sense of what is going on to make decisions accordingly. Subsequently, we propose three steps that those responsible for public interaction on nuclear energy can take and repeat, which are: sensing, analysing, and interacting[7]. These steps, and how we approached them during this research, are explained in the following paragraphs.

[7] Even though it is also good practice to add probing to the cycle (e.g. conducting small experiments to assess what happens), probing is not part of this research as we did not plan for interventions of any type.

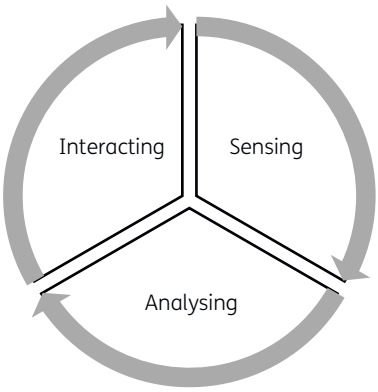


Figure 2.1: Action perspective: a constant loop of sensing, analysing, and interacting.

2.1 Sensing

Sensing, or monitoring, means keeping track of what is being perceived, stated, written, experienced, around the topic at hand. It involves having the right “radars” in place to notice current states and movements on a specific topic. There are multiple ways to sense: in this project, we employed a literature scan for a view on what is already known, a case study of comparable technologies and a media analysis. These are a way to sense what is going on, albeit retrospectively. One method to sense in (near) real-time is by means of surveying, but also activities such as walk-in sessions for citizens can be effective to hear what is concerning the (local) public.

2.1.1 Literature scan

Despite, or maybe because of, the changing role of nuclear energy in the energy domain (globally), quite some research has been conducted already on the dynamics around trust (or acceptance/attitude). The first step, as for any research project is therefore to scan the field to get a view on what is already done, known, and applicable to the research at hand. The team conducted a broad scan, which was structured by means of a template to map research specifications and, especially, trust determinants. With this literature scan we looked at trust dynamics in nuclear energy, international comparison of the same topic in several other countries and the different lenses people themselves have on the topic.

The scan of the field was done in a few ways:

- A literature search in Scopus[8], based on keywords such as “public trust in nuclear energy”, “trust determinants and nuclear energy”; and “public attitude towards nuclear energy”. Added to this was an international search using the same keywords but with countries added (i.e., England, France, Denmark, Germany, Finland, Belgium), of which the results can be found in 3.1.1.
- Studying publications from key institution, such as the Belgian Nuclear Research Centre SCK CEN, Raad voor de Leefomgeving en Infrastructuur, and Centraal Bureau voor de Statistiek and the research platform SHARE.
- A search via Google, based on similar keywords as for the Scopus search, for relevant publications in popular media.
- A search in the Eurobarometer.

[8] Scopus is a multidisciplinary database of scholarly literature containing abstracts and citations for academic articles across various fields (https://www.elsevier.com/products/scopus)

- An exchange amongst the researchers (NRG PALLAS and TNO) of respective highly appreciated publications.

To harmonise the results of the literature scan, a spreadsheet Excel sheet was created to categorise and summarise findings, e.g. regarding target groups, location, research methodology, and trust determinants.

2.1.2 Case study comparable technologies

To understand how trust dynamics work for other energy technologies, we conducted a comparative case study into four energy technologies: carbon capture and storage (CCS), hydrogen, wind, and geothermal energy. For each of these technologies, literature reviews were carried out recently (Broecks et al., 2021; TNO, 2022, 2024; van de Grift & van Lidth de Jeude, 2024). These reviews, as well as most studies on public responses to energy technologies, focus on public acceptance rather than public trust, so acceptance is chosen as the focus of this case study.

We used these literature reviews, as well as an expert consultation with the authors of these reviews, to answer the following questions:

1. What are the determinants of acceptance?
2. How has acceptance developed over time?
3. How has acceptance influenced the technology's development?
4. What technology-specific dynamics are present in the development of acceptance?
5. What are knowledge gaps and future research questions?

The expert consultation consisted of written formats that four experts filled out, focused on these five questions, among others. A session was then organized with these to compare findings across technologies and discuss opportunities for further research.

2.1.3 Historical patterns

We looked at historical patterns of how public opinion is formed by certain events and how the government and other relevant stakeholders responded to it, to be able to path a new way of understanding trust among the public. Therefore, we have conducted a qualitative and non-exhaustive reading on nuclear energy in Dutch newspapers between 1940 and 2024. We collected data from historical newspapers from the website Delpher for the period 1940 – 1999 and used the media database of LexisNexis for the period 1990 – 2024. From the company LexisNexis we specifically looked in the databases of Nexis and Nexis Newsdesk. We were advised by LexisNexis to exclude social media from this study, as sentiment analysis is not perceived as accurate enough yet.

This way, we could limit our search. For our search in Delpher and LexisNexis we included national and local news articles from the Netherlands. The length of the article needed to be more than 250 words, which is the minimum length of newspapers, to exclude for example advertisements. Our main keywords were "kernenergie" (nuclear energy), "kernreactor" (nuclear reactor), and "kerncentrale" (nuclear power plant), which had to be mentioned in the title of the newspaper. Other keywords (e.g. patronen, vertrouwen, and gevoel) were included to find the articles that reveal the sentiment on nuclear energy. An example of the overall keyword search used for Nexis:

titleCS:(kernenergie* OR kerncentrale* OR kernreactor) AND (publiek vertrouwen OR vertrouwen OR risico OR angst OR kriti* OR criti* OR mening* OR opini* OR verantwoordelijk* OR democrati* OR motivatie* OR proces* OR onderzoek* OR patronen OR patroon OR politi* OR sentiment* OR
gevoel* OR verschil* OR vergelijk* OR hoop OR hopen OR gevoel* OR goed OR "niet goed" OR discuss*) AND wordcount>250 AND sourcecountry:("The Netherlands")

Duplicates articles were left in the search as the number of articles on the same topic served as an indicator of its significance and impact on discussions or events around that time. Articles that mentioned events from abroad were excluded unless the article mentioned the influence on the Dutch sentiment and policies. Newspapers that are only about the workings of nuclear power plants were also excluded. LexisNexis and Delpher both provided a coverage overview of the published Dutch news articles on nuclear energy. We used the peaks in these overviews as an indicator to guide our search for the most important events in history.

2.2 Analysing

Analysing is meant to make sense of the data gathered in the former step; why do we see what we see? This can be done by adding the interpretative capacities of experts; by modelling techniques that place phenomena in relation to each other; or a combination. To analyse what we found in our literature study and media mining exercise, in this project we applied *complex system modelling* to analyse how these findings relate to and influence each other. In addition to looking at dynamics, we added lenses or frames to the analytical framework to give us more insights into the diverse ways people perceive this topic (see 2.2.2).

Besides complex system modelling there are other ways to analyse: found data can be structured, categorized, and prioritized by a group of experts for instance. Or quantitative methods can be employed such as agent-based modelling, that simulates behaviours among agents with varying inputs to understand what happens if a variable changes. These methods can be applied instead of systems modelling or complement it.

2.2.1 Modelling trust dynamics

Based on information gathered in the “sensing” step, the team in sub-groups created four sketches of conceptual models to structure and relate the found data. Consequently, the research team concluded that giving insight into causal interdependencies would add the most innovative insights to the research field. This was done via the casual loop diagram, based on the System Dynamics methodology.

System dynamics is a method applied to analyse complex (socio-technical) systems (Sterman, 2000). It helps to develop an understanding of complex societal and organisational phenomena, with their underlying principles and emergent processes. It starts with gaining insight into the structure of the system and understand why the problem is occurring and from there determining what can be done.

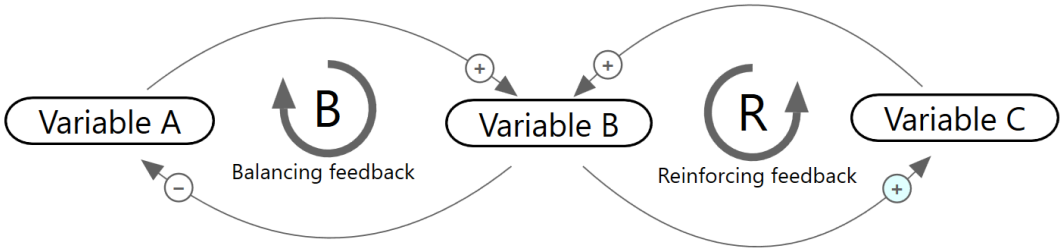


Figure 2.2: Example Causal Loop Diagram (CLD).

A causal loop diagram (CLD) is a popular approach for visualising the causal structure of the dynamic complexity of problems and is an example of how to analyse a system (Niks et al, 2022). The main elements of a causal loop diagram (CLD) are variables and causal relationships between variables. The causal relationships have a direction and polarity and can have a relative strength and delay. The direction gives information on what is the cause and what is the effect. The polarity gives information whether the effect will be an influence in the same or opposite direction of the cause. E.g. in the figure above in increase in variable A will lead to variable B being having a higher value than it otherwise would have had. An increase in variable B will lead to variable A having a lower value than it otherwise would have had. By following cause and effect we gain insight in the variation of effects, but we can also discern the differences between first order (i.e. direct effects, such as higher costs lead to less demand), to second and third order cause and effects (i.e. more indirect and longer-term effects, such as less demand leading to a deterioration of the market for a certain product, less innovation, etc). In addition to this, you can gain insight into feedback effects.

As mentioned, feedback mechanisms are of influence on the dynamic complexity of a problem. Within a CLD these feedback mechanisms are visualised with an R (reinforcing) or B (balancing) and a title that captures the dynamic behaviour. Reinforcing feedback amplifies change and balancing feedback counteracts change.

In this project we used the MARVEL tool, developed by TNO, which is a method to analyse relations between variables using enriched loops: "'MARVEL aims to construct a model of the perceived problem situation, and assesses how events or interventions influence it. It is a method to explore a complex situation and its dynamic response to events or interventions by developing a model of the hypothesised underlying causal structure. The model includes variables and causal relations which vary in strength and speed. The model is based on the mental models of stakeholders, which are elicited during joint modelling sessions ("group model building" or GMB). The method assists the modelbuilding team and stakeholders to achieve a shared understanding and control of the situation with minimal effort." (Veldhuis et al, 2015; Veldhuis et al, 2024). We realise that in this project we only touched upon the potential of such a diagram with the current team of experts to gain a perspective on trust dynamics; it requires additional iterations with a wider stakeholder group for a substantiated application in practice.

2.2.2 Analysing through frames

Nobel Prize–winner Robert Shiller describes in his book Narrative Economics (2019) that people make sense of the world by telling themselves stories (Shiller, 2019). These stories can be regarded as frames that help people to make sense of all they know and hear about the topic of nuclear energy. In turn, these frames can serve as an analytics tool to

understand how trust is shaped, and how weights are attributed to factors mentioned in our trust dynamics model. To this end, an overview of these frames derived from literature and media is presented in chapter 4.2.

2.3 Interacting

The nature of this research is mainly to give insights into dynamics that can help inform policy makers on shaping policies and interactions with the public. The previous sensing and analysing steps however lead to valuable insights and considerations for public interaction. In this step, we bring together these considerations for interaction in relation to the trust dynamics analysis, wherever relevant complemented by literature and examples from practice. Note that we are not (and, as an independent research body, should not be) proposing concrete interventions with the public.

2.3.1 Applying insights & further research

Once a foundation of insights and the dynamics explaining them has been laid, it becomes more feasible to derive activities, practices, and policies to follow up on these insights. This is especially a task for the policy makers involved, however, the research team has set itself to describe relevant implications and make suggestions. This has been done via a workshop in which all results from the analyses have been structured, and implications have been drawn. This exercise also leads to the identification of the unknowns and what needs to be studied further, resulting in a knowledge roadmap focused on these unknowns and how to tackle them in future research.

3 Sensing

3.1 Literature scan: trust determinants and dynamics in nuclear energy

In this section, we discuss results from studies investigating the various factors that affect the public acceptance of nuclear energy. As discussed in Chapter 1.3.2, public acceptance is commonly defined as an attitude (a positive or negative response) in this literature. As a result, the terms (public) 'acceptance' and (public) 'attitude' are often used interchangeably.

The goal of our literature review was to identify general trends in the literature and spot interesting directions for further research. The review does not serve as a meta-overview of all factors that may be relevant to the formation of public acceptance. A recent report by the RIVM (2024) does in turn systematically review European studies on the factors that influences attitudes toward nuclear energy by the general public and by local communities. These factors included sociodemographic characteristics, environmental characteristics, individual knowledge, ideas & convictions, psychological aspects, and aspects of communication & information provision. Based on the factors presented in the report, several observations can be made:

- Most studies focus on attitudes of the general public rather than local communities.
- Even though many of the factors are only supported by a single study, their direction is commonly in line with factors found in studies into other energy technologies (see Chapter 3.2), further supporting these relationships.
- Socio-demographic characteristics, (age, gender, etc.), objective knowledge of nuclear energy, and environmental attitude have unclear or mixed effects on attitude.

A study by RLI (2022) identified five core values that are central to the concerns of citizens with nuclear energy:

- Energy security: the degree to which citizens and companies can trust in the availability of sufficient energy for their needs.
- Affordability: the degree to which the costs of the energy system are acceptable.
- Safety: the degree to which possible damage to public health, the economy or the environment stays within manageable limits.
- Sustainability: whether the impact of nuclear energy on the living environment, the climate and nature is acceptable.
- Fairness
    - Procedural fairness: the degree to which the decision-making process proceeds honestly and transparently.
    - Distributive fairness: the degree to which costs and benefits are divided across societal groups fairly.

We employ these core values to structure further findings from the literature search.

Energy Security

Nuclear energy may contribute to energy security in two distinct ways. First, nuclear energy may be used to mitigate the fluctuations in electricity supply caused by the variability of wind and solar energy. Second, nuclear energy may reduce the dependence on individual regimes for fuel supplies because uranium deposits are distributed across the globe (OCED/AIEA, 2023).

A recent poll by Populytics (2023) showed that the goal of the Netherlands to be independent from other countries for its energy supply is the highest priority of Dutch citizens (15.0% of assigned points), with the limitation of power failures being the fourth highest priority (10.3% of assigned points). Such concerns can take further precedence in case of further global instability. For example, Dutch citizens were of the opinion (in 2022) that the war in Ukraine increased the urgency to invest in renewable energy (84% agree) and in nuclear energy (60% agree) (European Commission, 2022). Citizens experiencing these energy security risks as higher are likely to be more positive about nuclear energy (RIVM, 2024).

Affordability

Complexity and stringent safety requirements bring uncertainty to the timelines for construction and to the eventual commissioning of a nuclear power plant, as reflected in the variation in costs and construction times (ENCO, 2020; Robb Stewart & Shirvan, 2023). This translates to a high interest rate on loans (for Hinkley point C interest is 75% of the $/MWh, (ENCO, 2020)), which can prevent private investors from investing in nuclear energy. As a result, the government has almost always been involved in the financing of nuclear power plants. On the other hand, better planning, experience, and a large labour force may reduce the price of building new nuclear power plants (Bechtel, 2016; Xu, 2018).

In a recent poll by Populytics (2023), the affordability of the energy system is the third highest priority of Dutch citizens (11.3% of assigned points). In other studies, cost perceptions (e.g. monetary expenses for construction or price of generated electricity) of nuclear energy have shown to be one of the most important determinants of public attitudes; lower cost perceptions lead to more positive attitudes toward nuclear energy (Ho et al., 2019).

Safety

Experts assessments of risk differ substantially from public views of risk (Diaz-Maurin, 2018; Perko, 2014). For example, expert risk perceptions of X-rays and natural radiation were found to be significantly higher those of the general public, while the opposite was true for nuclear waste and nuclear accidents (Perko, 2014). Studies into the public's mental models of ionizing radiation show that there is also more fear of artificial than of natural radiation (Železnik et al., 2016). The public also tends to be averse to risks with low probability but large consequences. As this describes the nuclear risk profile, it makes nuclear energy psychologically unfavourable compared to most other technologies (Europese Commissie, 2002). Citizens also struggle to make risk-risk trade-offs, like trading the risks of nuclear energy with those of climate change (Pidgeon et al., 2008).

These patterns may aggravate citizens' concerns about the safety of nuclear power plants (Bird et al., 2014; European commission, 2010) and the occurrence of nuclear incidents may have substantial effects on public attitudes (Gupta et al., 2019; Mulder, 2012a). Gaining more knowledge on ionizing radiation may not alter risk perceptions of nuclear energy (Perko et al., 2012) as the effect of objective knowledge on both risk perceptions and public attitude is unclear (RIVM, 2024). The most recent poll on priorities in the Dutch energy system did not include safety concerns (Populytics, 2023), so how important safety concerns are to Dutch citizens compared to other values is currently unclear.

Sustainability

In the Netherlands, 93% of citizens over the age of eighteen believe that the climate is changing (CBS, 2023). Yet, limiting the effects of climate change was only the sixth most important priority (9.0% of assigned points) for Dutch citizens in designing the energy system, according to a recent poll (Populytics, 2023). Climate change concern is associated with more negative attitudes of nuclear energy (Corner et al., 2011; RIVM, 2024; Sonnberger et al., 2021), while environmental attitudes tend to have unclear effects on public attitude (RIVM, 2024). This difference indicates the need to distinguish between climate change and overall ecological impact.

For many of the opponents of nuclear energy in the Netherlands, the main concern is the radioactive waste being produced (Populytics, 2023). A nuclear power plant produces around thirty kilograms of trans-uranic elements per TWh_e (Jansma, 2005), which dominate the long-term radiotoxicity of nuclear waste. Finland and Sweden have started construction of underground repositories for their spent nuclear fuel, while other countries have studied the subject in great depth (as represented in publications from ANDRA, COVRA, PSI, SANDIA and more).

Fairness

Apart from the more general impact of nuclear energy discussed previously, citizens may also be concerned about the distribution of the costs and benefits of nuclear energy. For example, when local communities carry an unfair burden due to the construction and operation of power plants, when distribution of the costs associated with financing nuclear power plants are distributed unfairly, or when the costs and benefits of nuclear energy are unfairly distributed across generations (RLI, 2022).

According to a recent poll (Populytics, 2023), Dutch citizens prioritize having rich citizens pay more for changes to the energy system (11.7% of points) over reducing the burden for future generations (8.3%) and limiting the effects on the living environment (8.0%). *How* decisions around nuclear energy (e.g. for the location of power plants) are made may also be important to citizens: involving local citizens (9.7% of points) and not forcing citizens into decisions (8.7% of points), although they prioritized less than many other issues.

The effect such considerations around distributive and procedural fairness may have on public attitude around nuclear energy is currently unclear (RIVM, 2024), although extensive studies into other technologies have pointed to fairness being a key issue for public attitude (see Chapter 6.2).

3.1.1 International perspective on nuclear trust dynamics

The general opinion and political stance with respect to nuclear energy differs substantially between countries, highlighting the complicated and controversial topics related to the technology. Further study into the origin of these differences might provide insight into public trust around nuclear energy. Therefore, the present research investigated the historic and current stance towards nuclear energy (including societal and political groupings) for the following countries: England, France, Belgium, Denmark, Germany, Finland, and Sweden. For sake of brevity, only the main findings are discussed here.

- The building of nuclear power plants is dependent on politics. Different political figures, parties and traditions therefore influenced the trajectory of nuclear power per country. This becomes apparent when studying the effects of the oil-crisis in the 70's. In France, the ambitious nuclear power program (the Messmer plan) was enacted without public or parliamentary debate as this was not conventional for

highly technical/strategical decisions (this we also see reflected in the part on frames in chapter 4). In Denmark[9] however, the oil-crisis sparked a large debate on the use of nuclear energy, which eventually led to the decision of the Danish government to drop nuclear power. More recently, following the 2011 Fukushima accident, Chancellor Merkel announced a “nuclear moratorium” in Germany, in fear of a tremendous success for the nuclear critical Greens (Hake et al., 2015). The current political landscape is the product of past decisions, meaning there is a “path-dependence” regarding to the current political stance on nuclear energy in a country (Hake et al., 2015).

- The reigning sentiment in a country is important for the newbuild of nuclear power plants. For example, in France the Messmer plan by that time was received well by the public as they wanted to be energy-independent (Carle, 1994). In Finland, the culture and trust in technology and institutions made it easy for stakeholders to argue rationally for nuclear power (Lounasmeri, 2021). In Denmark, the Netherlands and Germany, the reigning anti-institutional movement following the Vietnam war led to protest groups framing nuclear power with an “all-powerful and dictatorial government” (Hake et al., 2015), highlighting the possible malicious use of plutonium and causing the closure of various reactors, including the Dutch-German Kalkar reactor (Blackmore, 2013; Buns, 2017; Kirchhof, 2020).
- Information campaigns, transparency and public engagement are important for the success of a nuclear agenda, because people are unfamiliar with the topic. In Germany, the concerns of local farmers living nearby a reactor were not addressed and initiated large-scale protests (Uekoetter, 2012), while in France, following the Messmer plan, there was focus on transparency and a large educational campaign (Carle, 1994), which might have prevented such protests. In the UK, currently Hinkley Point C is being constructed; experiences of the public during this construction serve as a source of inspiration for citizens in Borsele[10] that united around this same topic (the Borsele Voorwaarden Groep). Nationally in the UK, the main concern surrounding nuclear energy is the waste. Notable is also that a significant number of people think greenhouse gasses are produced during operation (Nuclear Industry Association, 2024).
- Lastly, in most considered countries the public opinion has become more positive in the past couple of years (BVA & Orano, 2021; Nuclear Industry Association, 2024; Olsen, 2022). Although the exact reason is unclear, it might be due to a larger need of emission free electricity and an overall change in dogma.

The underlying causes for decisions made around nuclear energy are difficult to pinpoint and the sequence of events is almost impossible to untangle. Whether it was the ruling anti-authoritarian sentiment or the unfair treatment of local farmers that caused the large protests in the Netherlands and Germany in the 70s and 80s is unclear, but both likely had an influence on public opinion. Further study into these historical patterns is needed to identify root causes and explanatory mechanisms of long-term changes in public attitude toward nuclear energy. Nevertheless, the literature study and international perspective did help this research to focus in the next phase (Analysis), by upholding and substantiating the categories of Energy security; Affordability; Safety; Sustainability; and Fairness, and by adding trust dynamics that reflect the connection to politics, trust in institutions and government, and public engagement.

[9] Nuclear power in Denmark - Wikipedia
[10] Bezoek Hinkley Point C & Omgeving Inwoners | Verslag v3

3.2 Case study comparable technologies

Here we summarise the primary conclusions of the case study of comparable technologies, focused on the determinants of acceptance, changes in acceptance over time, the impact of (a lack of) acceptance on the technology and any supporting policies, and dynamics in acceptance. A more extensive report on this case study will also be published.

Determinants of acceptance

- A person's positive or negative attitude toward energy technologies tends to be explained primarily by (1) the (perceived) effects (e.g. risks, benefits, costs) of the technology, (2) fairness (procedural, distributive and recognition), (3) institutional trust, (4) place-based factors (e.g. place attachment, proximity to installations), (5) personal factors (e.g. values, knowledge) and (6) socio-demographic factors.
- The technologies' perceived effects are the predominant factor explaining citizens' attitudes. As discussed in 3.1, these effects tend to focus on sustainability, energy security, affordability, and safety. At a local level, other experienced effects may play a role as well, such as construction activities, visual impact, or local employment effects.
- The predominance of the technology's perceived effects in explaining public attitudes has two major implications. First, attitudes may strongly depend on the configuration of the technology (e.g. the source of the fuel, the siting of the infrastructure or the sector the technology is applied in), as well as any alternative solutions to the problem the technology aims to tackle (e.g. other energy technologies, energy demand reduction, energy imports).
- Second, citizens' attitudes may be changed through emphasis framing, or by emphasising particular effects of the technology over others in communication about the technology (Druckman, 2004). How stakeholders, such as governments, NGOs or scientists frame technologies in their communication may therefore strongly affect public attitude toward the technology (Druckman & Bolsen, 2011). Chapter 4.2 shows which frames are commonly used by stakeholders in the nuclear energy field.

Changes in acceptance over time

- Little is known about how acceptance, trust, and their determinants develop over time as most studies to date are cross-sectional.
- Key concepts are defined and measured inconsistently across studies and data collection is sometimes haphazard. As a result, aggregating data across studies is complicated.
- Two studies on the public acceptance of nuclear energy have tracked changes in acceptance over a long time period (Gupta et al., 2019; Mulder, 2012a). These studies show that acceptance shifts strongly over time between positive and negative, potentially due to nuclear incidents, as well as changes in energy security. One of these studies develops a method for aggregating survey data from the US. This method might be used to aggregate Dutch or European data as well, although it is currently unclear where this data is of sufficient quality for such aggregation.

Impact of acceptance of technology & policy development

- A lack of public acceptance has previously led to the cancellation of projects (e.g. wind or solar parks), additional regulation for siting (e.g. distance requirement for wind turbines) and changes in national policies for technological development (e.g. moratorium on shale gas developments or a reduction of subsidies for carbon capture and storage).

Dynamics in acceptance

- In the field of energy technology acceptance, little attention has been paid to the dynamics that could drive the development of acceptance over time. Instead, most studies have focused on investigating the individual-level determinants of acceptance (e.g. beliefs, norms, and emotions). To foster insight into dynamics, the field should expand its theoretical and methodological repertoire (see Chapter 7 for further discussion on methods). At least three types of dynamics should be investigated:
    - Some of these dynamics are technology specific. For example, attitudes toward Hydrogen and Carbon Capture and Storage are highly dependent on which of the possible technological configurations (e.g. onshore/offshore, green/blue hydrogen) takes precedence (Broecks et al., 2021; TNO, 2024). Attitudes toward the industrial applications of the technologies may also be highly intertwined with how citizens view industry, industrial policy and whether or how government aims to subsidize investments in industry (Broecks et al., 2021). These dynamics introduce many interdependencies to how these technologies may develop and how attitudes toward them take shape.
    - Other dynamics are similar across technologies. Some examples of such dynamics are discussed in Chapter 4.1, such as the formation of local identities and a sense of familiarity. Other examples of such dynamics are social contagion (Rozin & Royzman, 2001), social representations (i.e. making the strange familiar by reducing the technology to ordinary images and categories) (Upham et al., 2020), social amplification of risk (Kasperson et al., 1988), or the formation of technological legitimacy (Markard et al., 2016).
    - A third type of dynamic may take place across technologies, where developments in one technology affect developments in other technology. A primary example of such a dynamic is controversy spillovers (Cuppen et al., 2020), where citizens draw on earlier experiences with technology in their responses to a new technology.

3.3 Historical patterns: trust dynamics over time via media study

Introduction

The philosopher George Santayana once said: "Those who cannot remember the past are condemned to repeat it."(Santayana, 1905). The same holds true for the history of nuclear energy. In the past 80 years there has been a cycle of “considering and positively viewing on nuclear energy”, “a disaster occurring”, and a “period of silence and disinterest in nuclear energy”. This part of the research serves to better understand the sentiments shaping this cycle, to in turn gain a broader perspective on the dynamics of public trust.

With the help of the media database tools Delpher and LexisNexis, we collected news articles between 1945 and 2024. Based on our keywords and filters mentioned in Section 2.1.3 we merged the coverage overviews of both media platforms, which resulted in a general coverage overview Figure 3.1. The peaks in this coverage overview were used to guide our search for the most important events in history. Based on our non-exhaustive readings, eight eras were identified (see Figure 3.2). The dates separating each era of Dutch nuclear history are chosen for illustration only, in order to highlight the most pertinent

themes of the period. The border between one and era and the next was usually quite "fuzzy"; in reality, topics usually increased or decreased in importance gradually.

In this section we will first briefly distinguish the eight eras, after which we will provide more context for each. This section ends with a summary and closing words with the main insights.

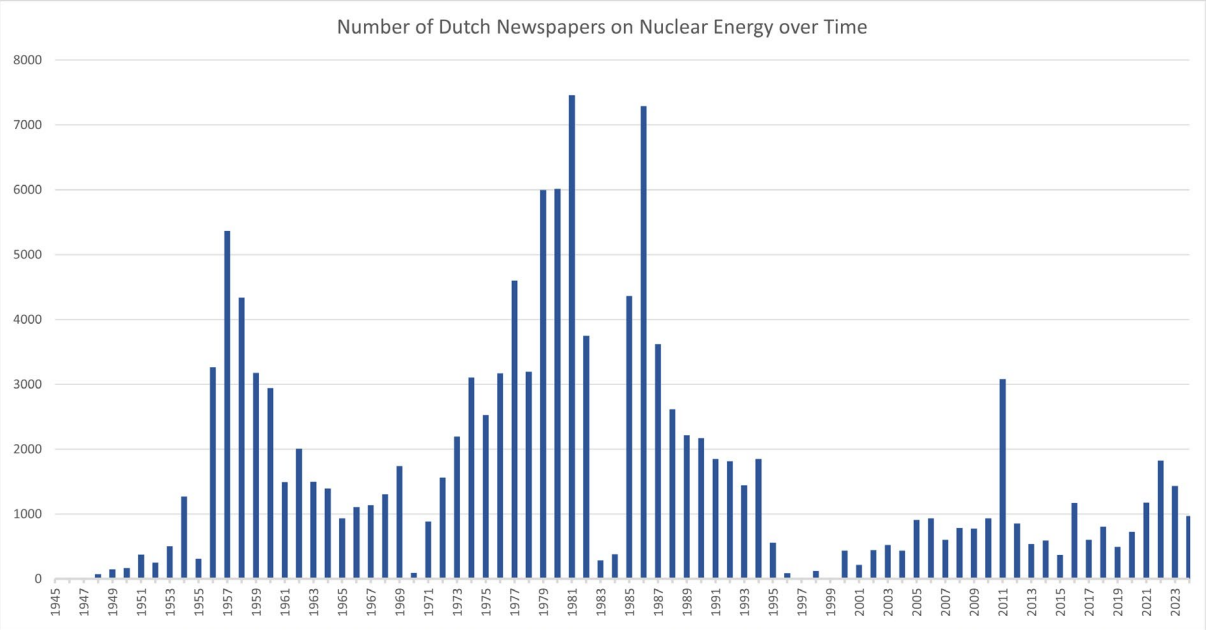


Figure 3.1: Coverage overview of published Dutch news articles on nuclear energy between 1945 and 2024.

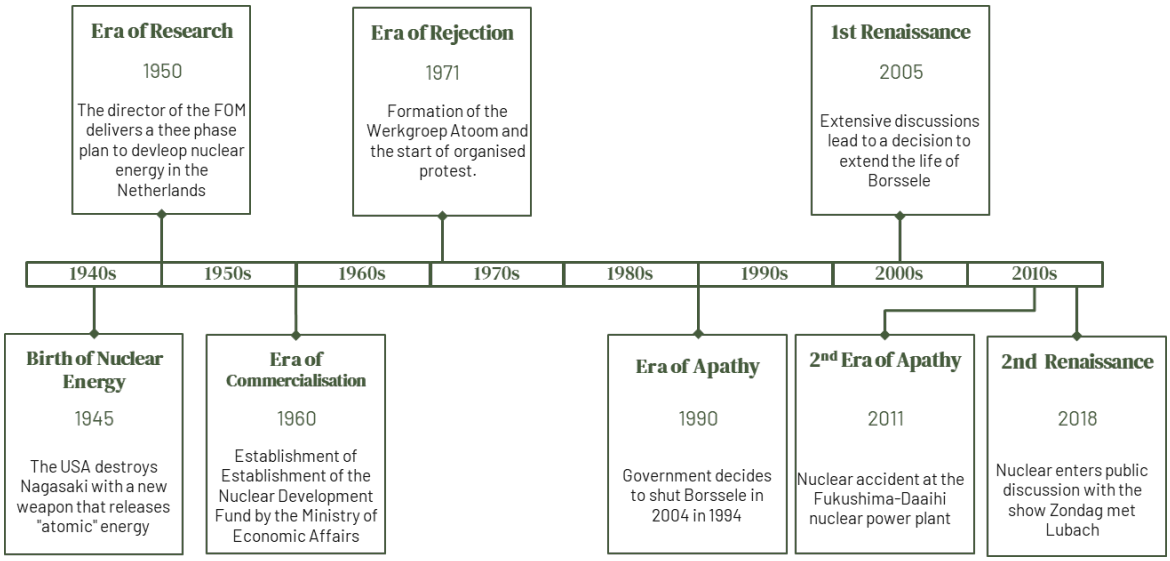


Figure 3.2: 80-year history of nuclear sentiment in the Netherlands divided into seven relevant eras.

Overview of the Seven Eras

The seven eras can be distinguished as follows:

1. **Birth of Nuclear Energy [1945 – 1950]:** This period saw the concepts of nuclear energy and radiation, alongside the terrifying potential of nuclear weapons, introduced into the public consciousness for the first time.
2. **Era of Research [1950 – 1960]:** As the Dutch government, industry, and scientific community became more aware of the possibilities posed by nuclear energy, significant funding and discussion and early plans were dedicated to the field. Significant fear still surrounded the topic, and many talks and interviews were hosted to reassure the public. The atmosphere was one of cautious optimism.
3. **Era of Commercialization [1960 – 1971]:** As knowledge surrounding the possibilities and impossibilities grew, several commercial nuclear projects took shape against a backdrop of curious excitement mingled with apprehension.
4. **Era of Rejection [1971 – 1994]:** In tandem with similar trends playing out in neighbouring countries and the United States, what had been present as underlying concern grew into a mainstream pushback against nuclear energy. The accident at Chernobyl in 1986 only served to confirm the fears of the people.
5. **Era of Apathy [1994 – 2005]:** Following the decisions to suspend all future nuclear power plant development, to close Dodewaard and to limit the lifetime of Borsele, public discussion dropped off significantly. In many ways, the negative public opinion on nuclear energy was shaped by the realisation that end of nuclear power was in sight. =.
6. **1st Renaissance [2005 – 2011]**: Public sentiment began to shift positively for the first time following the Chernobyl accident in 1986. Over the years, the public and political discussions increasingly leaned towards supporting the construction of new nuclear reactors until the Fukushima nuclear accident in 2011.
7. **2nd Era of Apathy [2011 – 2018]:** The Fukushima nuclear accident had a significant effect on the public and governmental support of building new nuclear reactors, as people were reminded of the disastrous consequences of a nuclear accident. For a while, news on the subject was scarce, and the coverage that did exist was predominantly negative.
8. **2nd Renaissance [2018 – 2024]:** After the Fukushima nuclear accident, the public experienced a second positive shift, once again opening the discussion and support for building new nuclear reactors.

Extended Description of Eras of Dutch Nuclear History

1. Birth of Nuclear Energy [1945 – 1950]

Disregarding some early reports of German efforts on a new “atomic” bomb, nuclear energy entered the public discourse in the Netherlands with the news that the USA had bombed Hiroshima with a new weapon of far greater destructive force than conventional weapons, the atomic bomb. Much discussion in the Netherlands revolved around the great responsibility humanity had bestowed upon themselves; that of the power of the atom.

2. Era of Research [1950 – 1960]

This era is characterized by significant amounts of funding being directed from various Ministries into nuclear research, such as into the establishment of the Reactor Centrum Nederland in Petten, and the early Joint Establishment for Nuclear Energy Research between the Netherlands and Norway. These actions, taken in the early 1950s, preceded a broader public discussion. Nuclear power, beyond its use as a weapon, was only just beginning to enter the public consciousness. This changed rapidly in 1955 in the wake of the First

International Conference on the Peaceful Uses of Atomic Energy in Geneva, a wide-ranging event that for the first time allowed nuclear scientists and engineers from around the globe to speak freely on the topic of nuclear energy and its applications. Thirty-two Dutch nationals attended, along with members of the Dutch press (Nations, 1956). The mood was decidedly euphoric and full of possibilities, a sentiment that carried over into the newspapers published in the Netherlands.

Another large step up in the levels of public discourse on the topic came with the public exhibition “Het Atoom” in 1957. The House of Representatives (Tweede Kamer), in cooperation with Euratom (the European Atomic Energy Community, also established 1957 for the purpose of stimulating and directing the growth of a nuclear industry in Europe) and many other commercial partners sought to raise public understanding (and thereby establish the necessary societal support for their far reaching plans) by setting up a public exhibition close to Schiphol, which included a functioning reactor. The exhibition was highly successful, with over 750,000 visitors over the three months (Het Rotterdamsch Parool, 1957). Multiple nuclear projects took off around the Netherlands, investigating the applications of the atom to the fields of agriculture (to create disease resistant strains of grain), power (to generate electricity, solving the energy deficit in Europe at the time) maritime (to power ships), and medicine (to treat certain cancers and perform medical imaging).

3. Era of Commercialization [1960 – 1971]

As nuclear research projects reached maturity significant amounts of discussion revolved around the development of nuclear energy for power production. Several utility companies and other industry groups formed various working groups and commissions to study and recommend the construction of the Netherland’s first nuclear power plant. In 1965 the utility companies the SEP (Samenwerkende Elektriciteits Productiebedrijven), the PZEM (Provinciale Zeeuwse Energie Maatschappij), and the Joint Nuclear Power Plant of the Netherlands (NV GKN) entered a joint project for the construction of the Dodewaard nuclear power plant, to be the Netherland's first electricity producing reactor. With some exceptions from the more careful perspectives of industrialists and universities, an atomic future seemed guaranteed, with the director of the SEP going as far as to say "After a year or 10 everybody will be used to it. " (Algemeen Dagblad, 1963). Notably, the director of the newly founded Reactor Centrum Nederland Jaap Goedkoop did state in 1961 *" I do not foresee coal and petroleum being displaced by nuclear energy anytime soon. "* (De Gooi- En Eemlander, 1961). Only towards the end of this period did any major pushback against nuclear energy occur.

4. Era of Rejection [1971 – 1994]

Rising concerns over the safety of nuclear power led to the formation of the first organized protest groups in 1971. This era is marked by the highest levels of public engagement with nuclear energy, with wide ranging protests across the country, particularly over the disposal of low level radioactive waste in the sea, the operation of the experimental KSTR reactor in Arnhem (Handelsblad, 1973), the fast breeder reactor project in Kalkar (Trouw, 1974), and then proposed disposal of high level waste in the salt domes in Drenthe. Counter to this growing negative sentiment, the SEP, with support from the government, proceeded with the construction of the Netherlands second nuclear power plant, Borsele. Construction began in 1969, and the power plant was connected to the grid in 1973. This divergence between the viewpoints of the public and that of the government over this period appears numerous times. Another example is the prolonged support from the Dutch government for the Kalkar project, despite sustained and vigorous protest from parts of the Dutch public. Put simply, the government and the government and considerable sections of the public were on different pages, with a government putting forward policies and plans that were

incongruent with the increasingly more commonly held idea that nuclear energy was a dangerous technology with negative implications for society, democracy, and health.

The accidents at Three Mile Island in the United States in 1979 only served to confirm the fears of the people. There was worldwide concern about the safety of nuclear power plants, with many doubts being put forward about the calculated promises of safety. Attempts were made to assure the public of the safety of Borsele, nevertheless, criticism intensified.

The year 1981 saw one of the highest levels of discourse, with 15.000 people participating in protests against the continued operation of Dodewaard and with democracy itself said to be threatened by the protests (Dagblad, 1980). In parallel, the “Brede Maatschappelijke Discussie” (“Broad Societal Dialogue”) pointed towards a slightly negative turn in general opinion. Nevertheless, the government decided to go forward with building new nuclear reactors. Nuclear power had moved from a possible solution to Europe’s energy problems to a symbol of war, centralized power, and more deeply, the continuation down the path of endless growth, which with the publication of the Club of Rome report was strongly questioned.

The nuclear accident at Chernobyl in Ukraine in 1986 only served to reinforce this image and was in many ways the nail in the coffin for nuclear energy. After the accident, discussions about closing the nuclear reactors in The Netherlands took place. In 1992, a survey showed that half of the respondents was in favour of closing existing reactors, 88 percent did not want to build new nuclear reactors, and 60 percent would not want to build new reactors even if they had become safer (Het Parool, 1992). Consequently, the government was considering between 1992 and 1994 to close the nuclear reactors in Dodewaard and Borsele. While GroenLinks, PvdA and D66 were in favour of closing the nuclear reactor in Dodewaard the majority of the government did however first not agree (NRC, 1994a; Trouw, 1992). In 1994, the government decided to keep the nuclear reactor in Borsele operational until the end of 2003 (NRC, 1994b). However, the SEP (Samenwerkende Elektriciteitsproductiebedrijven) decided to close the small nuclear power plant of (60 MWe) in Dodewaard because of expected economic inefficiencies (AD, 1997).

5. Era of Apathy [1994 – 2005]

With the suspension of all decision making for new nuclear power plants in the Netherlands following the Chernobyl accident, the topic of nuclear energy fell out of the public discourse, marked by the low amount of discussion and articles published in this era. There was simply nothing to discuss – the case had convincingly been made that nuclear energy was not worth pursuing. Dodewaard quotes the lack of positive outlook for nuclear energy as one of their reasons for shutting down in 1997 (AD, 1997).

6. First Nuclear Renaissance [2005-2011]

After the Chernobyl in 1986, it took until around 2005 for the public sentiment around nuclear energy to shift. It remained in favour until the nuclear disaster in Fukushima in 2011. The discussion took a turn mainly due to three reasons: climate change, rising oil and gas prices sourced from instable countries such as Russia and the Middle East, and limited (green) energy supply (De Telegraaf, 2006b). There was increasing awareness that climate change caused by fossil fuel emissions affects the land, food resources and livelihood of people. According to van Geel, a member of CDA and the State Secretary of Environment, more nuclear reactors can help to comply with the Kyoto treaty from 1997, that set binding emission reduction targets for 37 industrialized countries and economies in transition and the European Union (BN, 2005). The latter reason was also emphasized by the European Committee that said that the energy supply of nuclear energy is essential in the upcoming

50 years (Haagse Courant). In general, one respondent summarized the overall sentiment*: "Nuclear energy is cheap, safe and clean."* (De Telegraaf, 2006b).

Another factor that could have contributed to the positive shift in public sentiment was the ongoing debate about whether to close Borsele in the early 2000's. The nuclear reactor could as first agreed stay open till 2003, however the energy production company EPZ which owned the nuclear reactor claimed there was no hard agreement to close by then. The judge decided in favour of EPZ. But this decision would not have mattered if it turned out against EPZ: the new CDA-cabinet Balkenende that took office in July 2002, has written in their cabinet agreement that the nuclear reactor of Borsele could stay open till at least 2007. CDA was known for years to be a proponent of nuclear energy and that's why there was again space to hope for the Dutch nuclear power plant industries (Trouw, 2002): *De kerncentrale in Borsele had zijn langste tijd gehad, dacht iedereen. Maar sinds het aantreden van het kabinet-Balkenende gloort er weer hoop voor het bolwerk van de Nederlandse kernenergie."*

The positive sentiment was shown by a survey in 2005 which showed that 70 percent of the respondents were positive about new nuclear reactors and that 53 percent wouldn't mind to have one nearby (Haagse Courant). However, seventy-five percent of the respondents do think that the problem of nuclear waste needs to be resolved before discussing nuclear energy. Other counterarguments were mainly due to safety concerns (De Telegraaf, 2006b). People were afraid of terrorism attacks and the scale of a nuclear disaster when something does happen (NRC, 2005): *"Nuclear energy is far too dangerous. It may go right 1,001 times, but that one moment it goes wrong is one too many."* (De Telegraaf, 2006b). Overall, the majority of respondents, 68 percent, saw nuclear energy as a solution, but believed that sustainable energy should remain a priority (De Telegraaf, 2006b; NRC, 2005).

Between 2005 and 2011 the public sentiment around nuclear energy grew only more positive (De Telegraaf, 2006a). The CDA-cabinet Balkenende was a proponent of nuclear reactors. As the resistance declined, the discussion about building new nuclear reactors in the Netherlands was initiated by the cabinet and intensified over the years as it gained more political support (AD, 2006; De Volkskrant, 2006; Trouw, 2008). However, the government was unable to grant a permit for building a new nuclear reactor before March 11th, 2011 when the nuclear accident in Fukushima happened and drastically changed the public sentiment (De Volkskrant, 2012; PZC, 2011).

7. Second Era of Apathy [2011 – 2018]

The Fukushima accident in 2011 brought up a wave of suppressed fear that the public had for years about the disastrous impact of a nuclear accident (Giesen, 2011). A report of Het Sociaal en Cultureel Planbureau in 2010 showed that people's main association with nuclear energy has been and still was fear of nuclear accidents and radioactive pollution. Fear especially grows, when there is the perception of little control and the possibility of a deadly fate. While the Fukushima accident did not result in any direct casualties, people were reminded of the unforeseen and uncontrollable scale of impact a nuclear accident can have on people's lives, livelihoods and costs (Dekker et al., 2010; Giesen, 2011). As a consequence of the Fukushima accident, the sentiment in the Netherlands became more negative and the discussion around nuclear energy fell flat again (De Volkskrant, 2012).

One highlighted discussion took place in 2016 as Minister of Public Health, Edith Schippers, announced to increase the radius of iodine distribution from 25 to 100 km around a nuclear reactor (Stem, 2016). Citizens were concerned that this decision was the result of the numerous incidents in the Belgian nuclear reactors and their deteriorating condition (Algemeen Dagblad, 2016). However, the decision was made before numerous incidents in

Belgium in 2014 in in alignment with Belgium and Germany to better protect citizens, especially pregnant women and young children, in case of a nuclear accident (Algemeen Dagblad, 2014a, 2014b). Five years after Fukushima, and many politicians are still against it, highlighting the significant impact of the accident (De Stentor, 2016).

8. Second Nuclear Renaissance [2018 -2024]

After the Fukushima accident in 2011, the discussion around nuclear energy fell flat. The sentiment started to change around 2018. One of the events that influenced the public sentiment was an episode of the show "Zondag met Lubach" about nuclear energy in 2018. Arjen Lubach, the presenter of the show, argued that in order to reach our national climate goals, nuclear energy should be taken more seriously (De Twentsche Courant Tubantia, 2018; Trouw, 2018). His episode broke the taboo around nuclear energy, causing an immediate effect in public opinion (De Twentsche Courant Tubantia, 2018). A survey after the episode, showed that half of the respondents are in favour of nuclear energy. The VVD-faction leader Klaas Dijkhoff used this momentum to advocate for new nuclear reactors. As such, nuclear energy was back on the agenda (De Twentsche Courant Tubantia, 2018).

The biggest concerns that were discussed in the media were the costs of building new nuclear reactors, the limited amount of uranium, nuclear waste which future generations have to deal with, and nuclear disasters (NRC, 2021). Proponents on the other hand focused on the safe, cheap, clean, and constant energy supply nuclear reactors can provide. Other energy sources such as coal, oil, and gas, are not clean and can even lead to more deaths, while nuclear energy causes less fatalities in comparison (Dagblad van het Noorden, 2018; Trouw, 2018).

During the elections of 2021, Mark Rutte, party leader of VVD, advocated even more strongly for nuclear energy, arguing that nuclear energy is necessary in the energy mix to meet the Dutch Climate Agreement set in 2019. This agreement contains a set of measures and agreements between organizations and companies in The Netherlands to reduce CO2 emissions by 2030 (Trouw, 2019, 2021). The discussions around climate change during the elections were mostly linked with nuclear energy, showcasing the increasing importance of this topic. After VVD won the Second Chamber Elections, building new nuclear reactors became part in the discussions during the formation table. As such, the cabinet, existing of VVD, D66, CDA and CU, planned to make nuclear energy part of the energy mix with solar, wind and geo energy (De Telegraaf, 2022). This plan was made easier by European Committee's decision to label nuclear energy "green" in March 2022. The decision was made to make nuclear energy more attractive for company investments with the goal advance climate goals (Dagblad van het Noorden, 2022). Since then, the government has conducted market consultations and is actively seeking locations to build new nuclear reactors (BNR, 2024). In parallel, small modular reactors (SMRs) seem to get increasingly more attention[11].

Overview of Era Topics

Table 1 provides an overview of the topics discussed in each era in the section "Extended Description of Eras of Dutch Nuclear History". The table showcases which issues were identified to be important to Dutch politicians and the public.

[11] SMRs are out of scope of this report.

Table 3.1: Important topics discussed over the past eras

Birth of Nuclear Era (1945 - 1950)	Era of Research (1950 - 1960)	Era of Commercialization (1960 - 1971)	Era of Rejection (1971 - 1994)
Proliferation of nuclear weapons	Energy Supply & Independence	Energy Supply & Independence	Sea dumping of waste
	Nuclear weapons	Nuclear weapons	Improper waste dumping in Arnhem
	Fear of nuclear accidents	Fear of nuclear accidents	Disposal of waste in salt domes
	Possible applications of nuclear technologies across many fields	Possible applications of nuclear technologies across many fields	Three Mile Island accident and its implications on Dutch nuclear
		Debate on insurance for nuclear reactors	Safety of operating Borsele and KSTR in the Netherlands, and Kalkar in Germany
		Dodewaard selection for 1st Dutch NPP	Public action against Dodewaard
		Development of a nuclear-powered ship reactor at RCN	Borsele nuclear reactor – to close it or not.

Era of Apathy (1994 - 2005)	1st Nuclear Renaissance (2005 – 2011)	2nd Era of Apathy (2011 – 2018)	2nd Nuclear Renaissance (2018 – 2024)
Proliferation	Climate Change	Disastrous impact of nuclear accidents	Climate Change and goals
Radioactive waste	Energy dependence: fluctuating prices due to unstable countries	Safety of nuclear reactors	Energy dependence on Russia – high gas prices due to war
Lack of public support	Safety of nuclear reactors		Safety of nuclear reactors
	Nuclear waste for future generations		Nuclear waste for future generations
	Energy Supply – limited resources		High building costs of nuclear reactors
	Discussion new nuclear reactors		Discussion new nuclear reactors
	Borsele nuclear reactor – to close it or not		Possibilities for SMR's
	Fukushima nuclear accident		

What happened will happen again(?)

The historical analysis shows a great swing in public sentiment around nuclear energy in both the positive and the negative direction. As the analysis shows, there are four main topics of discussion when it comes to nuclear energy: safety (e.g. nuclear accidents, proliferation, and nuclear waste), sustainability (e.g. climate pollution, change, and nuclear waste), affordability (e.g. energy prices and construction prices of nuclear reactors), and energy security (e.g. constant energy supply), largely confirming what is found in literature.

Citizens have been quick to change their opinion when a nuclear accident happened, whether it happened nearby or further away, such as in the cases of the small Belgian nuclear accidents in around 2016 or the Fukushima nuclear accident in 2011. This sparked discussions about closing nuclear reactors, particularly during the era of rejection and the period between the first and second nuclear renaissances, as people grew increasingly concerned for their health and livelihoods. Moreover, people have not forgotten the use of nuclear energy in atomic weapons during the second world war and the threats of atomic bombs made during the cold war, and thus have feared persistently over the years for nuclear proliferation. Consequently, safety has remained a top priority and primary concern for citizens.

From the end of 2000 onwards the topic of climate change and pollution became increasingly important. Climate change affects the livelihood, safety, and existence of people and as the consequences of this change became more apparent, citizens and politicians placed more value on sustainable energy resources. Moreover, energy independence from instable countries has been an issue for decennia, as energy supplies sourced from instable countries abroad were limited resulting in fluctuating energy prices.

This brief look at the history of nuclear energy in the Netherlands teaches us several things. The first is that events tend to repeat themselves. Everything that has happened repeatedly, is likely to happen again. Especially the first and second nuclear renaissance show similarities in events: a disaster happens, discussions about nuclear energy falls flat, when enough time has passed and energy security or livelihood is threatened, a politician or political party picks up the topic again and discussions about building new nuclear reactors continue. Knowing this pattern, the government can better anticipate on future events that will likely have a significant effect on public opinion, such as nuclear accidents.

Second, trust in the government diminishes when there is a divergence in viewpoints on the fundamentals of nuclear energy between government and the public. The failure of nuclear policies proposed in the 1970s and 80s can be traced to this divergence. Therefore, the government should take steps to ensure that they are connected to “the situation on the ground”, and form policies that consider the current fears, pain points, and general state of public opinion as much as possible and make it clear that this is the case.

Third, looking at Figure: 3.1, one can see that the topic of nuclear energy is more prominent in the 20th century than in the 21st. When the Fukushima nuclear accident took place in 2011, a peak in media coverage occurred, but was not as widely reported as when the nuclear accidents took place in the 70’s and 80’s. After the accident in 2011, the media coverage also subsided as quickly as it started. When the government decided during the first and second nuclear renaissance to build new nuclear reactors, the media coverage and public sentiment hence seem remarkably similar to the fifties and sixties.

This brief historical analysis of public sentiment and trust in nuclear energy over the past 80 years highlights the key issues and concerns that have shaped public opinion over time, feeding into the Analysis of the next chapter, such as the impact of an accident and the connection to geopolitical tensions. This historical review also takes the first steps into identifying the stakeholders in the discussion and policy arena and gives a preview of the government's response to public discourse, which informs the considerations to be made in the Interacting phase. A complementary sentiment analysis could even provide a better understanding of the influence each topic has on shaping public sentiment while shedding light on the interaction between the government, media, and the public, helping to clarify how this relationship impacts public trust.

4 Analysing

4.1 Modelling: the nuclear causal loop diagram

To add to our current understanding from the sensing steps, we applied causal loop diagramming as an analytical tool (based on System Dynamics), because it emphasises the complexity of public perceptions and trust in nuclear energy by looking at the underlying causal structure. As described in 2.2.1, we assume this diagramming to be of added value because the way trust in nuclear evolves depends on 1) the interconnectivity of its underlying factors; 2) the different actors and interests that interact with the dynamics of the system; 3) and the potential that resistance to policy decisions arises.

Gaining insight into the causal structure of this issue helps to understand the behaviours we observe in the system, and how to anticipate dynamics caused by feedback loops. In turn, by doing so, better informed policies may be devised and implemented. The system dynamics model allows for a multidisciplinary approach, and for including multiple perspectives into a single model. Hence, we looked at a diverse set of underlying causes respecting their interdependency, and not treating them as separate stovepipes. It is important to note that variables included in the model are based in existing literature (as outlined in 3.1) and research conducted in our sensing phase. The causal links between the variables are based on existing literature and supplemented with hypotheses based on expert opinions of the research team. The causal links have not been validated with other experts. In effect, this model is an argued, albeit first attempt, and is meant to evolve as this topic evolves.

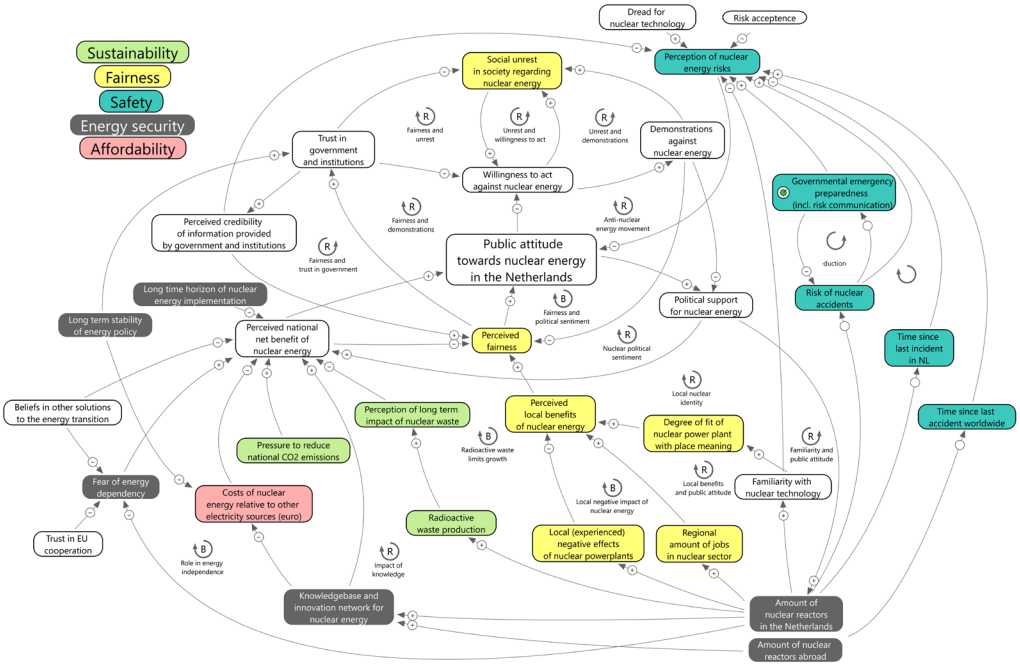
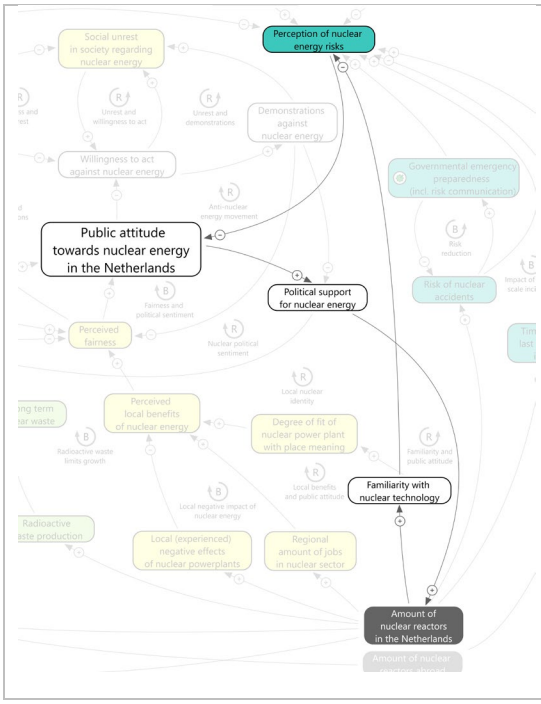


Figure 4.1: Overview of the nuclear causal loop diagram.

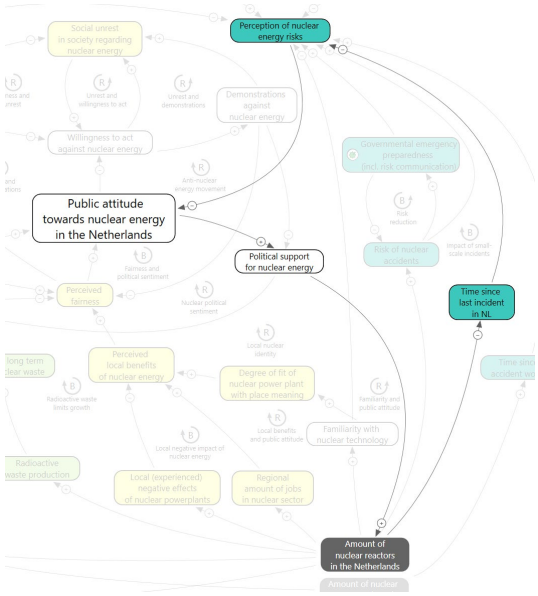
Figure 4.1 shows an overview of the model. The top left shows a legend of five categories: sustainability (green), fairness (yellow), safety (teal), energy security (grey) and affordability (pink). A full description of the model is included in Appendix A. The definitions of all factors in the model, based on literature and expert opinion, are described in Appendix B. Public attitude is directly influenced by three variables: *perception of nuclear energy risks*, *perceived net benefit of nuclear energy* and *perceived fairness*. However, these three elements do not stand in isolation; it is important to look at the bigger picture to see broader connections and feedback effects. Model insights explain the causal mechanisms that take place in the system. Considering the structure of the model and the interactions in the system, a few mechanisms are identified as most prominent.

Fragility of the perception of nuclear risks

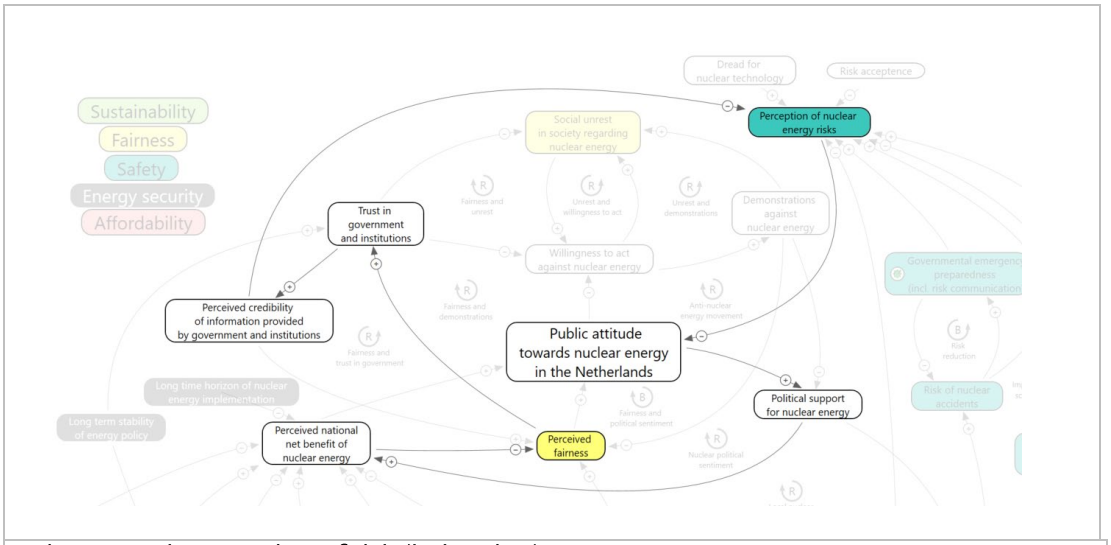
The perception of risks of nuclear energy has a direct influence on public attitude, but the causal interactions underlying this variable make its dynamics complex and fragile. Many variables have a relationship with the perception of nuclear risk, and they all work in their own way. Risks, incidents, and accidents in the world, as might be expected, have a negative impact on the perception of risk, no matter where in the world they occur. Increased governmental preparedness leads to an actual reduction of risk, yet at the same time, it increases the publics' awareness of and therewith perception of the risks. What this shows, is that the more objective risks can clash with subjective risk perceptions. On the contrary, familiarity with the technology and the perceived credibility of information from government and institutions have a dampening effect. These dampening effects do not seem to hold on a longer timeframe, however, as building familiarity with a technology is more or less achieved at some point. Less obvious causes also come into play, such as the dread surrounding nuclear technology, which is enhanced by, for example, displays of nuclear accidents in popular culture such as film.
Besides direct causes of the perception of risks, multiple feedback loops have a reinforcing or balancing effect on both the perception of nuclear energy risks and the public attitude towards nuclear energy in the Netherlands. These are described in the following overviews.



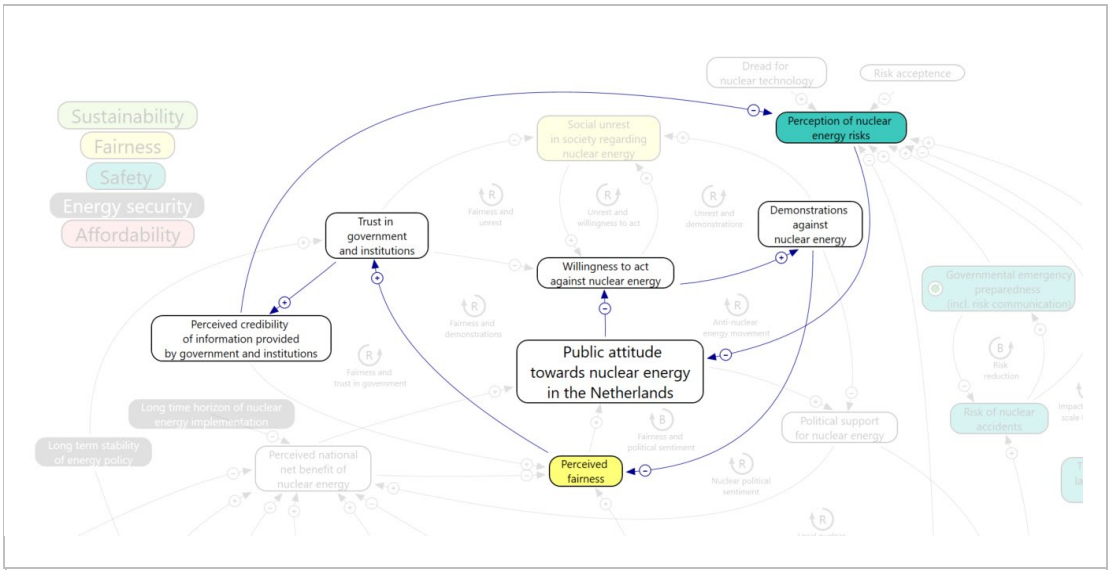
Familiarity and public attitude (reinforcing)
Familiarity with nuclear technology has an influence on the perception of nuclear energy risks. If people become more familiar with nuclear technology their perception of nuclear energy risk lowers. Lower perception of nuclear energy risks leads to more positive public attitude towards nuclear energy, which in turn increases the amount of political support for nuclear energy. This feedback dynamic does take place over a long period of time. There are significant delays in both increasing the number of reactors and for the public to become familiar with the technology. The feedback dynamic can however have a significant reinforcing effect both in raising and erasing positive public attitude.



Impact of small-scale incidents (balancing)
The more reactors in our country, the greater the probability of a nuclear incident. We deliberately use the term incident here, because even an incident contained to the nuclear power plant site in the Netherlands can impact the perception of risks. As we have seen in the historical analysis, in time the effect of these incidents will fade. Therefore, this impact is included as “time since last incident in the Netherlands”. If an incident occurs the effect can carry over to public attitude and lower the political support, which can in turn lead to more or fewer nuclear reactors.



Fairness and perception of risk (balancing)
Increased political support for nuclear energy can positively affect the perceived national net benefit of nuclear energy. However, if these benefits negatively influence the balance between national and local benefits, they then lower the perceived fairness. Perceiving the decision-making government by government as unfair can lead to a decrease in the trust in government and institutions and in turn influence the way people perceive information coming from them. People who perceive less credibility in information from government and institutions will have higher perceptions of nuclear risks, given the significant role government plays in nuclear energy.

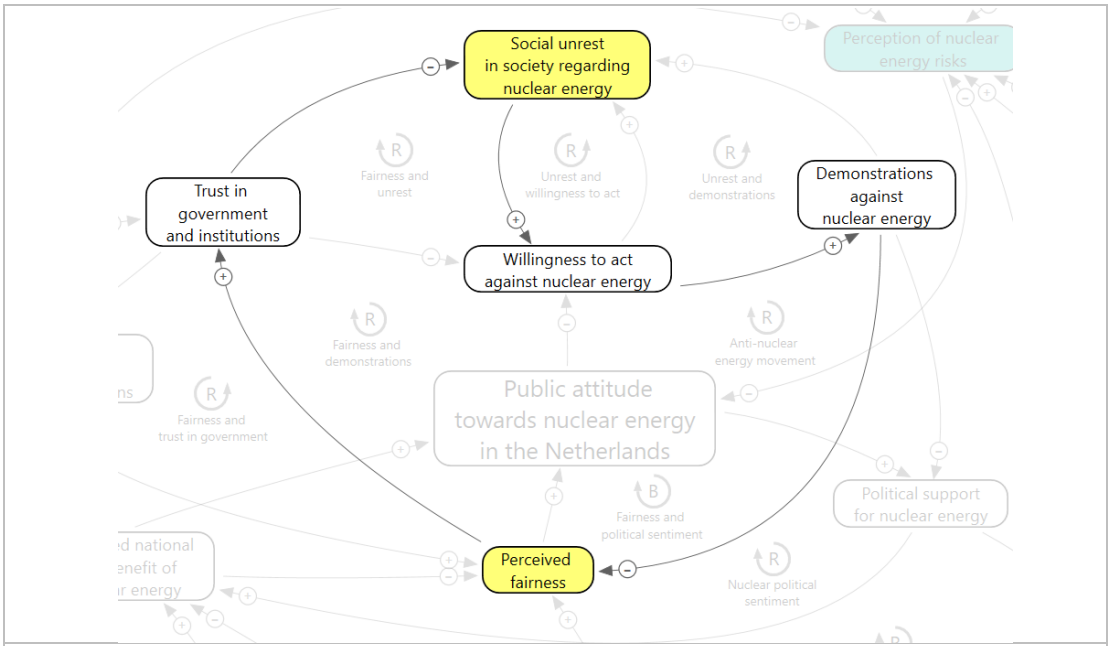


Trust in government and perception of risk (reinforcing)
An increase in the perceived risks of nuclear energy, will influence public attitude negatively. A negative public attitude towards nuclear energy will increase the willingness to act and in turn also the number of demonstrations against nuclear energy. With more demonstrations, the perceived fairness will decrease which will lead to less trust in government, a lower perceived credibility of information, resulting in even more perception of risks.

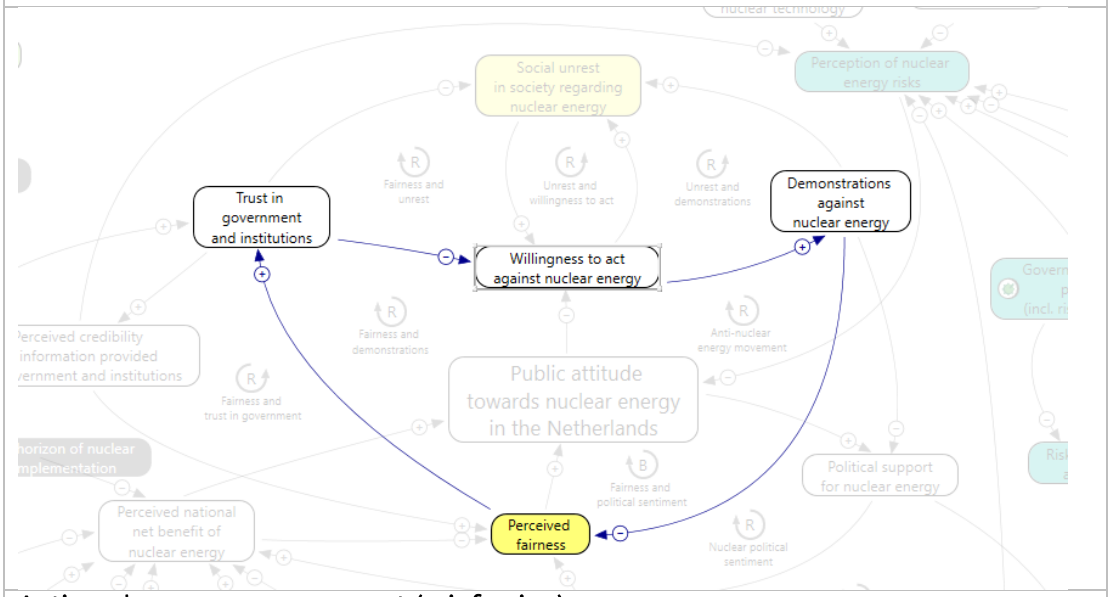
When dealing with nuclear energy, it is important to be aware of the fact that the perception of the risks of nuclear energy is fragile. Incidents and accidents can have an immediate influence on the perception of risks and through that influence the political sentiment. This political sentiment can put in motion feedback structures in which people's perceived fairness, trust in government, and credibility of information come into play, amplifying negative risk perception. The fragility lies in the fact that variables like *trust in government* and *credibility of information* are not connected solely to nuclear energy, so there is dependency on a broad sentiment in society regarding government and institutions. The other part of the fragility is the result of the fact that incidents and accidents can have a short-term consequence, while the familiarity with the technology probably takes more time to take effect.

The dependence and influence of trust in government

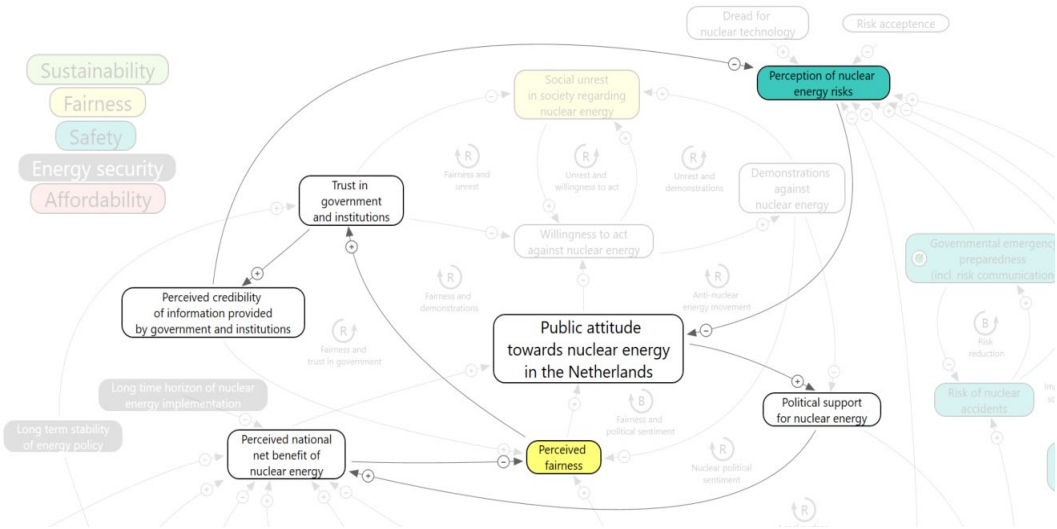
Trust in government is important within the domain of trust in nuclear because it influences the part of the system that impacts 'social unrest', and the willingness of people to act on their opinions. Also impactful is the fact that *trust in government* influences the *perceived credibility of information of government and institutions*. When there is a low perception of the credibility of information, people are less likely to believe the information provided by the government. When people are less likely to believe the information that is provided, this can lead to higher *perception of nuclear energy risks*. It can also lead to lower levels of *perceived fairness*, because information detailing the process and explaining how this is fair to all residents of the Netherlands may be overseen. Besides these direct causes and effects, the mechanisms between *'trust in government', 'perception of risk' and 'perceived fairness'* as shown below with different feedback loops are important. In addition, attention should also be paid here to the role of *policy stability*. This stability affects the degree to which people trust the government. The significance of *trust in government* becomes even bigger when realising that the extent of trust in government is not all solely dependent on the subject of nuclear energy. Trust in government is also dependent on other societal issues, therefore nuclear energy cannot be seen separate from broader societal developments.



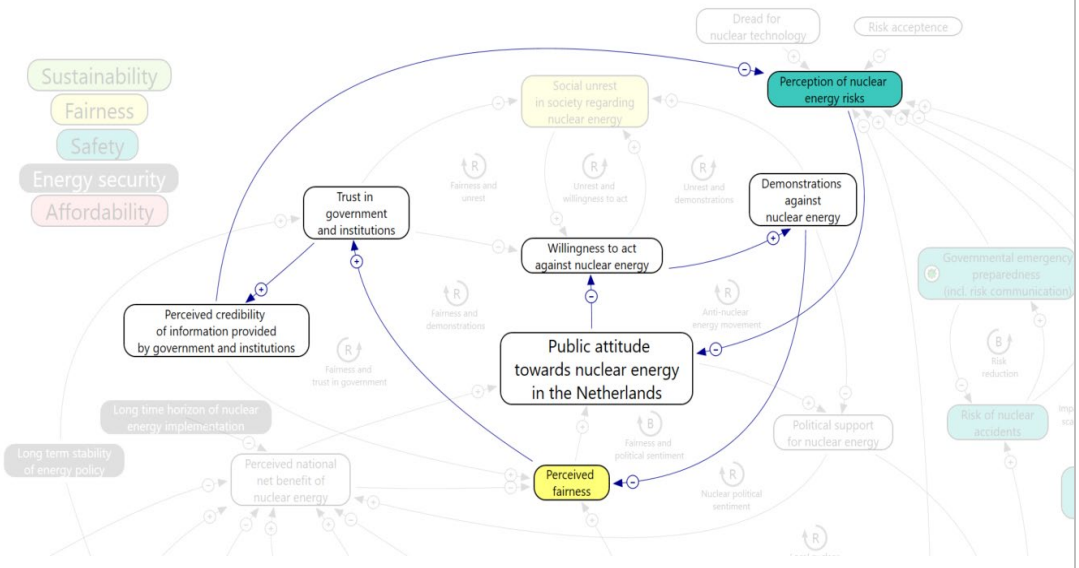
Fairness and unrest (reinforcing)
When trust in government increases, this will lead to less social unrest in society regarding nuclear energy. This will lower the willingness to act against nuclear energy and therefore lead to less demonstrations, which will result in an increase in the perception of fairness. A higher perception of fairness in turn will lead to more trust in government.



Anti-nuclear energy movement (reinforcing)
Even when people do not experience social unrest in society, they can participate in demonstrations driven by their negative attitude towards nuclear energy, and/or because of their amount of trust in government and institutions. The number of demonstrations can have an influence on the perceived fairness of people, which can even further escalate their attitude towards nuclear energy.



Fairness and perception of risk (balancing)
When there is less risk perception of nuclear energy, this will affect the public attitude and the political sentiment. More political support will positively affect the national net benefit of nuclear energy, but it can also negatively influence the perceived fairness when people have the idea that there is too much focus on the national rather than the local benefits. When this is the case, trust in government will decrease and influence the way people perceive information from government and institutions. People who perceive less credibility in information from government and institutions will have higher perceptions of nuclear risks.



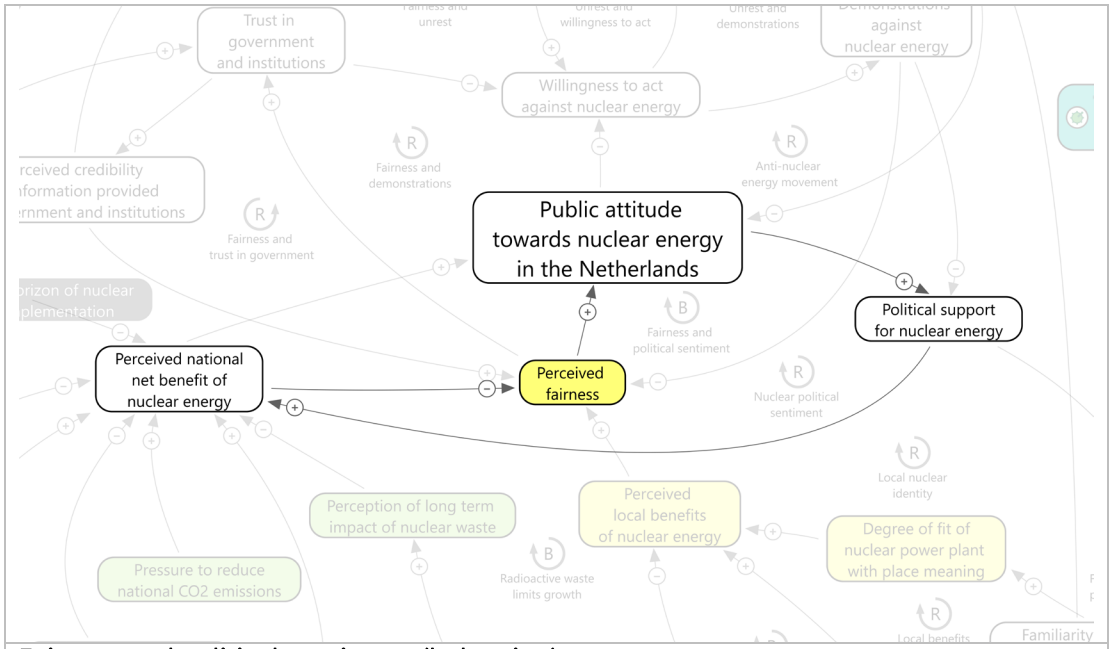
Trust in government and perception of risk (reinforcing)
When there is more risk perception of nuclear energy, this will affect the public attitude. A negative public attitude around nuclear energy will increase the willingness to act, and with that also the occurrence of demonstrations against nuclear. With more demonstrations, the perceived fairness will decrease which will lead to less trust in government, a lower perceived credibility of information and with that even more perception of risks.

The impact of local benefits and personal diversity to perceived fairness

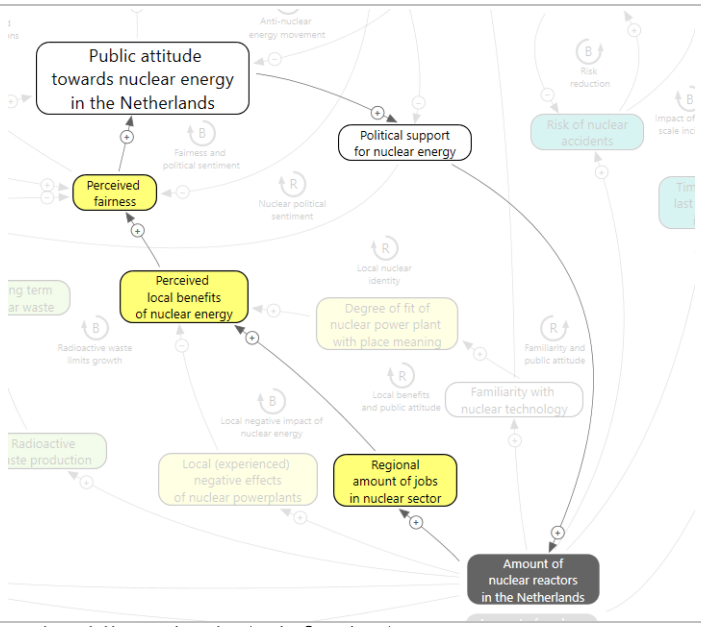
Perceived fairness directly influences public attitude towards nuclear energy and the amount of trust in government. Perceived fairness is dependent on both national benefits and local benefits. The perceived national net benefit is not purely economical, but also takes into account the *pressure to reduce national CO_2 emissions*, and the *perception of long-term impact of nuclear waste*. These variables can be interpreted as contributing to a concept such as intergenerational fairness.

Perceived local benefits are negatively impacted by *local (experienced) negative effects of nuclear power plant,* such as the impact of new transmission lines, or building activities. Benefits are perceived to be higher if there is a higher number of *regional jobs in nuclear sector*. Finally, the *degree of fit of nuclear power plant with place meaning* influences the *perceived local benefits*: this explains the phenomenon that a nuclear power plant can become part of the identity of the region over time. As shown below in the feedback loop 'local nuclear identity', this can have a reinforcing effect. With the case of gas drillings in Groningen fresh in our minds, we have been reminded how important it is to pay attention to local (experienced) negative effects and burdens. Not paying attention to these local benefits and negative experiences can initiate various feedback loops via perceived fairness.

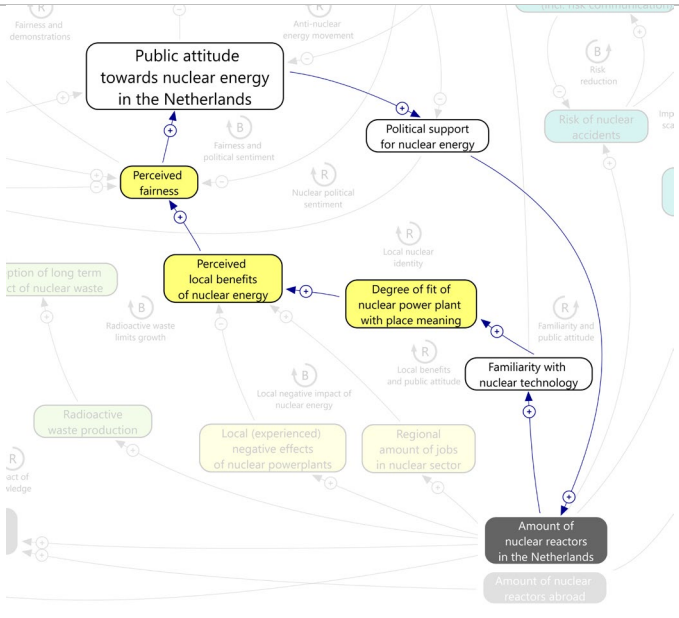
As with the perception of risk, perceived fairness is not predictable and highly heterogenic. What is fair for one citizen, is unfair for another, hence the importance of being aware of how this plays out in distinct societal groups.



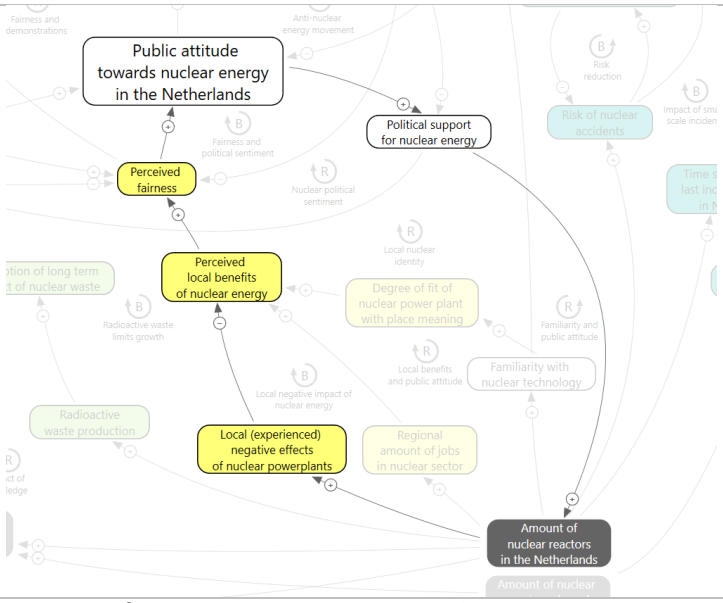
Fairness and political sentiment (balancing)
If the national benefit is perceived to be out of balance with local benefits, the perceived fairness will decrease, leading to a more negative attitude and less political support. This will have a balancing effect on the national net benefit and dampens the effect on fairness.



Local benefits and public attitude (reinforcing)
An increase in the number of nuclear reactors can lead to a higher number of regional jobs in the nuclear sector, which will lead to a better perception of the local benefits while affecting people's perceived fairness. This in turn will lead to a more positive public attitude towards nuclear energy, which influences the political support for nuclear energy. This mechanism has a reinforcing effect in the system.



Local nuclear identity (reinforcing)
Once a region identifies their identity as a "nuclear energy region" and thereby becomes more familiar with nuclear technology, this can lead to more support for nuclear energy via place meaning. Place meaning can increase the perceived local benefits, leading to greater perceived fairness, a more positive attitude towards nuclear energy and ultimately more political support, which in turn may increase public acceptance of (building more) nuclear reactors in the Netherlands.

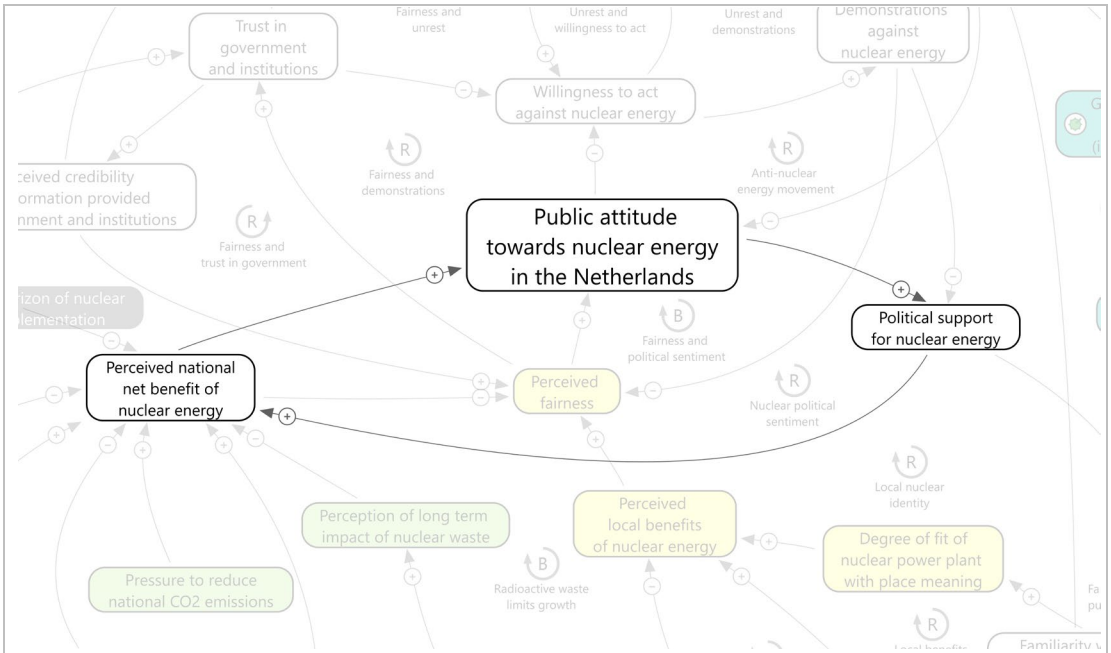


Local negative impact of nuclear energy (balancing)
An increase in the number of nuclear reactors can lead to more experiences of local negative effects; this will lead to a lower perception of the local benefits which will affect peoples perceived fairness. This in turn will lead to a more negative public attitude towards nuclear energy, which influences the political support for nuclear energy. As a result, less nuclear reactors may be realised in the Netherlands. In this way this mechanism has a balancing effect in the system.

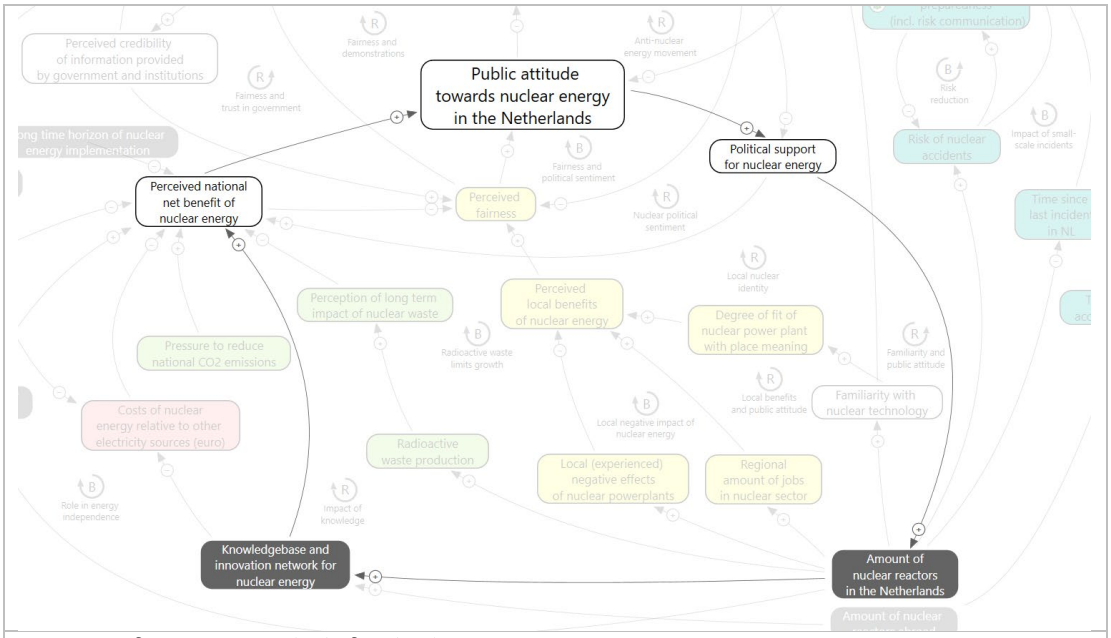
Fluctuation of national net benefit over time

The national net benefit of nuclear energy is a result of multiple causes, some of them more quantifiable than others. This benefit is therefore not one figure, but is the perception one has, when balancing the various underlying variables. Besides personal preferences and appreciation, it also depends on societal developments, as shown in the historical analysis. Developments regarding climate change, geopolitical tensions surrounding energy supplies, and the development of alternative technologies cannot be separated from how people assess the national net benefit of nuclear energy. The feedback loops depicted below show us that in these complex systems, there is not just one explaining story to tell; it is always necessary to explore the multiple ways in which elements of the system interact with each other.

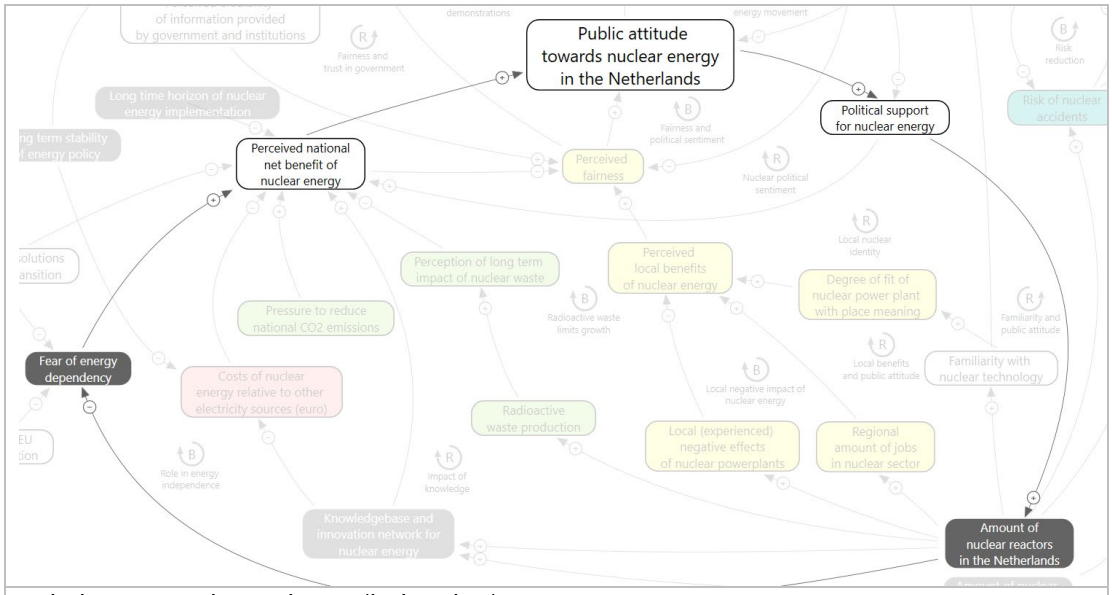
With *national net benefit* we see both reinforcing and balancing effects. A political sentiment that is pro nuclear energy can stimulate the national net benefit and with that further increase public attitude. This reinforcing effect is also present with an increase in knowledge and innovation which further stimulates the national net benefit and creates more foundation for investments in nuclear reactors. On the other hand, the number of nuclear reactors shall not grow unrestrained, this can be seen with the balancing feedback loop of energy dependency. When there is less fear of energy dependency, there is less perceived national net benefit of nuclear energy which will influence the attitude and the political support. Another inhibiting effect takes place in relation to the perception of long-term impact of nuclear waste; the effect hereof grows once there are more nuclear reactors. More negative attention for this will decrease the national net benefit and from there influence the public attitude and political support. Lastly, developments around other energy technologies and the assessment of costs and benefits can reinforce competition.



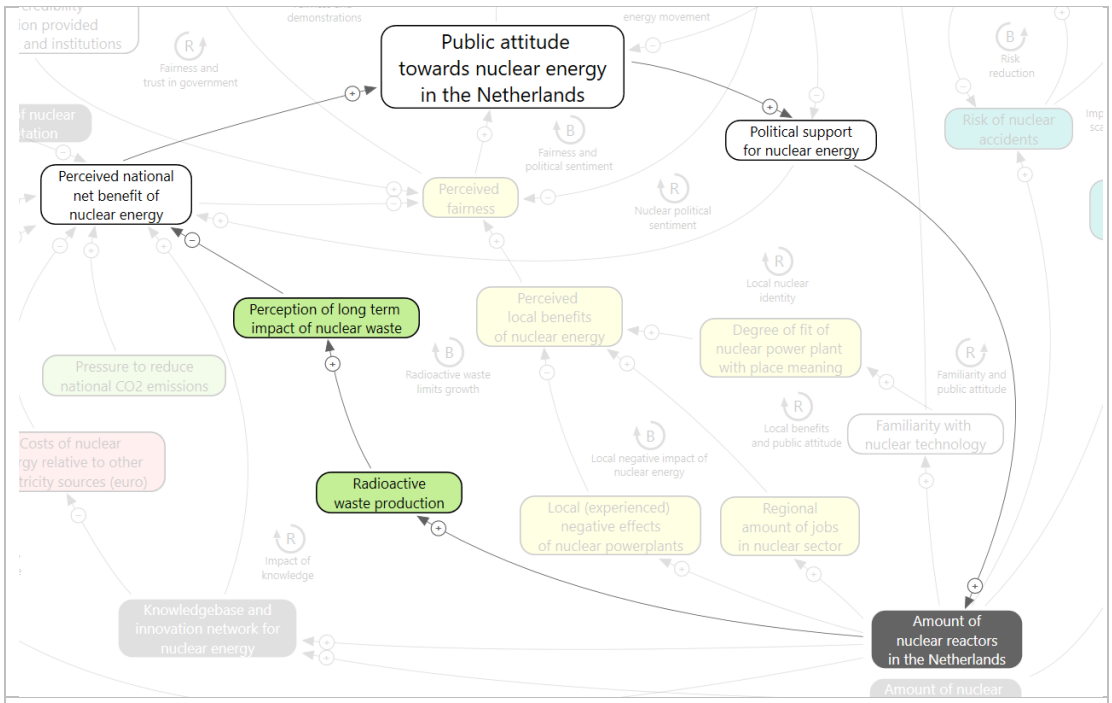
Nuclear political sentiment (reinforcing)
The political sentiment oriented at the national benefit has a positive influence on the public attitude, which further amplifies the political sentiment.



Impact of knowledge (reinforcing)
Having a knowledge base and an innovation network for nuclear energy can act as reinforcing mechanisms. This knowledge base gets stimulated by the number of nuclear reactors in the Netherlands. The knowledge base and the innovation network stimulate the perceived national net benefit of nuclear energy which, via public attitude and political support, can result in more nuclear power plants being built. The opposite also holds true; if the innovation network is not present or weak, through lessened acceptance, the number of nuclear reactors might decline.



Role in energy dependency (balancing)
With an increase in the number of nuclear reactors in the Netherlands there will be less fear of energy dependency. Less fear will have a negative influence on the national net benefit, and thereby dampen the public attitude while simultaneously decreasing political support for nuclear energy.



Radioactive waste limits growth (balancing)
An increase in the number of nuclear reactors also leads to more radioactive waste, which may have a negative influence on the perception of the long-term impact of nuclear waste and thus lead to less perceived net benefit. This in turn will affect the public attitude and dampen the political support for nuclear energy.

4.2 Frames analysis: narratives around nuclear energy

A dominant view one holds of something, as in our case nuclear energy, influences the weight attributed to factors in the causal loop diagram. In other words, the model depicts which factors influence each other and whether this influence is positive or negative; the strength of this relationship however is determined by the perspective one takes towards the topic. In (international) literature there are several dominant frames that have been identified about nuclear energy. We take studies by Sovacool et al. (2021) and Vossen (2020) as our main sources to describe the ones we find most relevant for our study: ecomodernism, nucleocracy or responsive innovation, social practice, energy justice, and lastly, becoming more prominent due to the current geopolitical tensions, the security frame. Below we will explain these frames, wherever relevant with additions from media sources, and their implications.

Ecomodernism frame

Central to ecomodernism is the belief that clean, scalable, and reliable energy sources are critical to addressing global challenges like climate change (Vossen, 2020). Ecomodernists argue that nuclear power, with advancements in reactor design and safety, can provide a reliable and dense source of energy capable of meeting growing global demands while minimizing greenhouse gas emissions. They contend that, far from being a dangerous relic of the past, nuclear technology, when integrated with renewable energy sources and other innovations, can be a cornerstone of a sustainable, high-tech future (Vossen, 2020). It can be assumed that people applying this lens give less prominence to perceived risks, which directly influences their attitude positively, and there is basis of trust towards nuclear organisations and researchers. The current attention for SMRs (Small Modular Reactors) by, for instance, big tech organisations[12], can be regarded as driven by this ecomodernist frame.

Nucleocracy or responsive innovation frame

This narrative focuses on how developments around nuclear energy are largely driven by experts and technical specialists, in a process that is state-led, technocratic and sometimes even antidemocratic, i.e. without democratic support (Sovacool et al., 2021). The public then perceives a lot of secrecy around nuclear developments. This is a phenomenon familiar in France (Sovacool et al., 2021), and is not unknown to the Netherlands, too, as platforms such as LAKA[13] are founded on the idea that there is secrecy around the nuclear energy program in the Netherlands. An increased dominance of this frame could lead to an increase of social movements and protests, influencing trust dynamics such as trust in government and institutions, but also dread, as drawn in the causal loop diagram. A counter-frame is that innovations and developments around nuclear energy are conducted in a responsive and transparent way.

Social practice frame

The success of the energy transition relies to an extent on a more active role of citizens; to become energy producers, be more flexible in their energy demand, unite in decentralized local energy collectives, etc. Energy policy is to an extent based on this notion of the actively participating citizen, i.e. the energy system as a social practice. Nuclear energy however challenges this notion, as the complexity of nuclear energy generation and the expertise required makes it impossible for citizens to take a leading role (Sovacool et al., 2021). This frame has an effect on how stable the energy policy is perceived to be, in turn affecting trust

[12] See for instance https://fortune.com/2024/11/21/tech-nuclear-energy-google-microsoft-amazon-ai/
[13] Laka.org | Informatie over kernenergie

in government, while more favourably positioning energy technologies that are more connected to decentralisation such as solar and wind. In relation to trust dynamics, it is thus useful to outline transparently how these two policy goals (active and passive energy consumers) interact.

Energy justice frame

This frame has different sides to it, in line with the types of justice that can be distinguished in this case and were described in chapter 3.1. The first one relates to just diffusion of risk: communities around nuclear facilities are exposed more than those further away, although all benefit from it in the same way. Another aspect is intergenerational justice, also mentioned by Sovacool et al. (2021): as there are no permanent solutions for disposing nuclear waste, in this frame it is perceived as a burden on future generations. Also, the business case for scaling nuclear energy in the Netherlands is, due to its long-term nature, based on a lot of assumptions about future cost levels of economics, resources and renewables, which in hindsight can prove for future generations that the costs are never to be met by the monetary benefits of the extra plants. Another aspect of justice is the mining of resources (uranium) to power nuclear energy production, which mostly takes place in vulnerable regions, affecting the wellbeing and health of miners and local communities (Sovacool et al., 2021). The positive energy justice frame being shared to plead for nuclear energy, is the fact that it can make the country less dependent on other countries, safeguarding that energy will remain available for society and that the generation of it is done while respecting democratic standards (Vossen, 2020). In the causal loop diagram, this frame thus materialises mostly through perceived fairness and impacts in the local context, and the determinants related to longer-term aspects such as the building process and waste storage.

Security frame

This narrative is becoming more omnipresent: tensions in the world are rising and we find ourselves in a new era of growing geopolitical tensions. Widely people are more apprehensive about the future, and nations are increasingly preparing for instability or even worse. In parallel, more investments are made to become more resilient as a nation. Nuclear energy is also influenced by this frame, not in the least because from early on it has been connected to nuclear bombs and war (as also described in 3.3). From a perspective of energy security and resilience, as also shown in the causal loop diagram, investing in nuclear energy can be a way to achieve this. Another way this frame is used, is by reviving the perceived connection between national security strategy and nuclear facilities, as some countries (for instance, the US[14]) are already planning to upscale their nuclear weapons industry. In public interaction initiatives around nuclear energy, it is important to be aware of potential growing attention for this frame.

Frames are a filter

Overall, what these frames show is that providing factual information and evidence can only go so far to install trust; people often hold a frame or lens that filters this information in way that fits this frame. Interestingly, we can identify how once dominant frames wain and resurface, in connection to patterns we recognised in the historical view of chapter 3.3. The relative peace of the 90s for instance gave prominence to ecomodernist optimism and is now again giving way to the security frame. Rather than going against such frames, it is important to acknowledge them and take them seriously. And regardless of the frame, transparency is key, whether it is to take away a sense of secrecy; make clear what considerations have been made, or to disconnect the nuclear energy program from national security strategy.

[14] U.S. rushes to revive nuclear weapons industry as global tensions mount - Nikkei Asia

5 Interacting

The insights from the former steps of Sensing and Analysing help to inform and shape directions for public interactions. In this chapter we share considerations on interacting with the public, based on, and clustered by, our findings in this study. These considerations are explained with practitioners in mind; in the next chapter we elaborate further on what some of these mean for policy makers. Lastly, many of these considerations can be applied to different nuclear energy scenarios; upscaling, downscaling or maintaining the situation as is.

Interaction considerations for trust in government, perceived fairness, and potential unrest

A factor that unites many studies and practices on public trust and interaction on nuclear energy by the government and related institutions (e.g. Laes et al., 2004; Mays et al., 2016), and as confirmed by our literature study, is a call to invest time and resources. The goal for these investments is to 1) facilitate dialogue via different channels (from live interactions, to involving important local community structures, and social media) 2) make relevant data easily accessible and presented in an appealing manner that resonates with people's values and daily lives. Corresponding to this, for ensuring trust, emphasis is put on sustainability of the interaction: only in a continuous cycle where knowledge grows transparently and feeds into public information, trust can be built up. Even more so around risk communication (which will be elaborated upon more later), sustainability of communication is key, as interaction needs to occur not only in times of "crisis", but also before, and after (Železnik et al, 2016). This calls for a programmatic approach for public interactions, with recurring sensing (e.g. yearly surveys) to keep a “barometer” of trust; and communication tools such as an online platform[15] with information and interaction possibilities (e.g. a forum); which could be complemented by citizen science tools and offline participation activities, such as exhibitions or workshops. Leading in this approach, given their significant role, is the government, in close cooperation with decentral government and safety organisations. Embedded in the approach should also be local representatives of important community structures and oppositional groups.

The actions taken throughout the programmatic approach should aim to foster (perceived) fairness by developing participation procedures that are perceived as fair by relevant stakeholder groups, by accounting for the distribution of the impacts of nuclear energy developments over regions and over time, and by recognising different concerns. Procedural fairness can be fostered by following best practices for engagement outlined elsewhere in chapter 8, as well as by being transparent about the goals and scope of participation (i.e. how are decisions made, what decisions are still open to input from stakeholders). Distributive fairness can be fostered by rebalancing the local risks by generating stronger local benefits (e.g. providing employment opportunities for local businesses) and by developing a better understanding of intergenerational injustices surrounding nuclear energy. Finally, recognition can be fostered by creating space for stakeholders to express their various concerns (in which cultural and artistic organisations can also play a part).

A way to potentially validate these concerns is through citizen science, sometimes also referred to as “crowd science”, “citizen science”, or “networked science”. Here members of the public are empowered to contribute to measurement and information gathering.

[15] This could be an addition to the Ministry’s website Kernenergie in Nederland | Kernenergie in Nederland

This type of science has for instance been valuable in the context of radiation monitoring (Tacu, 2020).

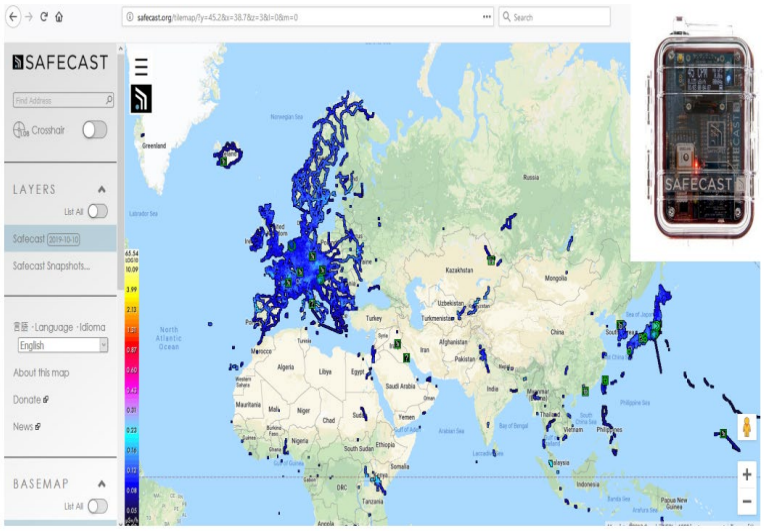


Figure 5.1: Snapshot of the Safecast online platform. Note: From “Power of the people: A review of citizen science programs for conservation.”, by Macphail & Colla, 2020, Biological Conservation, 249.

Citizen science initiatives may be useful tools for communication and engagement between experts, policymakers, and the public (an example of such a tool is found in figure 8.1). Furthermore, citizen science allows individuals of various backgrounds and skill levels to develop and/or participate in programs collecting information about the world around them, to broaden their knowledge about the topic; and give more meaning to what they see policy makers do. Citizen science tools for radiation measurements have in some instances even led to an increased trust towards government (Tacu, 2020). As from experience we know that citizen science projects may develop irrespective of support from authorities, it is important to take a proactive stance towards this: consider what role citizens can play in Sensing, how data quality and sound analyses based upon these are best ensured.

Another school of thought to consider in relation to trust in interactions, relates to what is called "transactional analysis". This theory originally stems from psychoanalysis, and reflects the standpoints from which one is communicating, and the effect this has on the receiver[16]. Usually the “parent” and “child” relationship is taken as the prime metaphor for this. Once the sender communicates as a “parent” (e.g. knowing what is best, paternalistic), a response as from a “child” can be expected (being square, no actual dialogue). In contrast, it is in a position of equals that a fruitful dialogue can takes place. In this case, the sender for instance also communicates uncertainties, and mutual expectations are made explicit. This approach was also applied in a TNO project on the interaction between the social housing sector and their tenants around renovation programs for sustainability (De Koning et al., 2019). In this project, organisations were looking for ways to improve communication with tenants around renovations of their house, sometimes even requiring temporary relocations. By suggesting to redesign messages and communication channels to be more transparent and accessible, also to discuss concerns and insecurities, communication professionals felt they could significantly impact the wellbeing of tenants.

[16] Transactional analysis - Wikipedia

Lastly, in a healthy democracy, there is room for opposition. In fact, if dealt with wisely, this can turn into what we call “constructive conflict”. Constructive conflict, for instance between policymakers and resistance groups, can be highly beneficial. It encourages diverse perspectives and fosters a more inclusive decision-making process. By then engaging in open dialogue, both parties can identify potential issues and collaboratively develop more effective and equitable policies. This dynamic can also enhance transparency and accountability, ultimately leading to more resilient policy outcomes.

Interaction considerations for local identity, local economy, and the building process

If one changes perspectives from a nation-wide level, which is more the focus of the paragraph on “trust in government”, to a local context where a power plant can be part of daily life, one can discern other determinants at play that influence trust. In the latter perspective, the emphasis is more on local impacts, such as construction activities, housing for construction workers, impacts on the local economy such as new jobs and services, and the visual impact of new infrastructure. This is evidenced by priorities voiced by active groups of citizens connected to the region of the plant, such as the Borsele Voorwaarden Groep. Interaction efforts should change accordingly and focus more on practical implications and concrete assurances, representing different citizen groups, local community, and economic structures (e.g. schools, churches, and local business associations) and municipalities[17].

Furthermore, there is a subset of determinants that can be distinguished during the building process of a plant (which, interestingly, for a large part accounts for phases of decommissioning, too, see Laes (2014)). A useful exercise is to distinguish which trust dynamics are at play at the various stages of the life cycle of nuclear power plants. A first draft result of such an exercise is given in figure 8.2. This overview outlines the most common know phases of a NPP construction process (top layer) and matches these phases with considerations the public will assumingly have conjointly. The bottom layer reflects the trust dynamics that we assume will be most prominent during these distinct phases, and what consequently deserves most attention, and when, in interacting.

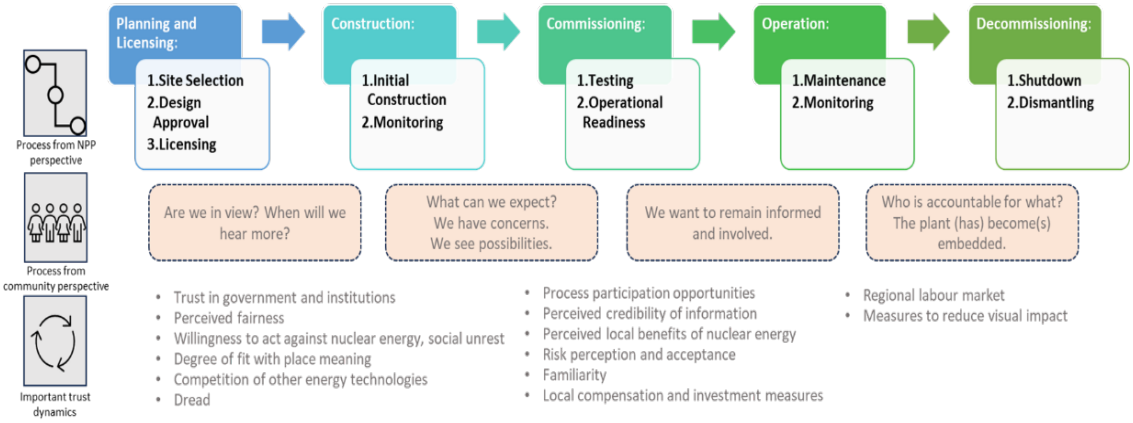


Figure 5.2: First draft of an overview of NPP life cycle with trust dynamics

[17] The Ministry of Climate and Green Growth has already outlined their local public participation approach, containing basis principles such as making everyone feel heard and involved, and making all stakes transparent: Participatieplan Kernenergie Deel 1 ; Voornemen en voorstel voor participatie (12 februari 2024) - Nieuwbouw kerncentrales

A related aspect about locality, and which deserves careful consideration, is the level of societal "discomfort" or "discontent", which is found to be significantly higher in regions outside of the Dutch metropolitan area Randstad (Van den Berg & Kok, 2021). Opposition towards building or decommissioning of plants has understandable feeding ground in areas perceived to be already in a compromised position. For instance, in the phase of outlining the 'Regio deals[18]', there should be extra attention for what sensitivities are already present in the area.

The history of the selected site may also strongly impact the dynamics that will be at play once design approval and/or licensing starts. For example, studies show that regions familiar with nuclear developments may be more conducive to new developments because the nuclear power plant(s) may have become familiar to inhabitants of the region, as well as a component of local identities (Venables et al., 2012). If the stakeholders (e.g. municipalities, grid operators) involved in these developments have historically invested in trust building and developing fair procedures with local inhabitants, a region may also be more conducive to new developments. Accounting for the region's history and particularities in site selection – using, for example, social site selection procedures (Brunsting et al., 2015) – will therefore help to select those sites where new nuclear developments are likely to find fertile ground.

Interaction considerations for energy security, affordability & independence

Highly relevant for these dynamics, which are typically shaped by far broader international, political, and economic trends, is the fact that the business model underlying the choice for nuclear energy must be based on assumptions. Assumptions about geopolitical tensions, changing energy demands, prices of renewables, ownership models for NPPs and so on. It is here that trust is shaped as scenarios uphold, or not. Offe (1999) states that truth is about *telling* the truth (e.g. about the risks of storing waste). Hence, considerations need to be made about transparency and communicating progressive future insights, which may be uncomfortable for policy and policy makers. This is ideally done in close cooperation with experts and institutions (economists, consultants, universities, researchers).

Technological (e.g. renewable energy, energy storage) or geopolitical developments (e.g. oil and prices) may weaken or strengthen the energy independence benefits offered by nuclear power plants, alternating its relative value for the Dutch energy portfolio. Some explorative studies show that public attitude may weaken and strengthen along with developments in the energy independence benefits offered by nuclear power plants (Gupta et al., 2019), implying that nuclear energy attitudes may change along with new technological or geopolitical developments. This in fact points to the relevance of consulting experts on foreign affairs and geopolitical strategy when defining interactions on nuclear energy.

Interaction considerations for perception of nuclear energy risk and governmental emergency preparedness

How government and experts approach risk often differs strongly from how the public approaches risks: emphasising rational explanations and statistical figures in interactions, often mismatches with gut feelings and emotions, and may even lead to misunderstanding and distrust. The public assesses risk not only through familiarity with the topic, but also signals from someone's social environment (Claassen & Kerckhoffs, 2018).

Social media is a prominent arena for discussing these emotions associated with the risks of nuclear energy (Perko, 2015). A large-scale study on Twitter (now "X") showed that supportive tweets of nuclear often mention clean energy, low CO2 emittance and sustainable future, while cynical tweets are indeed more threat and risk related: they mention the threat to the environment, human life, and safety (Khatua et al., 2020). As

[18] Regio Deals | Rijksoverheid.nl

mentioned earlier, it is thus essential for those involved in public interaction to have a presence online and facilitate two-way dialogue. In most countries (except Finland), utilisation of social media by nuclear institutions however is poor (Perko & Martell, 2020).

Risk communication is thus a strand of its own, involving stakeholders such as RIVM; the ministries of Health, Welfare and Sport and Infrastructure and Water Management; safety organisations (e.g. Veiligheidsregio); and municipalities and provinces. Guiding principles for these parties is to be honest, frank, and open during communication; talk about actions taken for risk mitigation rather than the resulting reduction in risk; do not appear to be trying to settle the question of whether a risk is acceptable; and aim the risk communication at the concerns and information needs of a specific target audience (Covello et al. 1988).

In case of an actual incident or accident, constant communication is essential to demonstrate competence and control (Bisconti, 2018). Requirements for public communication for these situations have been provided by Euratom BSS Directive and NSD (Perko et al., 2016), while a toolbox for communication regarding nuclear energy has been produced by the IAEA[19].

Dealing with individual differences in interaction

Each of the interaction considerations discussed in this chapter need to be adapted to the specific individuals that stakeholders aim to interact with; the public is not one homogenous body. Socio-demographics can point to differing opinions; for example, a recent study shows that citizen segments in favour of building new power plants consist primarily of men (Populytics, 2023). Another study shows that older and highly-educated citizens are also slightly more positive about nuclear energy (CBS, 2023). Viewpoints on nuclear may also be shaped by the values people hold, for instance on the relationship between humans and nature, or the priority given to being energy independent[20]. Lastly, groups may be by the various roles and positions citizens take up, such as members of households, employees, entrepreneurs, or community advocates. As a result, interaction plans should be adjusted to the contextual level it targets, addressing, or at least acknowledging, those factors that are most influential per context. An example of these levels is given in Figure 5.3.

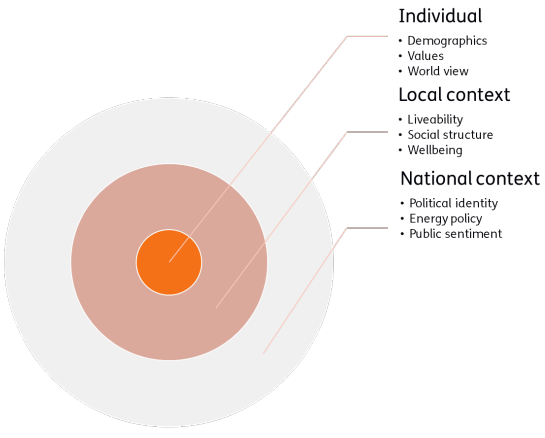


Figure 5.3: What determines trust in context.

[19] IAEA Nuclear Communicator's toolbox

[20] A very useful guide for policy makers on values and identities can be found here: JRC Publications Repository - Values and Identities - a policymaker's guide

6 Policy implications

This report shows how policy makers can deal with trust dynamics through sensing, analysing, and interacting. Throughout chapters three to five, ideas are discussed for conducting these steps in the policy process. In this chapter, we discuss several principles that should be considered in the design of such a process. These principles are based on the conclusions drawn from our analysis, substantiated with several common – but often overlooked – principles for good research practice. Many of these principles can be applied to different nuclear energy scenarios; upscaling, downscaling or maintaining the status quo.

Deal with trust dynamics through sensing, analysing, and interacting

Public trust in nuclear energy develops dynamically; trust comes about through complex interactions between the features of nuclear energy, its supporting policies (e.g. for regional investments), communication and engagement activities of stakeholders, adjacent policy issues (e.g. for other energy technologies), and how citizens process these topics simultaneously. Trust cannot be controlled or steered, but actions can be taken that are more likely to foster than damage trust. A better understanding of trust dynamics may help to design policy and engagement processes that work with rather than against these dynamics.

- **Develop a better understanding through sensing activities about the (historical) patterns that have shaped public trust in nuclear energy.** The sensing activities carried out throughout this project serve as a baseline for understanding patterns in public trust, but additional (longitudinal) data collection and analysis is needed to test the interrelationship between public trust and personal or environmental characteristics (see Chapter 7.2 for more details on how such research could proceed). For example, trust in nuclear energy may be highly intertwined with political identity, shaped by the values that citizens hold and tied to visions on what the energy system of the future should look like. Historical evidence shows that public discourse and trust are highly variable. The nature of the discourse changes over time, possibly affecting which concerns are at the forefront when citizens give opinions or make decisions. For example, the discourse today is far more focused on the benefits to climate change mitigation and energy security rather than concerns about incidents or radioactive waste disposal. The current state of nuclear energy policy also shows parallels with historical developments and developments in other countries that should be explored further.

- **Treat the trust in nuclear energy of the general public and the trust in nuclear power plants of communities living near them as distinct and interacting phenomena throughout this sensing process.** These two types of trust develop through different dynamics that require separate sensing activities. For example, the trust of local communities is highly tied to how they interact with stakeholders developing nuclear power plants. The trust of the general public is instead more dependent on public discourse and the envisioned policy direction for nuclear energy. Local dynamics may shape discussions around the fairness of nuclear power development, moving fairness considerations to the forefront of public discourse

and public policy. The analysis process should elucidate such interactions between the local and national level.

- **Build interaction activities that depart from an understanding of public trust as a complex phenomenon, using sensing and analysing activities.** To align with best practices in citizen engagement, these activities should be guided by transparency, backed by data and supportive of public dialogue. These activities should focus on relationship building and incorporating new insights gained throughout the interaction process. Only when these activities take on a dynamic character by moving through iterative steps of sensing, analysing, and interacting, can public trust dynamics contribute to constructive policy making.

Account for biases, diversity, conflict, and methodological shortcomings

Throughout the suggested process of dealing with trust dynamics, four characteristics of public trust should be accounted for:

- **Reflect on the presence of biases when interpreting the outcomes of sensing, analysing, and interacting.** Cognitive biases, or systematic, universally occurring distortions in human decision making (Korteling et al., 2023), can affect how people process information and make decisions around nuclear energy. For example, proponents or opponents of nuclear energy may only see information that confirms the views they currently hold (confirmation bias; Taber & Lodge, 2006). Any results gleaned from surveys, focus groups or media analyses may therefore reflect cognitive biases rather than the dynamics they aim to elucidate. Awareness of these biases may help to spot common issues in the interpretation of data collected throughout the policy making process (see Korteling et al., (2023) for an extensive overview of biases).

- **Scrutinize data collection methods, not just results.** Many of the common methods used in the field of energy technology acceptance have shortcomings (see also chapter 10). These methods tend to take 'snapshots' of trust, commonly reasoning from a single frame of nuclear energy and targeting citizens with specific characteristics (e.g. with skills and resources to participate in online surveys). The insights gleaned from these snapshots are valuable but repeating them over time and with variations in frames and survey designs is needed to evaluate these methods' robustness. Besides critically assessing the bias present in the applied methods (independence of the initiator, response bias, question wording, etc.), policy makers should interpret the results from these methods in light of their shortcomings. Perusing critical reviews or comparing several studies with different methods conducted at different moments in time may help to reveal to what degree such shortcomings have affected the studies' results.

- **Design diverse interaction activities with low barriers to entry.** The group of citizens that tends to participate in these activities is rather homogeneous. This 'participation-elite' is likely to be male, of higher age, and more highly-educated and tends to have a higher income (Movisie, 2023; TNO, 2022; Tonkens & Hurenkamp, 2019). The outcomes of such activities will therefore not reflect the diversity of perspectives held among the public on nuclear energy. Citizens with a lack of interest in the topic, a lack of necessary language skills or with distrust in the political system may withhold from participating. This issue may be exacerbated when the participating segment of the public holds strongly differing views from the rest of the public. For instance, as also mentioned in the previous chapter, surveys point out that older, highly educated men may indeed hold more positive views on nuclear energy than other societal groups (CBS, 2023; Populytics, 2023). To tackle this issue, sensing and analysing activities should be used to

define and engage groups with varying views on nuclear energy. The barriers to participate in interaction activities should be kept as low as possible, to ensure these varying views can be fully recognized, which may foster the fairness of participation. Recent efforts in designing participation procedures (e.g. citizen councils) have made strides in combating this issue and should be expanded upon further.

- **Appreciate the value of conflict and mistrust throughout interaction.** Constructive conflict, for instance between policymakers and resistance groups, can be highly beneficial. It encourages diverse perspectives and fosters a more inclusive decision-making process. By engaging in open dialogue, both parties can identify potential issues and collaboratively develop more effective and equitable policies. This dynamic can also enhance transparency and accountability, ultimately leading to more robust policy outcomes.

Design a robust and adaptive policy process

The policy process outlined in this chapter could be described as an adaptive policy process, where the approach is continually refined via feedback gained through sensing, analysing, and interacting. Throughout the life cycle of nuclear power plants (NPPs) there may indeed be many opportunities for adaptivity, especially in the design of stakeholder engagement and participation procedures. However, there is a friction between such adaptivity and decision making around nuclear energy technology, where decisions may be 'locked-in' for decades due the nature of NPP's life cycles.

The life cycle of a NPP may transcend multiple generations, where support for nuclear power plants as a critical part of the energy transition may wax and wane. Historical evidence, as also portrayed in chapter 3.3, shows that such a pattern is exactly what has happened since the onset of developments in nuclear power, where opinions shift in response to nuclear incidents, changes in the public discourse or transformations in the energy system (Gupta et al., 2019; Mulder, 2012b). The particular dynamics of these changes are not yet properly understood, but if such patterns keep repeating themselves, nuclear energy may enter a stage of limited support during the envisioned life cycle of newly built power plants.

A solution to this thorny problem may be to strengthen the robustness of policy making for changes in public trust dynamics. Such an approach to policy design would imply that the envisioned role of nuclear energy is specified for various alternative futures, not only those that fit the current narrative for the energy transition or for the economy of the future. For example, by elucidating the role of nuclear energy in alternative economies or in aiding the sustainability transition of industry and shipping (e.g. through the use of Small Modular Reactors). Such an exercise should not be limited to professionals but should be opened for input by the general public. Doing such an exercise may help to strengthen the public and political support for decisions made on nuclear energy and may foster public trust by reinforcing the fairness of decision making.

7 Further research

7.1 Intended outcomes of further research

Finally, if it is decided to further develop this adaptive policy process, with sensing, analysing, and interacting activities, research is needed to give this a solid foundation. This research should focus on developing methodologies, toolboxes, or best-practices for stakeholder interaction, communication, and public debate at all levels of society (national, regional, local) during all foreseeable circumstances (e.g. new initiatives, accidents). Not pursuing any strong research actions in the domain of public trust, may leave nuclear initiatives vulnerable to sudden changes in public opinion in part because of poor handling of people's trust.

There is a growing body of scientific evidence suggesting that social science methodologies can help to foster public trust in nuclear energy, by improving communication, transparency, and community engagement (SHARE, 2020). Four of the key areas that such research can support are:

Addressing public concerns
Social science research, particularly through surveys, interviews, and focus groups, helps identify the specific concerns, misconceptions, and values that shape public opinion about nuclear energy (Corner et al., 2011). Studies show that trust in nuclear energy correlates strongly with people's perceptions of safety, environmental impact, and whether they feel adequately informed. By identifying these factors, more targeted (communication) strategies can be developed that address public concerns directly, fostering trust.

Improving communication
Studies indicate that clear, transparent, and consistent communication from nuclear industry leaders and policymakers helps mitigate fear and uncertainty around nuclear energy. Social scientists have demonstrated that providing context for radiation risks and explaining safety measures in relatable terms improves public understanding and lowers perceived risk, which enhances trust (Renn & Levine, 1991).

Improving stakeholder engagement and participation
Community engagement methodologies, such as participatory decision-making and consensus conferences, have been shown to improve trust in nuclear projects (Bergmans et al., 2014). Research indicates that when communities are given a voice in nuclear project planning, especially regarding waste management and site selection, their support and trust levels increase. Examples include Finland and Sweden, where local community involvement in nuclear waste repository planning correlated with higher acceptance and trust.

Providing policy guidance
Social science research emphasizes the importance of public trust in regulatory institutions overseeing nuclear safety. Studies show that communities are more likely to trust nuclear projects if they believe that regulatory bodies are competent, independent, and transparent (Slovic, 1993). Social science methodologies, such as ethnographic studies and policy analysis, provide insights into the relationship between regulatory practices and public perception, helping design trust-building policies.

Together, these insights demonstrate that social science methodologies play a significant role in shaping public trust in nuclear energy by helping design strategies that align with the public's values, improve communication, and foster more meaningful community involvement.

Key research lines

To achieve the intended outcomes outlined in chapter 7.1, prolonged and coherent research is necessary along five research lines:

1. Monitor trust dynamics and attitudes

Why – Current methods take 'snapshots' of citizens' trust and attitudes and use frameworks at the individual level to explain changes in trust and attitude. Yet, attitudes have been shown to change dynamically over time and under the influence of events or interpersonal communication. Currents methods fail to capture such dynamics and may fail to reach underrepresented groups in society.

How – (1) Develop a monitor for public responses to energy technologies that is repeated systematically, e.g. via (social) media monitoring and targeted (informed-choice) questionnaires, (2) develop new indicators, e.g. through modelling exercises , historical case studies or cross-country comparisons, that are able to capture trust dynamics and promote their use in survey studies, (3) develop indices based on existing historical data, (4) explore alternative ways of capturing public responses that are easy to access and capable of targeting hard to reach groups, e.g. via futuring techniques[21], (5) develop methods to explore how perceptions on nuclear change in response to interpersonal communication or deliberation about nuclear energy.

2. Explore alternative scenarios and solutions

Why – Current methods use a single nuclear energy frame in the information that is presented to respondents (see chapter 7.2). Yet, responses to information may be highly dependent on how the information is framed. By reasoning only from the currently dominant framing of the policy problem and solution space, these methods limit their applicability and hamper the robustness of their results. Alternative frames of the problems nuclear energy aims to tackle, as well as the suite of possible solutions (e.g. degrowth, energy demand reduction), should be explored to determine whether the results of studies are robust to slight changes in framing, as well as applicable to frames that may become more dominant in the future. For example, how does the development of e.g. SMRs influence public trust dynamics? What does the trust in other technologies (renewables, fusion) mean for public trust in nuclear fission?

How – (1) Explore alternative futures and the role of nuclear energy within them (e.g. through alternative nuclear energy technologies like SMR's), as well as each futures' impacts (e.g. on safety, economic growth, employment, emission reduction), e.g. through futuring techniques or other methods for public deliberation (2) Design studies to explore citizen responses to each of these alternative futures, including the current most likely scenario's for developing nuclear energy e.g. through informed choice questionnaires. These studies should tie into those exploring trust dynamics under research line 1.

3. Develop novel communication and information provision methods

Why – The insights gained through research lines 1 and 2 should be used to develop new methods for communication and information provision that are adaptive and can deal with

[21] The techniques are used to explore imagined futures together with stakeholders, for example through multimedia installations (Hajer & Pelzer, 2018).

trust dynamics. These methods should aim to provide citizens with sufficient high-quality information to participate in public debate around nuclear energy, for example in the procedures developed in research line 4.

How – (1) Develop methods to establish information needs to enable public or groups of citizens to form an opinion and/or participate in the debate, e.g. via serious gaming or citizen science (2) establish communication schemes for emergency preparedness that provide clear instruction and information on possible (dose)risk that is relevant to the individual, (3) develop communication programmes that inform the public on the various applications of ionising radiation (including energy), and their advantages and drawbacks.

4. Develop novel stakeholder engagement and participation procedures

Why – Research line 4 should focus on developing adaptivity in stakeholder engagement and participation procedures, as well as tackling common issues surrounding the core goals and concepts in this field. For example, concepts, such as acceptance or 'draagvlak', may promote an instrumental focus of public engagement practices. Not only do such instrumental approaches deviate from best practices in public engagement, but they also ignore the value of civic vigilance or scepticism in the health of democracy and the processes constituting it.

How – (1) Develop methods to co-create a focal concept and framework for public engagement that is shared across stakeholders, such as policy makers, technology developers and civil society groups. Example methods to apply are the creation of labs or collaboration workshops to (re)design public spaces.

5. Translate research findings to policy guidance and good practice

Why – The insights gained throughout research lines 1 to 4 should be used to develop policy guidance for dealing with trust dynamics. It is currently unclear whether current policy processes around nuclear energy are capable of being adaptive and of dealing with trust dynamics. This research line should first determine to what degree such a gap between current and envisioned practice exists. Afterwards, the research line should focus on designing practical guidance (e.g., materials, trainings) for policy makers, as well as guidance for structural organizational changes that may be needed to ingrain adaptivity as part of the policy process in the future. Given the life cycle of nuclear power plants, guidance needs to go beyond the current generation of policy makers and aim to ensure dealing with trust dynamics becomes part of the organization's core.

How – (1) Analyze current decision making and public engagement procedures around nuclear energy, (2) determine opportunities for including adaptivity (3) design practices that could foster the adaptivity of the policy process.

7.2 Knowledge roadmap

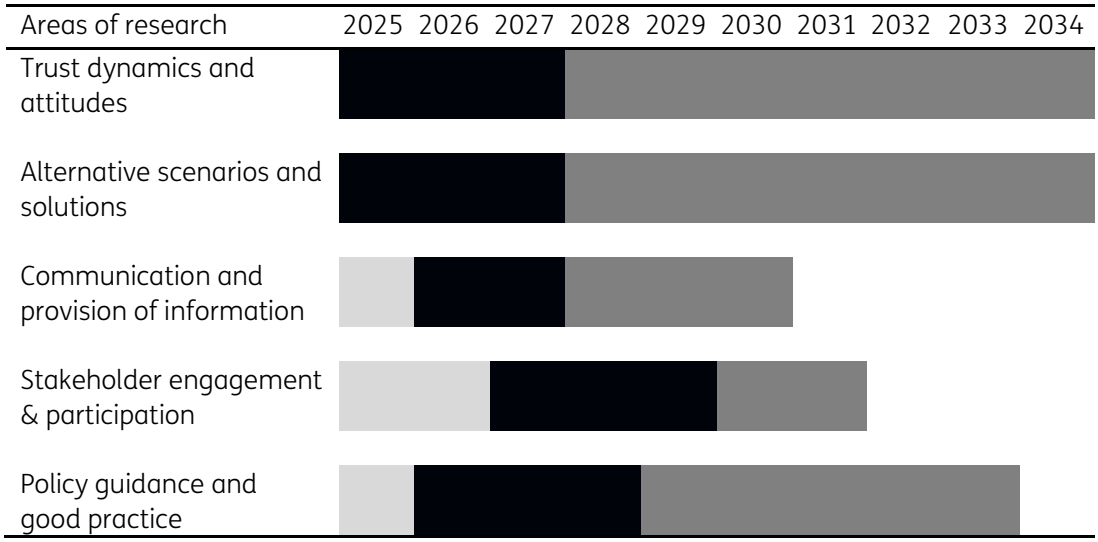
The knowledge roadmap for enhancing public trust in nuclear energy prioritizes understanding trust dynamics and attitudes, alternative scenarios, communication, effective engagement strategies, and policy guidance. Over a ten-year timeline, the agenda will progress the five research lines through three phases: preparational, research, and implementation.

Two of the key research lines (trust dynamics and alternative scenario's) should start as soon as possible, as the results from these research lines should provide the primary inputs for developing communication materials, stakeholder engagement procedures and policy guidance from 2026 onwards. The latter three research lines should already enter a

preparation phase next year and focus on sharpening the goals and intended outcomes and delineating the scope of the activities to be carried out, based on the results from the first two research lines. After 3 to 5 years of preparation and research these research lines should enter an application phase, where key research activities are repeated (e.g. in case of the public trust monitor) and where to be developed activities are further refined.

The knowledge roadmap outlined below will be further detailed in 2025 through an additional publication.

Table 7.1: Timeline of the roadmap for social science research in public trust. Colour coding for the different research stages: ■ preparational phase, ■ research phase, ■ implementation phase.



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Appendix A

Causal Loop Diagram description

Our causal loop diagram (CLD) of trust in nuclear energy is split into five categories: Sustainability, Fairness, Safety, Energy security and Affordability (see figure 9-1). This is in line with the four main topics identified in the nuclear history on public sentiment (see section 5.3. Summary & Closing Words) and the five different values the RLI distinguishes in their report (RLI, 2022) and coincides with the usage of these categories in our Sensing step.

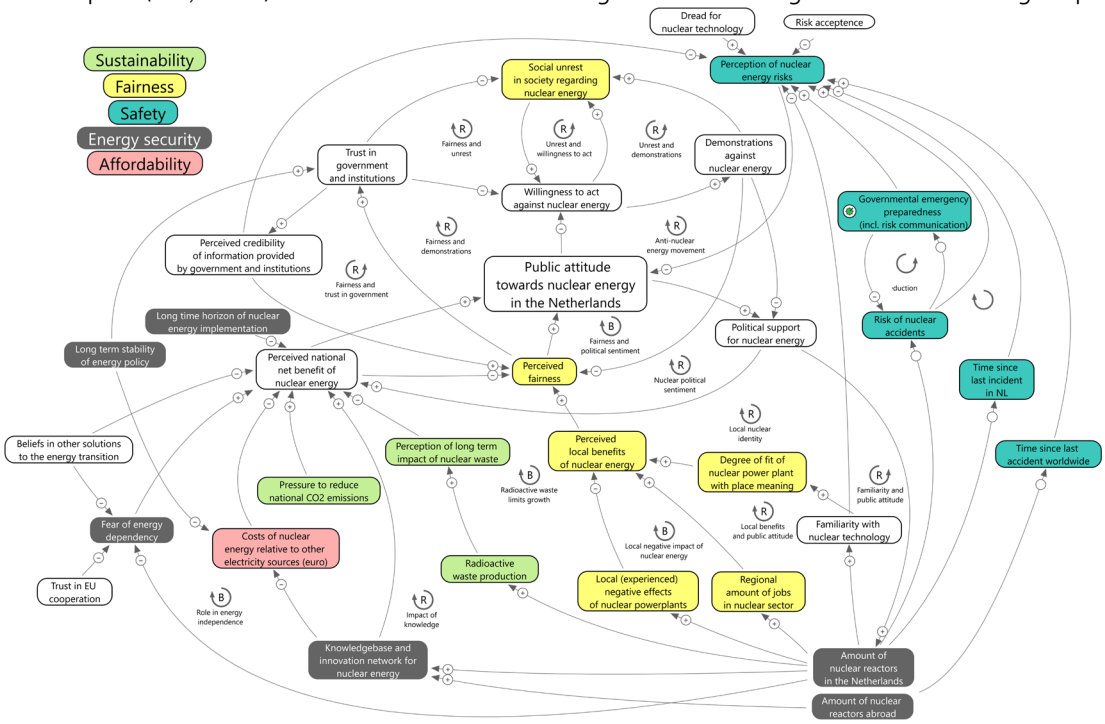


Figure 7.1: Causal loop diagram trust in nuclear energy (bigger picture can be found in the Appendix)

Public Attitude Towards Nuclear Energy in the Netherlands

The goal of our model is to understand public trust dynamics around nuclear energy in the Netherlands. The centremost variable in the model however is *public attitude towards nuclear energy* in the Netherlands. This is because during the modelling process we found this to be a very influential node, being influenced by different concepts from literature such as perceived fairness and risks. We define public attitude as: *the general sentiment and opinions held by the public concerning the use of nuclear energy in the country as an evaluative judgement (e.g. positive or negative).*

Those separate opinions are affected by three direct influences: *perception of nuclear energy risks*, *perceived national net benefit of nuclear energy* and *perceived fairness*.

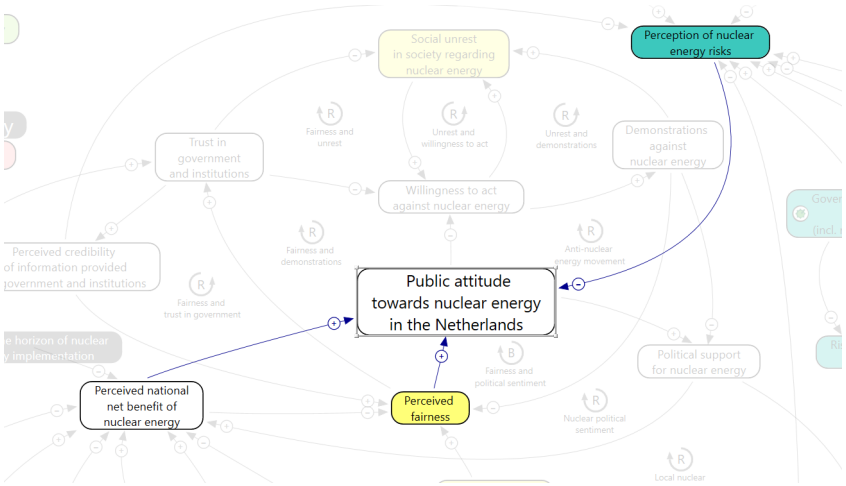


Figure 7.2: Public attitude and its three directly influencing variables

The **perception of nuclear energy risks** refers to how individuals and society at large assess the potential dangers associated with nuclear energy, including environmental, health, and safety risks. This perception influences public opinion, policy decisions, and willingness to accept nuclear energy. The **perceived national benefit of nuclear energy** is the public's understanding of the gains nuclear power offers to the nation, particularly in terms of energy security**,** economic growth, and environmental sustainability**.** What remains when perceived costs are matched with benefits, is the 'net' benefit. **Perceived fairness** refers to the public's judgment on whether nuclear energy policies are implemented in a way that is equitable and just, both in terms of risks and benefits, and in decision-making participation.

Safety

The safety domain contains variables such as time since last incident in NL, time since last accident worldwide, and risks for nuclear accidents. These variables can be observed or are calculated using an established framework. The model also includes less tangible variables which are not a result of an established framework but are formed by perceptions of individuals. This is for example the variable *perception of risks*. In the model a distinction is made between incidents and accidents. Roughly speaking an incident is contained to the nuclear site and an accident has consequences crossing the border of this site. A safety incident in the Netherlands will impact the Netherlands, while an incident in France is already unlikely to be of consequence. Lastly, a higher of **familiarity with nuclear technology** in society will have a decreasing effect on the height of the risk that is perceived.

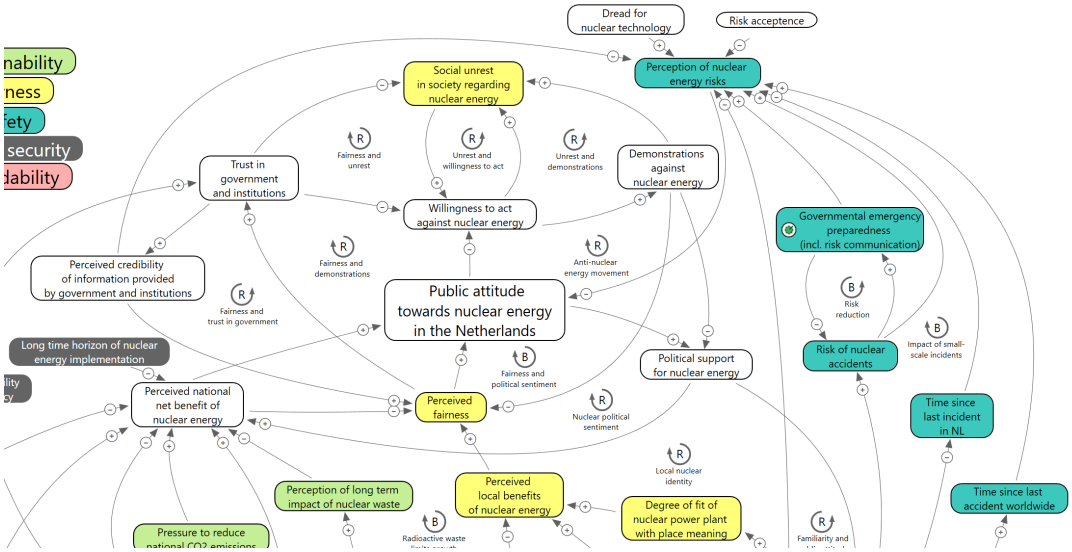


Figure 7.3: Safety category and related variables

Related to safety are **trust in government and institution**s, **social unrest in society regarding nuclear energy**, **willingness to act against nuclear energy** and **demonstrations against nuclear energy**. These variables show feedback structure. The amount of **trust in government and institutions** influences the **perceived credibility of information provided by government and institutions** and their level of **willingness to act against nuclear energy.** This holds not only for nuclear energy but is observed in delicate political issues.

Fairness

Perceived fairness influences the amount of **trust in government and institutions,** and it has a direct influence on **public attitude towards nuclear energy in the Netherlands**. One way **perceived fairness** is formed is by individuals weighing the **perceived national net benefits of nuclear energy** against **the perceived local benefits of nuclear energy**. If these are in balance it will lead to a generally higher perceived fairness. If there is a very high national benefit, but there are only local impacts and little local benefits there will be a general lower perceived fairness. The perceived national net benefit is not purely economical, but also takes into account the **pressure to reduce national CO2 emissions**, the **perception of long-term impact of nuclear waste**. These variables can be interpreted as contribution to a concept such as intergenerational fairness. Perceived local benefits are formed by individuals and can be in general lower because of local **(experienced) negative effects of nuclear power plant** such as the impact of the transmission lines, or the construction activity, etc. It can be higher if there is a higher number of **regional jobs in nuclear sector.** Finally, we included the variable **degree of fit of nuclear power plant with place meaning.** Is explains the phenomenon of that a nuclear power plant can over time become part of the identity of the region.

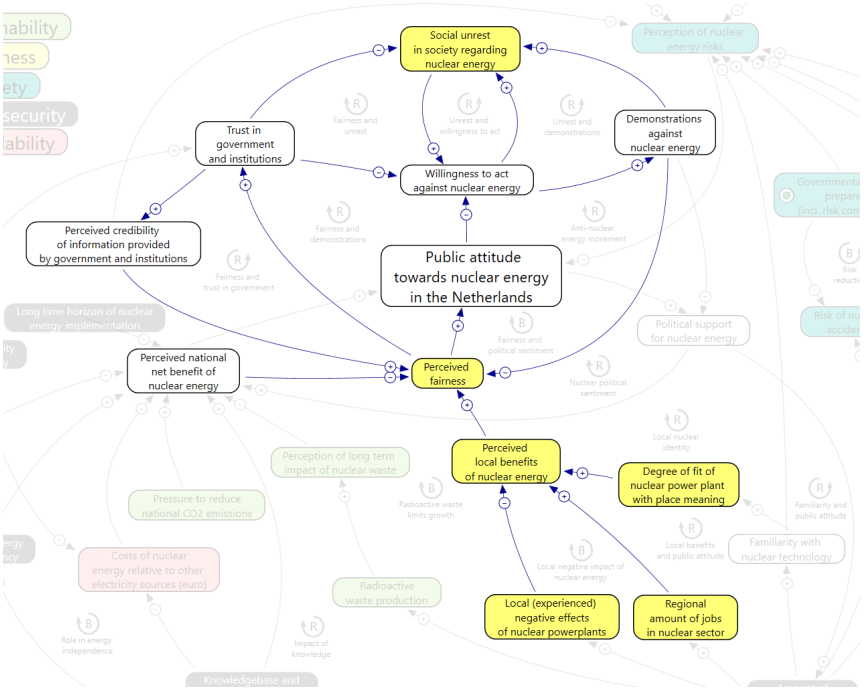


Figure 7.4: Fairness category and related variables

Sustainability

The higher the **pressure to reduce national CO_2 emissions** leads to a higher **perceived national net benefit of nuclear energy** since nuclear energy has and is perceived as a form of energy production with limited CO_2 emissions. A higher **perception of long-term impact of nuclear waste** will the deduct from the perceived benefits. A higher actual **radioactive waste production** will lead to a higher perception. The step to perception is included because it is not easy for people to grasp the concept of radioactive waste, and the perception of the impact also has to do with whether a long-term storage plan is in place and whether people are aware of it.

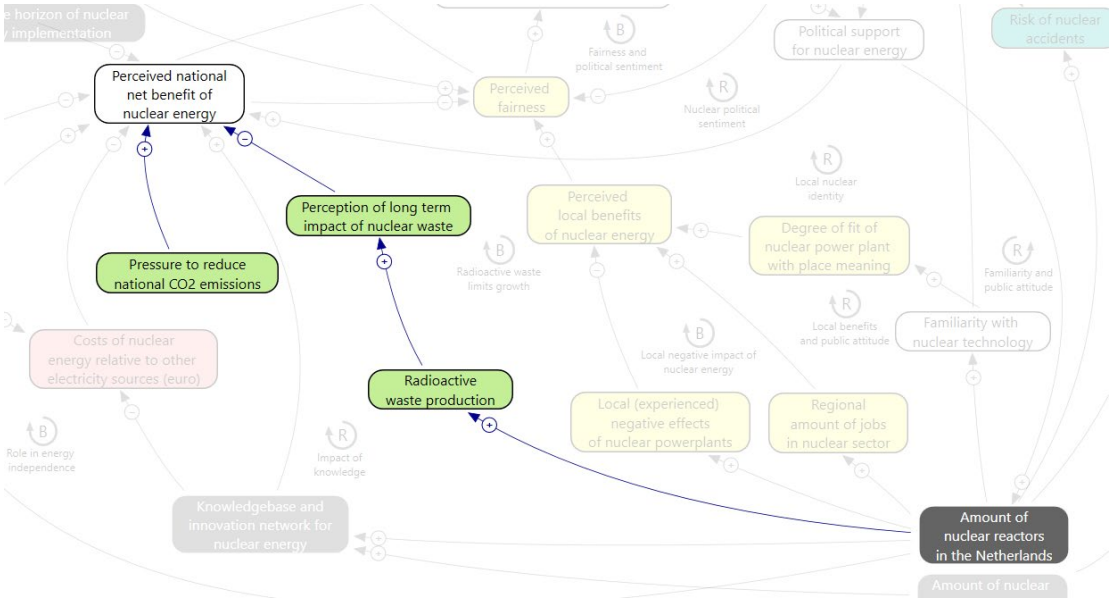


Figure 7.5: Sustainability category and related variables

Energy security and affordability

Energy security is a topic influencing the **perceived national net benefit of nuclear energy.** If there is a higher **fear of energy dependency** due to for example the Dutch gas-fields closing, generally the perceived benefits will rise. This **fear of energy dependency** is in turn influenced by the **trust in EU cooperation** and **beliefs in other solutions for the energy transition** both could alleviate the fear of energy dependence. As one can see in the historical media analysis of the previous chapter, it is a recurring topic of national discussion. The number of nuclear reactors abroad will also influence this, because it will lead to a better knowledge- and innovation base. Having this a higher **knowledgebase and innovation network for nuclear energy** can drive down **cost of nuclear energy relative to other electricity sources** and it can directly be perceived as a national benefit.

Nuclear power plants have a long-term implementation horizon which can conflict with the **long-term stability of energy policy.** If this is lower both the **cost of nuclear energy** and the **trust in government and institutions** will be influenced downward. Phrased differently, changing the national energy policy mid-lifecycle can have large financial and reputational impacts.

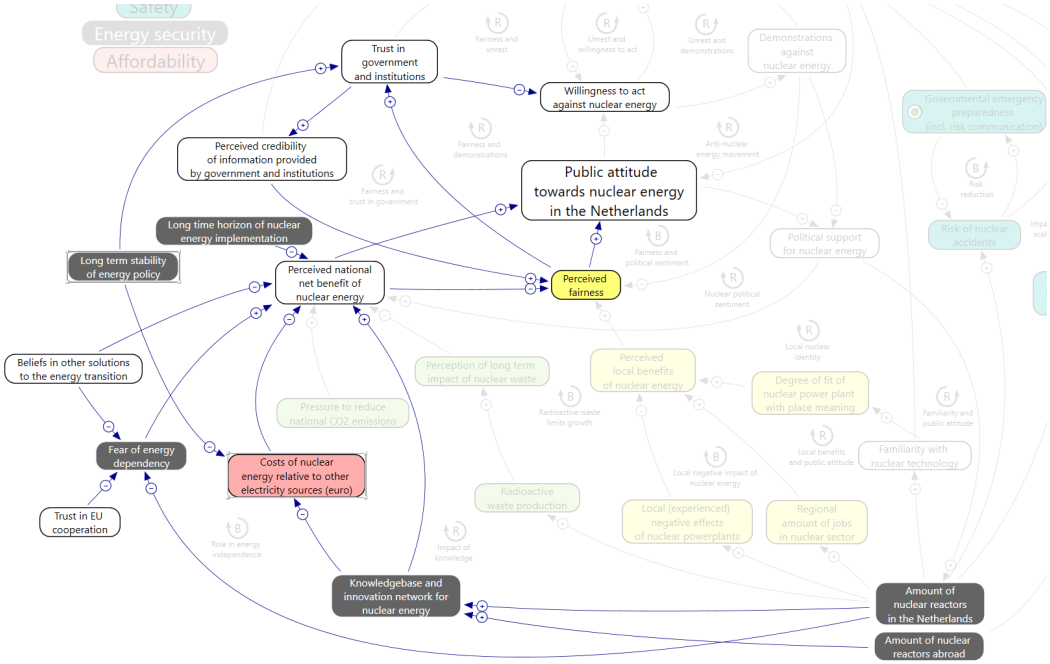


Figure 7.6: Energy security category and related variables

Appendix B

Definitions variables Causal Loop Diagram

Trust in government and institutions
Trust in government and institutions refers to the public's and stakeholders' confidence in the ability of governmental bodies and regulatory institutions to make informed, transparent, and responsible decisions about nuclear energy policies. This trust stems from both the actions taken by these institutions and the perceived integrity and intentions behind those actions.

Perception of nuclear energy generation risks
Perception of nuclear energy generation risks refers to how individuals and society at large assess the potential dangers associated with nuclear energy, including environmental, health, and safety risks. This perception influences public opinion, policy decisions, and willingness to accept nuclear energy.

Risk acceptance
Risk acceptance is the degree to which the public and policymakers are willing to tolerate the potential dangers and uncertainties associated with nuclear power, including safety, health, and environmental risks.

Perceived national net benefit of nuclear energy
The perceived national benefit of nuclear energy is the public's understanding of the gains nuclear power offers to the nation, particularly in terms of energy security, economic growth, and environmental sustainability. What remains when perceived costs are matched with benefits, is the 'net' benefit.

Public attitude towards nuclear energy in the Netherlands
the general sentiment and opinions held by the public concerning the use of nuclear energy in the country as an evaluative judgement (e.g. positive or negative).

Fossil fuel prices (excluding uranium)
Fossil fuel prices (excluding uranium) represent the fluctuating cost of non-renewable energy sources like coal, oil, and natural gas, which can affect the attractiveness of nuclear energy investments.

Fear of energy dependency
Fear of energy dependency refers to concerns about reliance on foreign energy sources and the associated risks to national security and economic stability.

Competition of other technologies (PV, wind, biomass, etc.)
The competition of other technologies refers to the presence of alternative energy sources like wind, solar, and biomass that challenge the economic and political feasibility of nuclear energy by offering lower costs or greater public support.

Dread for nuclear technology
Dread for nuclear technology refers to the fear and anxiety associated with the potential dangers of nuclear energy, including catastrophic accidents and long-term risks like radiation. The term dread is chosen because it is associated with for example end of humanity or a nuclear winter. Culturally symbols or topics such as the radioactive symbol, cockroaches, mushroom clouds, mutations, etc. can be evoked when thinking of nuclear technology.

Process participation opportunities
Process participation opportunities refer to the chances for public involvement in the decision-making processes around nuclear energy policies, from consultation to active influence.

Feasibility of nuclear energy policy
Feasibility of nuclear energy policy is the likelihood that a country's nuclear energy policies can be successfully implemented, accounting for technical capabilities, financial constraints, and political will.

Risks for nuclear incidents
Risks for nuclear incidents refer to the potential for catastrophic events involving nuclear power plants, such as meltdowns, leaks, or failures, and their consequences for public safety and the environment.

Radioactive waste production
Radioactive waste production refers to the generation of hazardous materials during nuclear energy production that require long-term storage and management to prevent environmental and health risks.

Long-term damage to environment
Long-term damage to the environment refers to the persistent environmental harm caused by nuclear energy production, including contamination from radioactive materials and the depletion of natural resources.

(Social) media coverage of nuclear risks and disaster
(Social) media coverage of nuclear risks and disasters refers to the role of both traditional media and social media platforms in shaping public perceptions of nuclear energy, particularly in relation to disasters and accidents.

Costs of nuclear energy relative to other electricity sources (euro)
The costs of nuclear energy relative to other electricity sources refer to the overall financial comparison between nuclear power and alternatives like wind, solar, or natural gas, accounting for both capital expenses and operational costs.

Social unrest in society regarding nuclear energy
Social unrest in society regarding nuclear energy refers to the public dissatisfaction and potential protests or resistance against nuclear energy, driven by concerns about safety, health, and the government's decision-making processes.

Number of nuclear reactors in the Netherlands
The number of nuclear reactors in the Netherlands refers to the number of operational nuclear power plants in the country and their role in national energy production.

Governmental emergency preparedness (including risk communication)
Governmental emergency preparedness (including risk communication) refers to the government's ability to respond to nuclear incidents, ensuring both operational readiness and effective communication with the public.

CO_2 intensity of nuclear electricity generation
CO_2 intensity of nuclear electricity generation is the measure of **carbon emissions** produced per unit of electricity from nuclear energy

Long time horizon of nuclear energy implementation
The long-time horizon of nuclear energy implementation refers to the extended timeline necessary to develop and operate nuclear power plants, from initial planning stages to full energy production.

Long term stability of energy policy
Long-term stability of energy policy refers to a consistent and predictable framework that supports investment, innovation, by aligning with long-term goals like sustainability and energy security while remaining adaptable to change. Conversely, a non-stable policy is marked by frequent shifts, unclear regulations, and inconsistent goals.

Regional number of jobs in nuclear sector
Regional number of jobs in the nuclear sector refers to the number of employment opportunities created in regions where nuclear energy facilities are developed, with a focus on both direct and indirect jobs.

Perceived fairness
Perceived fairness is the public's assessment of whether the distribution of risks and rewards related to nuclear energy is **just** and whether the decision-making process is inclusive and transparent.

Willingness to act against nuclear energy
Willingness to act against nuclear energy refers to the degree of public readiness to oppose nuclear energy development, through actions such as protests, lobbying, or advocacy, based on safety, environmental, or ethical concerns.

Degree of fit of nuclear power plant with place meaning
Degree of fit of nuclear power plant with place meaning is the extent to which a nuclear power plant is compatible with the local environment, culture, and economy, considering both practical and symbolic aspects of the area.

Familiarity with technology
Familiarity with technology is the public's level of understanding and comfort with nuclear energy technology

Perceived credibility of information provided by government and institutions
Perceived credibility of information is the public's assessment of how reliable and trustworthy the information provided by governments and institutions is, especially regarding nuclear energy policies and risks.

Local (experienced) negative effects
Local (experienced) negative effects are the tangible and perceived drawbacks experienced by communities living near nuclear plants, including environmental risks, economic changes, and social impacts.

Perceived local benefits of nuclear energy
Perceived local benefits of nuclear energy refer to the advantages that local communities believe nuclear energy brings, including economic growth, job opportunities, and improvements to infrastructure and public services.

Local compensation and investment measures
Local compensation and investment measures refer to the financial and non-financial benefits provided to communities living near nuclear energy projects to offset potential negative impacts.

Measures to reduce visual impact (cooling or underground transmission cables)
Measures to reduce visual impact refer to the strategies implemented to minimize the visual footprint of nuclear power plants and associated infrastructure, such as cooling towers or transmission cables.

Demonstrations against nuclear energy
Demonstrations against nuclear energy are public protests and advocacy actions organized by individuals or groups opposing nuclear energy, typically driven by concerns about safety, environmental impact, or long-term risks.

Extremism, riots, unlawful protest against nuclear
Extremism, riots, and unlawful protests against nuclear energy refer to radical actions taken by individuals or groups in opposition to nuclear energy, often involving illegal activities or violent demonstrations.

Competition of other nuclear technologies
Competition of other nuclear technologies involves the comparative advantages and disadvantages between different types of nuclear energy technology, including factors like cost, environmental impact, and public opinion.

Government support for nuclear energy
Government support for nuclear energy includes both financial incentives (such as subsidies) and regulatory policies aimed at encouraging the development and expansion of nuclear energy as part of the national energy strategy.

Time since last incident in the Netherlands
Time since the last incident refers to the length of time that has passed since the last nuclear incident or event in the Netherlands, this does not have to be an accident within the power plant but can also be an incident on site.

Time since last accident worldwide
Time since the last accident worldwide refers to the length of time that has passed since the last nuclear accident worldwide.

Number of nuclear reactors abroad
The number of nuclear reactors abroad refers to the number of operational nuclear reactors in other countries

Knowledge base and innovation network for nuclear energy
Knowledge base and innovation network for nuclear energy encompasses the scientific expertise, research institutions, and technological innovations involved with nuclear energy.

Activity of (international) protest network
Activity of (international) protest network describes the coordinated actions of international groups opposing nuclear energy, including protests, advocacy, and campaigns that influence public opinion and policy.

Framing towards energy independence
Framing towards energy independence refers to the narrative that nuclear energy can help a nation achieve self-sufficiency in energy production, reducing reliance on imports and increasing energy security.

Framing toward future generations
Framing toward future generations refers to the strategy of promoting nuclear energy as a responsible solution for addressing the long-term energy needs of future generations, with a focus on sustainability and security.

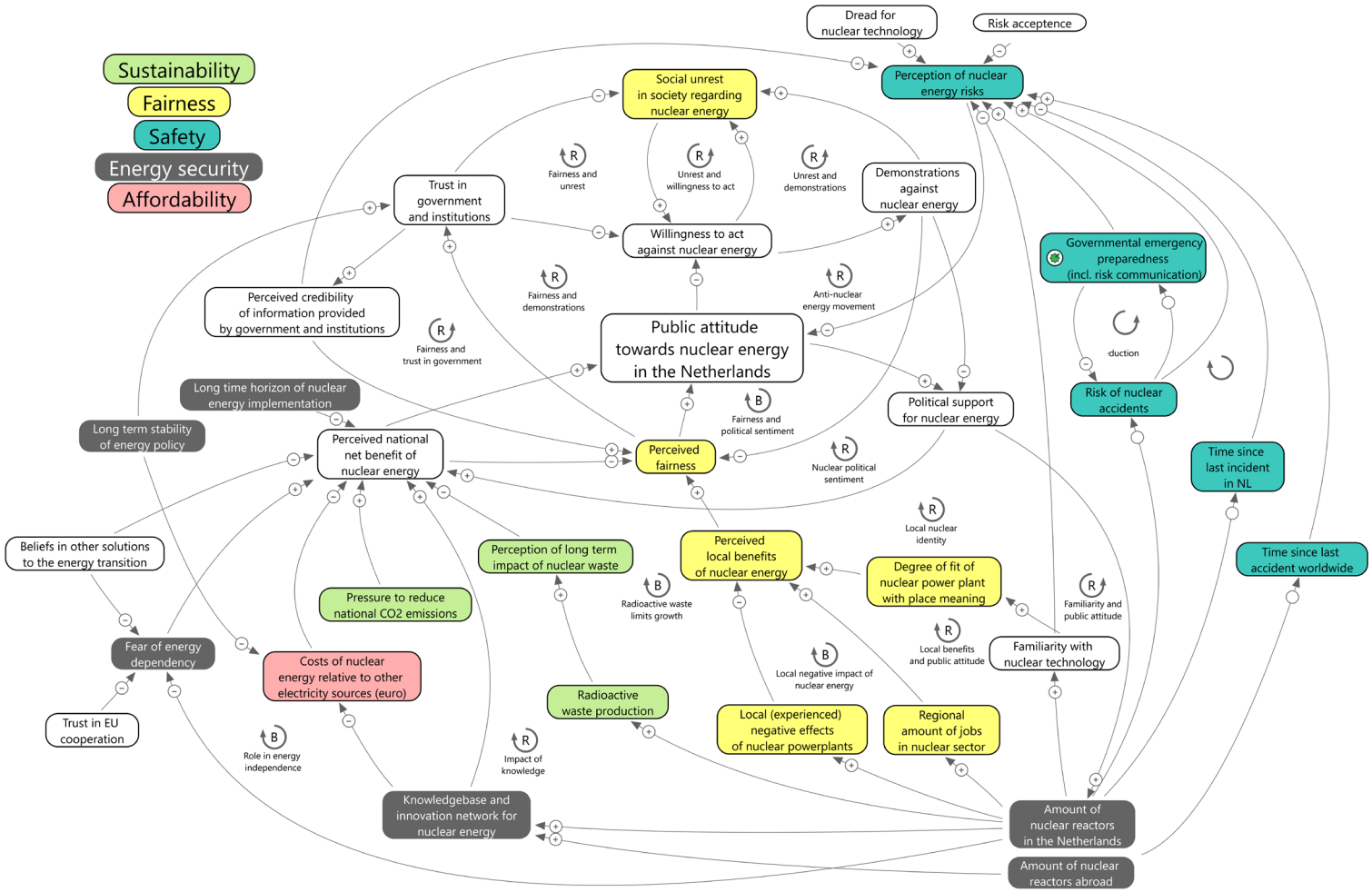
Framing towards affordability
Framing towards affordability is the narrative that nuclear energy, despite its initial high costs, provides long-term economic benefits, making it a financially viable option compared to other energy sources over time.

Negative experiences with other social issues (housing, nitrogen, etc.)
Negative experiences with other social issues refer to the public scepticism and mistrust generated by past policy failures in areas such as housing, environmental management, or public health, which can negatively influence attitudes towards nuclear energy.

Pro-nuclear energy movements
The organized efforts of nuclear industry representatives and advocates to influence government policies, regulatory decisions, and public attitudes towards nuclear power.

Appendix C

CL Trust in nuclear energy



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