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A world's dilemma 'upon which the sun never sets': The nuclear waste management strategy (part III): Australia, Belgium, Czech Republic, Netherlands, and Romania

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ABSTRACT

Radioactive waste management programs are vital activities required to provide conclusiveness, efficiency, and stability in supporting nuclear power programs around the globe. As more countries develop nuclear power generating programs and/or rapidly decommission nuclear power plant sites, access to radioactive waste storage/disposal facilities is of great concern. Discussed in Parts I and II of this series, countries are at different stages of progression in fulfilling moral and legal obligations with regard to managing created radioactive wastes and spent nuclear fuel.

Part III considers countries not reviewed in Parts I and II – Australia, Belgium, Czech Republic, Netherlands and Romania. This work also contemplates influencers impacting radioactive waste management programs, as well as discusses consent and science-based siting essentials.

1. Introduction

> "It is fundamentals that matter — not the trappings. (Alice Cunningham)"
>
> – Agatha Christie, The Labours of Hercules

Parts I and II[1] in this series of academic review papers provided the introduction, purpose and background, as well as the need for adding 'stability' as a sustainability principle to the topic of radioactive waste management. Parts I and II also provide an accounting of radioactive waste management programs in each corner of the globe. However, a number of countries with actively relevant radioactive waste management programs were not covered in these previous publications, and are now considered within Part III - Australia, Belgium, Czech Republic, Netherlands, and Romania.

These previous publications deliberated how nations are developing their own paths to solving the radioactive waste management challenge, and at varying speeds. Observations suggest that while there is a 'no-one-size-fits-all' solution to developing a radioactive waste management program, one can take note of certain common factors inherent to these various ongoing programs around the world. In Part III, the sustainability model for radioactive waste management is more fully described,

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improving its relevancy to the conversation. Its inter-relation to the ten observed common influencers associated with radioactive waste management programs is also portrayed.

2. Nuclear energy & radioactive waste management sustainability

Sustainability[2] and sustainable concept models[3] are those practices seeking to strike the right balance between the economic, environmental, and societal goals of the present generation, without causing an excessive burden/harm to any future generation. Over the past decades, incorporating sustainability models into practices has become more mainstream. More so, the climate change discussion since the early 1990's has emphasized the importance of the 'circular economy[4]' over the historically traditional 'linear economy[5]'. As Matlz et al., explains, one challenge with using sustainability models becomes how to achieve "'socially responsible' goals … at the expense of some other socially desirable outcome" (*Maltz* et al., *2018*).

The global nuclear industry has developed successful methods demonstrating that the nuclear fuel cycle incorporates sustainability concepts and practices. From an economical point of view, uranium has been thought of as an abundant natural resource when compared with fossil fuels, as recycling or the reprocessing of spent fuel rods helps to increase uranium utilization efficiency (*Gao and Ko, 2014*). The reprocessing of spent nuclear fuel gives added value to justifying nuclear power as a sustainable source of energy because a closed nuclear fuel cycle recirculates the energy in uranium of spent nuclear fuel and "the concentration of fission products so that the volume of waste is 100 times less than if the fuel rods were directly placed in repositories" (*Suppes and Truman, 2006*). During the decommissioning phase of a nuclear power plant, recyclability may act as a key driver to fulfilling the sustainability promise of nuclear power, where it is estimated that about 81% of materials may be recycled and therefore is not as limited in this respect as might be expected by many casual observers of the nuclear fuel cycle (*Stamford and Azapagic, 2012*).

To improve the sustainability requirements for managing policies for the high-level waste challenge in developing/operating a deep geological repository, two widely recognized sustainability models are the Life Cycle Assessment[6] (LCA) and Life Cycle Sustainability

[2] The concept of 'sustainability' evolved in the academic lexicon in the mid-1980s: *Portney, K. (2015). Sustainability (MIT Press essential knowledge series). Cambridge, Massachusetts: The MIT Press*; Sustainability is meeting the needs of the current generation without compromising the needs and requirements for high standards of living of future generations, which is the foundational principle for sustainable development practices: *Report of the World Commission on Environment and Development: Our Common Future,* http://www.un-documents.net/our-common-future.pdf*, Accessed February 7, 2020*; It should be observed that sustainability is not a modern concept, but rather is the merging, connecting and integration of several past ideas: *Pfister, T., Schweighofer, M., Reichel, A., & ProQuest. (2016). Sustainability (Key ideas). Abingdon, Oxon; New York: Routledge*; Preserving the normal functioning and viability of the radioactive waste management system leads to sustainability: *Sustainability. (2014). Dictionary of Energy*; Conserving and improving resources so these can contribute to improved human welfare for future generations is a requirement of sustainable practices. Thus, there is an argument to be made that reprocessing of spent fuel is required to lend the aura of sustainability over spent fuel disposal programs and the nuclear fuel cycle: *Kennedy, Donald. (2007). Sustainability. (EDITORIAL) (Conference notes). Science, 315(5812), 573*; A survey of 2100 mechanical engineers and 800 students shows a sizable belief "that sustainable engineering is a trendy name for what used to be called good engineering": *Brown, A. (2011). SUSTAINABILITY. Mechanical Engineering, 133 (11), 36–41.*

[3] Models that mesh environmental issues with the "social, cultural and the economic in everyday life": *Wells, P., & ProQuest. (2013). Business models for sustainability. Cheltenham: Edward Elgar*; A multi-objective quantitative economic model: *Bouchery, Y., Ghaffari, A., Jemai, Z., & Dallery, Y. (2012). Including sustainability criteria into inventory models. European Journal of Operational Research, 222(2), 229–240*; "Sustainability can be defined broadly or narrowly, and the definition is context dependent": *Zhang, Luna Reyes, Pardo, Sayogo, Zhang, Jing, Pardo, Theresa A., & Sayogo, Djoko S. (2016). Information, models, and sustainability: Policy informatics in the age of big data and open government (Public administration and information technology; 20). Cham: Springer.*

[4] This model is "gaining traction as an approach for achieving local, national, and global sustainability": *Schroeder, P., Anggraeni, K. and Weber, U. (2019) 'The Relevance of Circular Economy Practices to the Sustainable Development Goals', Journal of Industrial Ecology, 23(1), pp. 77–95.* https://doi.org/10.1111/jiec.*12732*; "gain[ing] increasing attention from policy makers, industry, and academia": *Mayer, A.* et al. *(2019) 'Measuring Progress towards a Circular Economy: A Monitoring Framework for Economy-wide Material Loop Closing in the EU28', Journal of Industrial Ecology, 23(1), pp. 62–76.* https://doi.org/10.1111/jiec.*12809*; "enshrined in [Chinese] law as an official national development goal": *Mathews, J. A. and Hao Tan (2011) 'Progress Toward a Circular Economy in China', Journal of Industrial Ecology, 15(3), pp. 435–457.* https://doi.org/10.1111/j.1530-9290.2011.00332.*x*; "takes into account many of the impacts on the environment of resource consumption and waste": *Bruel, A.* et al. *(2019) 'Linking Industrial Ecology and Ecological Economics: A Theoretical and Empirical Foundation for the Circular Economy', Journal of Industrial Ecology, 23(1), pp. 12–21.* https://doi.org/10.1111/jiec.*12745*.

[5] An economic linear model where the focus is to use raw materials to make a product, which is then disposed: *From a linear to a circular economy* https://www.government.nl/topics/circular-economy/from-a-linear-to-a-circular-economy*, Accessed February 07, 2020*; widely considered an unsustainable economic model "based on the take, and dispose paradigm": *Sillanpää, Ncibi, Ncibi, Chaker, & ProQuest. (2019). The circular economy: Case studies about the transition from the linear economy. London: Academic Press*; "The intrinsic mechanics of the linear economy … wasteful 'take - make – dispose' flow is detrimental to the environment": *Sariatli Furkan. (2017). Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability. Visegrad Journal on Bioeconomy and Sustainable Development, 6 (1), 31–34*; An "increase of awareness [on the limits of the] linear economy [required] the design of a new model of economic organization": *Bonciu, F. (2014). The European Economy: From a Linear to a Circular Economy. Romanian Journal of European Affairs, 14(4), 78–91*; The linear economy is based on "consumption-disposal", whereas the circular economy is "based on consumption-recycling": *Akimoto, K., & Futagami, K. (2018). Transition from a Linear Economy toward a Circular Economy in the Ramsey Model. IDEAS Working Paper Series from RePEc, IDEAS Working Paper Series from RePEc, 2018.*

[6] This model has become more "widely used to evaluate the environmental impacts of emerging technologies and to enhance decision making towards sustainable development": *Yuan Yao. (2016). Models for Sustainability. BioResources, 12(1), 1–3*; Uses the interpretive process to "evaluat[e] energy, water, and other natural resource use … with a good or service from "cradle to grave"": *Life Cycle Assessment. (2014). Dictionary of Energy*; "sophisticated models are necessary to provide insights for policy development": *Anex, R., & Lifset, R. (2014). Life Cycle Assessment. Journal of Industrial Ecology, 18(3), 321–323*; "a cradle to grave environmental approach", *Curran, M. (2015). Life cycle assessment student handbook. Hoboken, New Jersey; Salem, Massachusetts: Scrivener Publishing: Wiley*; "LCA methods can provide support for process development": *Rauch S., Piepenbreier F., Voss D., Albert J., Hartmann M. (2019) LCA in Process Development: Case Study of the OxFA-Process. In: Schebek* L., *Herrmann C., Cerdas F. (eds) Progress in Life Cycle Assessment. Sustainable Production, Life Cycle Engineering and Management. Springer, Cham.*

Assessment[7] (LCSA). A hybrid/combination model of these forms the basis of the radioactive waste management sustainability model (Fig. 1), which was first presented in Parts I and II of this series. It should be noted that this combined model may be used for developing sustainable policies and pathways for managing low-level and intermediate-level wastes as well, and is not necessarily devoted to the management of high-level waste[8] and deep geological repository development. That being said, the LCA model emphasizes the impact of the designed system on the environment over its life cycle, including human health. LCSA[9] extends the LCA concept by adding social imperatives as a focus into the framework *(Schaubroeck and Rugani, 2017)*. In this vein, the authors added the additional motivation of 'stability' to the LCA model to consider the role of the legal framework in place, the ability of the regulatory system to provide sufficient oversight - while responding efficiently to change – and, their roles accelerating or hindering informed decision-making.

The basic LCA model of 'economy, environment, and society' assists the model's user "to better understand impact[s], leading to informed decision making" *(The Chemical Engineer (929), 2018)*. However, the LCSA/LCA hybrid model (presented as Fig. 1) is a natural forward progression of the LCA model addressing some observed limitations to adequately consider the sustainability of the entire system of radioactive waste management as a complete whole. The basic LCA model only incorporates environmental, economic and social criteria causing a number of academics to seek more radical innovation to capture broader sustainability goals. Through recognition of the limits of previous models, a better understanding of overall sustainability solutions is achieved with a broader vantage point *(Rocha et al., 2019)*. By broadening the scope of the basic LCA model to include 'stability', this requires practitioners in nuclear sciences "to think about how to [more effectively] communicate their results to decision makers" *(Gloria et al., 2017)*. Using the LCSA/LCA hybrid radioactive waste management sustainability model enables systems to "convert the big[ger] picture" into daily practices *(Mcateer, 2019)*.

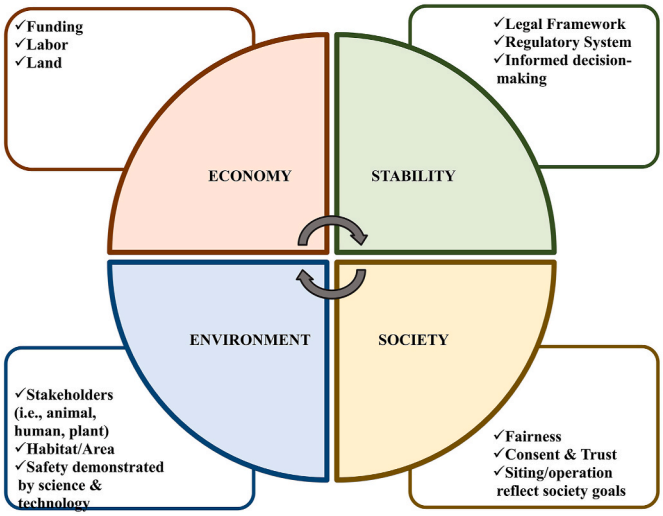

Fig. 1. Radioactive waste management LCSA/LCA hybrid sustainability model.

Given the proposed extended timeframes for high-level radioactive waste management programs, sustainability is a fundamental imperative. A radioactive waste management program which strikes the right balance among the sustainability building blocks has the greater potential to lead to successful completion and operation of a long-term deep geological disposal facility. However, sustainability models are no guarantee of success, as these programs must move forward apace despite numerous headwinds, including "increase[ed] public [and] regulatory pressures, as well as [implied organization] social responsibility" *(Erdil, 2019)*.

The LCSA/LCA hybrid radioactive waste management sustainability model aims at maintaining forward progression for the siting/construction/operation of a long-term deep geological disposal facility for high-level waste and spent nuclear fuel, without losing focus on the "ethical, social and political variables, [including] respecting the environment" *(de Oliveira et al., 2019)*. The radioactive waste management sustainability LCSA/LCA hybrid model shown in Fig. 1 is divided into four distinct, but overlapping concepts:

1. **Economy** – Main features include the funding mechanism in place to provide sufficient assets to site, construct and operate waste management facilities and/or deep geological repository. This also includes access to skilled labor, as well as land for siting the repository (especially critical for countries with limited land area).
2. **Environment** – Requires that the needs and concerns of stakeholders (i.e., animal, human, plant) whom could potentially be impacted by a repository are adequately investigated and addressed. The lasting impacts to the geographical area/habitat should not impose a greater burden or risk of harm from one generation to the next. For high-level waste, this is demonstrated through environmental impact assessments, with safety assured over a period of 10,000 years through use of up-to-date science and technology.
3. **Society** – Radioactive waste and spent fuel management is a general 'societal' undertaking, but siting/constructing/operating low-level

[7] This assessment model is used to achieve "higher levels of economic productivity through diversification, technological upgrading and innovation … promote development-oriented policies … [and], improve … global resource efficiency": *Van der Meer, Yvonne, Leal Filho, W., Azul, A., Brandli, L., Özuyar, P., Wall, W., … Aachen-Maastricht Institute for Biobased. (2019). Life Cycle Sustainability Assessment*; "consists of the three methods - life cycle assessment, life cycle costing and social life cycle assessment": *Neugebauer, S., Martinez-Blanco, J., Scheumann, R., & Finkbeiner, M. (2015). Enhancing the practical implementation of life cycle sustainability assessment - proposal of a Tiered approach. Journal of Cleaner Production, 102, 165*; Alberti et. al., concludes that "the three pillars of sustainability (economic, social, and environmental) are seldom considered together" which can hinder the usefulness of sustainability assessment tools: *Albertí, J., Balaguera, A., Brodhag, C., & Fullana-I-Palmer, P. (2017). Towards life cycle sustainability assessent of cities. A review of background knowledge. Science of the Total Environment, 609, 1049–1063*; "Social sustainability … receives less attention due to complicated explanations and difficult quantifications": *Ma, J., Harstvedt, J., Dunaway, D., Bian, L., & Jaradat, R. (2018). An exploratory investigation of Additively Manufactured Product life cycle sustainability assessment. Journal of Cleaner Production, 192, 55–70*; "When it comes to LCA, geopolitical elements" are generally overlooked and "further work is needed … to develop the geopolitical [dimension]": *Sonnemann, G., Gemechu, E., Adibi, N., De Bruille, V., & Bulle, C. (2015). From a critical review to a conceptual framework for integrating the criticality of resources into Life Cycle Sustainability Assessment. Journal of Cleaner Production, 94, 20–34*.

[8] Fig. 1 displays the sustainability model for high-level waste when considering the development of a deep geological repository. For low-level and intermediate level waste management and activities, the displayed model's general concepts can be used, though minor variations may be needed.

[9] Could also be referred to as a Consequential life cycle assessment (CLCA). CLCA's attempt is to include "accurate estimates of the sustainability impacts of various alternatives, including indirect consequences of any change": *Roos, A., & Ahlgren, S. (2018). Consequential life cycle assessment of bioenergy systems – A literature review. Journal of Cleaner Production, 189, 358–373*; "Consequential LCA is based on market information to identify which activities are affected by a change": *Pehme, S., Veromann, E., & Hamelin, L. (2017). Environmental performance of manure co-digestion with natural and cultivated grass – A consequential life cycle assessment. Journal of Cleaner Production, 162, 1135–1143*; "CLCA is potentially very broad, depending on what impacts are considered significant": *Jones, C., Gilbert, P., Raugei, M., Mander, S., & Leccisi, E. (2017). An approach to prospective consequential life cycle assessment and net energy analysis of distributed electricity generation. Energy Policy, 100, 350–358*; "Consequential life cycles measure the "impact" part of the sphere of influence": *Weidema, B., Pizzol, M., Schmidt, J., & Thoma, G. (2018). Attributional or consequential Life Cycle Assessment: A matter of social responsibility. Journal of Cleaner Production, 174, 305–314*.

Fig. 2. The ten radioactive waste management influencers.

waste facilities and/or geological repositories does impact one group of citizens more than it will impact other groups, due to their proximity to the chosen location. Therefore, siting processes must be fair and transparent to maintain confidence and trust between the public and decision-makers, as well as the organization responsible for overseeing construction and operation of the facilities and repository.

4. **Stability** – Especially the siting/constructing/operating a deep geological repository is a long-term process over a period of decades, though for other facility types not as long. In either case, the legal framework and regulatory system must provide sufficient support and oversight to these processes, while processing change in a controlled and forthright manner. Listening is a key feature for both the public and policy-makers. Nuclear science practitioners and policy-makers must consider how to more effectively communicate with each other and the public *(Sanders M & C, 2016 and 2019)*.

2.1. The "ten labors of hercules" - radioactive waste management influencers

Within the Radioactive Waste Management LCSA/LCA Hybrid Sustainability Model (Fig. 1), one can observe ten influencers[10] impacting the system of radioactive waste management and spent fuel disposal. Shown in Fig. 2, these influencers are chosen because each has the ability to enormously impact the character, development, and outcome of a radioactive waste management and spent fuel disposal program. Though overlapping and/or oft time competing, each in its own province exerts a compelling force on decision-making processes. When developed collaboratively, positive engagement with these influencers contributes to success. Where there is an organized system of engagement, with frequent communication patterns and processes in place, these influencers can serve as a net positive to the entire system of radioactive waste management and spent fuel disposal initiatives *(Carlson et al., 2020)*.

Communication,[11] of course, is an ever-present challenge. Organizations and nuclear science practitioners often struggle to develop "effective communication and advocacy strategies" *(Rashid, 2013)*. Communication, though essential, is not placed in Fig. 2 as its own 'influence' category. Mainly, this is because it forms an integral part of numerous influencer categories (i.e., organization, political, psychological, social).

Displayed in Fig. 3, each influence category is further sub-divided into two (2) pillars. Other sub-sub pillars are also evident, but for the purpose of this discussion and for the sake of clarity, only two (2) main pillars for each influencer are presented. While the intent is not to discuss each influencer individually within Part III, there are a few points worth highlighting. First, these influencer pillars are envisioned to support sustainability initiatives, forming an ***Integrated Radioactive Waste Management & Spent Fuel Disposal Sustainability Strategy***. Second, a key challenge/opportunity to any consent-based radioactive waste management and spent fuel disposal sustainability strategy is the social influencer category or citizen engagement. According to Hallström et al. (2019), key challenges in this area include: (1) busy lifestyles, (2) mobile populations, and (3) citizen's lack of understanding of the broader sustainability issues *(Hallström et al., 2019)*. One must therefore plan to engage in deeper long-term learning and communication processes, than simply going into communities and talking. Such talking initiatives do not have the ability to necessarily "facilitate the deeper, long-term goals of sustainability" (*ibid.*).

The 'Psychological' influencer has proven to be an Achilles heel when discussing radioactive waste management and spent fuel disposal

[10] A person or expression having a "significant impact or serves as an inspiration": *Morgan, S. (2018). Influencers. The Missouri Review, 41(4), 5–10*; A platform, whose policy perspective, has a lobbying network to feed information back to the central system, *Luca, D., & ProQuest. (2020). Mapping the Influencers in EU Policies. Cham, Switzerland: Palgrave Macmillan*; "Blessed are the influencers for they will make a true difference - through policy, vision, drive, innovation and ideas - in the course of information": *Anonymous. (2014). THE INFLUENCERS. SC Magazine, 25(12), 20–23*; Having the ability to make notable contributions to an industry and to help the industry evolve: *Alison Cooke Mintzer. (2013). The Influencers. Plan Sponsor, N/a*; A sphere of influence that exerts a transformative effect over an extended period of time: *The influencers. (2019). International Financial Law Review, International Financial Law Review, Jun 26, 2019*; "influencers gather information, educate … about critical issues and try to secure the best outcome": *Pike, K. (2017). The influencers. Independent Banker, 67(5), 26–29.*

[11] "signifying practices are forms of communication": *Communication. (2011). Dictionary of Visual Discourse: A Dialectical Lexicon of Terms*; "face-to-face communication requires knowledge of how the task structure and the social context affect … patterns": *Hessels, R., Holleman, G., Kingstone, A., Hooge, I., & Kemner, C. (2019). Gaze allocation in face-to-face communication is affected primarily by task structure and social context, not stimulus-driven factors. Cognition, 184, 28–43*; "decision-makers are best served with the highest-quality (scientifically sound, unbiased and reliable), timely and policy-relevant information": *European Foundation for the Improvement of Living Working Conditions. (2013). Communication strategy. Luxembourg: Publications Office*; The most effective communication strategy is one which develops a person's or groups' awareness of environmental issues based on the values they believe in: *Maryani, E., & Darmastuti, R. (2017). The 'Bakul Gendong' as a communication strategy to reject the construction of a cement factory in Central Java. Public Relations Review, 43(1), 46–55*; A communication strategy may "employ person-to-person contacts and attempts to reach mass audiences through print, broadcast, and electronic media. Coordinating these various efforts is critical to the short- and long-term success …": *United States. Government Accountability Office. (2005). U.S. public diplomacy interagency coordination efforts hampered by the lack of a national communication strategy: Report to the Chairman, Subcommittee on Science, State, Justice, and Commerce, and Related Agencies, Committee on Appropriations, House of Representatives. Washington, D.C.]: U.S. Government Accountability Office.*

strategies. These emotional decision-making[12] processes should be "driven by rational calculations involving an analysis of costs and benefits, [but often] are driven by gut feelings" *(May, 2017)*. This can make it difficult to devise a stratagem to reach each individual of the target audience when devising consent-based processes. However, other studies demonstrate there is something to be gained in engaging the public in joint-decision-making. Studies show collaborative initiatives bring a "sense of control, stronger feelings of achievement and happiness, and a reduced sense of regret" *(Xin Wang et al., 2017)*.

Another factor to consider with emotional decision-making processes is the cultural heritage of a particular group connecting a people to the land. For instance, native people may have a different emotional attachment to the land, than other individuals possess. Canada's Nuclear Waste Management Organization's (NWMO) Adaptive Phased Management Plan recognizes this pillar's value by establishing processes "that respect and honor Indigenous people's culture and their unique status and rights[13]" *(Sanders M & C, 2020)*.

Behavioral decision-making[14] consists of internally utilized transactions to evaluate information, and then reconciling potential consequences for a chosen choice. These are interpretive processes where bias and information conflict, and where one must choose between possible gains and risk *(Schwartz et al., 2011)*. Though humans engage in varied minor and major behavioral decision-making constantly throughout the course of a day, it is not inferred that "this contemplation is always or completely reasoned […] nor is it to say that everyone is equally adept at such choice making" *(Paternoster and Pogarsky, 2009)*.

Our conflicting "rational" and "irrational" fears constitute a vital component to these behavioral decision-making transactions. At times, nuclear science practitioners can show disdain for the publics' seemingly irrational radiation phobias and/or mis-informed biases. Consider the following statement posed to the authors in Western Pennsylvania during the 2011 Fukushima event:

> "I am nervous living near a nuclear power plant. Should there be an incident [at Beaver Valley Nuclear Power Plant], I am concerned how I will be able to evacuate my family because radiation can get into a car's engine and cause it to stop working." (Name withheld, female, age 40–50)

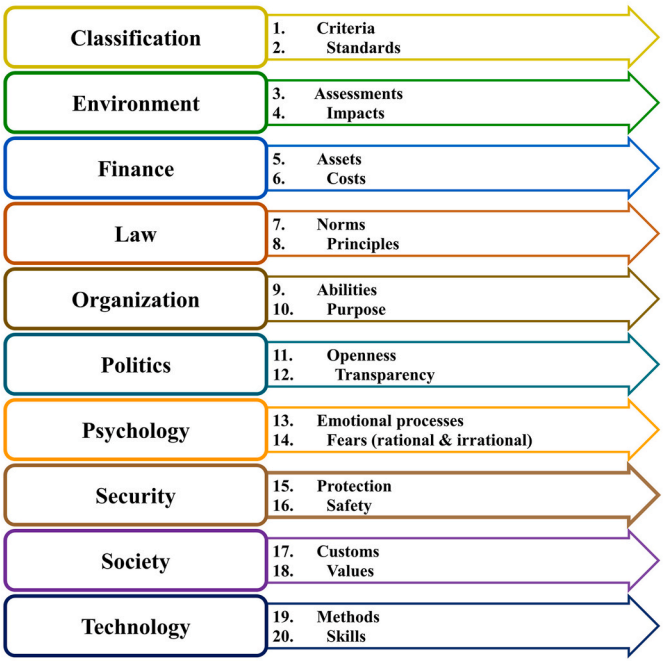

Fig. 3. The twenty pillars structuring the radioactive waste management influencers.

Within the statement exist both rational and irrational contexts, which must be adequately addressed. These are exhibited in Fig. 4. How one develops a strategy to respond to these rational and irrational anxieties is central to solving the radioactive waste management and spent fuel disposal challenge, so public consent is obtained. Resolving anxieties by the general public requires a listening attitude and an ability to display empathy. The factual response must comingle with the listening attitude and empathy expressed for the particular situation.

2.2. Consent, science and radioactive waste management

Current practice for siting an interim storage facility or deep geological repository has moved toward a hybrid consent/science-based siting model, as laid out in Fig. 5. Historically, the prevailing wisdom for

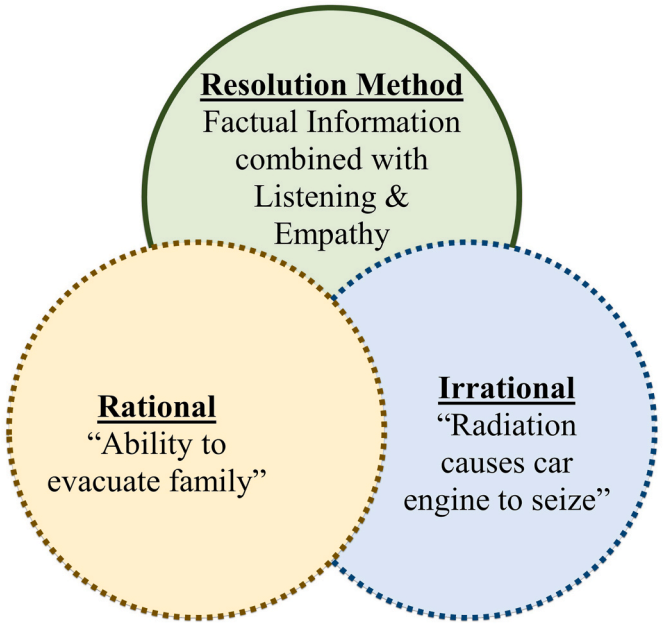

Fig. 4. Rational and irrational resolution paradigm.

[12] *Also see:* ***Ananya, A.*** *(2019) 'Psychological factors affecting economic decision making: An understanding of emotional and motivational factors in lay terms', Indian Journal of Health & Wellbeing, 10(10–12), pp. 373–376. (Accessed: 4 February 2020);* ***Takagishi, H. et al.*** *(2014) 'The Role of Cognitive and Emotional Perspective Taking in Economic Decision Making in the Ultimatum Game', PLoS ONE, 9(9), pp. 1–7.* https://doi.org/10.1371/journal.pone.0108462*;* ***Sarlo, M. et al.*** *(2012) 'Temporal Dynamics of Cognitive–Emotional Interplay in Moral Decision-making', Journal of Cognitive Neuroscience, 24(4), pp. 1018–1029. doi: 10.1162/jocn_a_00146.*

[13] Recognized and affirmed in section 35 of the Constitution Act (1982): see https://laws-lois.justice.gc.ca/eng/const/page-16.html#h-52, Accessed February 04, 2020.

[14] Individuals reach decision in two layers – "First they review fundamental options, then examine details of one or a few of the options chosen": *Etzioni, A. (1985) 'Guidance Rules and Rational Decision Making', Social Science Quarterly (University of Texas Press), 66(4), pp. 755–769. (Accessed: 4 February 2020)*; "If information is not available upon which to base such a decision … [the] task is a confusing one … which does not permit the [individual] a rational choice": *Friedman, M. P. (1967) 'Quality and Price Considerations in Rational Consumer Decision Making', Journal of Consumer Affairs, 1(1), p. 13.* https://doi.org/10.1111/j.1745-6606.1967.tb00790.*x*; "Grounding our policy choices in the best available knowledge will advance the interests of society most effectively": *Higgins, P. A. T. (2008) 'SCIENCE IN THE POLICY PROCESS: Rational Decision-Making or Faustian Bargain?', Bulletin of the American Meteorological Society, 89 (5), pp. 688–690. (Accessed: 4 February 2020)*; "advocacy, politics, and sound bites seem to override sound science, rational discourse and clear decision-making": *Jordan, M. (1996) 'Facts and rational decision-making', Vital Speeches of the Day, 63(3), p. 77. (Accessed: 4 February 2020).*

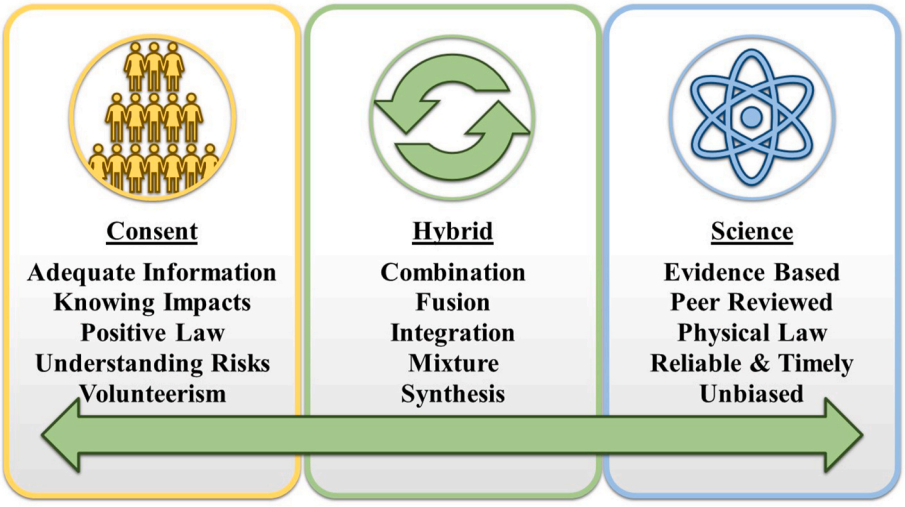

Fig. 5. Radioactive waste management hybrid model.

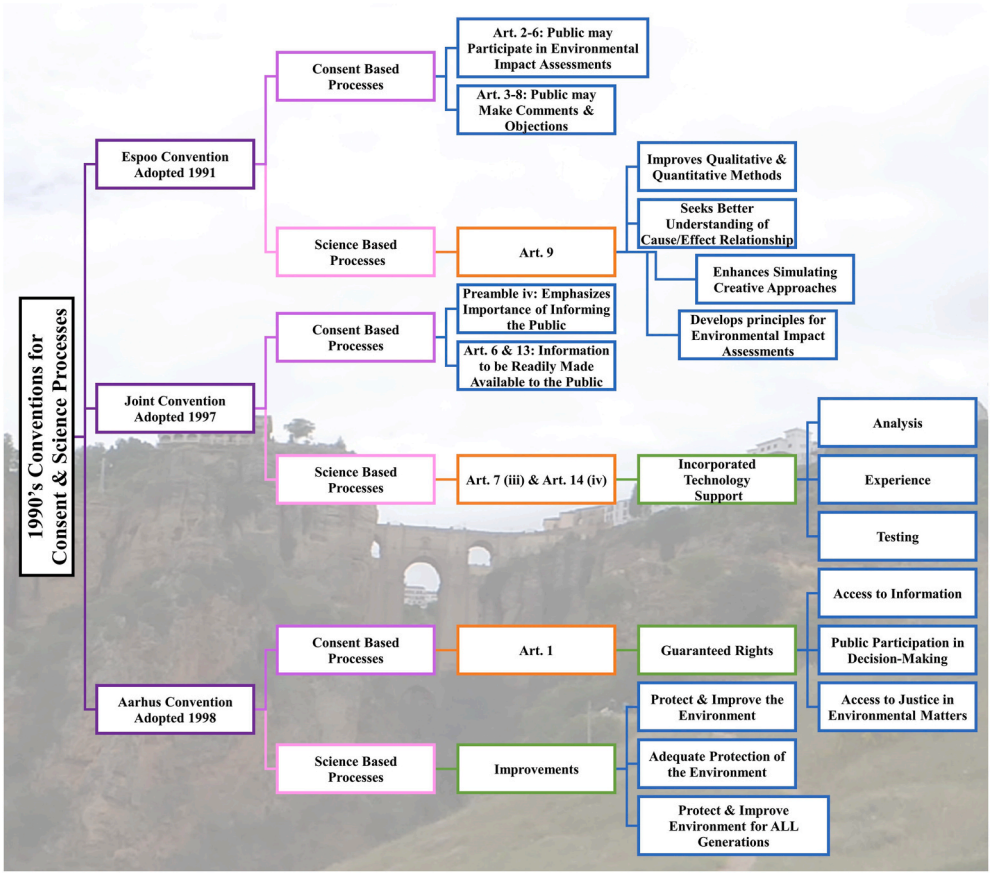

Fig. 6. 1990's conventions emphasizing consent and science processes.

conducting radioactive waste management and spent fuel repository siting was to focus on the science and drag the public along for the ride. It was thought that making a clear and overwhelming science argument would be sufficient to overrule public objections to repository siting. However, there is - and has been - a shift from a more traditional "decide, announce and defend" model, focused on technical assurance, to one of "engage, interact and co-operate" which is demonstrated is Figs. 7 and 8 (*Pescatore and Vari, 2003*). Evidence from the Swedish and Finnish geological repository siting programs for high-level waste – with an emphasis on public participation - suggests that using a science-focused-based program is deficient.

In the last decade, numerous countries have begun to focus on 'consent-science-based' processes for the siting of a deep geological repository (e.g., France, Germany, United Kingdom). The new word of the

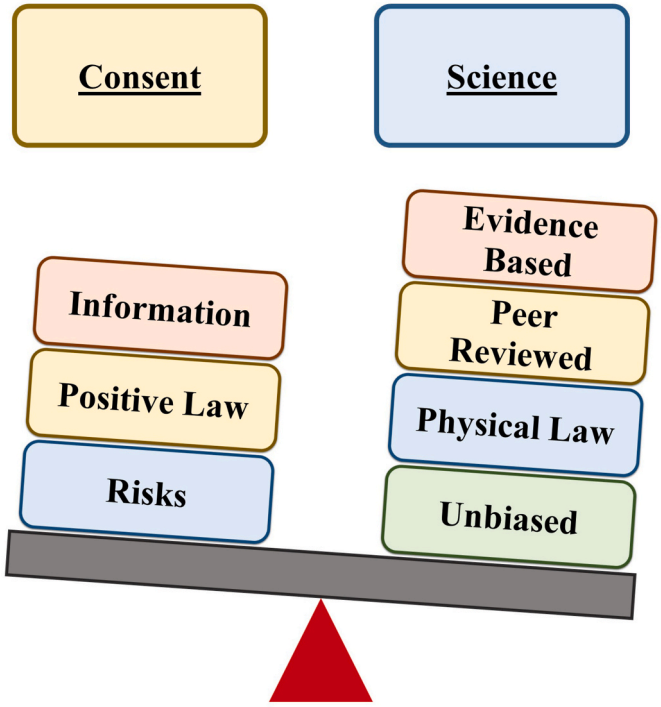

Fig. 7. Pre-1990's public policy consent/science model.

day for moving forward with repository siting is 'volunteerism', as "consent,[15] whether express or tacit, must be fully voluntary in order to bind" (*Sartorius, 1981*). Professor Richard Flathman states consent is a play in three acts:

Act 1: Having mentally digested the information provided in the prologue, the informed individual understands what he/she consents to.

Act 2: The individual is emotionally attached to the question, and its outcome. Therefore, the individual "intend[s] to consent to it".

Act 3: The individual communicates his/her desire to consent, with his/her motion to consent transmitted via the established method (*Flathman, 1972*).

The challenge in Act 3 is the established method for the affected group, or groups of persons, to communicate their consent for siting a repository. What method does one use to ascertain consent? Does one use a referendum, polling, or public meetings, etc.? It is difficult to absorb the entire community on these issues and for gauging consent. Therefore, other academics would argue - given the murkiness of these issues - it is better to "focus instead on … promoting … basic interests" (*Wright, 2019*).

In the 1990's, the international community came together in various capacities to enhance both substantive and qualitative use of both scientific methods and public participation for matters of environmental concern affecting the greater community and of a potential transboundary nature. Language on both topics was enhanced through treaty obligation - Espoo Convention,[16] Joint Convention,[17] and Aarhus Convention[18] (see Fig. 6). Through language, the international community sought to align responsibility to protect and preserve the environment from potentially harmful activities within their jurisdiction which could have a detrimental impact to neighboring countries in consultation between States (*M.C. & C.E. Sanders, 2019*).

It is quite evident when considering the forward-thinking conventions from the 1990's - promoting protection of the environment and incorporating public participation into sustainability models - this decade marks a major shift in public policy goals. Especially, the Aarhus Convention is a red-letter international legal step ensuring public participation, and thereby consent, is obtained for noteworthy proposed activities having a significant effect on the environment, including nuclear projects.[19] This dramatic public policy shift in international thinking is highlighted in Figs. 7 and 8, [20].

3. Country specific radioactive waste management and spent fuel disposal programs

Radioactive waste management[21] is based on internationally

[15] "consent of the governed is [the] fundamental … source of the legitimacy of the state and its authority": *Somin, I. (2000). Revitalizing consent. Harvard Journal of Law & Public Policy 23(3), 753–806*; "one man [can] not dominate another through governmental control absent consent because we are all equally members of the human race": *(1998). Original consent. Washington State Bar News, 52(2), 41-[ii]*; "consent of the governed is (at least) a logically necessary condition of political obligation and authority": *Beran, H. (1977). Political authority & (and) consent. Bulletin of the Australian Society of Legal Philosophy, 1977(2), 1–5*; "Governments … deriv[e] their just powers from the consent of the governed": *The Declaration of Independence para. 2 (U.S. 1776)*; "the State, i. e. civil or political society, is not a mere aggregation of human beings in pursuit of some common aim, but that it is a moral entity, having a natural and organic growth and continuity": *Briggs, E. B. (1901). Sovereignty, and the consent of the governed. American Law Review, 35(1), 49–55.*

[16] Date of Adoption: 1991 and entered into force on 10 September 1997; CONVENTION ON ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT, https://www.unece.org/environmental-policy/conventions/environmental-assessment/about-us/espoo-convention/enveiaeia/more.html, Accessed February 9, 2020.

[17] Date of Adoption: September 5, 1997 and entered into force, June 18, 2001; JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT, https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste, Accessed February 9, 2020.

[18] Date of Adoption: June 25, 1998 and entered into force, October 30, 2001; Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, https://ec.europa.eu/environment/aarhus/, Accessed February 9, 2020.

[19] See Article 6, 1, (a) and references to Annex I, *CONVENTION ON ACCESS TO INFORMATION, PUBLIC PARTICIPATION IN DECISION-MAKING AND ACCESS TO JUSTICE IN ENVIRONMENTAL MATTERS*, https://ec.europa.eu/environment/aarhus/, Accessed February 6, 2020.

[20] See *Bergmans, A., Sundqvist, G., Kos, D., & Simmons, P. (2015). The participatory turn in radioactive waste management: Deliberation and the social-technical divide. Journal of Risk Research, 18(3), 347–363.* The Authors find that from the 1990's "National policies for long-term management of radioactive waste … [have turned to a] more participatory approach".

[21] "has long been treated by policy makers as a technical and industrial process": *Cotton, M. (2018) 'Environmental Justice as Scalar Parity: Lessons From Nuclear Waste Management', Social Justice Research, 31(3), pp. 238–259. doi: 10.1007/s11211-018-0311-z*; Includes a "program of data management and digital preservation activities": *Pinnick, J.* et al. *(2018) 'A Case Study: Management and Exploitation of the Nuclear Decommissioning Agency Geoscience Data Archive', New Review of Information Networking, 23(1/2), pp. 99–110.* https://doi.org/10.1080/13614576.2018.*1544089*; Are those actions undertaken to protect people and the environment by [ultimately] placing "used nuclear fuel [and other high-level waste] within a deep geological repository in a suitable host rock formation": *Kremer, E. P. (2017) 'Durability of the Canadian used fuel container', Corrosion Engineering, Science & Technology, 52, pp. 173–177.* https://doi.org/10.1080/1478422X.2017.*1330024*; Activities for managing radioactive waste involve the use of purpose built "deep geological repositories (*e.g.*, repository for high-level waste, repository for low- and intermediate-level waste, combined repository): *'Radioactive waste management' (2018) Nuclear Law Bulletin, (101), p. 88*; United Kingdom "government policy indicates that geological disposal is the preferred option for the long-term management of radioactive wastes": *Padovani, C. (2014) 'Overview of UK research on the durability of container materials for radioactive wastes', Corrosion Engineering, Science & Technology, 49(6), pp. 402–409*; The management of generated radioactive waste "was not considered to be consequential [during the initial] development of civilian nuclear energy": *Nowlin, M. C. (2016) 'Policy Change, Policy Feedback, and Interest Mobilization: The Politics of Nuclear Waste Management', Review of Policy Research, 33(1), pp. 51–70.*

recognized principles[22] and standards[23] to protect people and the environment (*Maringer* et al., *2013*). It involves using various long-established methods, including spent fuel reprocessing,[24] recycling[25] or re-use,[26] and disposal[27] of spent nuclear fuel and other radioactive wastes created through "power generation, defense uses, and other activities" (*Sanders M & C, 2016*). The storage and disposal of spent nuclear fuel and other high-level, long-lived radioactive wastes require disposal in a deep geological repository with passive safety systems for thousands of years (*Schröder* et al., *2016*). The Nuclear Energy Agency[28] confirmed in 1999 there is increased confidence among experts "in the short- and long-term

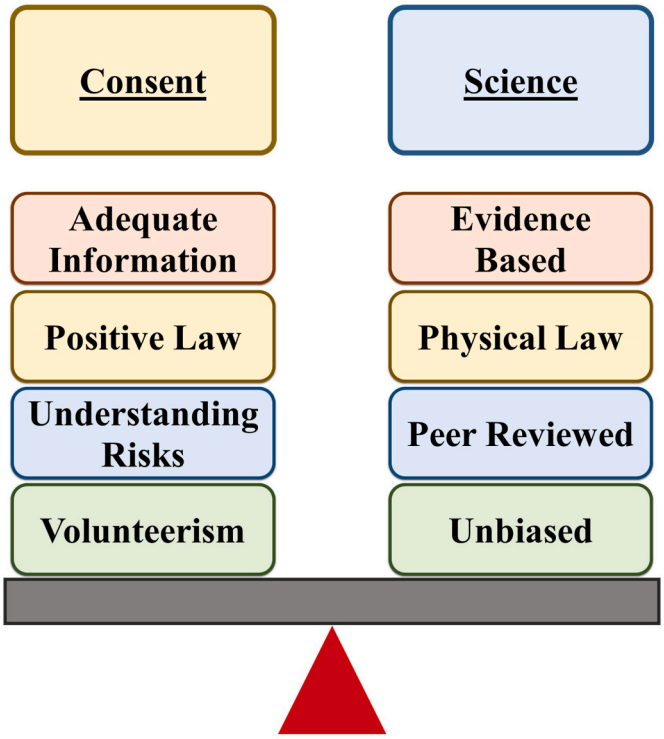

Fig. 8. Post-1990's public policy consent/science model.

safety of the geologic disposal[29] option … [including] several technical and licensing reviews of safety assessment studies of deep repository systems" (*OECD, 1999*).

Low-level (LLW) and intermediate level (ILW) waste accounts for the majority of generated radioactive waste, which can be disposed of in near surface or sub-surface facilities (depending on type of waste). Methods for managing dry LLW include volume reduction, involving compaction and/or incineration (*Tsoulfanidis, 2018*). To enable waste forms to be more safely and conveniently handled, waste immobilization techniques are employed to "convert raw waste, usually containing mobile contaminants, into a solid and stable form" (*Ojovan and William, 2013*). Immobilization technologies for radioactive waste disposal include cementation[30], bituminization, and vitrification. In the case of treatment of high-level wastes, vitrification is currently the most widely used technology (*Jantzen et al., 2013*). The minimization of radioactive waste is also a key component to successfully managing waste streams during the design (minimization at source), operation and decommissioning stages of facilities. Recycling and reuse of slightly contaminated materials, along with the reprocessing of spent nuclear fuel, emphasize the circular economic pathways contained within the nuclear fuel cycle. Additionally, materials can be safely released from regulatory control once so determined through proper procedures and processes (*International Atomic Energy Agency, 2009*).

Regarding the management of high-level waste and spent nuclear

[22] "management of radioactive wastes is governed by very specific legislation that draws on both the law on "conventional" waste management and nuclear law": *Vial, E. (2004) 'The Concept of Responsibility to Future Generations for the Management and Storage of Radioactive Waste', Nuclear Law Bulletin, (74), pp. 15–25.*

[23] "Safe disposal of radioactive waste is required in all countries using nuclear power, radioactive materials in medicine and in industry or research": *Bracke, G. (2012) 'Aspects of Final Disposal of Radioactive Waste in Germany', Turkish Journal of Earth Sciences, 21(1), pp. 145–152.*

[24] "Reprocessing of spent fuel is … considered an alternative to the waste problem": *Borges Silverio, L., & Lamas, W. (2011). An analysis of development and research on spent nuclear fuel reprocessing. Energy Policy, 39(1), 281–289*; Conserving resources and fuel availability [will be] a significant consideration the private [nuclear] industry: *Culler, F., & U.S. Atomic Energy Commission. (1957). An analysis of power reactor fuel reprocessing (ORNL; 2265 (del.)). Oakridge, TN: Oakridge National Laboratory*; "spent fuel reprocessing [may be] economically and politically important [as nations struggle with] the significant problem of nuclear fuel storage": *Roh, S., & Kim, W. (2014). How can Korea secure uranium enrichment and spent fuel reprocessing rights? Energy Policy, 68, 195–198*; "nuclear fuel reprocessing does have great potential": *Simpson, Michael F. (2013). Nuclear fuel reprocessing technologies and commercialization. Science and Technology of Nuclear Installations, Science and Technology of Nuclear Installations, Annual, 2013*; The "nuclear spent fuel reprocessing industry … require[s] new standards and methods": *Validation of analytical methods for nuclear spent fuel reprocessing. (2014). Progress in Nuclear Energy, 72, 115.*

[25] "Objectives include reducing radioactive waste disposed in a geologic repository": *United States. Government Accountability Office. (2008). Global Nuclear Energy Partnership DOE should reassess its approach to designing and building spent nuclear fuel recycling facilities: Report to Congressional committees. Washington, D. C.]: U.S. Govt. Accountability Office*; Recycling means to reduce waste and conserve resources. In the nuclear world, the term can be used interchangeably with the term reprocessing: *Alley, William M., and Rosemarie Alley. Too Hot to Touch: The Problem of High-Level Nuclear Waste, Cambridge University Press, 2012. ProQuest Ebook Central.* However, here, the term is referring to the reuse of previously contaminated materials into a new material form (*e.g.*, steel that is decontaminated, melted, and formed into a new useable object – not spent nuclear fuel).

[26] Decontamination allows for the removal of contaminated materials stuck on an item (*e.g.*, tools, instruments) with the object of reusing: *Ojovan, MI, & Lee, WE 2013, An Introduction to Nuclear Waste Immobilization, Elsevier, Oxford. Available from: ProQuest Ebook Central. [9 February 2020].*

[27] "Long-term storage and burial are the most important stages of managing radioactive wastes with respect to long-term safety": *Kulagina, T. A., Kulagin, V. A. and Popkov, V. A. (2018) 'Environmental Effects of Cavitation Technology for Radioactive Waste Management', Chemical & Petroleum Engineering, 53(11/12), pp. 738–744. doi: 10.1007/s10556-018-0414-2*; "Nuclear waste disposal has for many years been recognized as one that is as much political as technical": *Carter, L. J. (1985) 'Report on Reports- Social and Economic Aspects of Radioactive Waste Disposal: Considerations for Institutional Management', Environment, 27(2), pp. 25–28.*

[28] Originally established as the European Nuclear Energy Agency (ENEA) in February 1958, and its named changed to the Nuclear Energy Agency (NEA) in 1972. For more information, see: 'History of the OECD Nuclear Energy Agency', https://www.oecd-nea.org/general/history/, Accessed February 9, 2020.

[29] "expert panels have repeatedly determined that geologic disposal is necessary": *Krall, L. and Macfarlane, A. (2018) 'Burning waste or playing with fire? Waste management considerations for non-traditional reactors', Bulletin of the Atomic Scientists, 74(5), pp. 326–334.* https://doi.org/10.1080/00963402.2018.*1507791*.

[30] For an expanded view on this topic, the reader is referred to Chapters 15–17, Ojovan, M., & Lee, W. (2013). An Introduction to Nuclear Waste Immobilization (2nd ed., Elsevier insights An introduction to nuclear waste immobilization). Burlington: Elsevier Science.

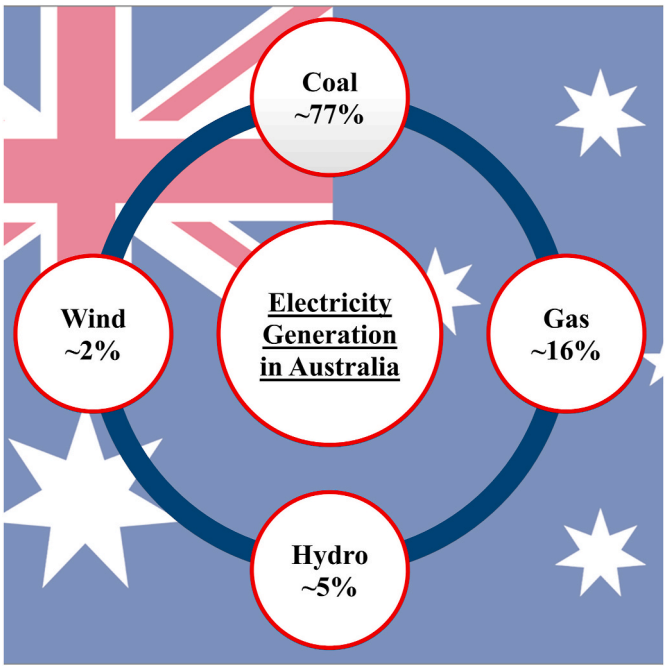

Fig. 9. Australia's electricity generation sources.

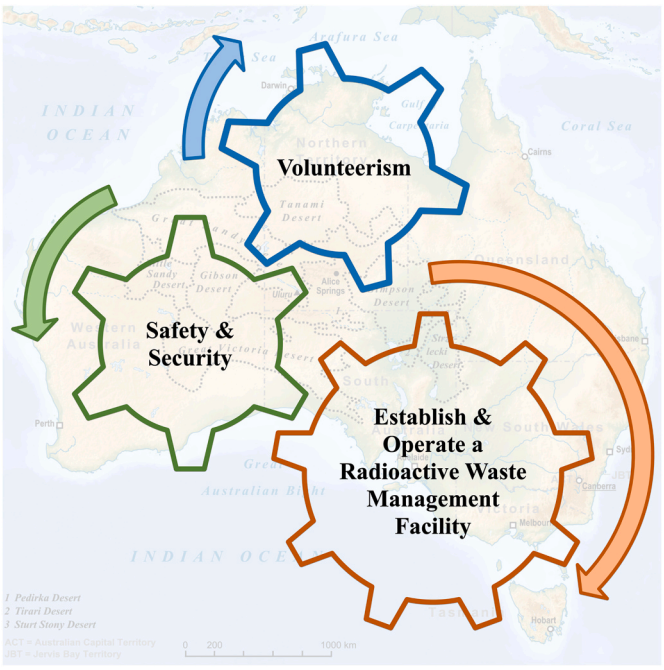

Fig. 10. 2012 Act's three core objectives.

fuel, countries are at different stages of progression in finalizing a repository. Sweden[31] and Finland have actively advanced programs, with Finland expecting to begin operating a high-level waste deep geological repository sometime during the 2020's.[32] Other countries are in the beginning stages for siting a repository (e.g., United Kingdom[33]), or restarting anew with the siting process (e.g., Germany[34]). Others still look rather asleep at the wheel (e.g., United States of America[35]). While each country is using different approaches to engage stakeholders[36] in the siting process, similarities and differences among these programs can assist in devising updated strategies for resolving key concerns shared among nations (*OECD, 2000*). In this, the third part in this series of review papers, a review of radioactive waste management and spent fuel disposal programs in Australia, Belgium, Czech Republic, Netherlands,

[31] See Svensk Kärnbränslehantering AB, 'How Forsmark was selected', https://www.skb.com/future-projects/the-spent-fuel-repository/how-forsmark-was-selected/, Accessed February 9, 2020.

[32] See 'General Time Schedule for Final Disposal', http://www.posiva.fi/en/final_disposal/general_time_schedule_for_final_disposal; Accessed February 9, 2020.

[33] See Vaugham, A., The Guardian, 'Search restarts for area willing to host highly radioactive UK waste': https://www.theguardian.com/environment/2018/jan/21/search-area-willing-host-highly-radioactive-waste-uk-geology, Accessed February 9, 2020; Also see, World Nuclear News, 'UK completes first steps in Geological Disposal Programme', July 02, 2019, https://world-nuclear-news.org/Articles/UK-completes-first-steps-in-Geological-Disposal-Pr, Accessed February 9, 2020.

[34] Repository Site Selection Act of 23 July 2013 (Federal Law Gazette I, p. 2553), For Text of the Act in German, see: Gesetz zur Suche und Auswahl eines Standortes für ein Endlager für hochradioaktive Abfälle (Standortauswahlgesetz - StandAG) http://www.gesetze-im-internet.de/standag_2017/BJNR107410017.html#BJNR107410017BJNG000100000, Accessed February 9, 2020.

[35] The Yucca Mountain Project was put to bed in 2010 by the Obama administration, when funding was halted for the licensing process: *MEEHAN, K. (2017) 'Waste No One Wants', State Legislatures, 43(5), pp. 18–21*; A House spending bill for the Department of Energy slashed funds to revive the licensing process in 2019: *Martin, G., Las Vegas Review Journal, 'House bill guts funding for Yucca Mountain nuclear waste site',* https://www.reviewjournal.com/news/politics-and-government/house-bill-guts-funding-for-yucca-mountain-nuclear-waste-site-1663361/, *Accessed February 9, 2020*; In February 2020, then President Trump signaled that he now "opposes the long-delayed Yucca Mountain nuclear waste repository": *Gardner, J., Reuters, 'Trump halts support for Yucca Mountain, Nevada nuclear waste dump',* https://www.reuters.com/article/us-usa-trump-nuclearpower-yucca/trump-halts-support-for-yucca-mountain-nevada-nuclear-waste-dump-idUSKBN20101J, *Accessed February 9, 2020.*

[36] "A stakeholder is a person or other actor with special concern and interest in an issue": *Sjöberg, L. (2003). Attitudes and Risk Perceptions of Stakeholders in a Nuclear Waste Siting Issue. Risk Analysis, 23(4), 739–749*; "One who has an interest or share in land, property, treaty rights, or other aspects of a decision": *Burger J. (2011) Introduction: Stakeholders and Science. In: Burger J. (eds) Stakeholders and Scientists. Springer, New York, NY*; "Stakeholder theory provides concepts and frameworks for identifying, classifying, and categorizing stakeholders": *Aaltonen, K., Kujala, J., Havela, L., & Savage, G. (2015). Stakeholder Dynamics During the Project Front-End: The Case of Nuclear Waste Repository Projects. Project Management Journal, 46(6), 15–41*; "It is customary in the course of infrastructure projects such as deep geological repositories to involve all the relevant parties": *'Radioactive waste management' (2019) Nuclear Law Bulletin, (102), pp. 101–102;*; "Public trust is based both on track record and on perceived morality and values": *Lopez, C. R. and Pescatore, C. (2003) 'A new profile for regulators in radioactive waste management', NEA News, 21(2), pp. 15–17*; "Cooperative behavior between an organization and its stakeholders is maximized when relational partners share both core values and strategic priorities": *Bundy, J., Vogel, R., & Zachary, M. (2018). Organization–stakeholder fit: A dynamic theory of cooperation, compromise, and conflict between an organization and its stakeholders. Strategic Management Journal, 39(2), 476–501*; "participatory modeling provides a platform for integrating scientific knowledge with local knowledge": *Voinov A., Gaddis E.B. (2017) Values in Participatory Modeling: Theory and Practice. In: Gray S., Paolisso M., Jordan R., Gray S. (eds) Environmental Modeling with Stakeholders. Springer, Cham*; See also: *Martell, M., & Ferraro, G. (2014). Radioactive waste management stakeholders map in the European Union corrigendum: Report May 2014. (EUR (Luxembourg. Online), 26692). Luxembourg: Publications Office.*

and Romania is provided. Departing from past precedent, these countries are grouped in alphabetical order, instead of geographic location.

3.1. Australia - officially the commonwealth of Australia

Quick Facts – Australia (*Nuclear Power in Australia*).

1. Australia has no operating nuclear power generating plants.
2. Australia has access to the largest known uranium reserves, with three currently operating mines.
3. Australia plays an active role in the nuclear fuel cycle, as all its mined uranium is exported.

3.1.1. Historical overview & law

In 1788, eleven ships arrived at Botany Bay with the first European settlers.[37] Thus, began the European history of what is called Australia[38] (*Atkinson, 1997*). However, a hunter-gatherer society (the Aborigines) was long established on the continent (*Hirst, 2014*). Australia enjoys laying claim to being "one of the oldest, most stable, and most inventive parliamentary and social democracies" (*Wright, C., 2014*), and is able to boast voting into power one of the world's first social-democrat led governments. Bonnell and Crotty argue, however, that especially on the conservative side of government, there has been for some time an emphasis on the "affirming stories of the rise of a new, democratic nation" and an active attempt to downplay "the historical harm done to Indigenous Australians" (*Bonnell and Crotty, 2008*). As part of the British Empire, Australia played an active role in both World Wars[39] that took place during the previous century.

Australia does not currently have operating nuclear power plants due to restrictive laws. There are discussions on a number of fronts to determine whether nuclear power might be right for Australia[40], given the country's overreliance of fossil fuels to generate electricity and its international obligations for fighting climate change.[41] As shown in Fig. 9 (information from *Geoscience Australia, 2020*), Australia's dominate source of fuel used to generate electricity is coal.

Should Australia choose to seriously pursue nuclear power, the

[37] The Bass Strait region was colonized by the British only a decade later: *Boyce, J 2013, 1835: The Founding of Melbourne & the Conquest of Australia, Schwartz Publishing Pty. Ltd, Melbourne*; "The arrival of the First Fleet heralded monumental and often catastrophic changes to the lives of the indigenous peoples": *Turbet, P 2002, First Frontier: The Occupation of the Sydney Region 1788–1816, Rosenberg Publishing, Dural, NSW*; Colonization of Australia entered a new phase during the post-World War II years as "suburbanization [became] the expression of a property owning democracy": *Davison, G. (1995) 'Australia: The First Suburban Nation?', Journal of Urban History, 22(1), pp. 40–74*; "land bridges—like those connecting Australia with parts of South East Asia—made possible migration into the Australian continent approximately 55,000 to 60,000 years ago": *'Gorman, E., Beattie, J., & Henry, M. (2016). Histories of climate, science, and colonization in Australia and New Zealand, 1800–1945. Wiley Interdisciplinary Reviews: Climate Change, 7(6), 893–909*; "Western Australia was founded as Australia's first free colony in June 1829": *Bush, F. (2012). The Convicts' Contribution to the Built Environment of Colonial Western Australia between 1850-1880*.

[38] "Australia … [was] reach[ed] by *H. sapiens* entirely through the tropical world": *Bellwood, P 2013, First Migrants: Ancient Migration in Global Perspective, John Wiley & Sons, Incorporated, Somerset*; The settler's attitudes toward the native societies were much the same as in the United States, especially during the age of 'Manifest Destiny' during the 1840's – 1860's. The attitude found expression in practices that the settlers were entitled to the land*; Barber, Judith. (1999). 'Concerning our national honour': Florence Nightingale and the welfare of Aboriginal Australians, Collegian, 6(1), 36–39*; International law began to develop in the 16th century from "recognition of the relationship between Indigenous peoples and European colonists", *Mazel, O. (2009). The evolution of rights: Indigenous peoples and international law. Australian Indigenous Law Review, 13(1), 140–158*; The great impact of European settlement and Aboriginal policies of the 19th and early 20th centuries are seen through the lens of the Kuwarra Aboriginal people – "They have lost their land, their original ritual life, and much of their language": *Liberman, K. (1980). The Decline of the Kuwarra People of Australia's Western Desert: A Case Study of Legally Secured Domination. Ethnohistory, 27(2), 119–133*; In 1988, at the time of Australia's 200th Birthday celebration, it was remarked that "Australia's native people, who now constitute only 1.4% of the 16.5 million population, have been mired in poverty and neglect": *Tifft, S. and Dunn, J. (1988) 'AUSTRALIA Doing Their Forefathers Proud But a 200th birthday bash is clouded by the aborigines' plight', TIME Magazine, 131 (6), p. 46*; "It is estimated that 70 per cent of the world's uranium is located on, or adjacent to, the lands of First Peoples": *Graetz, G. (2015). Energy for whom? Uranium mining, Indigenous people, and navigating risk and rights in Australia. Energy Research & Social Science, 8, 113–126*.

[39] During World War I, Australia suffered 61,514 casualties, 153,500 wounded or gassed service personnel, with 3600 taken prisoner. In total, over 330,000 men and women served overseas: *Beaumont, J. (2014). Broken nation: Australians in the Great War. Crows Nest, NSW: Allen & Unwin*; In 1926 the Repatriation Department estimated that some 20,000 ex-servicemen had died from their war wounds, while in 1937 it was asserted that the number surpassed the 60,000 mark. While the Great War ended in 1918, this did not mark the end of war related deaths, *Larsson, Marina. (2009). A disenfranchised grief: Post-war death and memorialisation in Australia after the First World War. Australian Historical Studies, 40(1), 79–95*; During World War II, the Australian and American forces fought long and difficult vital campaigns in New Guinea and the Solomon Islands from early 1942 through the end of the war: *Dean, & Dean, Peter J. (2013). Australia 1942 in the shadow of war. Cambridge: Cambridge University Press*.

[40] A 2010 national survey showed that 42% of respondents (a majority) would be willing to accept nuclear power if it would help tackle climate change. Following Fukushima, 40% were not willing to accept nuclear power to tackle climate change. However, in a academic article, Bird, et. al., notes that "Reluctant acceptance of nuclear power is a fragile attitudinal state easily swayed": *Bird, D., Haynes, K., Van den Honert, R., McAneney, J., & Poortinga, W. (2014). Nuclear power in Australia: A comparative analysis of public opinion regarding climate change and the Fukushima disaster. Energy Policy, 65, 644*; "the next generation of nuclear power plants offer [Australia] the potential for improved sustainability, financial performance, proliferation resistance, safety and reliability" in pursing nuclear power generation: *Owen, A. (2011). The economic viability of nuclear power in a fossil-fuel-rich country: Australia. Energy Policy, 39(3), 1305–1311*; "Australia is set to reopen debate on expanding its nuclear power industry": *Finkel, Elizabeth. (2006). Australia weighs nuclear power. (SCIENCE SCOPE). Science, 312(5779), 1455*; "The South Australian Nuclear Fuel Cycle Royal Commission [undertook] 'an independent and comprehensive investigation into the potential for increasing South Australia's participation in the nuclear fuel cycle": *Diesendorf, M. (2016). Shunning nuclear power but not its waste: Assessing the risks of Australia becoming the world's nuclear wasteland. Energy Research & Social Science, 19, 142–147*.

[41] "nuclear power, along with some renewable penetration, can reduce greenhouse-gas emissions to the level required to meet [Australia's] climate change-mitigation goals, for the lowest relative cost": *Hong, S., Bradshaw, C., & Brook, B. (2014). Nuclear power can reduce emissions and maintain a strong economy: Rating Australia's optimal future electricity-generation mix by technologies and policies. Applied Energy, 136, 712*; "There has been no improvement in Australia's climate policy since 2017": *Goodman, J. BBC News,* https://www.bbc.com/news/world-australia-50869565*, Accessed February 10, 2020*; See also Morton, A., 'The Guardian, Coal from six biggest miners in Australia produces more emissions than entire economy'*:* https://www.theguardian.com/australia-news/2019/nov/01/six-biggest-coalminers-in-australia-produce-more-emissions-than-entire-economy*, Accessed February 10, 2020*; In 2016, the country's new science minister ordered the nation's premier science agency to "put the focus back on climate science": *Dayton, L. (2016). Australia's new government makes an about-face on climate research. Science, Science, 08/05/2016*.

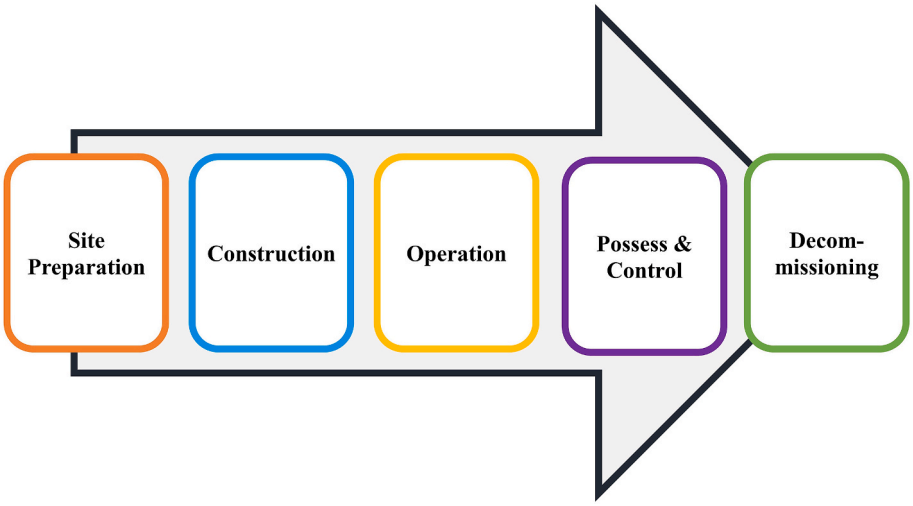

Fig. 11. Arpansa stages of licensing for a nuclear facility.

country has access to vast resources of uranium deposits,[42] including mining activities at a few sites. Furthermore, Australian Nuclear Science & Technology Organization (ANSTO) owns and operates a modern 20 MWt Opal research reactor. Additionally, the Australian Safeguards & Non-proliferation Office[43] (ASNO) and the Australian Radiation Protection and Nuclear Safety Agency[44] (ARPANSA) are considered to be modern world class organizations. Therefore, the country already has access to the technologies and expertise required. Australia has previously dabbled with nuclear power. In the late 1960's, the Jervis Bay Nuclear Power Plant was proposed to be built on the coast of New South Wales. Two rounds of tenders were evaluated, but the government decided not to proceed with the project *(Healey, 2014a)*.

3.1.2. Government & legislative regime

Created in 1901, the Commonwealth of Australia is one of the oldest continuous democracies in the world, founded in the liberal democratic tradition[45] (*Healey, 2014b*). The European settlers[46] that first established homes, farms, and towns did so during an 'age of revolution' in the late eighteenth century, bringing with them the ideals championed during this time of enlightenment[47] (e.g., Burke, Paine, Rousseau, Voltaire). True, Australia initially served as a penal colony causing the development of a "dominant military caste … with close bureaucratic administration" during its formative years, but the awareness for the colony's commercial advantages increased the introduction of free settlers to the country's shores (*Walter, 2010*).

Australia's legal system is a common law system rooted in the English model. The chief of state is the British monarch,[48] with head of government lead by a Prime Minster. Australia's parliament is bicameral - divided into a Senate (76 seats) and a House of Representatives (151) seats (CIA Factbook, Australia). Australia's strategic and foreign policy

[42] During the Manhattan project (World War II), and in the later 1940's, it was believed that uranium was a relatively rare metal. Due to potential economic benefits, the Australian government incentivized the private sector by offering financial rewards. This spurred growth in Australia's exploration activities and geologists discovered uranium and copper at Rum Jungle in the Northern territory in 1949, with two smaller deposits at Moline and South Alligator in 1950: *Sorentino, C. (1990). Uranium mining policy in Australia: One step forward and two steps backwards. Resources Policy, 16(1), 3–21*; In 1983, Australia's Federal government adopted the 'three mines' policy restricting mining to the Ranger and Narbalek mines in the Northern Territory and the Olympic Dam mine in South Australia. In 2012, Queensland's government opened the state to uranium mining: *"Queensland Lifts Uranium Mining Ban: Engineering, Geology, Mineralogy, Metallurgy, Chemistry, etc", 2012, Engineering and Mining Journal, vol. 213, no. 11, pp. 16*; "Australia has the world's largest known reserves of uranium, but accounts for only 11% of global yellowcake output, making it the third-biggest producer after Kazakhstan and Canada": *WSJ BLOG/Deal Journal Australia: Australia's Queensland Opens Door for Uranium Mining 2012, New York*; "Mining is a very lucrative export market in Australia, yet each state has the final say over whether to open more mines": *"Uranium Mining in Australia: Challenges & Opportunities", 2007, Asialaw, pp. 1.*; The Western Australian Mining Act 1978 does not expressly ban uranium mining – Section 8A. covers rights to oil shale and coal, while Section 9 covers gold, silver and other precious metals. The word 'uranium' is not mentioned within the act: *see Mining Act 1987, Act No: 107 of 1978,* https://www.legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_604_homepage.html, *Accessed February 10, 2020*; In 2008, Western Australia's government formally lifted a ban on uranium mining: *Western Australia Cabinet Formally Approves Uranium Mining 2008, New York*; "Between 1954 and 1971, about 10,000 t of yellowcake were produced in Australia at five locations": *Harries, J., Levins, D., Ring, B., & Zuk, W. (1997). Management of waste from uranium mining and milling in Australia. Nuclear Engineering and Design, 176(1–2), 15–21.*

[43] See https://dfat.gov.au/international-relations/security/asno/Pages/australian-safeguards-and-non-proliferation-office-asno.aspx, Accessed February 10, 2020.

[44] See https://www.arpansa.gov.au/, Accessed February 10, 2020.

[45] The Imperial Act of 1900 united the people of Australia into one Federal Commonwealth: *Bland, F. (1934). Government in Australia. Public Administration, 12(4), 381–391*; The Royal Commission on Human Relationships began in 1974 was tasked with examining the "family, social, educational, legal and sexual aspects of male and female relationships" (see final published report at https://trove.nla.gov.au/work/237869963?selectedversion=NBD14319040, Accessed February 11, 2020): *Hocking, J (ed.) 2016, Making Modern Australia: The Whitlam Government's* 21st *Century Agenda, Monash University Publishing, Clayton, VIC.*

[46] Indigenous populations had systems of government long before the European settlers arrived to the shores of the North American continent and Southwest Pacific – or CANZUS countries/states (Canada, Australia, Aotearoa/New Zealand, and the Unites States). These peoples had established laws or customs for collectively sustaining themselves governing resource use and allocation, settling disputes and how to organize their lives and communities: Nikolakis, *W, Cornell, S, & Nelson, HW (eds) 2019, Reclaiming Indigenous Governance: Reflections and Insights from Australia, Canada, New Zealand, and the United States, University of Arizona Press, Tucson.*

[47] "Participatory governance is considered by some to be at the apex of citizen engagement": *Brunet-Jailly, E, & Martin, J 2010, Local Government in a Global World: Australia and Canada in Comparative Perspective, University of Toronto Press, Toronto.*

[48] "The British monarch has no say in Australian government decisions": *Toohey, B 2019, Secret: The Making of Australia's Security State, Melbourne University Publishing, Melbourne.*

objectives center on maintaining a strong alliance with the United States, as well as growing its economic relationship with China and other Asian countries (*Strategic Comments, 2013*). Australia successfully weathered the 2008 financial crises, mainly because of the country's mining industry. Iron ore mined in Western Australia - and Queensland's coal - kept the country's economy afloat during this crisis (*Fiscor, 2010*), only to lead to a new set of political crises a decade later. Given the unprecedented bush fire season 2019/2020, Australians are questioning the morality of coal mining and shipment of coal for electricity generation at home and abroad.[49] Australia faces similar long-term concerns as those of any western democracy, including an aging population placing pressure on infrastructure[50], as well as environmental and climatic changes bringing about an increased cycle of excessive droughts and bushfires.[51]

3.1.2.1. Legislative framework. Australia has numerous Commonwealth acts - as well as state and territorial acts - governing the use of nuclear power, the permissibility to reprocess spent fuel, and radioactive waste management. The *National Radioactive Waste Management Act 2012*[52] (2012 Act) provides pathways for site selection to establish and operate a radioactive waste management facility. It repeals in its entirety the Commonwealth Radioactive Waste Management Act 2005. The 2012 Act consists of three primary core objectives,[53] shown in Fig. 10.

The 2012 Act also establishes procedures for the nomination of land, which must be made in writing and to the responsible minister. Nominations must provide evidence that affected Aboriginal groups have been adequately consulted, and that consent by any such group has been obtained.[54] Furthermore, the 2012 Act prescribes the National Repository Capital Contribution Fund to provide funds for radioactive waste management activities - its establishment, management, and fee payment.[55]

The *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) established the Australian Radiation Protection and Nuclear Safety agency.[56] The ARPANS Act's objective is to ensure that people and the environment are protected from the harmful effects of ionizing radiation.[57] The Act provides for the regulation of the operation of nuclear installations, and the management of radiation sources. It prohibits the following nuclear installations: nuclear fuel fabrication plants, nuclear power plants, enrichment facilities and reprocessing facilities.[58] The ARPANS Act grants powers to the CEO for regulating nuclear installations through a licensing system in five stages, displayed in Fig. 11(*Nuclear Legislation OECD - Australia*).

The *Nuclear Non-Proliferation (Safeguards) Act 1987* (the Safeguards Act) creates the legislative foundation for Australia's safeguards system implementing the country's obligations under the Nuclear Non-Proliferation Treaty, Australia's bilateral safeguards agreement with the International Atomic Energy Agency, and the Convention on the Physical Protection of Nuclear Material[59] (*ibid.*). The *Environment Protection and Biodiversity Conservation Act 1999* (the EBPC act) "focus[ses] Commonwealth involvement on matters of national environmental significance[60]" through establishing requirements for conducting an environmental impact assessment, as well as strengthening intergovernmental cooperation. The EBPC act establishes seven key objectives,[61] found in Fig. 12. Of note, the EBPC act promotes five principles of ecologically sustainable development.[62] Similar to the ARPANS Act, the EBPC Act prohibits the construction or operation of a nuclear fuel fabrication plant, a nuclear power plant, an enrichment plant, or a reprocessing facility.

3.1.3. Radioactive waste management

Operated by ANSTO, Australia's Open Pool Australian Lightwater (OPAL) reactor is a 20-MW multi-purpose reactor using low enriched uranium fuel supporting research activities in Australia. The majority of radioactive waste produced by ANSTO is low-level waste, which is shredded and compressed into 200 litter drums. These drums are then safely stored on-site (*ANSTO, Managing Waste*). Approximately 3.5 cubic meters of solid intermediate-level waste is generated each year from radiopharmaceutical production and reactor operations. Spent fuel from the OPAL Reactor is stored at ANSTO until its shipment overseas for permanent storage, or for reprocessing. The resultant waste from reprocessing activities undertaken in other countries (e.g., waste produced from the reprocessing of spent fuel sent to France) is returned and classified as intermediate-level waste, similar to waste already returned from France in 2015.

3.1.3.1. Permanent disposal. Currently, radioactive waste generated through nuclear medicine programs[63] or by ANSTO is stored onsite until a final repository is constructed and made operational. The department of Industry, Science, Energy, and Resources is responsible and tasked to develop a National Radioactive Waste Management Facility[64] (NRWMF) per the 2012 Act. Following four years of public consultation, the

[49] Australia exports more coal than any other country in the world: *Kormann, C., The New Yorker, 'When Will Australia's Prime Minister Accept the Reality of the Climate Crisis'*, https://www.newyorker.com/news/news-desk/when-will-australias-prime-minister-accept-the-reality-of-the-climate-crisis, *Accessed February 11, 2020*.

[50] Similarly, globalization has left its footprint on the Australian middle class - "factories are gone … public assets … sold off and the middle class [has] … left": *Glover, D 2015, An Economy Is Not a Society: Winners and Losers in the New Australia, Schwartz Publishing Pty, Limited, Melbourne*.

[51] *See Goodman, J., The BBC, 'What is Australia doing to tackle climate change'*, https://www.bbc.com/news/world-australia-50869565, *Accessed February 11, 2020*.

[52] Australia 2012 Act, National Radioactive Waste Management Act 2012, No. 29, 2012, *An Act to make provision in relation to the selection of a site for, and the establishment and operation of, a radioactive waste management facility, and for related purposes*, https://www.legislation.gov.au/Details/C2012A00029, Accessed May 01, 2020.

[53] Id. Section 3.

[54] Id. Section 7.

[55] Id. Section 6A.

[56] See https://www.arpansa.gov.au/about-us/what-we-do, Accessed February 17, 2020.

[57] See Section 3, Australian Radiation Protection and Nuclear Safety Act 1998, https://www.legislation.gov.au/Details/C2016C00977, Accessed February 17, 2020.

[58] Id. Section 10.

[59] See Section 3, Nuclear Non-Proliferation (Safeguards) Act 1987, https://www.legislation.gov.au/Details/C2016C00932, Accessed February 17, 2020.

[60] See Section 3 (2) (a), *Environment Protection and Biodiversity Conservation Act 1999*, https://www.legislation.gov.au/Details/C2019C00275, Accessed February 17, 2020.

[61] Id. Section 3 (1).

[62] Id. Section 3A.

[63] "[waste] is housed at a number of unsatisfactory interim sites … that were not designed for long-term storage", *Nagtzaam, Gerry. (2014). Pass the parcel: Australia and the vexing issue of a federal nuclear waste repository. Alternative Law Journal, 39(4), 246–248*; Western Australia operates a facility for wastes produced within its state, see: https://www.wa.gov.au/organisation/department-of-finance/mt-walton-east-intractable-waste-disposal-facility, Accessed February 17, 2020; see also Nicholson, L., The Sydney Morning Herald, 'Western Australia in nation's nuclear waste dump sights' https://www.smh.com.au/politics/federal/western-australia-in-nations-nuclear-waste-dump-sights-20131112-2xdzn.html, Accessed February 17, 2020.

[64] Previous attempts by the federal government to develop a repository on aboriginal land have been widely panned. In the late 1990's to early 2000's the government aborted a failed attempt to impose a repository on Aboriginal land in South Australia. A similar attempt in the Northern territory between 2006-2014 also failed: *Green, J. (2017). RADIOACTIVE WASTE AND AUSTRALIA'S ABORIGINAL PEOPLE. Angelaki, 22(3), 33–50*.

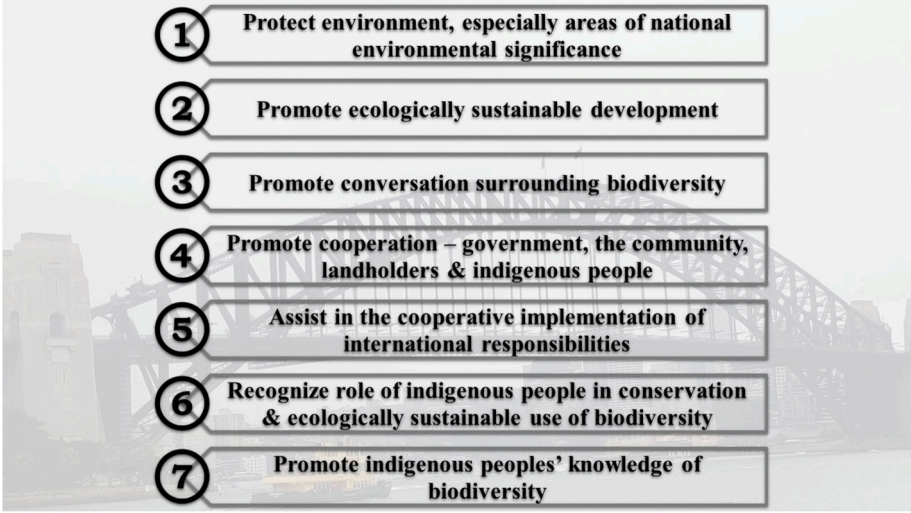

Fig. 12. The EBPC Act's seven core objectives.

government identified Napandee[65] - near Kimba in South Australia[66] - to host the NRWMF.

3.2. Belgium (kingdom of Belgium or koninkrijk belgië (Dutch), royaume deBelgique (French) and königreich belgien (German))

Quick Facts – Belgium (*Nuclear Power in Belgium*).

1. Seven nuclear plants produce roughly 50% of the country's electricity supply.
2. The mid 1970's saw Belgium's first commercial nuclear power reactor come online (i.e., 1974).
3. Over the past couple of decades, political support for nuclear activities in the country has waned.

3.2.1. Historical overview & law

'Little Belgium' is situated in the heart of Europe between the great powers of Germany, France, and the Netherlands (*Belgium, 2011*). Belgium enjoys a short coastline on the North Sea. The land area now known as Belgium was previously ruled by the French dukes of Burgundy. Belgium's geographic location and diversified economy has caused the country to become the center of European affairs.[67]

In 1477, Belgium became a Habsburg possession. Originally, a possession of the Spanish branch of the Habsburg dynasty, it changed hands to the Austrian branch in 1713. Belgium was incorporated into France in1795.[68] Following the Napoleonic wars, peace discussions known as the Congress of Vienna saw the European powers carve Europe into interest zones reestablishing the 'old order,' with the European powers merging Belgium with the Netherlands under King William I of Orange (*ibid.*). Belgium became an independent State in1830.[69]

The 1830 Belgium Revolution was a political upheaval brought about due to the general, economic, social and political conditions of the time. During this time of transition, Belgium was transforming itself from an agrarian society to a fledgling industrial nation (*Witte, 2009*) The country experienced the effects of industrialization earlier than many of its European neighbors[70].

By the early twentieth century, Belgium had a widely developed transportation infrastructure[71] and a 'modern' industrial base. However, despite its many modern features as a society, Belgian political infighting is dominated by regional interests – "the wealthier Dutch-speaking Flemish region in the north and the poorer French-speaking Walloon region in the south" (*Rayp, 2016*). A timeline of the modern development of Belgium is provide in Fig. 13.

In the post-World War II period, nuclear power development enjoyed wide support through all facets of Belgium society (*Verbruggen, 2013*). However, by the early 2000's, Belgium promulgated a nuclear phase out

[65] See https://www.minister.industry.gov.au/ministers/canavan/media-releases/national-radioactive-waste-management-facility-napandee-site, Accessed February 17, 2020; For the Site Characterisation Technical Report: Napandee the https://www.industry.gov.au/sites/default/files/2019-04/nrwmf_site_characterisation_technical_report_napandee.pdf, Accessed February 17, 2020. Also see, Boisvert, E., *'Federal Government chooses Kimba farm Napandee on the Eyre Peninsula for nuclear dump'*, https://www.abc.net.au/news/2020-02-01/kimba-farm-eyre-peninsula-chosen-for-nuclear-dump/11920514, Accessed February 17, 2020; Booth, E., 'New Bill supports radioactive waste facility', https://www.pumpindustry.com.au/new-bill-supports-radioactive-waste-facility, Accessed February 17, 2020; Gredley, R., and Cosenza, E., The Canberra Times, 'SA nuclear waste dump plan hits parliament', https://www.canberratimes.com.au/story/6628821/sa-nuclear-waste-dump-plan-hits-parliament/?cs=14231, Accessed February 17, 2020.

[66] "rural South Australia is an obvious location […] because it is losing its motor manufacturing industry, has suitable geology […] with very low population density": *Mark Diesendorf, Shunning nuclear power but not its waste: Assessing the risks of Australia becoming the world's nuclear wasteland, Energy Research & Social Science, Volume 19, 2016, Pages 142–147, ISSN 2214–6296.*

[67] The European Commission is the executive branch of the European Union and is located in Brussels, Belgium, https://ec.europa.eu/info/index_en, Accessed April 13, 2020.

[68] Following the French Revolution, Belgium was invaded and annexed by Napoleonic France in 1795.

[69] The country is often cited as an example of a "fabricated state": *Judge, J 2018, The United States of Belgium: The Story of the First Belgian Revolution, Leuven University Press, Leuven. Available from: ProQuest Ebook Central.*

[70] Economic, social, and medical needs moved the king and municipal leaders to design a comprehensive urban renovation plan between 1866 and 1893. "The plan included covering over the polluted and disease-infested waterways of the Senne river […] laying in new sewer lines […] facilitating networks of transport and communication; and constructing new housing stock for both middle- and working-class populations": *Silverman, D. (2011). "Modernité Sans Frontières:" Culture, Politics, and the Boundaries of the Avant-Garde in King Leopold's Belgium, 1885–1910. American Imago, 68(4), 707–797.*

[71] Railway building in Belgium was outlined with a view to integrate the country into a homogeneous whole, as well as to encourage the growth and spread of industrialization: *Block, G. (2011). Designing the Nation: The Belgian Railway Project, 1830–1837. Technology and Culture, 52(4), 703–732.*

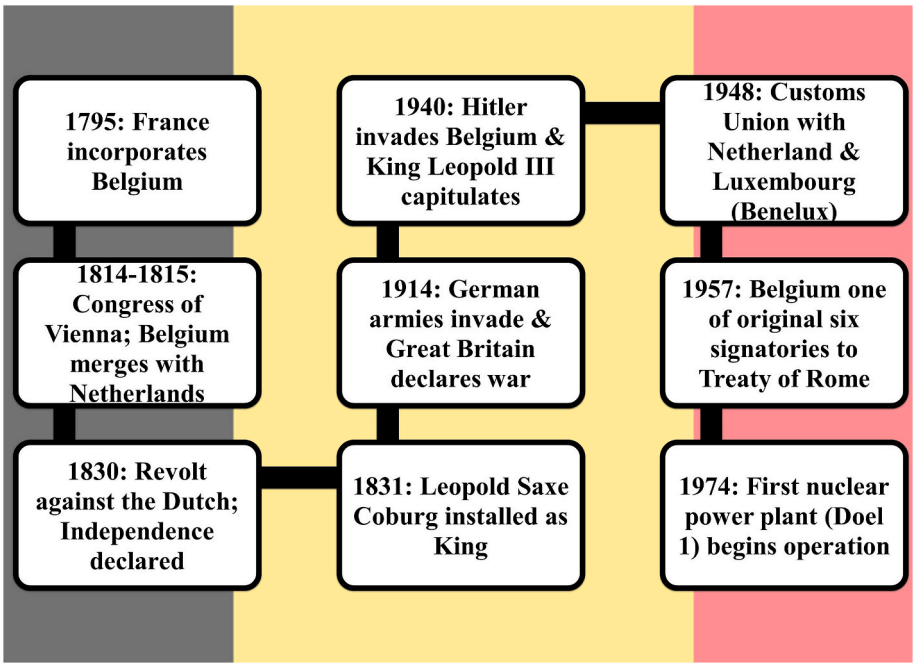

Fig. 13. Historical timeline of the development of a modern Belgium.

law[72] requiring all plants to close after 40 years of operating time, with a provision that this could be renegotiated in case of availability of supply within the country[73] (*Kunsch and Friesewinkel, 2014*). Belgium adopted nuclear technologies for peaceful purposes beginning in the 1960's and eventually its nuclear industry covered almost all activities in the nuclear fuel cycle. The major historical milestones displaying the development of nuclear infrastructure in Belgium are presented in Fig. 14 (information taken from *IAEA, Belgium*).

3.2.2. *Government & legislative regime*

Belgium is a federal parliamentary democracy under a constitutional monarchy.[74] The country operates under a civil law system based on the French Civil code. As a member state of the European Union, the country's laws are regularly influenced and amended as mandated. The country has a bicameral Parliament[75] consisting of a senate comprising 50 members and a Chamber of Representatives, comprising of 150 members. There are three levels of government – Federal, Regional and linguistic community (*CIA World Factbook - Belgium*). Political parties exert a great deal of control over the political agenda in Belgium, which are routed along linguistic lines[76] (*Walgrave* et al., *2008*). Such a diluting of a cohesive national identity - caused by a 'north'/'south' antagonist "Mason-Dixon" line[77] – has, at times, seemed to cause a collapse of national unity.

Belgium enjoys the reputation of experiencing protracted complex coalition negotiations for the forming of government.[78] In 2011, these

[72] Nuclear Energy Agency, Nuclear Law Bulletin, 2003 Act *on the Phase-out of Nuclear Energy for the Purposes of the Industrial Production of Electricity*, pgs. 99–102, http://www.ha.g4if.org/law/nlb/nlb71.pdf#page=99, Accessed April 11, 2020.

[73] News Article, DW, *Belgium broke law but can keep nuclear plants open, EU court rules*, https://www.dw.com/en/belgium-broke-law-but-can-keep-nuclear-plants-open-eu-court-rules/a-49787150, Accessed April 11, 2020; Daphne Psaledakis & Bate Felix, Reuters, *Belgium unprepared for phasing out nuclear power by 2025: grid operator*, https://www.reuters.com/article/us-belgium-nuclearpower/belgium-unprepared-for-phasing-out-nuclear-power-by-2025-grid-operator-idUSKCN1TT233, Accessed April 11, 2020.

[74] King PHILIPPE (since 21 July 2013), https://www.monarchie.be/en/royal-family/the-king, Accessed April 13, 2020; Heir Apparent Princess ELISABETH (born 25 October 2001), https://www.monarchie.be/en/royal-family/princess-elisabeth-duchess-of-brabant, Accessed April 13, 2020.

[75] See https://www.senate.be/english/federal_parliament_en.pdf, Accessed April 13, 2020.

[76] In August 1980, the Belgian Parliament passed a devolution bill and amended the Constitution, establishing "Community autonomy."

[77] The Mason-Dixon line consists of the border between Pennsylvania and Maryland, USA. The imaginary line shown on a map is named after the men who surveyed it in the 1760s. It later came to symbolize the division between the free Yankee northern states and the slave holding southern states. It cemented in the American mindset and culture the 19th century divisions of the American nation: *Phillip's Encyclopedia 200, 1st Edition*; The Mason-Dixon Line, as such, reflects the "family feuds, exploration, scientific advancement and the cultural conflicts between America's northern and southern states": *Walker, S., Boundaries: how the Mason-Dixon line settled a family feud & divided a nation, Candlewick Press 2014, Somerville, MA*.

[78] Crisp, J., The Telegraph, *Belgium names first female prime minister to lead caretaker government*, https://www.telegraph.co.uk/news/2019/10/28/belgium-names-first-female-prime-minister-lead-caretaker-government/, Accessed April 13, 2020; Stavrinou, R., NEWEUROPE, *Belgium's caretaker government granted special powers to stem COVID-19 spread*, https://www.neweurope.eu/article/belgiums-caretaker-government-granted-special-powers-to-stem-covid-19-spread/, Accessed April 13, 2020, Washington Post, *Without a Government for a year, Belgium shows what happens to politics without politicians*, https://www.washingtonpost.com/world/europe/without-a-government-for-a-year-belgium-shows-what-happens-to-politics-without-politicians/2019/12/19/5c13cb48-20de-11ea-b034-de7dc2b5199b_story.html, Accessed April 13, 2020.

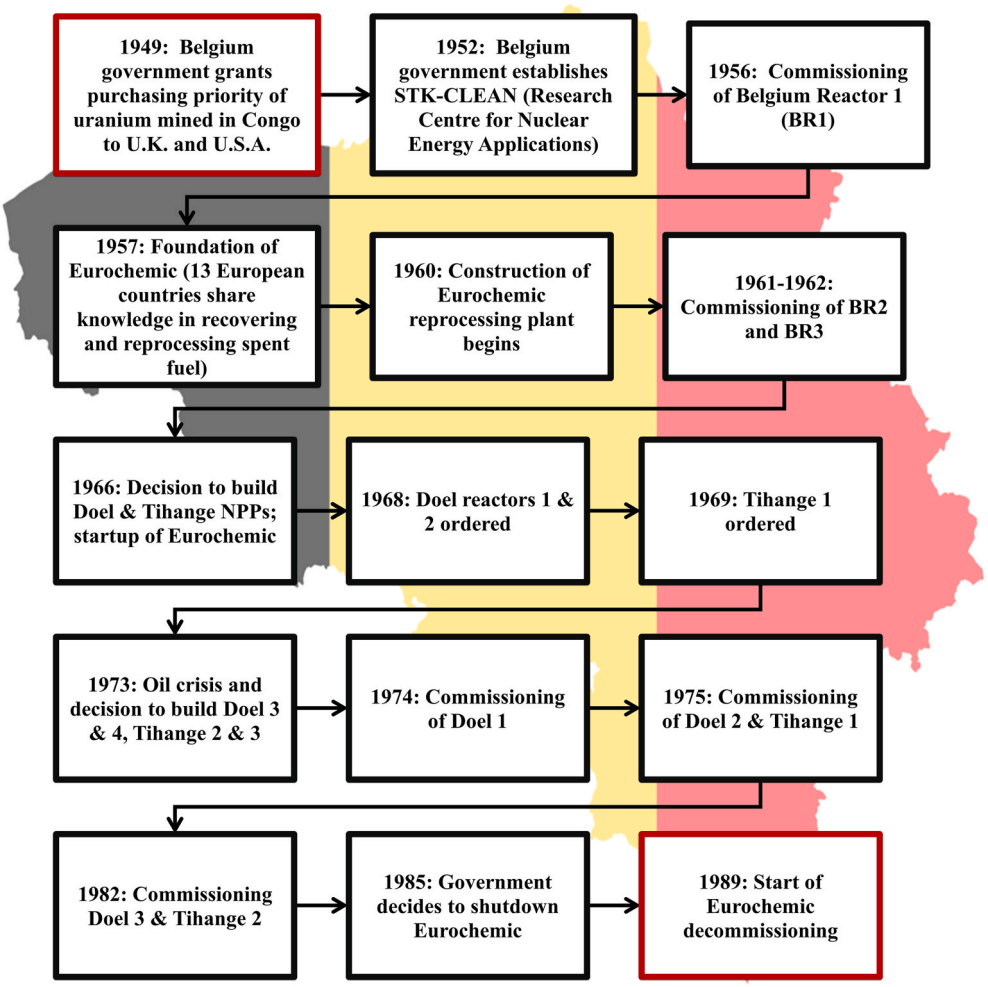

Fig. 14. Major historical nuclear milestones in Belgium 1949–1990.

negotiations were exceptionally extended - lasting for 541 days[79] (*Brans et al., 2016*). However, despite these setbacks, the wheels of government administration always roll forward, thanks to two bureaucratic features guaranteeing the continuity of daily government operations - the permanency of civil servants and established routines (*Bouckaert and Brans, 2012*). Belgium is absolutely beholden to foreign sources of fossil fuels, and this dependency is only expected to increase in line with the country's nuclear phase out actions (*CIA, Belgium*).

3.2.2.1. Legislative framework. Whilst government spheres of influence are distributed among the federal, state and regional powers - including the three linguistic communities (Dutch, French, and German) - policies impacting and regulating the nuclear sector remain the prerogative of the Federal Government. However, renewable energy activities are directed and controlled by the regions (*IAEA, Belgium*). As a member state of the European Union (EU), Belgium's legislative framework is based on EU regulations and directives[80]. Additionally, as a contracting party to many international conventions governing different aspects of nuclear and radioprotection policy, Belgium's legislative framework is further influenced by these requirements (OECD, Belgium). From the middle of the 20th century until 2001, Belgium's nuclear legislation was guided by Law of 29 March 1958, *The Protection of the Population against the Hazards of Ionizing radiation*. Belgium's nuclear law framework is presented in Figs. 15 and 16 (information taken from *IAEA, Belgium*).

3.2.3. Radioactive waste management

Throughout is 'nuclear history', Belgium has been involved with nuclear activities consisting of the majority of the nuclear fuel cycle. In addition to operating reactors,[81] there was a pilot reprocessing plant,[82]

[79] Guinness World Records, Belgium, *Longest time without a government in peacetime*, https://www.guinnessworldrecords.com/world-records/96893-longest-time-without-a-government-in-peacetime?fb_comment_id=905066956181868_1210018532353374/, Accessed April 13, 2020; Waterfield, B., *The Telegraph, Belgium to have new government after world record 541 days*, https://www.telegraph.co.uk/news/worldnews/europe/belgium/8936857/Belgium-to-have-new-government-after-world-record-541-days.html, Accessed April 13, 2020; Taylor, A., *Business Insider, A Look Back On Belgium's Record Breaking* 535 Days *Without Government*, https://www.businessinsider.com/belgium-government-elio-di-rupo-2011-12, Accessed April 13, 2020.

[80] See sections 6.1.2.1 and 6.1.2.2. in Sanders, M, & Sanders, C 2016, 'A world's dilemma 'upon which the sun never sets' – The nuclear waste management strategy (part I): Western European Nation States and the United States of America', Progress in Nuclear Energy, 90, pp. 69–97.

[81] Seven operational reactors at two sites.

[82] EUROCHEMIC facility, see: https://www.oecd-nea.org/cen/publications/68-eurochemic.pdf, Accessed April 29, 2020.

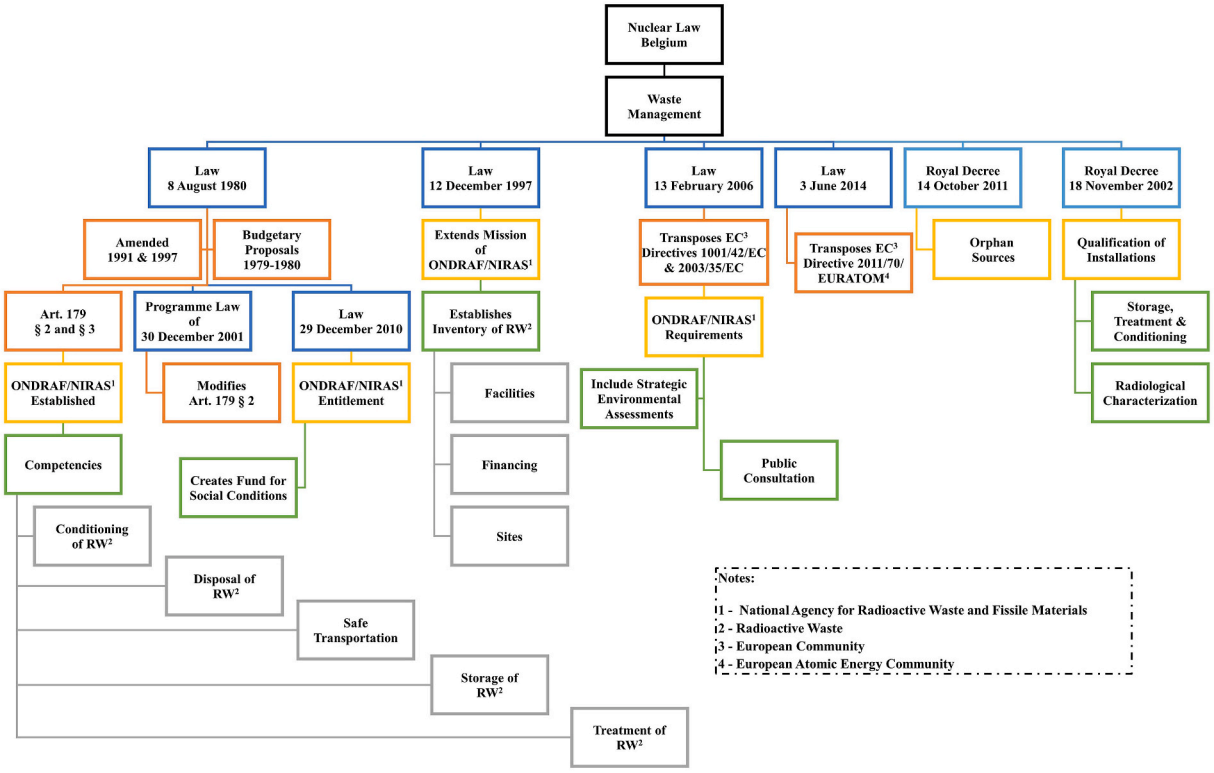

Fig. 15. Nuclear law Belgium – Nuclear Waste Management.

as well as fuel fabrication facilities[83] in the country. Belgium is a contracting party to the Joint Convention,[84] having signed the Joint Convention in December 1997. Belgium's legislative body gave its consent to this treaty's obligation by way of Law of 2 August 2002. Radioactive waste management activities in Belgium are arranged on pragmatic approaches, with waste management routes defined according to the final destination of the waste (*National Report Belgium, 2017*). Nuclear facilities either process or condition generated radioactive waste onsite and/or such waste is processed and conditioned at central facilities located in Dessel by the National Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) managed by Belgoprocess.[85] Belgium characterizes its radioactive waste into various categories, with the three most prominent categories described in Fig. 17.

3.2.3.1. Permanent disposal. From the mid-1970's, research has been ongoing in Belgium for using clay formations as a potential host geology for the ultimate disposal of category B and C level waste.[86] However, to date, no final national policy in this regard has been proposed. A schematic representation of the storage of conditioned waste in Belgium is presented in Fig. 18 (information taken from *IAEA Belgium*). Additionally, as part of the country's efforts to develop qualitative input data for designing a potential geological repository, Belgium operates the Hades Underground Laboratory - Europe's first underground laboratory built in a clay formation. The site conducts experimental research on geological disposal for high-level and/or long-lived radioactive waste. The facility is situated at a depth of 225 m in the core of the Boom Clay formation.[87]

The country has undertaken a number of initiatives over the years to seek input from stakeholders and to collect relevant assessed information to provide decision-makers with all facts regarding the permanent disposal of intermediate and high-level waste in the country. Of recent note, the first edition of the National Program was prepared in 2015. However, it is observed that this first edition is limited in scope, only providing "a description of the existing situation in terms of national policies, the implementation of these policies and the national framework for this implementation, without new normative content" (*National Report Belgium, 2017*). The report does not provide recommended concrete proposals for moving forward with a geological disposal facility in the country.

3.3. Czech Republic (Czechia) or ceská republika

Quick Facts – Czech Republic (*Nuclear Power in Czech Republic*).

1. The country has six nuclear reactors generating ~1/3 of its electricity.
2. The mid 1980s saw the first operation of a commercial nuclear reactor in the country.
3. Government policy is to increase nuclear generating capacity by 2040.

[83] Belgonucleaire (see: https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/047/28047120.pdf, Accessed April 29, 2020) and FBFC International (see: https://www.framatome.com/EN/businessnews-841/dessel-a-new-step-forward-with-the-dismantling-of-the-site.html, Accessed April 29, 2020).

[84] Shortened form for Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

[85] An industrial auxiliary subsidiary of ONDRAF/NIRAS, see: https://www.belgoprocess.be/eng/AboutUs.htm, Accessed April 29, 2020.

[86] For Category A classified waste, the plan is for Belgium to design and build surface disposal infrastructure for waste at Dessel. A safety case has previously been prepared by ONDRAF/NIRAS to obtain a construction and operating license. Once a license is granted it is believed that such a repository could be operational in about four years, with disposal and closure operations occurring over a period of ~100 years.

[87] Belgium Nuclear Research Center, https://science.sckcen.be/en/Facilities/HADES, Accessed April 30, 2020. For more information of disposal in clay formations, see http://publications.europa.eu/resource/cellar/a591d961-6ae7-40a7-aa1d-19562c40021e.0001.02/DOC_1, Accessed April 30, 2020.

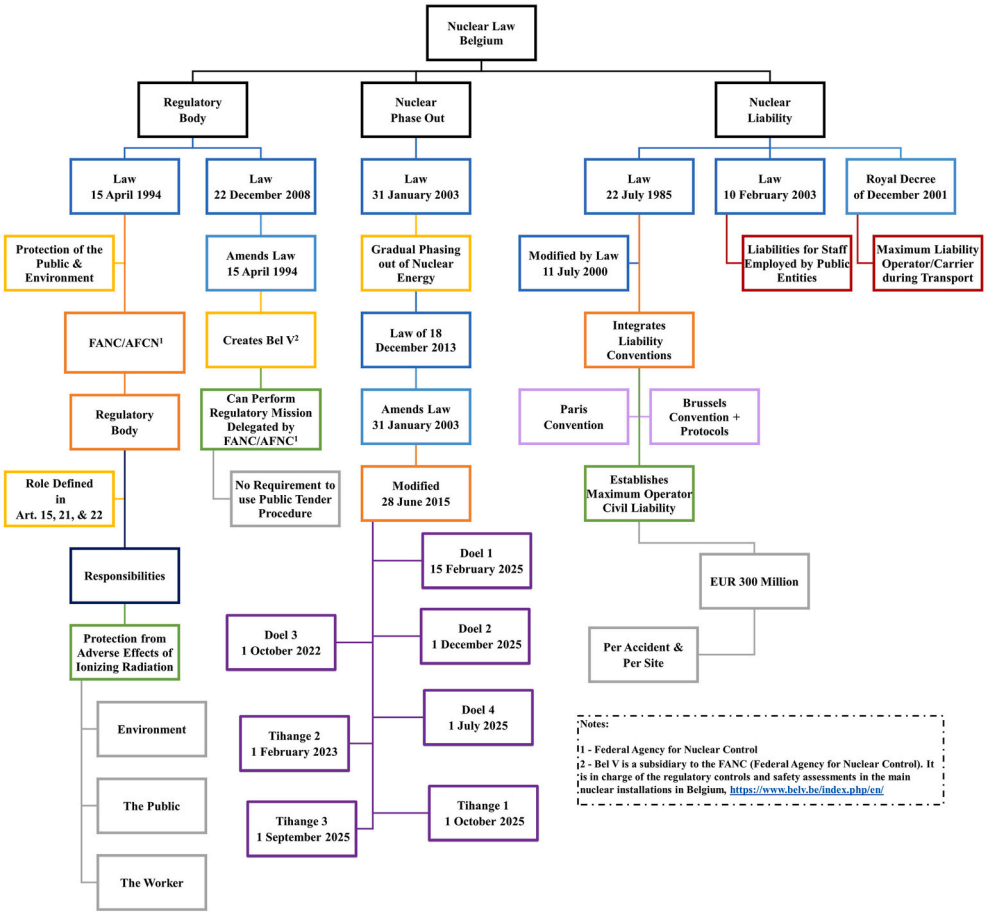

Fig. 16. Nuclear law Belgium – Regulatory Body, Nuclear Phase Out & Nuclear Liability.

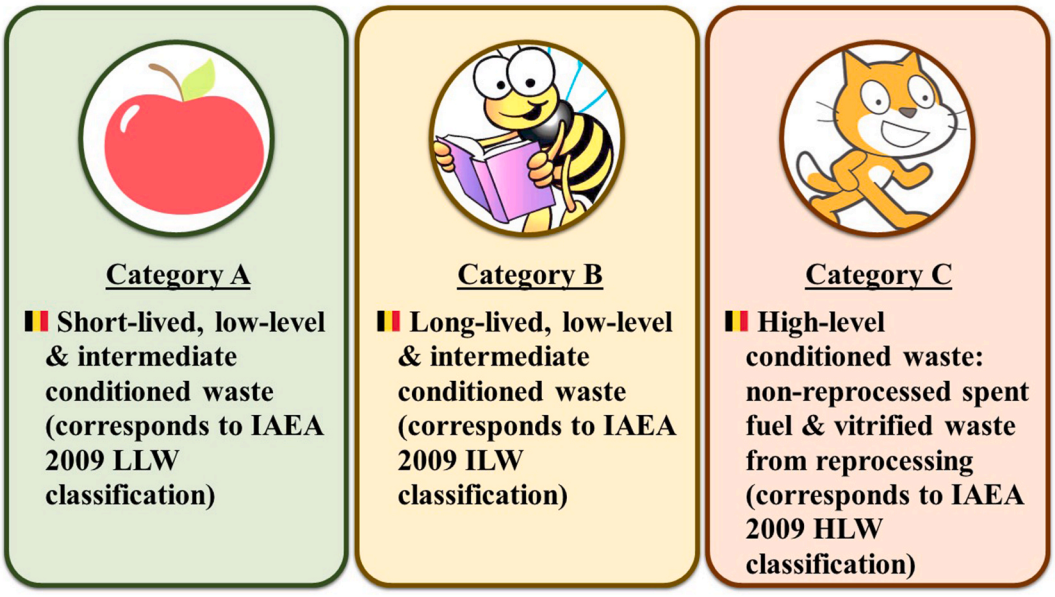

Fig. 17. Belgium's main radioactive waste categories.

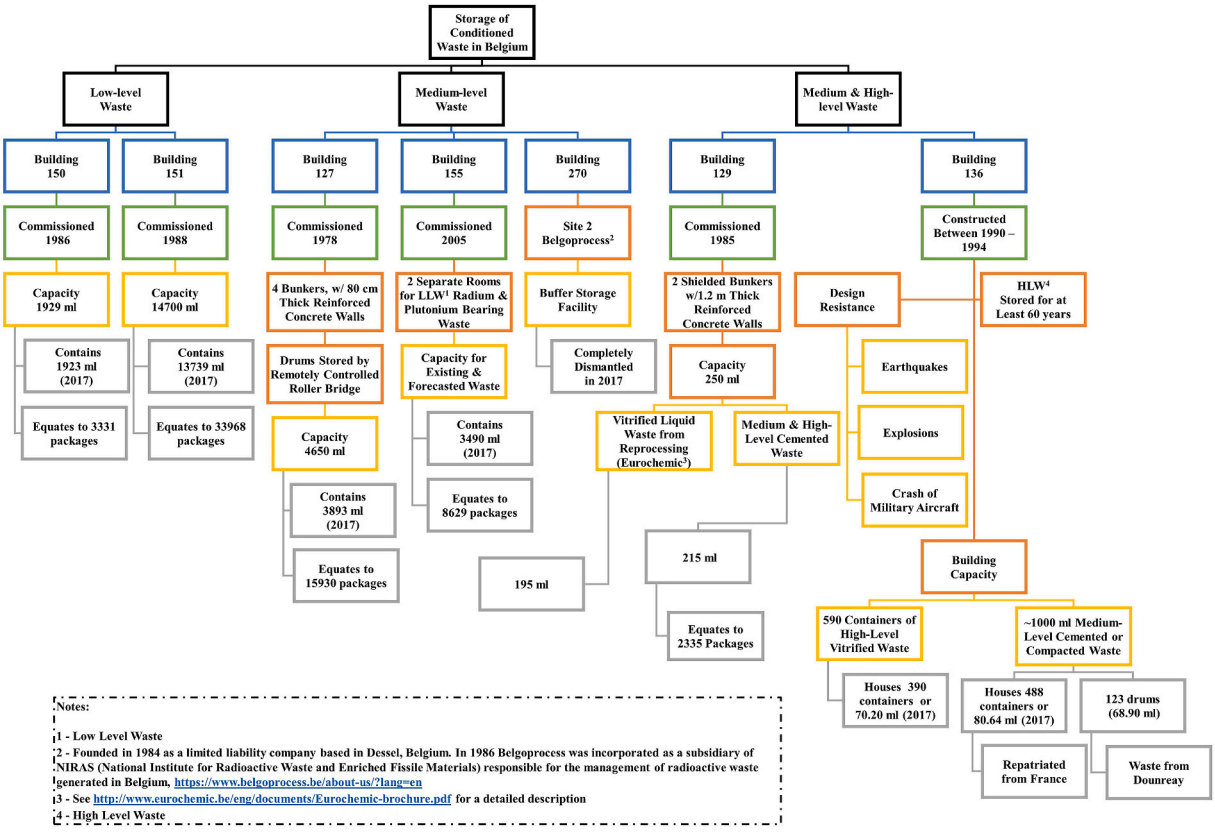

Fig. 18. Representation of the storage of conditioned waste in Belgium.

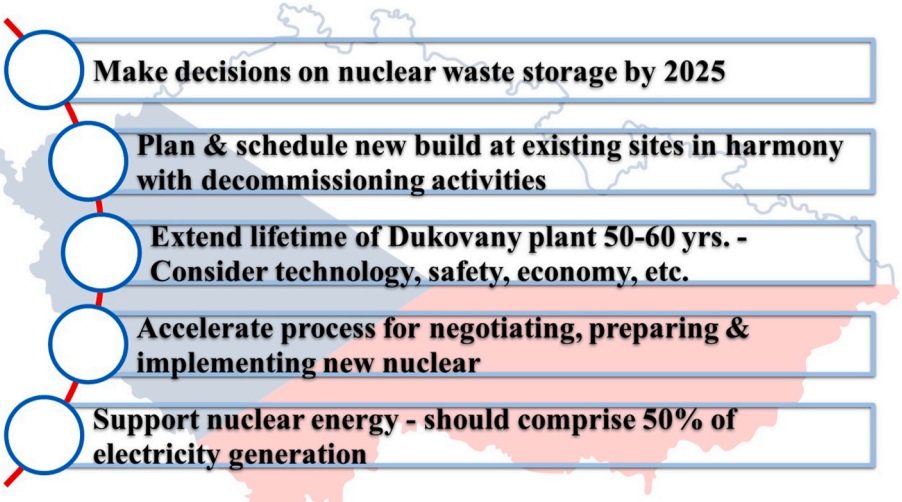

Fig. 19. Czechia's state energy policy for nuclear power.

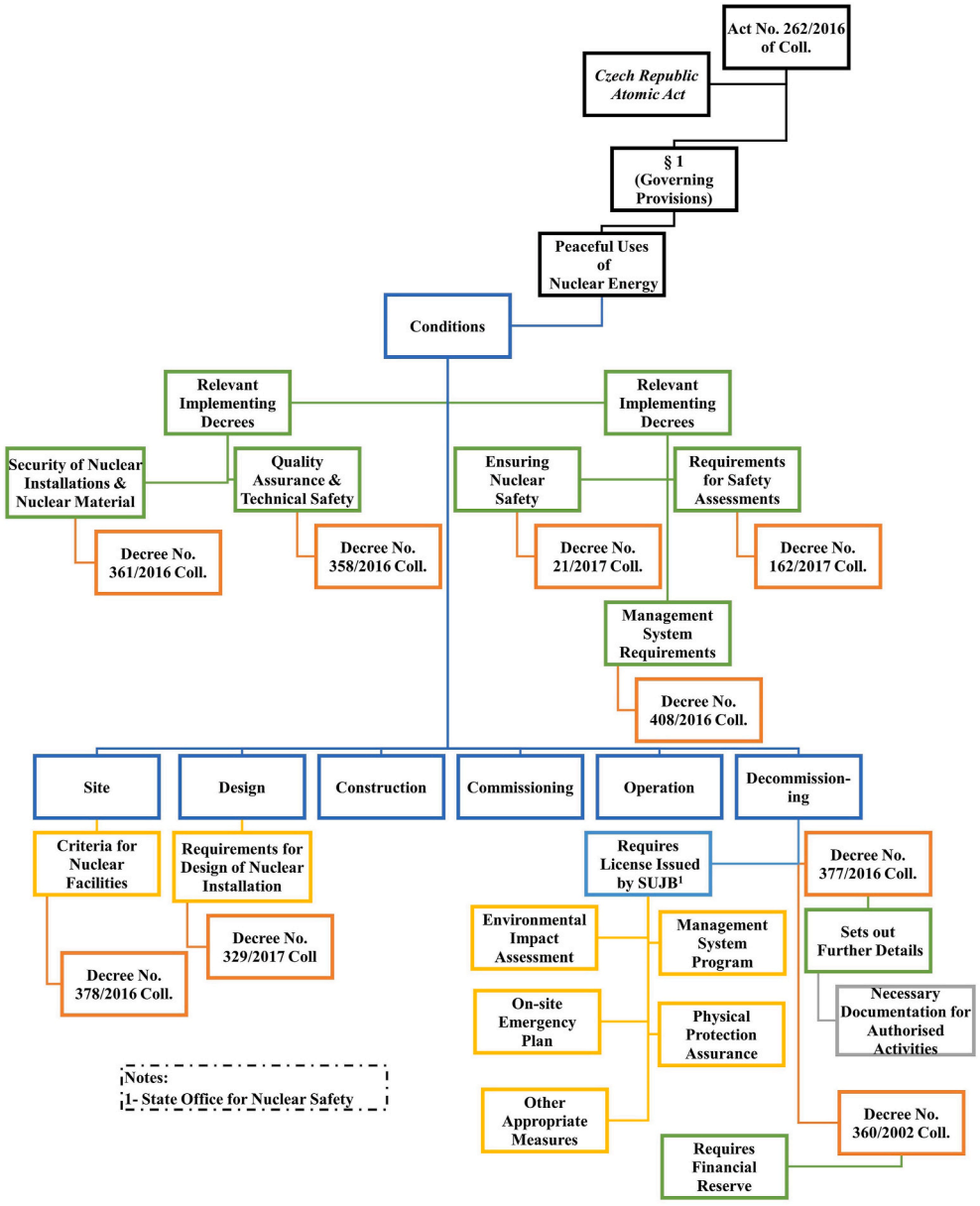

Fig. 20. a,b,cCzechia's atomic energy Act's governing provisions.

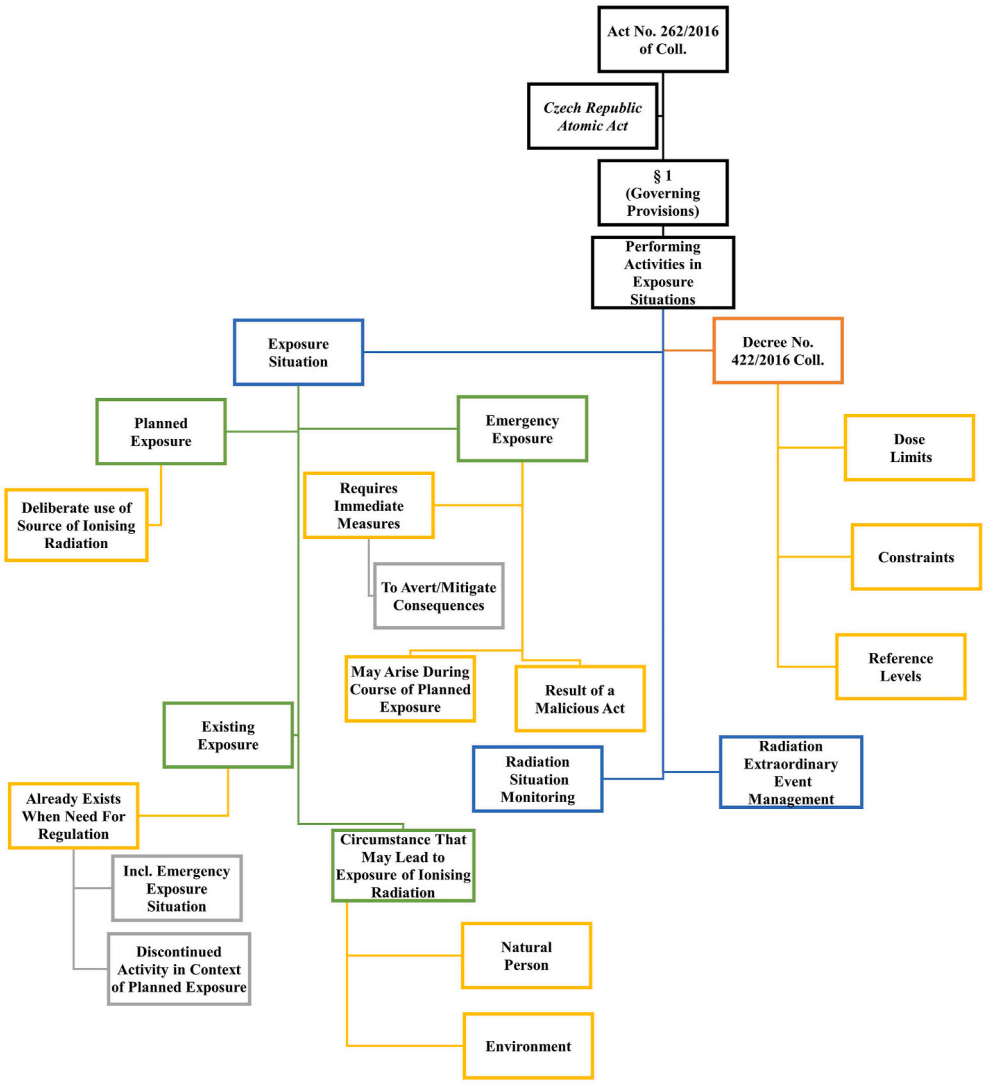

Fig. 20. (*continued*).

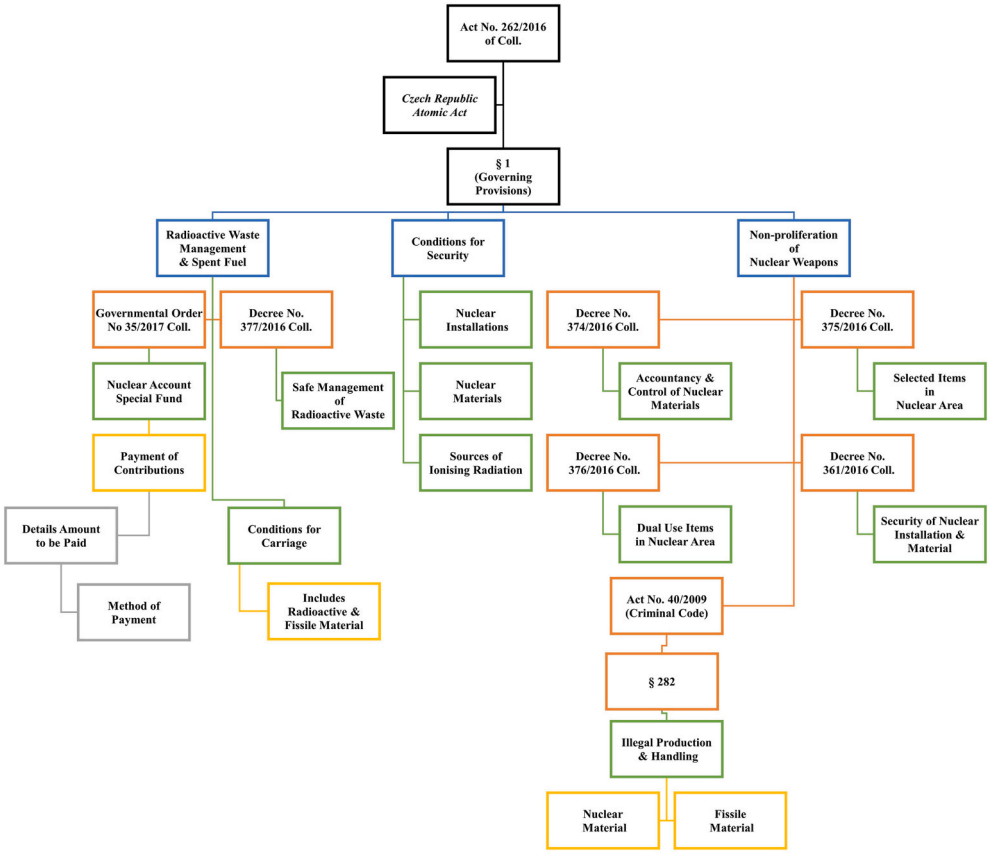

Fig. 20. (*continued*).

3.3.1. *Historical overview & law*

A country located in the heart of Europe, Czechia comprises the historical provinces of Bohemia[88] and Moravia.[89] The capital city Prague[90] has the historic distinction of being the place where the Thirty Years' War (1618–1648) began and ended.[91] The Austro-German Hapsburgs dynasty ruled Bohemia from 1526 to 1918 (*Czech Republic, Encyclopedia Britannia*). The Czech Republic was part of the Czech and Slovak Federative Republic that was formed into the common state of Czechoslovakia at the end of World War I, following the abdication of Emperor Charles I and the collapse of the Austro-Hungarian empire. In the years between World War I and World War II, Czechoslovakia's

[88] A sixteenth-century map displayed Europe as a female figure. Bohemia was portrayed as the figures heart: *Agnew, Hugh, and Wayne S. Vucinich. The Czechs and the Lands of the Bohemian Crown, Hoover Institution Press, 2004. ProQuest Ebook Central*; Czechs have a long, proud and storied history of the founding of the country – "They have all heard of the nation's ancestor Bohemus, who came to the country with his people and prophesied well-being and bounty from the top of the Říp mountain": *Charvat, Petr. The Emergence of the Bohemian State, BRILL, 2010. ProQuest Ebook Central.*

[89] "Until the middle of the twentieth century, decisive attention was drawn to the beginning of 'dual nationality' in the Czech lands, the beginning of the seven-hundred-year coexistence of the Czechs with the Bohemian and Moravian Germans": *Klapste, Jan. Czech Lands in Medieval Transformation: Czech Lands In Medieval Transformation, BRILL, 2011. ProQuest Ebook Central*; "Czech sociology was born with a special mission that imbued it with a sense of entitlement for widespread public respect: to guide the construction of the new nation and state": *Skovajsa, Marek, and Jan Balon. Sociology in the Czech Republic: Between East and West, Palgrave Macmillan Limited, 2017. ProQuest Ebook Central.*

[90] The city comprised three exiting cultures between 1780-1920 - Czech, German and Jewish – as well as two languages (Czech and German). The middle and lower industrial/worker classes spoke mostly Czech Czech, while German was spoken by the upper/noble classes with also mostly German-speaking Jews who controlled the high finance: *Sayer, Derek. (1996). The language of nationality and the nationality of language: Prague 1780–1920. (Czech Republic history). Past & Present, (153), 164.*

[91] On the 23rd of May 1618, the Emperor's representatives were thrown out of a window by Protestant citizens, falling 17 m. This is said by historians to be the beginning of the Thirty Years' War. In July 1648, Swedish soldiers breached the walls, and claimed the western part of Prague, the Malá Strana. For three days, the Swedes plundered the riches in the castle, palace, and monasteries: *Pantle, C., 'Trettioåriga Kriget: När Tyskland stod i lågor och Sverige blev en stormakt', (Original title: Der Dreißigjährige Krieg, Als Deutschland in Flammen stand [translated by Per Lennart Månsson]) Scanbook AB, Falun (Lind & Co.), 2018, ISBN: 978-7779-388-5.*

predominantly Czech leaders were mostly preoccupied with having to balance the conflicting demands of ethnic minorities within the republic, "most notably the Slovaks, the Sudeten Germans,[92] and the Ruthenians (Ukrainians)" (*CIA World Factbook – Czech Republic*). In the post-World War II years, the country fell within the Soviet sphere of influence. 1968 saw Warsaw Pact[93] troops invade the country to stop the liberalisation of the stringent communist philosophy. In 1989, the Communist Party was swept from political power in the 'Velvet Revolution[94]', followed by the 'Velvet Divorce[95]' from Slovakia in 1993. From this time period, Czechia has engaged in a 'west' Europe oriented direction - joining NATO in 1999 and the European Union in 2004.

Due to a lack of access to significant fossil fuel resources (e.g., oil and gas, as well as limited coal reserves), nuclear power generation was seen as a necessary compliment in addition to these other sources of energy production. Czechia's current nuclear power program is linked to the program begun in the former Czechoslovakia in the 1950s. However, it was the 1970s that was the harvest time for the country's nuclear power program with four reactors being built at the Dukovany site. In the mid-1980's, construction began at the Temelin site, with two units constructed and placed into commercial operation during the early 2000's. Going forward, State Energy Policy considers nuclear power to be desirable for the country. Several future considerations from this policy perspective are outlined in Fig. 19 (*IAEA Country Profiles – Czech Republic*).

3.3.2. Government & legislative regime

Czechia's government system is based on a parliamentary republic[96] headed by a president as chief of state and a prime minister whom serves as head of government (*CIA World Factbook - Czech Republic*). The country's legislature is bicameral - divided into a Senate[97] and Chamber of Deputies.[98] The Constitution of the Czech Republic[99] guarantees decisions of the government "respect the rights and freedoms of man and of citizens"[100] . State authority "emanates from the people"[101], and political decisions are conducted through majority approval[102], whilst respecting the views of the minority. When considering the sustainability model portrayed in Fig. 1. - with the added emphasis on 'stability' - it is worth remarking that approximately a two-year timeframe has been the average life span of a sitting cabinet in Czechia since 1992. Government stability within the country is vastly lower "than … the norm in Western Europe" (*Balík* et al., *2017*). Thus, one can see, in this instance especially, the importance for adding 'stability' as part of the sustainability model. Stability plays a key role in ensuring that negative impacts to the continuity of long-term decision-making processes and outcomes required for nuclear power programs, including radioactive waste management activities, as well as siting/constructing/operating a deep geological repository are minimized.

The country boasts a prosperous market economy and one of the lowest unemployment rates in the E.U. However, as is a common theme when describing western industrialized nations, the country faces long-term challenges of a rapidly ageing population placing greater demand

[92] An area comprised of 3.25 million German speakers "also called the Sudeten (Sudetenland), in the north of what is now the Czech Republic. Hitler used the grievances of these persons for the annexation of the Sudetenland by Germany as an outcome of the treacherous Munich Agreement supported by France and Great Britain: *Sudetenland. (2009). Brewer's Dictionary of Modern Phrase and Fable*; "The very identification of "Sudetenland" as a political concept (as opposed to simply "areas in which Germans live") was practically synonymous with the failure of Czechoslovakia as a state project": *Waters, Timothy William. (2006). Remembering Sudetenland: On the legal construction of ethnic cleansing. Virginia Journal of International Law, 47(1), 146*; Sudeten Germans were expelled from these areas at the conclusion of World War II pursuant to the Potsdam Protocols. It is argued that the Munich Agreement providing for Germany's annexation of such territories is null and void in international law because (1) Czechoslovakia's actions to cede this territory was made under duress and threat of force and (2) the German Federal Republic renounced all territorial claims resulting from this agreement: Schiller, *C. (1995). Closing a chapter of history: Germany's right to compensation for the Sudetenland. Case Western Reserve Journal of International Law, 26(2,3), 401*.

[93] "The treaty signed in Warsaw in 1955 between the Soviet Union and the eastern bloc countries of Albania, Bulgaria, Czechoslovakia, Hungary, East Germany, Poland and Romania was the Soviet response to NATO": *Warsaw Pact. (2009). Brewer's Dictionary of Modern Phrase and Fable*; "it was Roosevelt and Churchill who were probably indirectly responsible in helping the spread of Soviet power […] as a result of their sanctioning the Yalta Agreement" leading to "communist expansionism in Eastern Europe": *N. Wagner. (2012). NATO AND THE WARSAW PACT. Scientia Militaria, 8(4), Scientia Militaria, 01 February 2012, Vol.8(4)*; "The Warsaw Pact provided [the] basis for the presence of Soviet troops on the territory of some of the Eastern European countries": *United States. Congress. Senate. Committee on Government Operations. Subcommittee on National Security International Operations. (1966). Warsaw Pact, Its Role in Soviet Bloc Affairs. Study. S.l]: [s.n.]*.

[94] "A non-violent political revolution. The phrase originally applied to the peaceful overthrow of communism in Czechoslovakia in 1989": *Velvet Revolution. (2009). Brewer's Dictionary of Modern Phrase and Fable*; "The ideals of liberal democratic government [was simply the] reassertion of national heritage and not [seen] as something alien or imposed from outside": *Shepherd, Robin. Czechoslovakia: The Velvet Revolution and Beyond, Palgrave Macmillan Limited, 2000. ProQuest Ebook Central*; "Czechoslovakia is distinctive in that the two phases of transition to democracy – liberalisation and democratisation – occurred concurrently": *Balík, Stanislav,* et al. *Czech Politics: from West to East and Back Again, Verlag Barbara Budrich, 2017. ProQuest Ebook Central.*

[95] "The main reason Czechoslovakia disintegrated in 1992 can be explained quite simply: there was no strong Czechoslovak identity.": *Stolarik, & Stolarik, M. Mark. (2016). The Czech and Slovak Republics Twenty years of Independence, 1993–2013. New York: Central European University Press*; "It is worth noting that the term Velvet Divorce was popularized by Western journalists and not used by Czechs or Slovaks to describe the process of separation": *Chloupek, B., Hanks, Reuel, Lightfoot, Dale, & Jenswold, Joel. (2007). Young Czechs' Perceptions of the Velvet Divorce and the Modern Czech Identity*; "the marriage of these two states was never better than an uneasy union": *Ulc, Otto. (1996). Czechoslovakia's velvet divorce. (formal dissolution into Czech and Slovak states in 1992). East European Quarterly, 30(3), 331–352.*

[96] "Until 2012 the Czech Republic was almost unambiguously classified as a parliamentary regime": *Brunclík, M., & Kubát, M. (2016). Český demokratický rezim po roce 2012: Prechod k poloprezidencialismu? Sociologicky Casopis, 52(5), 625–646.*, but when the first directly elected president, Milos Zeman, attempted to bypass parliament and directly appoint a cabinet, the question becomes are countries with directly elected presidents a parliamentary republic or of a semi-presidential nature, as "evidence from other Central and Eastern [European] countries shows that directly elected presidents […] are sometimes prone to challenge the existing balance of power and prerogatives in their favor": *Hlousek, V. (2014). Is the Czech Republic on its Way to Semi-Presidentialism? Baltic Journal of Law & Politics, 7(2), 95–118*; When discussing forms of government in Central and Eastern Europe "some scholars tend to approach them as parliamentary regimes, others classify them as semi-presidential ones": *Miloš Brunclík, & Michal Kubát. (2014). Parlamentarismus nebo poloprezidencialismus? Spor o klasifikaci středoevropských demokratických režimů. Central European Political Studies Review, 16(2–3), 118–136*.

[97] 81 seats whose members are directly elected, see https://www.senat.cz/senat/index-eng.php?ke_dni=14.05.2020&O=12, Accessed May 14, 2020.

[98] Consists of 200 seats. Members to elected to this chamber are proportionally directly elected in 14 multi-seat constituencies, see https://public.psp.cz/en/sqw/hp.sqw?k=181, Accessed May 14, 2020.

[99] The Constitution of the Czech Republic of 16 December 1992, No. 1/1993 Sb. as amended by constitutional acts No. 347/1997 Sb., No. 300/2000 Sb., No. 395/2001 Sb., No. 448/2001 Sb., No. 515/2002 Sb., No. 319/2009 Sb., No. 71/2012 Sb. and No. 98/2013, https://www.senat.cz/informace/zakon106/zakony/ustava-eng.php?ke_dni=14.5.2020&O=12, Accessed May 14, 2020.

[100] Id. Article 1 (1).

[101] Id. Article 2 (1).

[102] Id. Article 6.

on pension and social services, as well as a problematic education system requiring reform, and access to skilled workers.

3.3.2.1. Legislative framework. Within the past five years, Czechia has made numerous advances in promulgating its nuclear legal legislative framework. Act No. 263/2016 Coll., Atomic Act ("the Atomic Act"), governs nuclear activities in the country and incorporates relevant legislation of the European Atomic Energy Community and the E.U. The Atomic Act regulates the peaceful uses of nuclear energy through each state and stage of progression - from siting thru decommissioning. The Atomic Act creates the legal foundations to guard against the inappropriate use of ionizing radiation and to promote the best utilization of nuclear energy and ionizing radiation, while adequately protecting the public and the environment from any harmful effects. The Atomic Act (2016) replaces the previous Act No. 18/1997 Coll., except for those issues dealing with nuclear third-party liability. Such specific matters will be addressed in newly promulgated legislation and remain valid until new legislation on this subject is adopted (*Nuclear legislation in OECD countries - Czech Republic*). A diagram displaying the main features of the Atomic Act is presented in Fig. 20a–c, and Czechia's Atomic Energy Act's Definition of Waste & Waste Management is explained in Fig. 21.

3.3.3. Radioactive waste management

Czechia ensures that disposal costs for created radioactive waste and spent fuel will not be burdensome to future generations by imposing a duty of care to producers to bear the cost of its management and disposal[103]. Such an imposed duty of care is in harmony with the 'polluter pays' principle, which forms an integral part of nuclear power programs around the world. Additionally, producers of radioactive waste and spent fuels are obligated to include minimization strategies in their work activities to do all that is necessary to reduce the generation of radioactive waste, when possible. A shallow land repository for radioactive waste is operated by Radioactive Waste Repository Authority (SÚRAO) within the Dukovany Nuclear Power Plant (NPP) site. It is designed to accommodate all future low-level radioactive waste from both the Dukovany and Temelín NPPs. SÚRAO[104] also maintains and operates low and intermediate-level facilities, providing for the safe disposal of radioactive waste in the country (*National Report – Czech Republic*). An overview of the radioactive waste repositories in the Czech Republic is presented in Fig. 22.

3.3.3.1. Permanent disposal. Czechia's program for the final disposal of spent nuclear fuel is well defined. As shown in Fig. 23, fuel is first removed from the rector and stored in a spent fuel pool before its temporary placement into interim dry storage. Czechia is expected to begin site selection around 2025, with eventual construction of a deep geological repository to begin mid-century. The commissioning of an eventual repository is planned for 2065. Currently, the country boasts dry cask-type spent fuel storage facilities at its two NPP sites[105].

Site selection will be based on volunteerism comprising two phases, along with active participation of interested host communities. Phase 1 consists of assessing available archived geological data, followed by initial non-invasive surface investigative activities at the pre-selected sites. Compiled information will determine which sites are candidates for Phase 2. Phase 2 investigation is the site depiction phase consisting of detailed invasive below surface methods to gather and study more detailed features of the host rock formation, including the drilling of deep boreholes (*Radioactive Waste Repository Authority website*).

3.4. Netherlands or nederland

Quick Facts – Netherlands (*Nuclear Power in the Netherlands*).

1.	Has a minor nuclear power generating program with one operating reactor.
2.	In 1973, the first commercial nuclear reactor began operation.
3.	Government policy to phase out nuclear power has been reversed.

3.4.1. Historical overview & law

A small country with a long reach, best describes the Netherlands. Netherlands, a country located in northwestern Europe along the North Sea, means low-lying country (*Encyclopedia Britannica - Netherlands*). The country became a commercial power during the 17th century through trade[106], by having one of the world's most expansive shipping capabilities for its time. This small nation established settlements and

[103] Readers are recommended the following resource for a further more detailed discussion on radioactive waste issues in the Czech Republic, including Slovak Republic and Poland: *A. Vokál, P. Stoch, - Czech Republic, Slovak Republic and Poland: experience of radioactive waste (RAW) management and contaminated site clean-up, Editor(s): William E. Lee, Michael I. Ojovan, Carol M. Jantzen, In Woodhead Publishing Series in Energy, Radioactive Waste Management and Contaminated Site Clean-Up, Woodhead Publishing, 2013, Pages 415–437, ISBN 9780857094353.*

[104] https://www.surao.cz/en/, Accessed May 28, 2020. The Richard repository includes the only certified test facility for testing waste containers in the Czech Republic. See: https://www.surao.cz/en/public/operational-repositories/richard-repository/, Accessed May 28, 2020.

[105] In operation between 1995 and 2006, the first interim storage facility at the Dukovany nuclear power plant has a capacity of 600 tonnes of heavy metals. In 2006, a second storage facility at the site, boasts a capacity of 1340 tonnes of heavy metals. The capacitiy provided by the second facility is deemed to be sufficient to provide storage for the remaining production of spent fuel for all four units at the site. Additionally, at the Temelín nuclear power plant site spent fuel storage has been conducted since 2010, with a capacity of 1370 tonnes of heavy metals.

[106] Built on the strength of mercantilism, Netherlands prospered through its vast trade networks and emerged as a superpower in the 17th and 18th centuries. However, this "golden age" saw 'endless' wars against the English, French and Spanish, while Dutch maritime might brought colonization to the Caribbean, East Indies and - for a while - part of Brazil, as well as North America: *Moore, John. (2013). Dutch treat: Take a voyage of discovery into the Netherlands' history. (BACK PAGE: PE finds places to go and things to do) (Het Scheepvaartmuseum in Amsterdam, Netherlands). Professional Engineering Magazine, 26(6), 80*; "since the late sixteenth century, [the Netherlands] has been one of the most successful economies in the world […], but never underwent an industrial revolution of the kind which typified the experiences of its neighbors Britain, Belgium, parts of France, and Germany": *Wintle, Michael. An Economic and Social History of the Netherlands, 1800–1920: Demographic, Economic and Social Transition, Cambridge University Press, 2000. ProQuest Ebook Central.*

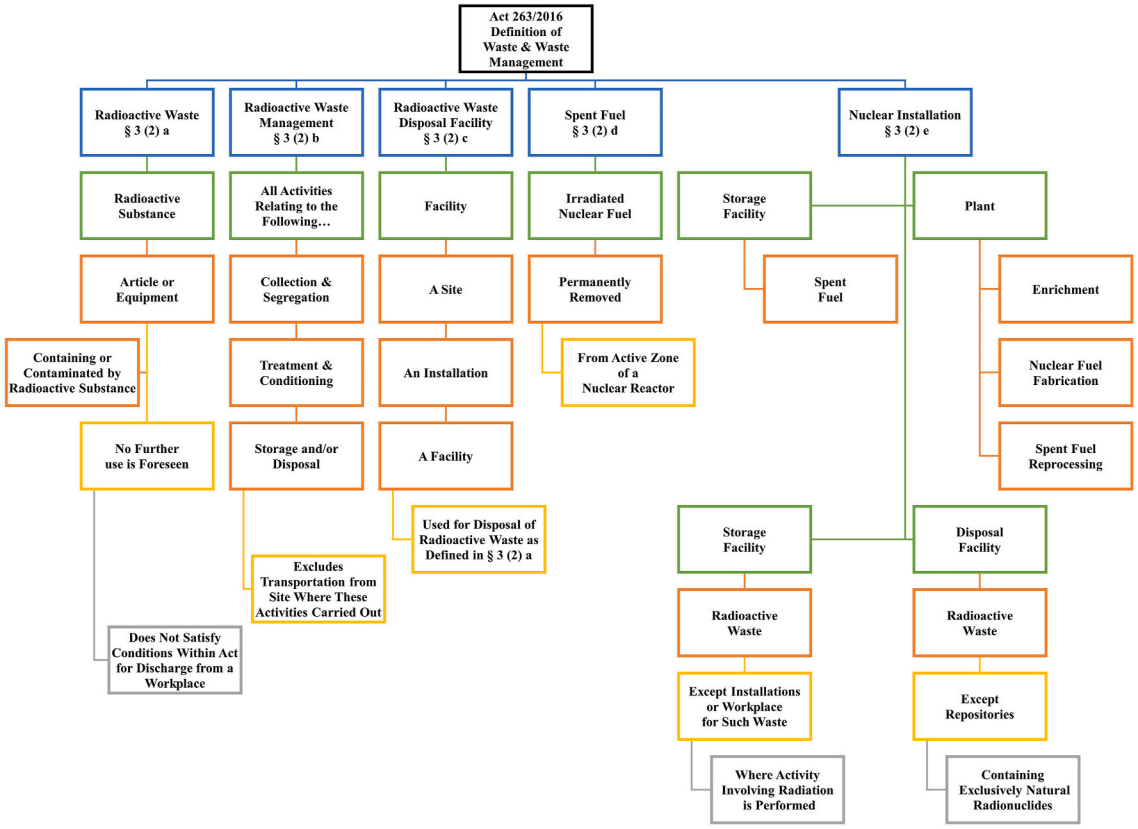

Fig. 21. Czechia's atomic energy Act's definition of waste & waste management.

colonies across the globe, including New Netherlands[107] in 1624. This settlement "grew to encompass all of present-day New York City and parts of Long Island, Connecticut, and New Jersey" (*History.com - New Amsterdam*). In 1579, the Dutch United Provinces avowed their independence from Spain[108], and finally in 1815 a Kingdom of the Netherlands was proclaimed. As mentioned in section 3.2.1, Belgium

[107] "Dutch North American colony founded by Peter Minuit in 1621, at the mouth of the Hudson River between the Delaware and Connecticut rivers. The British seized New Amsterdam in 1664, and secured the rest during the Anglo-Dutch war of 1672-74": *New Netherlands. (2001). In J. Haywood (Ed.), Andromeda encyclopedic dictionary of world history. Windmill Books (Andromeda International)*; "New Netherland may well have been the healthiest place for Dutch settlers to live, compared to any other part of the Dutch Atlantic world. But its climate did not earn the colony a preferential treatment from the West India Company": *Frijhoff, Willem, and Jaap Jacobs. Revisiting New Netherland: Perspectives on Early Dutch America, edited by Joyce D. Goodfriend, BRILL, 2005. ProQuest Ebook Central*; "is a very beautiful, pleasant, healthy, and delightful land, where all manner of men can more easily earn a good living and make their way in the world than in the Netherlands or any other part of the globe that I know": *Donck, A., Gehring, C.T., Starna, W.A., Goedhuys, D.W., & Shorto, R. (2008). A Description of New Netherland. Lincoln: University of Nebraska Press. muse.jhu.edu/book/11863.*

[108] William of Orange was an ambitious nobleman who led the opposition against Spain with military attacks in 1568 (William was shot and killed on July 10, 1584). The Twelve-Year Truce in 1609 brought a temporary cessation of hostilities, and in 1648 the Republic of the Seven United Low Countries received international recognition as a sovereign state with the signing of the Treaty of Westphalia in Munster at the conclusion of the Thirty Years' War: *Van Oostrom, Fits. (2008). The Netherlands in a nutshell: Highlights from Dutch history and culture. Amsterdam: Amsterdam University Press*; "The Revolt of the Seven Provinces in the Netherlands from the Dominion of Philip II, King of Spain, and the Establishment of these Republics, are remarkable events in modern history. The United Provinces […] not only opposed the measures of the most powerful monarch then in Europe […] but carried on a war for many years [… whilst] increasing in wealth and importance": *Lothian, W. (1780). The history of the United Provinces of the Netherlands, from the death of Philip II. King of Spain, to the truce made with Albert and Isabella. By William Lothian, D.D. one of the ministers of canongate. (Eighteenth century collections online). Dublin: Printed for Messrs. W. and H. Whitestone, Walker, Jenkin, E. Cross, White, and Beatty*; "[…] together are not to be seen in all the rest of Europe, as in this little plot of the Low-Countreys. It is likewise proper to this Nation (if left to themselves) to hate fraud [… and] no people under heaven drive a subtiler traffic, either by Sea or Land": *Strada, F., & Stapylton, R. (1667). The history of the Low-Countrey warres relating the battles, sieges, and sea-fights, betwixt the King of Spain, France, and the States of the United Netherlands: With several private instructions of embassadors, secret councels of warre, and letters from most princes of Christendom (Early English books online). London: Printed and are to be sold by Samuel Thompson … Robert Horn … Henry Mortlack … Peter Parker …*

declared itself independent from the Netherlands in 1830, forming a separate kingdom. The Netherlands largely stayed out of the hostilities during World War I[109], along with other acknowledged neutral countries in Scandinavia. However, declared neutrality did not prevent the country from experiencing the horrors of invasion and occupation during World War II, when among other tragedies, the city of Rotterdam[110] was completely destroyed by a German air attack. (*CIA World Factbook – Netherlands*).

Not only have the Dutch looked outward to the sea to build the country's economy through trade, but also land reclamation[111] activities have allowed for approximately 17% of the country's current land area to be reclaimed from the sea or lakes (*Brilliant Maps – Netherlands*). Remarking on the Netherland's reclamation efforts over the centuries, Grattan (2012) states:

> "This is a conflict not of days, nor of years, nor of generations, but of all time […] It is the concrete symbol of the everlasting fight of man with nature" (*Grattan, 2012*)

Such a statement portrays not only Netherland's nuclear power and radioactive waste management programs, but also all the nuclear power and radioactive waste management programs for peaceful purposes from the mid-20th century and onward around the world. Netherlands has one operating nuclear power reactor and nuclear energy is only a small fraction of total energy output in Netherlands. In 1955, the High Flux Reactor began to be constructed and criticality was achieved in 1961. The country's first commercial reactor - Borssele NNP - began producing electricity for national consumption in 1973. Though plans initially called for increasing nuclear power generation in the Netherlands, the accident at Chernobyl in 1986 dampened public enthusiasm for nuclear power.[112] The negative expressions of the public towards nuclear power led to the Dodewarrd NNP being permanently shut down in 1997. In consultation with the Dutch Government, an agreement was signed in 2006 with the owners of the Borssele NPP to allow the continued operation of the reactor through the conclusion of 2033. This agreement was transposed into Article 15 (Section A) of the of the Nuclear Energy Law (*IAEA Country Profiles – Netherlands*). Going forward, Netherlands enjoys a strong tailwind lifting a potential expansion of its nuclear power program, but also faces strong opposing headwinds. Both are presented in Fig. 24.

3.4.2. Government & legislative regime

The Netherlands is a parliamentary constitutional monarchy operating under a civil law system rooted in the French system, with a

[109] "Not only was the Netherlands militarily ill prepared for a European war, it was also uncertain about its obligations as a neutral state towards belligerents in the event of such a war". Having declared itself to be a neutral country, any soldiers who crossed into the Netherlands, while actively participating in the hostilities (*e.g.*, Belgium soldiers fleeing the advancing German armies) had to be interned. However, "this was not always straightforward": *Wolf, Susanne. Guarded Neutrality: Diplomacy and Internment in the Netherlands During the First World War, BRILL, 2013. ProQuest Ebook Central*; From the turn of the 19th to 20th centuries and up to the beginning of World War I in 1914, the Netherlands hoped for peace among its European neighbors. "In international politics the Netherlands kept clinging to a position of neutrality. Economic interests and the possession of the large and prosperous colonial territories lay at the basis of this attitude": *Klinkert, Wim. Defending Neutrality: The Netherlands Prepares for War, 1900–1925, BRILL, 2013. ProQuest Ebook Central*; "On the eve of World War I the Netherlands, officially neutral since 1839, faced a strategically precarious position because it was vulnerable to German power on the continent and British dominance at sea. To avoid being dragged into a European war, the Netherlands followed a policy of neutrality designed to convince other powers that it was determined to maintain its neutrality": *van Tuyll, H. P. (2000) 'The Dutch Mobilization of 1914: Reading the 'Enemy''s Intentions', Journal of Military History, 64(3), pp. 711–737.* https://doi.org/10.2307/120866; During World War I were the rights and duties of the declared neutrals afforded to these countries because such obligations and rights are codified in international law is a relevant question. One argument presented is that "belligerents realized that acting too harshly or too brashly might drive neutrals into the hands of the enemy" and therefore such privileges were not enjoyed due to the dictates of international law, but "what counted was bargaining" between the powers: *Den Hertog, J., Kruizinga, S., & "The first world war the end of neutrality?". (2011). Caught in the middle neutrals, neutrality and the first world war (Studies of the Netherlands Institute for War Documentation). Amsterdam: Aksant.*

[110] "Dutch security policy, therefore, was based on two main concepts: it would benefit strongly from a stable balance of power in Europe, and the neutrality was an armed neutrality": *Amersfoort, Kamphuis, Amersfoort, H., & Kamphuis, P. H. (2010). May 1940: The battle for the Netherlands (Brill ebook titles). Leiden; Boston: Brill.*; "In the early morning hours of 10 May 1940, troops from the German Wehrmacht's Sixth and Eighteenth Armies streamed into the Netherlands by land and by air. Within five days of this initial assault, the port city of Rotterdam had been destroyed by the German Luftwaffe; Queen Wilhelmina and her cabinet had fled to London; and the Commander-in-Chief of the Dutch army, General H.G. Winkelman, had surrendered": *Foray, J. (2010). The 'Clean Wehrmacht' in the German-occupied Netherlands, 1940–5. Journal of Contemporary History, 45(4), 768–787.*

[111] "The first stage was in the sixteenth and seventeenth centuries when many lakes north of Amsterdam were drained and reclaimed for agricultural use. Windmills were used to pump these lakes dry. Next, in the nineteenth century, Lake Haarlem became the largest lake drained in the Netherlands and one of the first to be drained using steam-powered pumps alone. Finally, in the twentieth century the Zuiderzee tidal estuary was drained and reclaimed, resulting in an additional 1650 km^2 of new land for agriculture, recreation, and urban expansion": *Hoeksema, R., Vlotman, Willem F., & Madramootoo, Chandra A. (2007). Three stages in the history of land reclamation in the Netherlands. Irrigation and Drainage, 56(S1), S113–S126*; "Land reclamation has been and still is one of the most interesting aspects of engineering in The Netherlands, where about 60% of the surface of the country is at or below sea level", *De Mulder, E., Van Bruchem, A., Claessen, F., Hannink, G., Hulsbergen, J., & Satijn, H. (1994). Environmental impact assessment on land reclamation projects in The Netherlands: A case history. Engineering Geology, 37(1), 15–23*; "transition from small-peasant farming society to one more dominated by urban elite investment and land-ownership in the sixteenth century was facilitated by the favourable institutional framework and flexible land markets which emerged through the reclamation context": *Curtis, Daniel R., & Campopiano, Michele. (2014). Medieval land reclamation and the creation of new societies: Comparing Holland and the Po Valley, c.800-c.1500. Journal of Historical Geography, 44, 93.* Also see *Van De Grift, L. (2013). On New Land a New Society: Internal Colonization in the Netherlands, 1918–1940. Contemporary European History, 22(4), 609–626* for a discussion on the policies of social planning in the post war years surrounding land reclamation activities.

[112] A similar public response is observed in many countries in Europe.

hereditary Head of State. The role of the Queen or King[113] is largely ceremonial, but the reigning Monarch does have limited influence directing the process of government formation. Parliament is the highest authority and guardian of the constitution with no judicial review. However, the Council of State (headed by monarch) may perform internal reviews. Additionally, approved international treaties "override all Dutch laws and also the constitution" (*Woldendorp* et al., *2000*). From the 1980's, Dutch politics is centered on maintaining the social compact ("polder model"), which seeks to encourage economic development through deregulation, whilst maintaining an adequate social safety net (*Financial Times -Netherlands, 2011*). The Dutch Parliament or "the States General" is bicameral, divided into two chambers: the Senate[114] (Eerste Kamer der Staten-Generaal) and the House of Representatives[115] (Tweede Kamer der Staten-Generaal) (*Netherlands - How Parliament Works*). The House of Representatives ensures that Government is carrying out its work in the manner specified and has a significant role in policy-making. The Senate's task is to 'accept' or 'reject' bills, but it does not have the right to amend legislation before it.

3.4.2.1. Legislative framework. Netherlands has a simplified hierarchy framing the use of nuclear technologies, detailed in Fig. 25. While there are various laws that are applicable to the governance of radioactive waste and spent fuel, the Nuclear Energy Act (KEW) is most prominent. KEW governs the appropriate use of nuclear activities, as well the proper management of nuclear materials. The law lays out rules of application, provides for the protection of persons and the environment, and entitles competent authorities with roles and responsibilities (*Nuclear Legislation in OECD Countries – Netherlands*). KEW endows The Authority for Nuclear Safety and Radiation Protection (ANVS) with independent powers to ensure nuclear safety and radiation protection are maintained, prepare for potential crises, and to confirm that adequate security and safeguard measures are preserved.[116] A diagram of KEW, other important related acts, and important decrees are presented in Figs. 26–28.

3.4.3. Radioactive waste management

Because the Netherlands has a fairly minor nuclear program, the amounts of spent fuel and radioactive waste needing to be managed is not cumbersome (*ENSREG website - The Netherlands*). The country uses a centralized storage site, hosting the facilities of the Central Organization for Radioactive Waste[117] (COVRA). Situated in Borsele - South-Western part of the Netherlands - COVRA is responsible for putting into practice Dutch policy in the field of radioactive waste management. COVRA's duty of care is to protect people and the environment while housing conditioned low, intermediate, and high-level waste in interim storage. COVRA's buildings are designed to provide interim storage capabilities for at least 100 years (*COVRA, website*).

3.4.3.1. Permanent disposal. A final decision on permanent disposal in the Netherlands will not occur until the turn of the next century (2100). Though it may appear, at first glance, that the country is putting off the decision-making burden onto future generations, this is not the case. Having created the interim storage facilities at COVRA, the country has created acceptable margins of flexibility in the decision-making processes. The 21st century will be used by the country to adequately prepare, design and take advantage of the radioactive waste management influencers to inform public policy for a permanent deep geological facility[118] to be operational around 2130 (*National Report – Netherlands*). Also, during this time, the country will engage in a dual track strategy by gathering insights from other national programs to better enlighten the Netherlands' program, as well as to take advantage of potential multi-national management options - should they become a reality. The retrievability of waste must be part of the design for a geological disposal facility, so that waste may be retrieved during its operation phase. Reprocessing of spent fuel is a decision that is left to the NPP operator. Borssele sends its spent fuel to France for reprocessing. Agreements are in place for the processing and return of the radioactive residues to the Netherlands. Spent fuel from research reactors is not reprocessed but is to be directly shipped to COVRA for interim storage.

3.5. Romania or România

Quick Facts – Romania (*Nuclear Power in Romania*).

1. The country has two nuclear reactors
2. The first reactor in the country began operating in the mid-1990's (1996); the second in the mid 2000's (2007).
3. Government policy leans toward strong support of nuclear energy and is planning on an expansion of the country's program.
4. Approximately 17% of power generation is obtained by the country's two reactors.

3.5.1. Historical overview & law

The story of Romania as a country is a story that may be referred to as a chameleon country. Given its geographical position - with a coastline on the Black Sea - the country has at time been controlled by the Poles, Hungarians, and Ottomans.[119] Romania as a self-governed state first took shape in the later part of the nineteenth century, with a ruling independent monarchy[120] in 1878 (*Romania, 2011*). The country

[113] Royal House of the Netherlands, Position and role as head of state, King Willem-Alexander https://www.royal-house.nl/members-royal-house/king-willem-alexander/position-and-role-as-head-of-state#:~:text=Positionandroleasheadofstate,the%20inhabitants%20of%20the%20Netherlands., Accessed June 04, 2020.

[114] https://www.houseofrepresentatives.nl/senate, Accessed June 04, 2020.

[115] The House of Representatives at work, https://www.houseofrepresentatives.nl/how-parliament-works/house-representatives-work, Accessed June 4, 2020.

[116] Nuclear Energy Act, Chapter II (The Authority for Nuclear Safety and Radiation Protection), Art. 3, § 3, https://wetten.overheid.nl/BWBR0002402/2018-10-16, Accessed June 04, 2020.

[117] https://www.covra.nl/en/, Accessed June 06, 2020.

[118] The Research Programme for the Geological Disposal of Radioactive Waste, referred to as OPERA, has reached two overarching decisions for the Dutch program: (1) waste can be safely stored in the clay media and this media presents a suitable host geology; (2) to make best use of public funds and available potential technologies, a long-term research program is required. See Deep Geological Disposal, https://www.covra.nl/en/radioactive-waste/deep-geological-disposal/, Accessed June 06, 2020. Also see 'Letter to parliament with integral policy response to reports on final disposal of radioactive waste', https://www.rijksoverheid.nl/documenten/kamerstukken/2018/05/14/integrale-beleidsreactie-onderzoeksprogramma-eindberging-radioactief-afval-opera-en-rapport-kwartiermaker-klankbordgroep-eindberging (Dutch Language), Accessed June 06, 2020.

[119] In 1856, the principalities of Wallachia and Moldavia achieved autonomy. In 1862, they were formally united under the name Romania. Official recognition of independence was declared in 1878.

[120] Carol Hohenzollern-Sigmaringen was the first modern king of Romania. See: The Economist Explains, What happened to Romania's monarchy? https://www.economist.com/the-economist-explains/2018/10/12/what-happened-to-romanias-monarchy, Accessed June 08, 2020; A Short History of the Romanian Monarchy, https://www.historia.ro/sectiune/general/articol/a-short-history-of-the-romanian-monarchy, Accessed June 08, 2020; Lakritz, L., INSIDER, https://www.insider.com/countries-used-to-be-monarchies-abolished-history, March 2, 2020, Accessed June 08, 2020.

supported the Allied Powers during World War I and was rewarded with new territories (most notably Transylvania). However, Romania allied itself with Germany during World War II and invaded the Union of Soviet Socialist Republics (USSR) as part of Operation Barbarossa[121] in the summer of 1941. The oil field at Ploiesti[122] helped to fuel the German war machine and was considered a strategic target for US bombing in1943.[123] Following an agreed armistice with the Soviets at the end of the war, the country fell into the Soviet sphere of influence.[124] From 1965, Nicolae Ceaușescu[125] ruled the communist Romanian People's Republic[126] until his execution following a coup in 1989 (*CIA World Factbook – Romania*).

The Romanian nuclear power program launched in the late 1960's. In 1971, the Institute for Nuclear Technologies was founded as a supporting organization providing technological support to move the country's nuclear program forward into the 21st Century. The nuclear power program moved forward in steady progression, seeing the country's first reactor become operational in 1996. The country's second reactor began operation in the mid 2000's. Romania is actively pursuing adding new nuclear capacity in the country with the likely completion of units 3 and 4 at the Cernavoda NPP Site (*IAEA Country Nuclear Profiles – Romania*). The major historical milestones achieved during the development of Romania's nuclear power program is provided in Fig. 29.

3.5.2. Government & legislative regime

Romania, a semi-presidential republic, functions under a civil law system. The Executive branch is divided into a chief of state (president) and a head of government (prime minister). The legislative branch is a bicameral Parliament consisting of a Senate[127] and Chamber of Deputies.[128] The country's most recent initial constitution is thirty years of age. It was adopted and approved by referendum in late1991.[129] The constitution declares the country to be a sovereign and independent state[130] that is based on the rule of law.[131] It seeks to infuse the ideals of democratic traditions as supreme values inherent to the Romanian people.[132] The constitution organizes the separation of powers between the branches of government,[133] and requires the mandatory observance of the constitution's supremacy.[134] The constitution pledges that the State will fulfill obligations deriving from international treaties,[135] which become part of national law once ratified by Parliament.[136] However, where there are provisions in a treaty that are contrary to the country's constitution, then treaty ratification may only occur following a revision to the Constitution.[137] Importantly, the constitution grants the people right of access to information in the public interest[138] and binds public authorities to provide information that is correct.[139] Enshrined in

[121] *Mulcahy, R. (2006) 'Remembering BARBAROSSA', World War II, 21(1), pp. 34–40*; "Romania and Finland in World War II provide examples of small nations caught in conflict between major powers, driving alliances and actions to survive", *Kaspar, E., & Us Army Command General Staff College Fort Leavenworth United States. (2015). Suffering What They Must: The Shifting Alliances of Romania and Finland in World War II.*

[122] "In August 1939, in a secret supplementary protocol to the Nazi–Soviet Pact, the German foreign minister, Ribbentrop, recognized that Bessarabia belonged to the Soviet Union's sphere of influence. Meanwhile, the German Reich secured control of Romania's oil fields": *Territorial Revisionism and the Allies of Germany in the Second World War: Goals, Expectations, Practices, edited by Marina Cattaruzza* et al., *Berghahn Books, Incorporated, 2012. ProQuest Ebook Central*, "From Ploesti alone came 27% of all Axis petroleum products, to feed the Nazi war machine": *Films for the Humanities & Sciences, Films Media Group, & WPA Film Library. (2011). The WPA Film Library Americans Bomb Ploesti Oil Fields, 1944. New York, N.Y.: Films Media Group*; By the outbreak of World War II, Romania was considered to be the largest oil producer in Europe. It was strongly believed at the outbreak of war that the Germans desired to take control of the Ploiesti oil fields and the potential invasion of the country by the Germans was imminent: *Snyder, E. 2016, "Operation Tidal Wave: Targeting the source of Germany's oil supply", World Oil.*

[123] The first attack occurred on August 01, 1943.174 B-24 Liberators travel 1200 miles to strike the oilfields at Ploesti, having taken off from bases in Libya: *Over the Cauldron of Ploesti: The American Air War in Romania*, https://www.nationalww2museum.org/war/articles/over-cauldron-ploesti-american-air-war-romania, Accessed June 08, 2020.

[124] Though under the Soviet sphere of influence, various authors suggest that the country either responded to Soviet demands or exercised its own approach to foreign policy: *Stanciu, C. (2018). Romania and the Third World during the heyday of the détente. Third World Quarterly, 39(10), 1883–1898.*

[125] "Ceausescu established the most pervasive Eastern European cult of personality": *Roper, Stephen D. Romania: The Unfinished Revolution, Taylor & Francis Group, 2000. ProQuest Ebook Central.*

[126] "Romanian society has transitioned from a centrally planned, communist dictatorship with crumbling infrastructure and a stifled democracy to a newly integrated member of the European Union", *Vaduva, S. (2016). Between Globalization and Integration, The Europeanization of Romania (*1st *ed. 2016. ed., SpringerBriefs in Economics). Cham: Springer International Publishing: Imprint: Springer.*

[127] https://www.senat.fr/senatsdumonde/english/romania.html, Accessed June 09, 2020.

[128] http://www.cdep.ro/pls/dic/site.home?idl=2, Accessed June 09, 2020.

[129] Constitution of Romania (1991), http://www.cdep.ro/pdfs/constitutie_en.pdf, Accessed June 09, 2020.

[130] Id. Article 1, (1).

[131] Id. Article 1, (3).

[132] LAW for the revision of the Constitution of Romania (The Law No. 429/2003 on the revision of the Constitution of Romania was approved by the national referendum of 18–19 October 2003, and came into force on 29 October 2003), http://www.cdep.ro/pdfs/reviz_constitutie_en.pdf, Accessed June 09, 2020. See Article 1, (3).

[133] Id. Article 1, (4).

[134] Id. Article 1, (5).

[135] Constitution of Romania (199); See Article 11, (1).

[136] Id. Article 11, (2).

[137] The Law No. 429/2003 on the revision of the Constitution of Romania; See Article 11, (3).

[138] Constitution of Romania (199); See Article 31, (1).

[139] Id. Article 31, (2).

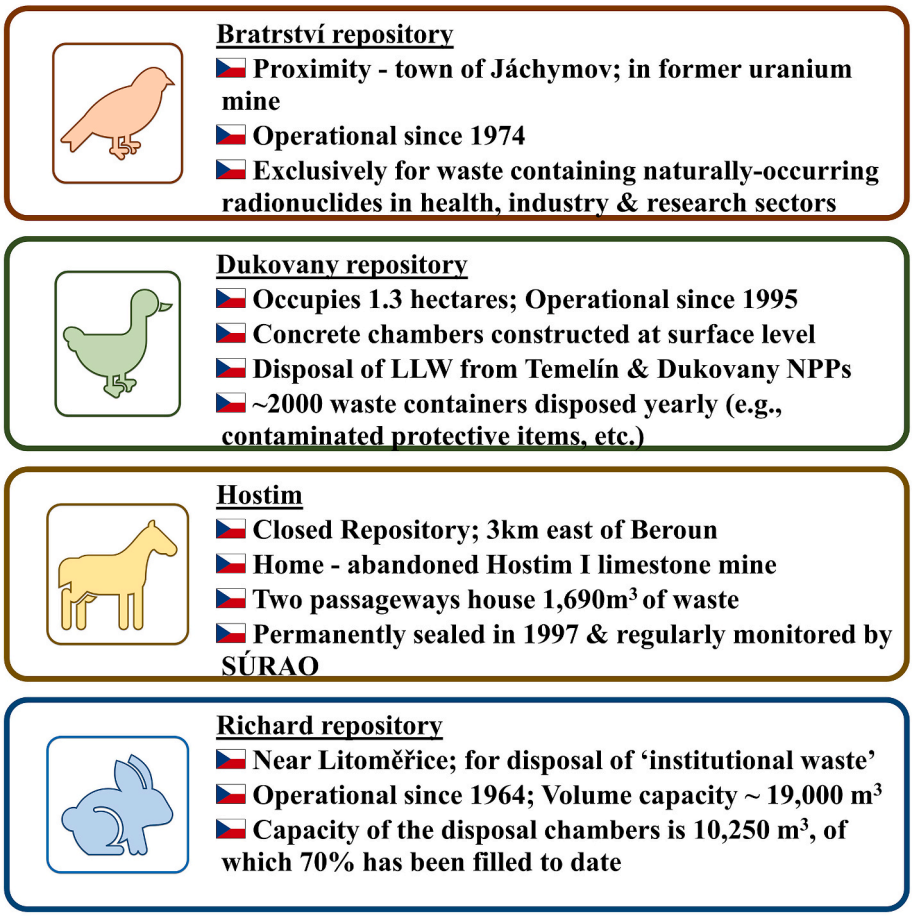

Fig. 22. Radioactive waste repositories in Czechia.

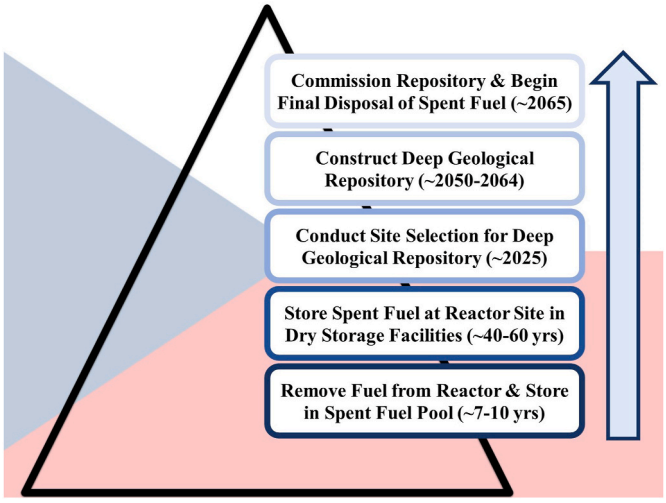

Fig. 23. Timeframe for storage & disposal of spent fuel in Czechia.

the constitution is a right to "a healthy, well preserved and balanced environment[140]", which natural persons and legal entities are duty bound to protect and improve.[141]

3.5.2.1. Legislative framework. The legislative framework for the safe deployment, regulation, authorization and control of nuclear activities in Romania is governed by Law no. 111/1996,[142] republished with subsequent completion and modification. The object of the law is to regulate, authorize and control activities for peaceful purposes.[143] Law no. 111/1996 ensures that nuclear safety conditions are applied to "protect occupationally exposed workers, the patient, the environment, the population and the property".[144] The law covers activities involving nuclear facilities, production-supply-manufacture of radioactive materials and ionizing radiation generating devices, and services provided to a nuclear facility.[145] Law no. 111/1996 designates the National Commission for Nuclear Activities Control (The Commission) as the

[140] The Law No. 429/2003 on the revision of the Constitution of Romania; See Article 33, (1).

[141] Id. Article 33, (3).

[142] http://www.cdep.ro/legislatie/eng/vol27eng.pdf, Accessed June 10, 2020. A link to Law no. 111/1996 is also found at: https://www.oecd-nea.org/law/legislation/romania.html, Accessed June 10, 2020. Other laws in the Nuclear legal framework include Law no. 105/1999 for ratifying the Joint Convention on the safe management of spent fuel and on the safe management of radioactive waste and Environmental Protection Law 265/2006.

[143] Id. Chapter 1, Article 1.

[144] Ibid.

[145] Id. Article 2, provides a full list of applicable nuclear related activities.

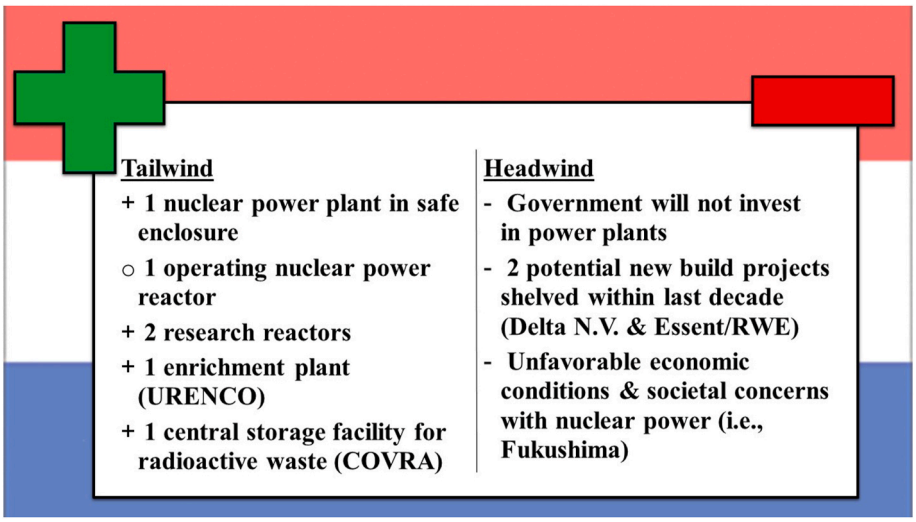

Fig. 24. Condition of the nuclear power sector in Netherlands.

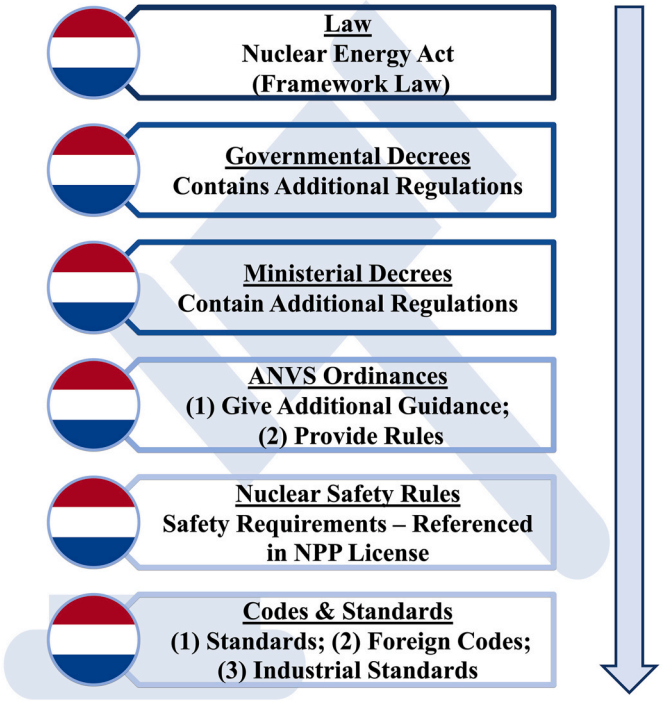

Fig. 25. Hierarchy of the legal framework for nuclear technology in the Netherlands.

competent national authority in the nuclear field.[146] The Commission is endowed with power to issue regulations in varied aspects of nuclear activities.[147] The Commission[148] elaborates strategy and public policy on nuclear safety, protection, non-proliferation, physical protection of nuclear material and facilities, transportation of radioactive materials, nuclear security and radioactive waste and spent fuel management. Each forms part of the National Strategy for Developing the Nuclear Field as approved by Government Decision.[149] The Commission also may grant authorizations and permits for the exercise of nuclear activities for exclusively peaceful purposes in various phases of a nuclear or radiological facility, outlined in Fig. 30.

The 2001 Law on Civil Liability for Nuclear Damages[150] (Civil Liability Law, 2001) was adopted in December 2001. The Civil Liability Law 2001 regulates the compensation of damage involving the peaceful utilization of nuclear energy in Romania.[151] The Civil Liability Law 2001 enshrines three fundamental international liability principles[152] into the Romanian Legal System, detailed in Fig. 31. Whilst liability is strict and exclusive to the operation - where the operator is able to prove that nuclear damage occurred (in whole or in part) from gross negligence or from an act or omission of a person, a competent court may relieve – in whole or in part - the operator from obligations to compensate the person so injured.[153] Additionally, an operator shall be exonerated from liability when nuclear damage is the direct result of armed conflict, civil war, insurrection, or hostilities. Liability of the operator is limited to not less than 300 million Special Drawing Rights (SDR)[154] for any one nuclear accident. Other provisions may further reduce the liability of the operator to set amounts when the difference is provided by the State from public funds.[155] Right to claim compensation for loss of life and personal injury must occur within 30 years from the date of the accident. Claims for compensation with respect to other

[146] Id. Article 4. See http://www.cncan.ro/main-page/, Accessed June 11, 2020.

[147] Id. Article 5 (1).

[148] Id. Article 35 detailing The Commissions Powers and Responsibilities, which include power to (a) initiate draft laws within its field of competence, (b) deliver opinion on all draft laws in the nuclear field, and (g) to cooperate with similar organizations from other states, to name a few.

[149] Id. Article 5 (2).

[150] Law No. 703/2001.

[151] Id. Article 1.

[152] The country is party to the 1963 Vienna Convention on Civil Liability for Nuclear Damage and to the 1997 Protocol to Amend this Convention.

[153] Law No. 703/2001, Article 5 (1).

[154] Id. Article 8 (1); The equivalent in ROL (Romanian Lei).

[155] Id. Article 8 (2) limitation not less than 150 million. See also Article 8 (3)–(5).

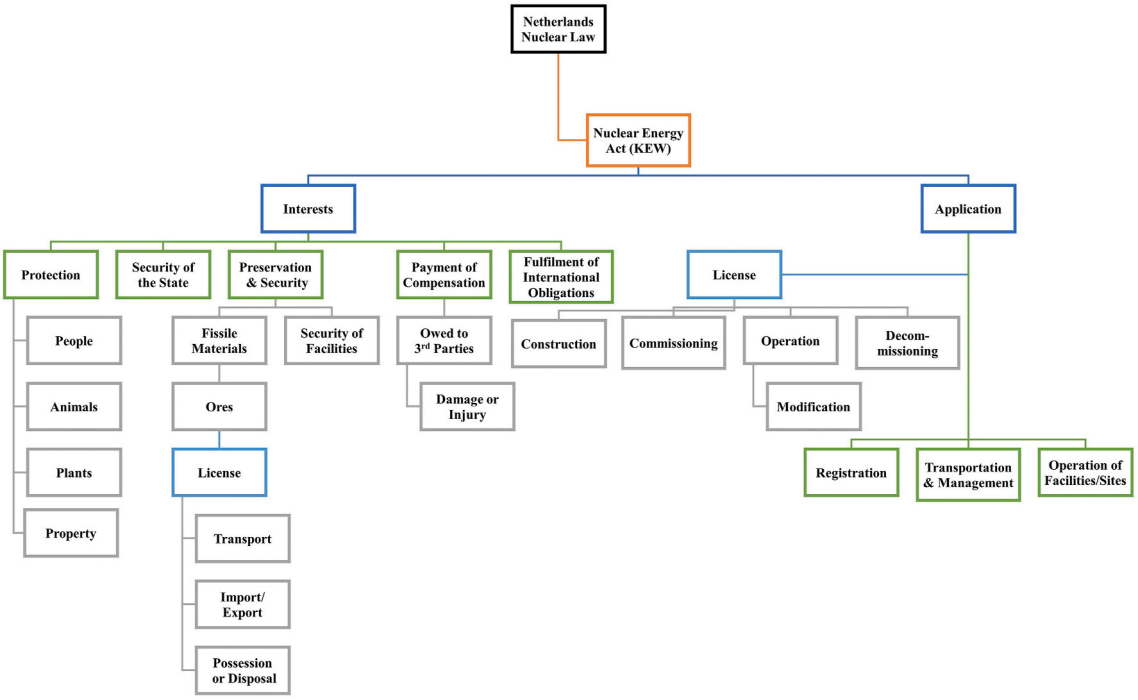

Fig. 26. Nuclear energy Act - Netherlands.

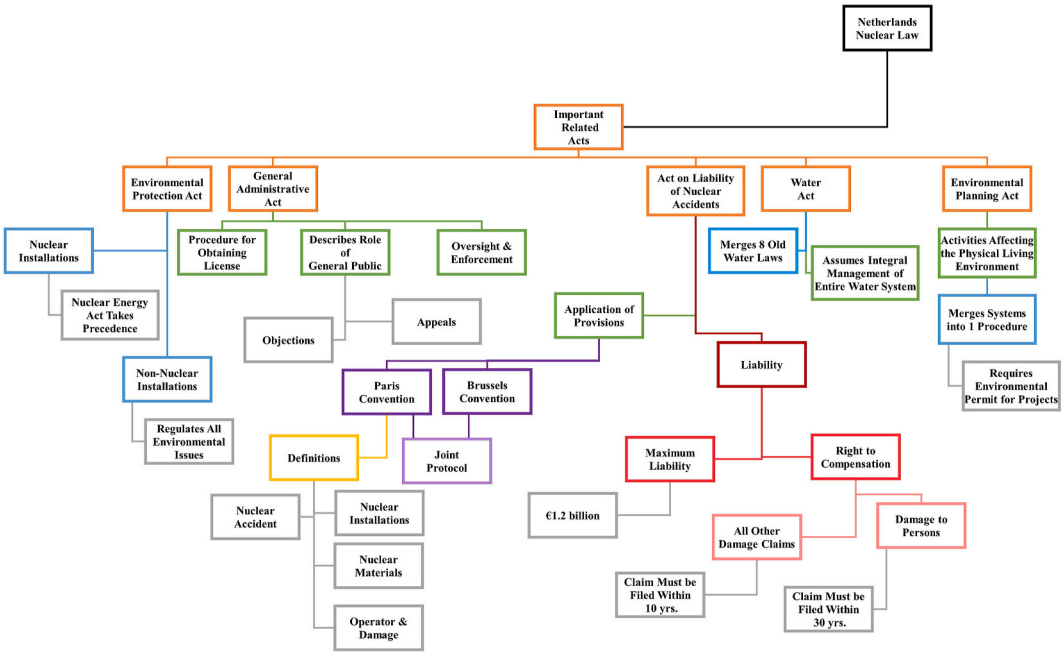

Fig. 27. Other important nuclear related acts in the Netherlands.

nuclear damage must be filed within 10 years from the date of the nuclear accident. It is further stipulated that the right to compensation is extinguished where an action is not brought within 30 years in respect to loss of life or personal injury,[156] or 10 years for other nuclear damage.[157] In all cases, an action must be brought within three years of the date upon "which the person suffering damage had knowledge or ought reasonably to have had knowledge of the damage and the identity of the liable operator[158]".

3.5.3. Radioactive waste management

Just over twenty years ago, in 1999, the Romanian Parliament through *Law no. 105/1999 for ratifying the Joint Convention on the safe*

[156] Id. Article 12 (1) a).

[157] Id. Article 12 (1) b).

[158] Id. Article 12 (2).

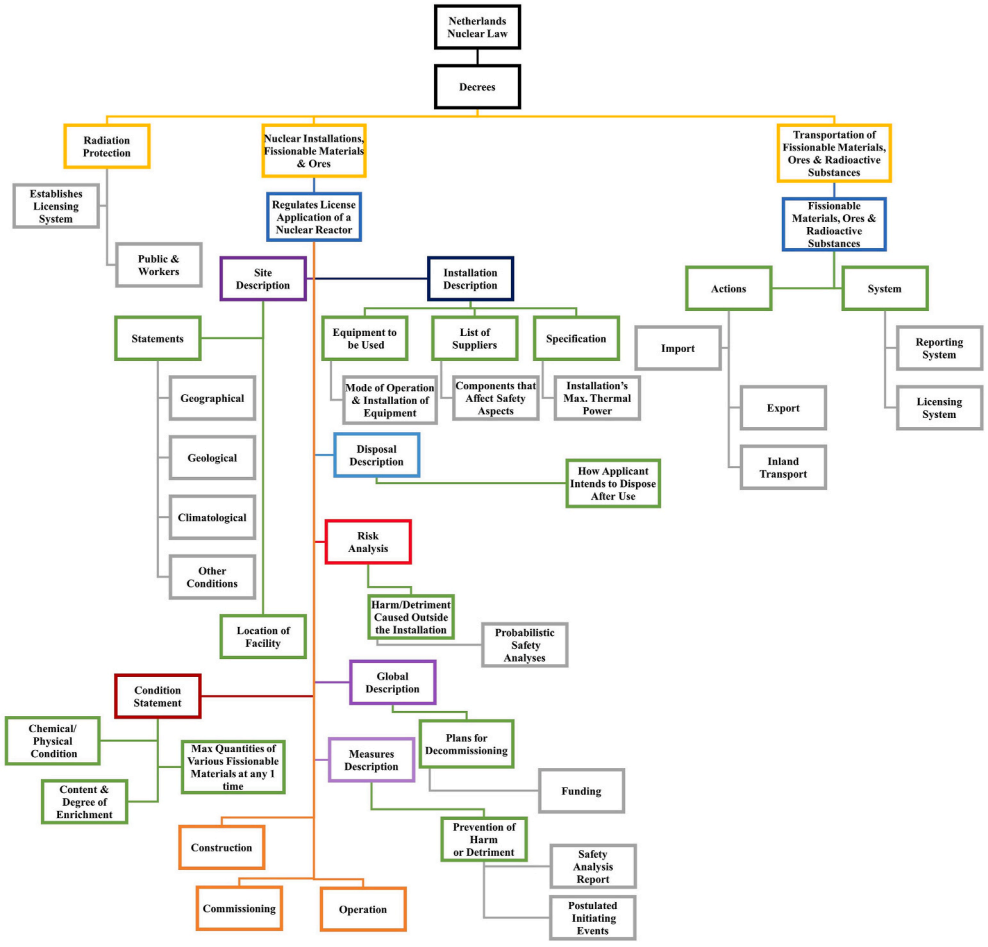

Fig. 28. Important nuclear related decrees in the Netherlands.

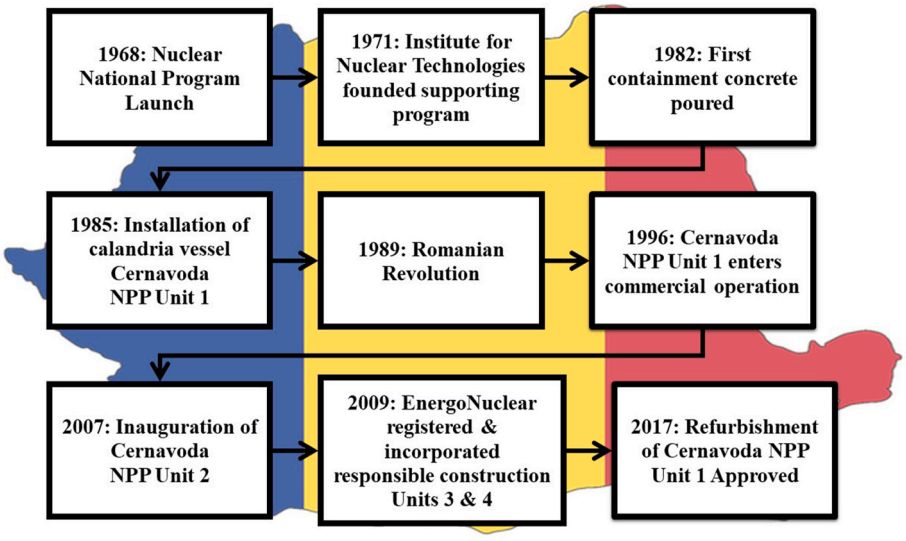

Fig. 29. Major historical milestones in Romania's nuclear power program.

management of spent fuel and on the safe management of radioactive waste[159] ratified the Joint Convention, incorporating it into the

[159] http://andr.ro/wp-content/uploads/2019/09/LEGEA-nr-105_1999-si-Conventie-comuna-gospodarire-deseuri-radioactive.pdf, Accessed June 11, 2020.

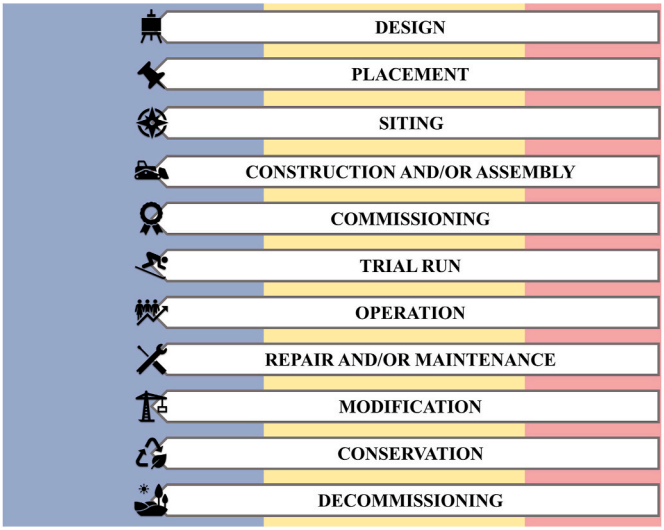

Fig. 30. Authorization and permitting phases for nuclear activities in Romania.

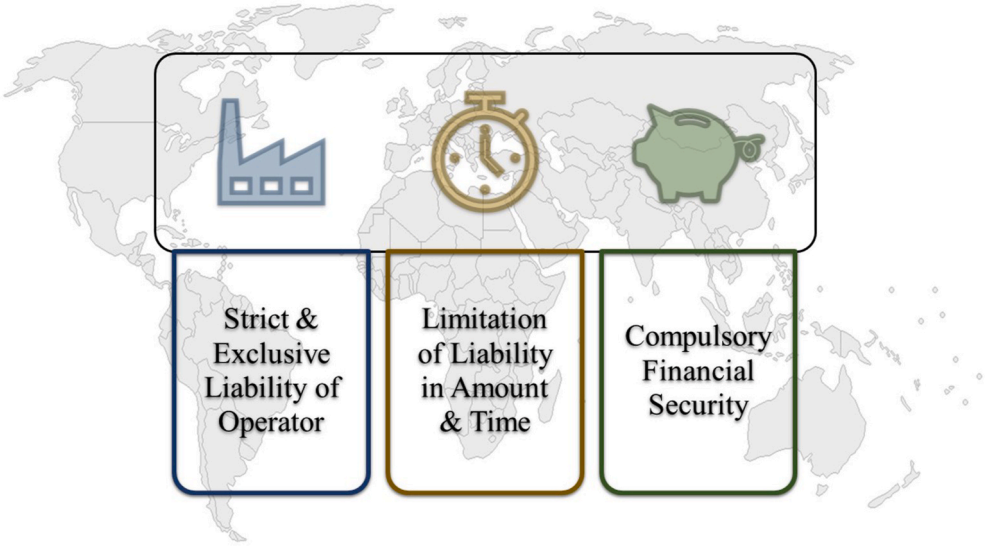

Fig. 31. The three fundamental principles of international nuclear liability.

country's legal framework. The ratification by the Romanian Parliament ensures that the country takes seriously the obligations of a contracting party requiring the safe management of radioactive waste into its waste management and disposal program. A central commitment is protecting people and the environment from harm now and into the future.

In 2004, the national radioactive waste and spent fuel management/disposal program[160] for the country was approved and establishes the context for the national strategy in these areas. Order no. 844 specifies an open fuel cycle policy for the country. This means that spent fuel is considered to be high-level waste designated for direct disposal following interim storage in a deep geological repository, without being reprocessed. An exception is made, however, for spent fuel from research reactors. Order no. 844 sets forth various objectives, as well as obligations of authorization holders, presented in Fig. 32.

With a capacity of 1506.77 m^3, the Solid Radioactive Waste Interim Storage Facility (DIDR) houses solid radioactive wastes following their pretreatment and treatment. Waste is placed into 220 L stainless steel drums. DIDR lies within the inner security fence of the Cernavoda NPP.[161] The three above ground structures have a design life of 50 years for the storage of low and intermediate level wastes (*National Report – Romania*).

3.5.3.1. Permanent disposal. Romania's spent fuel and radioactive waste management program is built on an integrated strategy taking into account the interdependencies of the steps involved for the careful management and final disposal of wastes. To safely manage the county's spent fuel and radioactive waste, a combination of appropriate engineered systems and controls will be applied. As shown in Fig. 32, the country adheres to the 'polluter pays principle', requiring that

[160] Order no. 844 of 2004, August 9, regarding the approval of "National Strategy on Medium- and Long-Term Management of Spent Nuclear Fuel and Radioactive Waste, including the Disposal and Decommissioning of Nuclear and Radiological Facilities", http://andr.ro/wp-content/uploads/2019/09/Ordin-nr.-844-din-2004.pdf, Accessed June 11, 2020.

[161] https://www.nuclearelectrica.ro/, Accessed June 11, 2020.

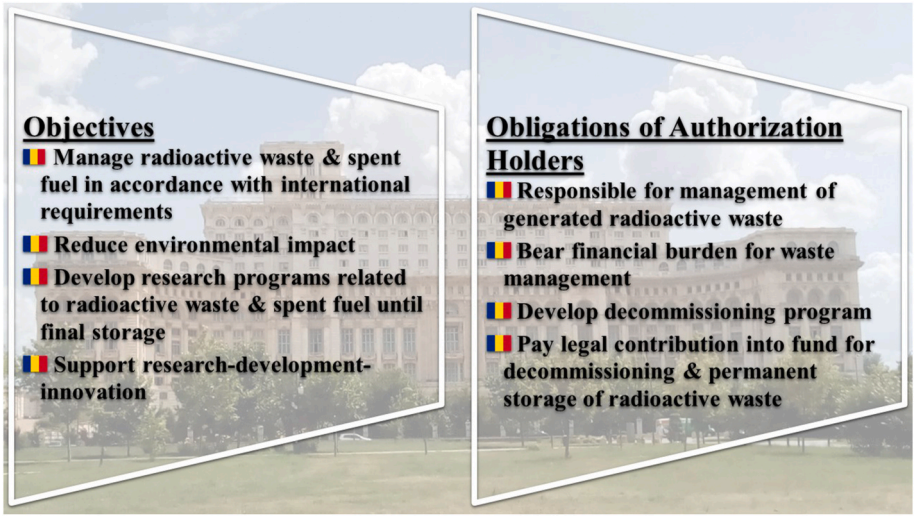

Fig. 32. Objectives and Obligations Outlined in Order no. 844.

authorization holders bear the financial burden for created waste and are statutorily obligated to pay into a fund for such purposes.

The decision of retrievability of final disposed waste is determined - a deep geological repository design will not provide for the retrievability of waste. Once spent fuel is removed from the NPP reactor core, it begins its journey vacationing for a period of six years in a spent nuclear fuel pool at the reactor site. Spent nuclear fuel is then transferred into dry storage for 50 years at the Dry Storage Facility (DICA) located on the Cernavoda site. The last phase of its journey involves the placement of the spent fuel in a purpose built deep geological repository for spent fuel and other long-lived radioactive waste. The expected operation of such a repository is planned for 2065. The disposal of low and intermediate-level short-lived waste is planned for final disposal in near surface facilitates. (*ibid.*)

4. Discussion & conclusions

As the world, and climate change discussions, continue to 'heat up' with the questioning of the continued sustainability of fossil fuel-based economies, one can observe that the global nuclear industry has developed successful methods demonstrating the sustainability features inherent to the nuclear fuel cycle. As a zero-emission electricity generating source of energy, nuclear power produces an abundant and stable amount of low carbon energy (second only to hydropower) used today compared to the intermittent and unpredictable wind and solar energy generation. From an economic view point, the reprocessing of spent fuel rods helps to increase uranium utilization efficiency and gives added value to justifying nuclear power as a sustainable source of electricity production. Recycling strategies during the decommissioning phase of a nuclear power plant play an important role by fulfilling the sustainability promise of nuclear power, where it is estimated that about 81% of materials may be recycled. Further, volume reduction involving compaction and/or incineration, as well as waste immobilization techniques, enable waste forms to be more safely and conveniently handled as a solid and stable form. Immobilization technologies for radioactive waste disposal, which include cementation, bituminization, and vitrification, comprise key components for successfully managing waste streams during the design (minimization at source), operation and decommissioning stages of facilities.

With regard to radioactive waste management and spent fuel disposal activities, these have historically incorporated three fundamental criteria in sustainability models - environmental, economic and social. However, presented within Parts I-III, the authors have suggested a more radical deviation to the traditional sustainability models to capture broader sustainability management goals. By broadening the scope of the basic LCA model to include 'stability', this requires practitioners in nuclear sciences and decision-makers to more effectively focus on informed-decision making processes and practices, as well as to develop and implement improved communication strategies. Using the broadened LCSA/LCA hybrid radioactive waste management sustainability model (Fig. 1) enables systems to "convert the bigger picture" into daily practices. As mentioned in Section 2.0, the combined model (Fig. 1) may be used for developing sustainable policies and pathways for managing low-level and intermediate-level wastes and is not necessarily devoted to the management of high-level waste and deep geological repository development.

Additionally, Part III presents and discusses the influencers impacting a radioactive waste management program (Fig. 2). Each influencer presented has the ability to exert pull/push influences that can move other influencers into opposing directions. Each influencer must be carefully weighted and enthused with a harmonious directional action to ensure the entire radioactive waste management program is moving forward in a similar direction. A holistic approach to overall radioactive waste management clearly expresses the economic benefit, sustainability, reputation and longevity of the intended program, as well as the overall nuclear industry. Part IV will discuss each influencer and their corresponding pillars in more detail.

Finally, once more, one can see that radioactive waste management programs are very country specific. Each country presented exhibits challenges and opportunities within their radioactive waste management program. Netherlands and Romania have provided themselves with flexibility by developing dedicated interim storage facilities. Other countries may wish to take advantage of similar systems to remove stresses in political and social discussions surrounding final disposal of radioactive waste and spent nuclear fuel. However, a note of caution must be raised in taking this route – one is gambling future generations will be more, and not less amiable, to siting and developing final deep geological repositories for radioactive waste management and spent fuel purposes. Kicking the can down the road may seem like a reasonable solution now, but may result in the can being thrown back at one.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

ANSTO, Managing Waste (Nuclear Facts), https://www.ansto.gov.au/education/nuclear-facts/managing-waste, Accessed May 01, 2020.

Atkinson, A., American Council of Learned Societies, 1997. The Europeans in Australia a History (ACLS Humanities E-Book). Oxford University Press, Melbourne; New York.

Australian Government, Geoscience Australia. Applying geoscience to Australia's most important challenges. https://www.ga.gov.au/scientific-topics/energy/basics. (Accessed 10 February 2020).

Balík, Stanislav, et al., 2017. Czech Politics: from West to East and Back Again. Verlag Barbara Budrich.

Belgium, 2011. Financial Times World Desk Reference.

Bonnell, Andrew, Crotty, Martin, Editor, Special, Heisler, Martin O., 2008. The politics of history in comparative perspective: Australia's history under howard, 1996-2007. Ann. Am. Acad. Polit. Soc. Sci. 617, 149–212.

Bouckaert, G., Brans, M., 2012. Governing without government: Lessons from Belgium's caretaker government. Governance 25 (2), 173–176.

Brans, M., Pattyn, V., Bouckaert, G., 2016. Taking care of policy in times of crisis: comparative Lessons from Belgium's longest caretaker government. Journal of comparative policy analysis. J. Comp. Pol. Anal.

Brilliant Maps, Land Reclamation in the Netherlands 1300 Vs 2000, https://brilliantmaps.com/netherlands-land-reclamation/, Accessed May 30, 2020.

Carlson, R.G., et al., 2020. Relational factors influencing parents' engagement in special education for high school youth with emotional/behavioral problems. Behav. Disord. 45 (2), 103–116. https://doi.org/10.1177/0198742919883276.

CIA World Factbook – Romania, https://www.cia.gov/library/publications/the-world-factbook/geos/ro.html, Accessed June 08, 2020.

CIA World Factbook - Australia, The World Factbook, Central Intelligence Agency, https://www.cia.gov/library/publications/the-world-factbook/geos/as.html, Accessed February 11, 2020.

CIA World Factbook - Belgium, The World Factbook, Central Intelligence Agnecy, https://www.cia.gov/library/publications/the-world-factbook/geos/be.html, Accessed April 13, 2020.

CIA World Factbook - Czech Republic, https://www.cia.gov/library/publications/the-world-factbook/geos/ez.html, Accessed May 06, 2020.

CIA World Factbook - Netherlands, https://www.cia.gov/library/publications/the-world-factbook/geos/nl.html, Accessed May 30, 2020.

COVRA, Mission and Policy, Website, https://www.covra.nl/en/organisation/mission-and-policy/, Accessed June 06, 2020.

de Oliveira, E.W.M., et al., 2019. The business of the business is not just the business: business sustainability as strategic element. Brazilian J. Manag./Revista de Administração da UFSM 12 (1), 41–53. https://doi.org/10.5902/1983465917339.

Encyclopaedia Britannia - Czech Republic, https://www.britannica.com/place/Czech-Republic, Accessed May 05, 2020.

Encyclopedia Britannica - Netherlands, https://www.britannica.com/place/Netherlands, Accessed May 30, 2020.

Erdil, N.O., 2019. A focus on sustainability as a core value. ISE: Indus. Syst. Eng. Work 51 (11), 34–39.

European Nuclear Safety Regulators Group (ENSREG), The Netherlands, http://www.ensreg.eu/country-profile/Netherlands, Accessed June 06, 2020.

Financial Times - Netherlands, 2011. Financial Times World Desk Reference.

Fiscor, S., 2010. Australia government proposes massive new mining tax. E&MJ - Engineering & Mining Journal 211 (4), 2.

Flathman, Richard E., 1972. Political Obligation 220.

Gao, F., Ko, W., 2014. Modeling and system analysis of fuel cycles for nuclear power sustainability (I): uranium consumption and waste generation. Ann. Nucl. Energy 65, 10–23.

Gloria, T., et al., 2017. Charting the future of life cycle sustainability assessment: a special issue. J. Ind. Ecol. 21 (6), 1449–1453. https://doi.org/10.1111/jiec.12711.

Grattan, T., 2012. Holland: the History of the Netherlands. Luton. Andrews UK Limited, Bedfordshire.

Hallström, L.K., Hvenegaard, G., Dipa, N.J., 2019. Citizen engagement in sustainability planning: patterns and barriers from hinton and wood buffalo, alberta, Canada. J. Rural Commun. Develop. 14 (2), 42–65.

Healey, J. (Ed.), 2014a. Nuclear Energy Debate. The Spinney Press, Thirroul.

Healey, J., 2014b. Australia's Political System. The Spinney Press, Thirroul.

Hirst, J., 2014. Australian History in 7 Questions. Collingwood, Victoria. Black, Incorporated.

History.com, 2010. New amersterdam, new Amsterdam becomes New York, History.com. June 1, 2020, Publisher A&E Television Networks, Last Updated July 27, 2019, Original Published Date February 9. https://www.history.com/this-day-in-history/new-amsterdam-becomes-new-york.

IAEA Country Profiles - Belgium, 2018. International Atomic Energy Agency. Country Nuclear Power Profiles, Belgium. Updated. https://cnpp.iaea.org/countryprofiles/Belgium/Belgium.htm. (Accessed 11 April 2020).

IAEA Country Profiles – Romania, 2019. IAEA country nuclear profiles, Romania. Updated. https://cnpp.iaea.org/countryprofiles/Romania/Romania.htm. (Accessed 8 June 2020).

IAEA Country Profiles – Czech republic, 2019. International atomic energy agency, country nuclear power profiles, Czech republic. updated. https://cnpp.iaea.org/countryprofiles/CzechRepublic/CzechRepublic.htm. (Accessed 13 May 2020).

IAEA Country Profiles – Netherlands, 2019. International atomic energy agency, country nuclear power profiles, The Netherlands. updated. https://cnpp.iaea.org/countryprofiles/Netherlands/Netherlands.htm. (Accessed 2 June 2020).

INTERNATIONAL ATOMIC ENERGY AGENCY, 2009. Policies and Strategies for Radioactive Waste Management, Nuclear Energy Series No. NW-G-1.1. IAEA, Vienna.

Jantzen, C.M., Lee, W.E., Ojovan, M.I., 2013. Radioactive waste (RAW) conditioning, immobilization, and encapsulation processes and technologies: overview and advances. In: Lee, William E., Ojovan, Michael I., Jantzen, Carol M. (Eds.), Woodhead Publishing Series in Energy, Radioactive Waste Management and Contaminated Site Clean-Up. Woodhead Publishing, pp. 171–272. ISBN 9780857094353.

Kunsch, P., Friesewinkel, J., 2014. Nuclear energy policy in Belgium after Fukushima. Energy Pol. 66, 462.

Maltz, E., Bi, H.H., Bateman, M., 2018. Benchmarking sustainability performance: the next step in building sustainable business models. J. Publ. Aff. 18 (3), 1. https://doi.org/10.1002/pa.1606.

Maringer, F., Šurán, Kovár, Chauvenet, Peyres, García-Toraño, Merimaa, 2013. Radioactive waste management: review on clearance levels and acceptance criteria legislation, requirements and standards. Appl. Radiat. Isot. 81, 255–260.

May, F., 2017. The effect of future event markers on intertemporal choice is moderated by the reliance on emotions versus reason to make decisions. J. Consum. Res. 44 (2), 313–331. https://doi.org/10.1093/jcr/ucw081.

Mcateer, P., 2019. With sustainability comes change. TD: Talent Develop. 73 (8), 42–47.

National Report, 2017. Czech republic, the Czech republic national report under the Joint convention on the safety of spent fuel management and on the safety of radioactive waste management, 6th Review Meeting. https://www.iaea.org/sites/default/files/national_report_of_czech_republic_for_the_6th_review_meeting_-_english.pdf. (Accessed 28 May 2020).

National Report – Netherlands, October 2017. National Report of the Kingdom of the Netherlands for the Sixth Review Meeting, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. https://www.iaea.org/sites/default/files/national_report_of_netherlands_for_the_6th_review_meeting_-_english.pdf. (Accessed 6 June 2020).

National Report – Romania, Romanian Sixth National Report, 2017. Romania Joint convention on the safety of spent fuel management and on the safety of radioactive waste management, the Sixth national report. https://www.iaea.org/sites/default/files/national_report_of_romania_for_the_6th_review_meeting_-_english.pdf. (Accessed 10 June 2020).

Netherlands - How Parliament Works. Democracy in The Netherlands. https://www.houseofrepresentatives.nl/how-parliament-works/democracy-netherlands. (Accessed 3 June 2020).

Nuclear Legislation in OECD Countries, Belgium, http://www.ha.g4if.org/law/legislation/belgium.pdf, Accessed April 15, 2020.

Nuclear Legislation in OECD Countries, 2008. OECD, Australia. https://www.oecd-nea.org/law/legislation/australia.pdf. (Accessed 17 February 2020).

Nuclear legislation in OECD countries, Czech Republic, 2020, https://www.oecd-nea.org/law/legislation/czech-republic.pdf, Accessed May 24, 2020.

Nuclear Legislation in OECD Countries – Netherlands, https://www.oecd-nea.org/law/legislation/netherlands.pdf, Accessed June 04, 2020.

Nuclear Power in Australia, World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx, Accessed February 10, 2020.

Nuclear Power in Belgium, World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/belgium.aspx, Accessed April 10, 2020.

Nuclear Power in Czech Republic, World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/czech-republic.aspx, Accessed May 03, 2020.

Nuclear Power in Romania, World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/romania.aspx, Accessed June 08, 2020.

Nuclear Power in the Netherlands, World Nuclear Association, https://www.world-nuclear.org/information-library/country-profiles/countries-g-n/netherlands.aspx, Accessed May 29, 2020.

OECD Nuclear Energy Agency, Radioactive Waste Management Committee, 1999. Strategic Areas in Radioactive Waste Management the Viewpoint and Work Orientations of the NEA Radioactive Waste Management Committee (Radioactive Waste Management (OECD Nuclear Energy Agency)). Danvers, Mass. OECD Nuclear Energy Agency.

OECD Nuclear Energy Agency, NEA Forum on Stakeholder Confidence in the Area of Radioactive Waste Management, 2000. Stakeholder Confidence and Radioactive Waste Disposal: Inauguration, First Workshop and Meeting of the NEA Forum on Stakeholder Confidence in the Area of Radioactive Waste Management, Paris, France, 28-31 August 2000 (Radioactive Waste Management (OECD Nuclear Energy Agency)). Nuclear Energy Agency, Organisation for Economic Co-operation and Development, Paris.

Ojovan, Michael I., Lee, William E., 2013. An Introduction to Nuclear Waste Immobilisation. Elsevier. ProQuest Ebook Central,. http://ebookcentral.proquest.com/lib/unlv/detail.action?docID=1576655.

Paternoster, R., Pogarsky, G., 2009. Rational choice, agency and thoughtfully reflective decision making: the short and long-term consequences of making good choices. J. Quant. Criminol. 25 (2), 103–127. https://doi.org/10.1007/s10940-009-9065-y.

Pescatore, C., Vari, A., 2003. Stepwise decision making for the long-term management of radioactive waste. NEA News 21 (2), 18–21.

Radioactive Waste Repository Authority (SÚRAO), How we ensure the safety of the deep geological repository, Website, https://www.surao.cz/en/public/deep-geological-repository/safety-of-dgr/, Accessed May 28, 2020.

Rashid, A., 2013. Efficacy of think tanks in influencing public policies: the case of Bangladesh. Asian J. Polit. Sci. 21 (1), 62–79. https://doi.org/10.1080/02185377.2013.793561.
Rayp, G., 2016. What determined the location of industry in Belgium, 1896–1961? J. Interdiscip. Hist. 46 (3), 393–419.
National Report - Belgium, Sixth meeting of the Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, October 2017, https://www.iaea.org/sites/default/files/joint-convention-rapport-be-2017-final-noannex.pdf, Accessed April 29, 2020.
Rocha, C., Antunes, P., Partidário, P., 2019. Design for sustainability models: a multiperspective review. J. Clean. Prod. 234, 1428–1445.
Romania, 2011. Financial Times World Desk Reference.
Sanders, M., Sanders, C., 2016. A world's dilemma 'upon which the sun never sets' – the nuclear waste management strategy (part I): western European Nation States and the United States of America. Prog. Nucl. Energy 90, 69–97.
Sanders, M.C., Sanders, C.E., 2019. Two roads in a yellow wood: consent or science based siting. International High-Level Radioactive Waste Management 2019 (IHLRWM 2019), Knoxville, Tennessee. March.
Sanders, M., Sanders, C., 2019. A world's dilemma 'upon which the sun never sets' – the nuclear waste management strategy (part II): Russia, Asia, and the Southern Hemisphere. Prog. Nucl. Energy 110, 148–169.
Sanders, M.C., Sanders, C.E., 2020. Nuclear Waste Management Strategies: an International Perspective. Elsevier (Academic Press), ISBN 978-0-12-813738-3. https://www.elsevier.com/books/nuclear-waste-management-strategies/sanders/978-0-12-813738-3. (Accessed 31 January 2020).
Sartorius, R., 1981. Political authority and political obligation. Va. Law Rev. 67 (1), 3–18.
Schaubroeck, T., Rugani, B., 2017. A revision of what life cycle sustainability assessment should entail: towards modeling the net impact on human well-being. J. Ind. Ecol. 21 (6), 1464–1477. https://doi.org/10.1111/jiec.12653.
Schröder, J., Rossignol, N., Van Oudheusden, M., 2016. Safety in long term radioactive waste management: insight and oversight. Saf. Sci. 85, 258–265.
Schwartz, B., Ben-Haim, Y., Dacso, C., 2011. What makes a good decision? Robust satisficing as a normative standard of rational decision making. J. Theor. Soc. Behav. 41 (2), 209–227. https://doi.org/10.1111/j.1468-5914.2010.00450.x.
Stamford, L., Azapagic, A., 2012. Life cycle sustainability assessment of electricity options for the UK. Int. J. Energy Res. 36 (14), 1263–1290.
Strategic Comments, 2013. Australia's government seeks new policy balance. Strat. Comments 19 (6), V–Vi.
Suppes, Galen J., Truman Storvick, 2006. Sustainable Nuclear Power. Elsevier Science & Technology (ProQuest Ebook Central).
The journey towards sustainability, 2018. TCE: Chem. Eng. Lond. (929), 12–14.
Tsoulfanidis, N., 2018. Nuclear energy: a volume in the Encyclopedia of sustainability science and technology series. In: Encyclopedia of Sustainability Science and Technology Series), second ed. Springer, New York.
Verbruggen, A., 2013. Belgian nuclear power life extension and fuss about nuclear rents. Energy Pol. 60, 91.
Walgrave, S., Soroka, S., Nuytemans, M., 2008. The mass media's political agenda-setting power: a longitudinal analysis of media, parliament, and government in Belgium (1993 to 2000). Comp. Polit. Stud. 41 (6), 814–836.
Walter, J., 2010. What Were They Thinking: 150 Years of Political Thinking in Australia. University of New South Wales Press, Sydney, NSW.
Wang, Xin, et al., 2017. Emotional experience and personality traits influence individual and Joint risk-based decision making. Soc. Behav. Pers.: Int. J. 45 (6), 881–892. https://doi.org/10.2224/sbp.6541.
Witte, E., Craeybeckx, J., Meynen, A. (Eds.), 2009. Political History of Belgium: from 1830 Onwards, ASP, Bruxelles. ProQuest Ebook Central. Available from:
Woldendorp, J., Keman, H., Budge, I., 2000. Party Government in 48 Democracies (1945–1998) Composition — Duration — Personnel, 2000. In: Dordrecht: Springer Netherlands, first ed. Springer, Imprint.
Wright, C., 2014. "A splendid object lesson": a transnational perspective on the birth of the Australian nation. J. Wom. Hist. 26 (4), 12–36.
Wright, R., 2019. Clicking through consent. Wayne Law Rev. 64 (2), 315–338.