



ISSN · 1431-5254  
32.50 €

## Nuclear Waste Disposal: An Exploratory Historical Overview

Hydrogen –  
Important Building Block  
Towards Climate Neutrality

10 Years  
of Phasing Out Nuclear Power

Issue 4  
2021

July

**Contents****Editorial**On the Road, Get Set – The Solved Challenge  
for Handling Radioactive Waste . . . . . 3**Inside Nuclear with NucNet**Explainer: Why the Belarus Nuclear Station  
has Caused Tensions with the EU . . . . . 6**Did you know?** . . . . . 7**Calendar** . . . . . 8**Feature | Decommissioning and Waste Management**Nuclear Waste Disposal: An Exploratory Historical Overview . . . . . 9  
Marcos Buser**Interview with Rita Baranwal**“One of our Priorities at EPRI is to Continue Making a Difference  
with Respect to Innovating, Including in Nuclear Energy”. . . . . 15**Serial | Major Trends in Energy Policy and Nuclear Power**Hydrogen – Important Building Block Towards Climate Neutrality . . . . . 19  
Hans-Wilhelm Schiffer and Stefan Ulreich**Energy Policy, Economy and Law**The Energy Charter Treaty at a Crossroads – Uncertain Times  
for Energy Investors . . . . . 30  
Max SteinIreland Must Assess Domestic Nuclear Energy. . . . . 35  
Allan Carson**At a Glance**The ERDO Association  
for Multinational Radioactive Waste Solutions . . . . . 38**Decommissioning and Waste Management**10 Years of Phasing Out Nuclear Power, 10 Years of Decommissioning,  
Dismantling and Transformation – How the Nuclear Power Segment  
of EnBW Has Successfully Reinvented Itself . . . . . 40  
Jörg MichelsCircular Economy – Lessons Learned, from and for Nuclear . . . . . 45  
Edward Kee and Ruediger Koenig with collaboration by Geoff Bauer and Julien HalfonWaste-informed Decommissioning in the USA, UK and Slovakia . . . . . 48  
Antonio GuidaTRIPLE C Waste Container for Increased Long-term Safety  
of HHGW Disposal in Salt, Clay and Crystalline . . . . . 54  
Jürgen Knorr and Albert KerberConcreting in Hot Cells – as Illustrated by the Example  
of a Central French Waste Treatment Plant . . . . . 63  
Joel BauerError Reduction in Radioactivity Calculation for Retired Nuclear Power  
Plant Considering Detailed Plant-specific Operation History. . . . . 67  
Young Jae Maeng and Chan Hyeong Kim**Research and Innovation**Czech Scientists to Recycle Fuel from Operating Nuclear Power Plants  
to Use for District Heating . . . . . 74  
Radek Skoda**News** . . . . . 76**Nuclear Today**Waste Not, Want Not – Innovations in Decommissioning Expertise  
Deserve to be in the Spotlight. . . . . 82

Imprint . . . . . 52

**Cover:**  
Steam generator removal in Neckarwestheim  
Unit 1 NPP (Courtesy of EnBW Kernkraft GmbH)**Contents:**  
“The Beast” – special band saw from Höfer & Bechtel  
for RPV dismantling (Courtesy of GNS Gesellschaft für  
Nuklear-Service mbH)

# Circular Economy – Lessons Learned, from and for Nuclear

Edward Kee and Ruediger Koenig with collaboration by Geoff Bauer and Julien Halfon

This article is part III of a 3-part series on challenges, opportunities and lessons-learned related to nuclear in the circular economy. Topics:

- I Nuclear New Build – How to Move Forward (atw 1/2021)
- II Nuclear Plant – End-of-Life Strategies
- III Circular Economy – Lessons Learned, from and for Nuclear

**Intro** In our first two articles in this series<sup>1</sup> we discussed challenges and strategies for nuclear new build and nuclear decommissioning. We have had the privilege to explore these questions with partners in the nuclear industry as well as in other energy business, in finance, and in politics – and we will continue these discussions in the coming months.

It is becoming increasingly clear that decommissioning and repurposing of energy property and plant will be a key factor in the business models of all parties engaged in the energy transition. **Figure 1** summarizes our initial conclusions in in “The Other End Of The Rainbow”.

The nuclear industry provides perhaps the most concise and extreme example in terms of technical and regulatory complexity and unit cost – but programmatically it sets the standard, not the exception for decommissioning. And yet, moving forward, the topic includes and transcends the simple, classic view of an asset life.

## New Market Opportunities

The following statement by Mr. Julien Halfon of BNP PARIBAS Asset Management sums up the new dimension<sup>2</sup>:

*“Secular trends are forcing companies to reconfigure their business models. Those that succeed will build more sustainable balance sheets by diversifying and taking advantage of key trends driven in part by populism but increasingly by regulatory pressure. ... The pre-funding of long-term liabilities for nuclear, oil & gas, power and mining companies can be seen as a leading opportunity to further develop and enhance a sustainable business model.”*

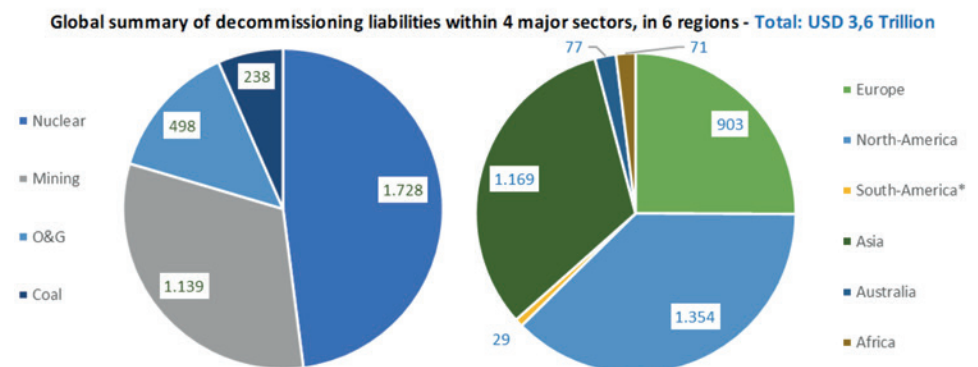
### A forward-looking view towards future energy markets:

- Over the next 2 or so decades, most expect that the world will be building an entire new, decarbonized energy infrastructure, with electricity taking a larger share of total energy mix and requiring new types of energy services (such as storage, P2X conversion, smart grid functionalities, frequency control, etc.)
- In parallel, the industrialized world will also be decommissioning the existing carbon-based energy producing and electricity generating fleet. In addition, the new energy system will have a greater share of shorter-lived assets, with decommissioning of the first and second and next generations of wind and solar farms and other facilities.
- In other words, we will need a highly efficient industrial structure to build, operate, and decommission several trillion Euros of energy assets in a 20-to-30-year period.

What lessons can be learned from the nuclear power industry in creating a sustainable “circular economy” in the electricity industry and energy markets? How can the nuclear power industry participate in the circular economy by addressing its own unique end-of-life challenges? What about the huge infrastructure build programme needed to decarbonize Europe and other industrialized countries with a mix of wind, solar, CCS, hydrogen, and new nuclear power. What is the best way to protect the communities and other stakeholders against future legacy issues?

**Figure 1**  
Insights gained in “Other End of Rainbow” (atw 2/21).

Indeed, the scale of the challenge, total global decommissioning liabilities, for existing assets have been estimated at conservatively USD 3,6 trillion<sup>3</sup> as represented in **Figure 2**:



**Figure 2**  
Decommissioning as a 3,6 Trillion Dollar Challenge.

1 See our articles in atw 01/2021 (p. 9) <https://www.yumpu.com/en/document/read/65168156/atw-international-journal-for-nuclear-power-012021/09> and atw 02/2021 (p. 46) <https://www.yumpu.com/en/document/read/65334113/atw-international-journal-for-nuclear-power-022021>  
 2 Reflecting a finding from this report: Decommissioning As A \$3,6 Trillion Challenge, The asset manager for a changing world, BNP PARIBAS Asset Management, May 2020 – <https://docfinder.bnpparibas-am.com/api/files/65DC8307-F884-47B9-BE20-660DB337B978?>  
 3 We note that this is a low estimate of a much larger reality. Larger amounts will be expected with better insights in South America and MENA and when renewables are fully reflected. Source: Decommissioning As A \$3,6 Trillion Challenge, The asset manager for a changing world, BNP PARIBAS Asset Management, May 2020 – <https://docfinder.bnpparibas-am.com/api/files/65DC8307-F884-47B9-BE20-660DB337B978?>

And of course, this amount will increase as current and ongoing new-build assets will also need to be decommissioned in a not-too-distant future. This will include many fossil-fueled power plants before their end of life due to decarbonization policies and renewable plants due to shorter asset life (i.e., due to technical limitations but also technological improvements). With this large wave of decommissioning come methodological questions, such as how to differentiate between the “cost” of decommissioning and an “investment” made to repurpose the site of the decommissioned facility.

### Elements of a Holistic Approach

With new technologies and new business models in a new market design, transfers of assets (i.e., along with decommissioning requirements, liabilities, and responsibilities) will be of growing importance.

As a starting point, a holistic approach to decommissioning will consist of at least these elements:

- Give assurance to the public – including local communities where new facilities (not just nuclear, but all other types of facilities) are to be developed – that funds for future decommissioning will be adequate and safe. Develop a system to ringfence the cost and secure the funding for the future liabilities to protect against negligent, or insolvent custodians of future legacy issues.
- Give assurance to investors in new energy facilities that the funds required and liabilities incurred for decommissioning can be determined early in the project development process, lowering risk and costs.
- Use a market approach, with best-in-class market participants and suitably fungible products, to enable smooth, safe, regulated industrial and economic division of labor. This includes the finance industry (see below).
- Achieve economic optimization: Energy companies do what they do best: build and operate a new energy system. Decommissioning specialty firms perform safe, efficient, and timely liability management.

- Develop the industrial skills to perform new build on the one hand and decommissioning on the other most efficiently – improving learning curves and economies of scale. Place risk where it is best managed.
- Make full use of opportunities to re-use and re-purpose the sites after decommissioning and tailor the approach to decommissioning to maximize the value of post-decommissioning uses.

### Financial Leverage

In this world with significant decommissioning activity, financial leverage becomes important:

- Learning curve, economies of-scale and specialized companies reduce the cost, and cost escalation, of decommissioning.
- Customized financial management and new financial products improve the overall financial performance of decommissioning companies and projects.
- Decommissioning planning that factors in the re-use of sites leads to shorter, more focused decommissioning and/or to higher value of the repurposed sites and infrastructure.
- Higher overall efficiency enables value-enhancing investments in the process.

The example in **Figure 3** gives an indication how an optimized decommissioning market can lead to significant economic benefits to project owners and to society. This example is based on just modest improvements for an individual site – the benefits would obviously multiply in an integral national, regional, and global energy portfolio.

### Financial Market Opportunities

In an analysis of the global decommissioning market, BNP PARIBAS Asset Management reached the following preliminary insights<sup>4</sup>:

*“By matching future decommissioning and remediation liabilities and avoiding potential cash flow drawdowns, a pre-funding strategy offers a number of financial benefits to companies. This has been observed in the case of the nuclear sector, which is the only one where pre-funding has*

*been systematic (even if not yet sufficient):*

- *Pre-funding improves efficiency of matching liabilities. Commodity prices are partially dissociated from remediation provisioning. ... Separate investments in financial assets, uncorrelated to commodity prices offer precious diversification benefits.*
- *It helps mitigate operating expenses volatility. ....*
- *It reduces balance sheet, cost of capital and credit rating pressures. Remediation obligations create a long-term debt that affect the financial standing of an operator. Pre-funding decommissioning can have a materially positive impact on ratings.*
- *It offers more exit optionality. Corporate strategic decisions or financial pressure may require the divestment of an asset<sup>5</sup>. ... The pool of potential buyers can (in part) be impacted by the ability to meet future remediation expenses.*
- *It opens up deleveraging opportunities. Best governance and practices may not involve leaving the financial assets and remediation liabilities on balance sheet but potentially transferring them to a separate entity.”*

This leads BNP PARIBAS Asset Management to conclude:

*“... the challenge facing society and the global economy is momentous. Going forward governments are likely to adopt a more holistic approach to taxation, expenditure, and regulation. Furthermore, there must be developments and support of new financial instruments and markets if the climate change challenge is to be addressed. ...”*

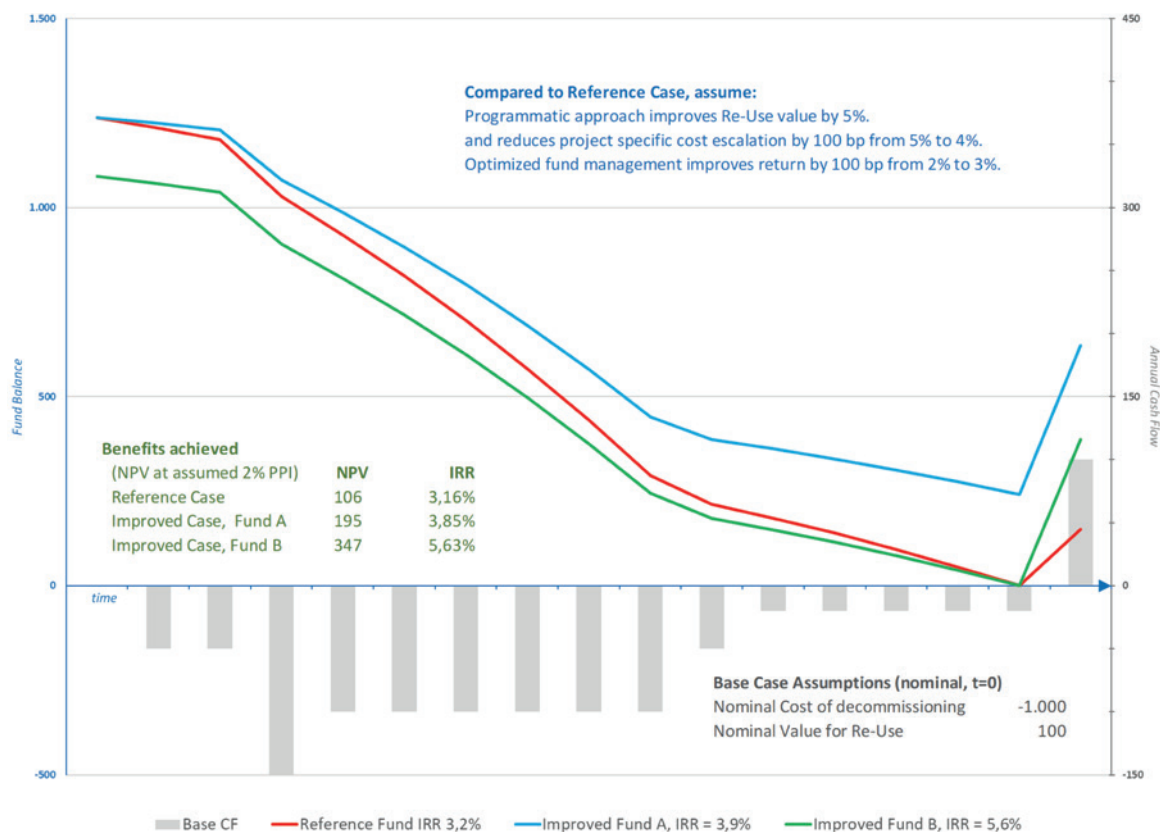
An important insight for asset owners is that a well-established decommissioning programme that considers historic, current, and future liability can enhance the value of their business, lower operating and financial risk, and enable the creation of new financial products and markets.

### Paradigm Shift

The end-of-life D&D activities and requirements for nuclear power plants are well-understood in principle, but there are a significant details and

4 Decommissioning As A \$3,6 Trillion Challenge, The asset manager for a changing world, BNP PARIBAS Asset Management, May 2020 – <https://docfinder.bnpparibas-am.com/api/files/65DC8307-F884-47B9-BE20-660DB337B978?>

5 Similar benefits apply in case of early decommissioning, driven by political decisions or following technical incidents.



**Figure 3** Financial Benefits of Holistic Decommissioning Market (simplified strawman example, with modest assumptions for possible improvements).

issues to address as the industry evolves.

The nuclear power industry provides excellent lessons learned in decommissioning – both in its shortcomings as well as in its successes. As new approaches and learning take place in the nuclear power industry decommissioning, these can be adapted to improve the entire energy industry approach to decommissioning.

**The paradigm shift needed for a circular economic approach to decommissioning consists of two key elements:**

- 1) To consider and manage plant closures as project development activities for new build programmes, rather than as an end-of-life issue.
- 2) To consider and manage funds to cover back-end liabilities as independent financial legacy that generate and secure value for future generations.

Such a paradigm shift promises the following advantages for the energy industries:

- well-funded decommissioning programmes<sup>6</sup> will not be an undue burden for asset owners;

- efficient planning and execution will enable effective repurposing of sites;
- financial structuring of funds for decommissioning will create value-enhancing assets for asset operators;
- the public will be protected against uncovered back-end costs.

For these benefits to be fully developed, more pro-active strategic efforts by industry players in the energy and financial industries as well as regulators, other governmental bodies and political stakeholders will be needed. The authors of this article look forward to participating in a developing community of interested parties.

**Authors**

This article is a thought piece by **Edward Kee** (USA) and **Ruediger Koenig** (EU) of **Nuclear Economics Consulting Group** (NECG, [www.nuclear-economics.com](http://www.nuclear-economics.com)). The authors highly appreciate the valuable professional support and expert inputs from **Geoff Bauer** of **Mercer Ltd.** ([www.uk.mercer.com](http://www.uk.mercer.com)) and **Julien Halfon** of **BNP PARIBAS Asset Management** (<https://www.bnpparibas-am.com/en/>).



**Edward Kee**  
 NECG CEO, Founder and Principal Consultant  
 edk@nuclear-economics.com

Edward Kee is an expert in nuclear economics. Mr. Kee provides advice to governments, investors, regulators, regulated and unregulated electricity companies, nuclear companies, and other parties.



**Ruediger Koenig**  
 Interim Manager and Executive Advisor, NECG Affiliated Consultant  
 rk@ruediger-koenig.com

Rudy Koenig supports market players in the clean energy industrial value chain, structuring complex business transactions in large capital projects and managing lean business operations. He has held executive responsibilities for suppliers in the nuclear front- and back-end and has helped a large utility investor develop and ultimately sell several nuclear new build projects.

<sup>6</sup> For example, e.g. see our Report to the EU Commission: [https://op.europa.eu/en/publication-detail/-/publication/3a94a52a-ec36-11e9-9c4e-01aa75ed71a1/language-en?WT.mc\\_id=Searchresult&WT.ria\\_c=37085&WT.ria\\_f=3608&WT.ria\\_ev=search](https://op.europa.eu/en/publication-detail/-/publication/3a94a52a-ec36-11e9-9c4e-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search) and this related report by the OECD Nuclear Energy Agency (NEA): [https://www.oecd-nea.org/jcms/pl\\_59705/ensuring-the-adequacy-of-funding-for-decommissioning-and-radioactive-waste-management](https://www.oecd-nea.org/jcms/pl_59705/ensuring-the-adequacy-of-funding-for-decommissioning-and-radioactive-waste-management)

Serving the nuclear community for more than 65 years

Don't miss  
the next issues!

Subscribe  
now.



**atw**

International Journal  
for Nuclear Power

[nucmag.com](http://nucmag.com)