The back-end of low carbon technologies: Closing down nuclear fuel cycle

Chair:
Tim Yeo, Chairman, The New Nuclear Watch Institute

Speakers:
Kristina Gillin, Principal Consultant, Nuclear Waste and Decommissioning, Vysus Group
Rauli Partanen, CEO, Think Atom Ltd
Dr Ben Heard, Founder, Bright New World
Martin Porter, Secretary General, World Nuclear Transport Institute
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Management of spent fuel and radioactive waste – A sustainability perspective

November 26, 2020

Kristina Gillin

Vysus Group
Introduction

Implementation of nuclear waste disposal facilities – A reality check ...

It is time to reflect

- At paradigm level
- Using a sustainability lens
What is the problem?

- Multi-generational timescales
- Fragmented landscape
- Part of a bigger picture
- Industry’s tendency to think:
  - Within the fence line
  - Until release from regulatory control
- Lack of true driver for implementation
Holistic approach needed

The nature of complex adaptive systems

- Self organising
- Constantly changing
- Non-linear
- Unpredictable
- Uncontrollable
- Can collapse
Cornerstones of a sustainability-based approach

Inclusive

Integrated

Asset-focused

Vision-based
Conclusions

• Surprises will occur – we need to plan for that
• Time to try new approaches
• Sustainability-based approach:
  • More logical
  • More likely to succeed
  • In line with general trends
Thank you

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SPENT NUCLEAR FUEL

WHAT KIND OF PROBLEM IS IT, ANYWAY?

NEW NUCLEAR WATCH INSTITUTE WEBINAR – NOVEMBER 2020

RAULI PARTANEN

THINK ATOM
NUCLEAR FUEL CYCLE AND PUBLIC HEALTH

- Spent fuel is so well managed that it has never hurt anyone.
- It gets less harmful with time.
- Deep geological storage has a safety margin of roughly one million times:
  - Absolute worst case scenario, max dose: 0.00018 mSv/year*
  - Threshold for health hazard: 100+ mSv/year

* Based on Onkalo Deep Repository’s environmental assessment.

Graph data: UNSCEAR 2008
Multiple solutions are available:
- Dry casks above ground.
- Geological repository.

Real question is: Do we want to have easy access to it later on, as a source of fuel in next generation of breeder reactors?

Spent fuel contents:
- About one percent of Uranium isotopes U235 and U236
- About one percent of various isotopes of Plutonium
- 3 to 4 percent of various fission products
- About 94 percent of Uranium Isotope U238
IS THERE A POLITICAL PROBLEM?

- Any nuclear waste solution needs a political decision to happen.
- Spent fuel issue is politically “toxic.”
- Often politicians can only lose by trying to solve the issue, so they don’t.
- Hence, there is an “unsolvable” waste problem.
SOLVING THE WRONG PROBLEMS?

After about 300 years, fission products have dropped below 1% of original.

Why nobody says this aloud?

After about 1,000 years, spent fuel is harmful only if ingested, because uranium is a toxic heavy metal, not because of radioactive dose.
SUMMARY

• Spent fuel is mostly a political problem, not a public health or an engineering problem.
• The industry has been solving a political problem as if it were public health or engineering problem.
• Is this (part of) the reason “solving it” has been so hard?
Food for thought:
Should we start solving the political / public acceptance problem instead of trying to solve the (non-existent) public health problem?

THANK YOU.

RAULI PARTANEN

THINK ATOM
RAULI WHO?

Science writer & analyst
Activist (Ecomodernist Society of Finland)
Co-founder & CEO of Think Atom

Sciencebook of the year

![2014: The World After Cheap Oil](image1)
![2015: Climate Gamble](image2)
![2017: ENERGIAIKA](image3)
![2020: The Dark Horse](image4)
WHAT IS THINKATOM

acak Non-profit, independent think tank & consultancy.
acak In a nutshell: How to use nuclear to decarbonize different sectors of our economy (power, heat, transportation).
acak https://thinkatom.net/publications/ (contributor)
Dr Ben Heard
Founder, Bright New World
World Nuclear Transport Institute

*The UK Nuclear Evolution – Learning From Experience*

Martin Porter – Secretary General
26 November 2020
• Perceptions of nuclear transport
• UK nuclear timeline
• Challenges
• Opportunities
Hollywood Blockbuster Recipe For Success

• Begin with powerful story line loosely based on a real event
  - A train carrying phenol suffers a series of mishaps and runs away without a driver

• Embellish the facts with some high drama
  - The train careers towards a sleepy town with lots of well-meaning people

• Secure the services of some A-list actors
  - Denzil Wasington, Chris Pine et al.

• Draw in the audience with a powerful advertising campaign
  - Unstoppable: 1,000,000 tons, 100,000 lives, 100 minutes

• Enjoy the success
  - $167,000,000 grossed and an Oscar nomination
1947 – Ministry of Supply begins the Sellafield with the primary purpose of Windscale being to produce defence material. (Concurrently, Springfields is developed to manufacture nuclear fuel).

1956 – Queen opens Calder Hall, the world’s first commercial-sized nuclear power plant.

1957 – Windscale Pile 1 fire.

60’s & 70’s – Reprocessing and enrichment added to the programme

1983 – ‘Windscale The Nuclear Laundry’ broadcast on UK TV
New nuclear

• Energy Act 2004 lays foundation for large-scale decommissioning
• Formation of Nuclear Decommissioning Authority supplemented by PBO/subsidiaries
• Focus on environmental remediation
UK nuclear current state

- Magnox reactors defueled
- AGR reactors approaching phased cessation of generation
- Commercial (THORP) reprocessing ended
- Domestic (Magnox) reprocessing programme coming to an end
- Contracted High Level Waste returns nearing completion.
- Reactor site and Sellafield decommissioning programme underway.
- Geological disposal facility (GDF) is planned for second half of the century
- Reactor new-build in its early stages
Challenges

• Perceptions of radioactive material operations are not always objective or scientific. Delays and denials of shipment remain as tangible risks to sea and air transport.

• The transport regulatory framework is not yet fully aligned to exploit some technological and operational advancements. Regulatory revision is a protracted process.

• Geologcal disposal as an end-state is still the subject of considerable debate.
Opportunities

• Redressing the waste site capacity challenges. Blanket coverage approach to waste characterisation now replaced by informed application of the waste hierarchy. Waste volumes being reduced by ‘extracting’ the radioactive portion. Concrete and metal being recycled up to free release.

• New approaches to managing spent fuel being worked up. Flask repurposing to dual-use (transport and medium-term storage) an option. Engagement with regulators is enabling new ways of working.

• Low carbon transport is available. New rail technology offers 76% less carbon emissions than road for equivalent payloads. Electricity offers zero emission rail transport. Mixed loads enable more efficient rail transports.
Summary

• UK nuclear programme is moving from ‘old’ generation and reprocessing to new generation, decommissioning and remediation.

• Nuclear materials have been transported for many decades without serious incident of release.

• The storage, transport and disposal of radioactive materials stimulates emotive debate.

• Many environmentally-positive innovations are helping nuclear to drive and realise carbon reduction.

• Enablement and encouragement from policy-makers and regulators is opening up opportunities. Key to progress.
Further information is available from WNTI:

- Website: [www.wnti.co.uk](http://www.wnti.co.uk)
- Email address: [wnti@wnti.co.uk](mailto:wnti@wnti.co.uk)
- Office: WeWork Aviation House, 125 Kingsway, London, UK.
- Telephone: 0207 580 1144
Innovative Solutions in the field of Used Nuclear Fuel management


Webex, November 26th, 2020

Mikhail Baryshnikov
Director, Department for Innovations and Technologies, TENEX
Growing Nuclear: More Used Nuclear Fuel Generation

Vision of SNF volume worldwide accumulation rate calculated for current NPP fleet size and SNF reprocessing rate

ROSATOM expert estimation, 2017
Key Requirements for the New Nuclear Fuel Cycle

✓ To decrease considerably amount and danger of waste to be disposed
  - Obligatory UNF reprocessing.
  - High level waste partitioning with the separate treatment of the different fractions.
  - Minor actinides transmutation.

✓ To enhance fissile materials consumption
  - Multi-recycling of U and Pu.
  - Pu ‘cleaning’ in the fast reactors.

✓ To comply with non-proliferation regime

✓ To be appropriate to reactor fleet
  Taking into account specifics of LWR, PHWR and FR
Used Nuclear Fuel is Quite Specific to be Directly Disposed
Better to split it and manage by fractions

Nuclear Waste components radiotoxity decrease
What to do with the different UNF fractions
After partitioning

Pu

Minor actinides (Am, Np, Cm) to be burn in Fast Reactors

U-238 to be re-used in PWR and Fast Reactors

U-235

Pu

0.16%

1.20%

1.00%

1.00%

0.16%

0.12%

0.12%

1.52%

2.00%

Hot Fraction (Cs+Sr) to be disposed and partly used in medicine and industry

Long-lived isotopes

Stable and short-lived elements

SNF components possible usage
UNF Partitioning Allows to Minimize NatU Consumption and Amount of Waste

Spent Nuclear Fuel Composition, reference kg*

*Expert estimation for SNF after 10 years of cooling  **As reprocessed uranium in UO₂ fuel  ***In MOX fuel
ROSATOM offers different innovative solutions in the field of UNF management

- **Comprehensiveness**: recycling of the useful materials (U, Pu, valuable isotopes) and minimization of the volume and danger of the waste to be disposed.

- **Emphasis on advanced scientific and engineering achievements**: involving the partitioning technologies, fast reactors, the best practices in the field of geological disposal of radioactive waste treatment.

- **Customizing**: ability to offer the Customer optimal NFC options

- **International cooperation** enhancement in different forms.
ROSATOM offers different innovative solutions
Naked Examples

• Recycling of the reprocessed Uranium in existing LWR. All the Russian RMBK type reactors (9 units of 1GW up to date) and one VVER type (Kola-2, 0.5 GW) are powered by RepU-fuel. ROSATOM serves EDF in purifying and enrichment of French RepU. Fennovoima NPP is contracted for RepU-based fuel. The program is in expanding RepU feeding for VVER-1000/1200.

• Recycling of the Pu recovered from the Used Nuclear Fuel. BN-800 Fast reactor is powered by MOX fuel made of the Pu extracted from VVER used nuclear fuel. REMIX fuel is designed as a ‘light MOX’ for multi-cycled usage in LWR. ROSATOM is ready for service of effective Pu utilization in its own NPP.

• UNF recovered isotopes production. Sr-90 is used for as a long time (~30 years) heat source; Cs-137 is widely used in gamma flaw detection, measurement techniques, food sterilization, pharmaceuticals, tumors radiotherapy, etc. Pu-238: NASA’s Perseverance Mars rover [successful launched from Cape Canaveral on July 30, 2020] is fed by reliable power source converting heat from a Pu-238 source; Cm-244 is the raw material for the most expensive material in the world – Californium: its official price in 2015 was 6.5 mln USD for 1 g; it is used on radiation therapy of tumors and spontaneous nuclear fission studies.

• Sustainable [Balanced] Nuclear Fuel Cycle. Includes solutions both in fissile materials recycling and radwaste disposal.
Balanced Nuclear Fuel Cycle
All the Russian UNF innovations in one place
Sustainable Nuclear Fuel Cycle
Complex of the Main Recycling Components

**Effective Package**
- Solutions in preparation and transportation of SNF to the Russian Federation and to return of HLW to the Customer: delivery of "turnover" TUK, the interim storage for the purpose of forming of the transport batch, temporary technology storage of SNF and HLW in the Russian Federation
- Development of infrastructure for HLW long-term storage and/or final isolation (geological disposal) at the Customer’s site; includes delivery of “non-returnable” casks

**UNF Reprocessing & HLW Fractioning**
- Radiochemical reprocessing of SNF in the Russian Federation with recovering of RepU and Pu
- Partitioning of the HLW for the purpose of "short-lived" fraction (Cs+Sr) separation
- Return of the "short-lived" fraction to the Customer. Adaptation of the HLW returned to the Customer’s infrastructure
- Long-term storage in the Russian Federation of the “long-lived” fraction, and temporarily unclaimed regenerated fissile materials, with their possible subsequent use, transmutation and conditioning for final disposal

**Recovered Nuclear Materials Fuel Fabrication**
- Fabrication of fresh fuel (MOX, REMIX, RepU) of the fissile materials recovered of the SNF
- Delivery to the Customer of the fuel made of RepU or U-Pu according to the program of fuel supply with replacement of natural uranium and with exception of accumulation of Pu, superfluous for development of the local nuclear industry
- Ensuring the maximum recycling of fissile materials in the existing reactor fleet

**Minor Actinides Transmutation**
- HLW partitioning with separation of Americium, neptunium, curium.
- Fabrication of elements (Am-rods) allowing to place minor actinides in the fast neutron reactor core.
- Long-term storage of Cm for its transmutation to Pu
- Am-rods irradiation in the fast neutron reactor during the standard campaign.
- Am-rods reprocessing with RW conditioning
We are certain that the future of world atomic energy is intrinsically linked to closing of the nuclear fuel cycle, and fast reactor technologies constitute an integral part of it…Considering the scientific and technological backlog we are convinced that the closed fuel cycle is no longer a distant prospect. And we are basically witnessing the first stage of this project’s implementation today. Closing of the fuel cycle will allow peaceful atom to become an environmentally safe source of energy with practically inexhaustible resources for millennia to come. There are all grounds to believe that such a comprehensive product will be offered to the market within the next 10-12 years. In terms of nuclear energy, it is almost tomorrow.”
In concern of Nuclear Power growth amount of the used nuclear fuel is to be increased.

The most reasonable solution is the new nuclear fuel cycle, based on rational approach to the UNF content.

ROSATOM is considered itself as a leader in the promotion of sustainability in the nuclear fuel cycle development.

Innovative solutions have to make sustainable UNF management.

The works are in progress. Results seem to be on the market in a decade.
Thank you for your attention!

Mikhail Baryshnikov
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Any questions?

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