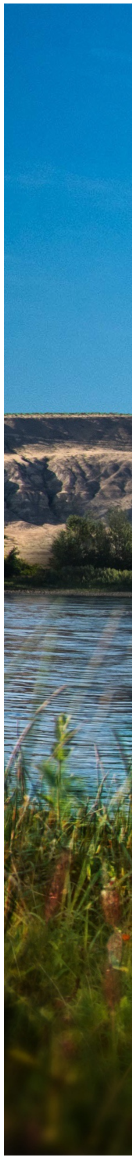

Pacific Northwest NATIONAL LABORATORY

IAEA
International Atomic Energy Agency
Atoms for Peace and Development

RemPlex & ENVIRONET Seminar

November 5, 2024

Sustainable Remediation and Decommissioning in Practice

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CENTER FOR THE REMEDIATION OF COMPLEX SITES
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Save-the-Date
2025 Global Summit on
Environmental Remediation
November 4-6, 2025
Pacific Northwest National Laboratory
Richland, Washington, USA
A hybrid in-person/virtual conference with in-depth case studies, topic-specific technical sessions, and a general poster session.
Visit www.pnnl.gov/remplexsummit
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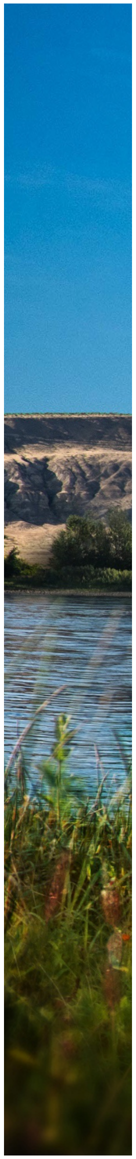


Today's Seminar and Speakers

Sustainable Remediation and Decommissioning in Practice

Paul Bardos
Managing Director
r3 environmental technology LTD

Sarah Bullock
Associate Contaminated Land/Materials Management Specialist
AtkinsRéalis

Kristina Gillin
Principal Consultant
Vysus Group

Elaine Porcaro
Chief Engineer
US DOE, Hanford Field Office

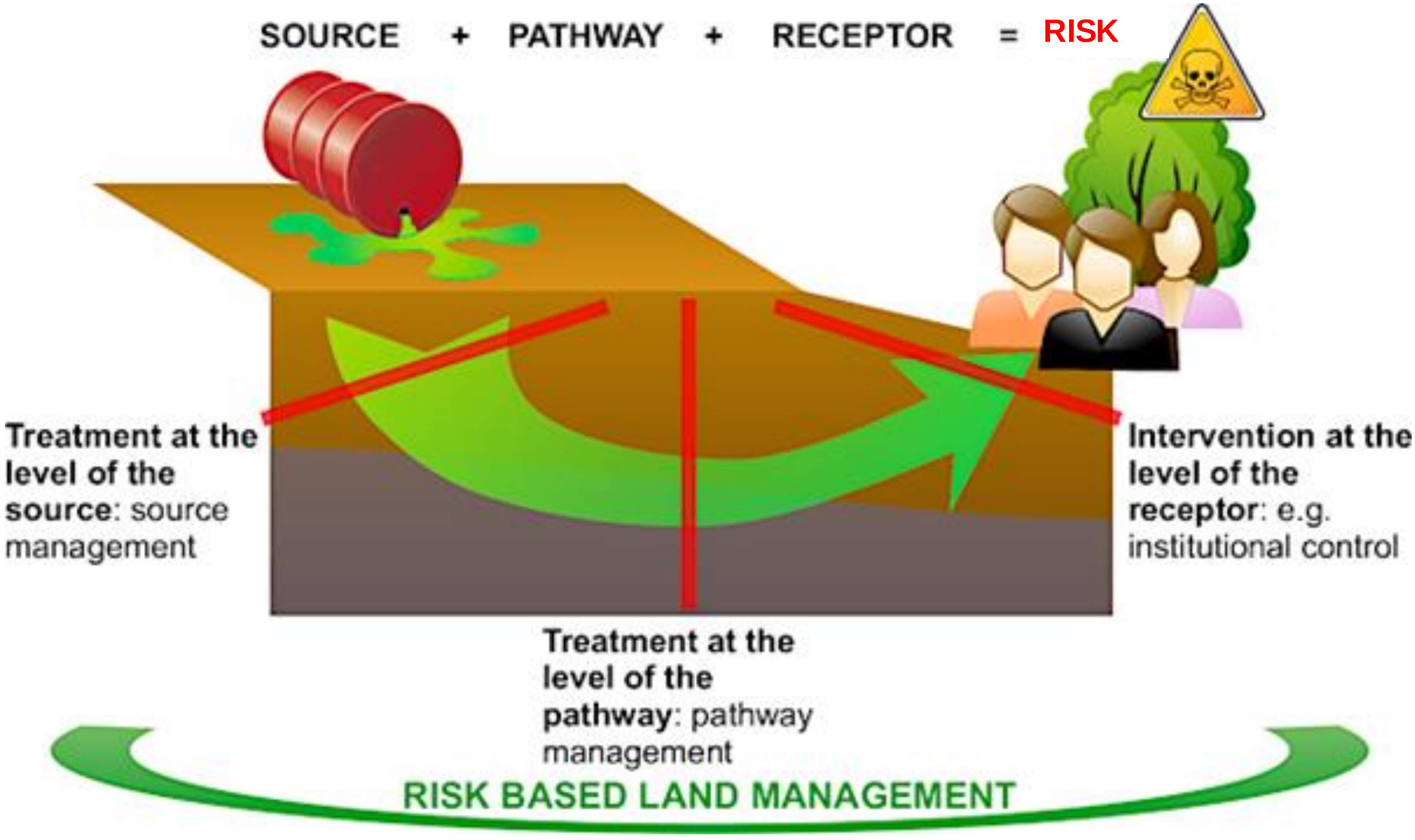
r3 environmental technology

Sustainable and risk-based land management in brief

- Paul Bardos, r3 environmental technology ltd, UK / Co-Chair SuRF-UK (www.claire.co.uk/surfuk)

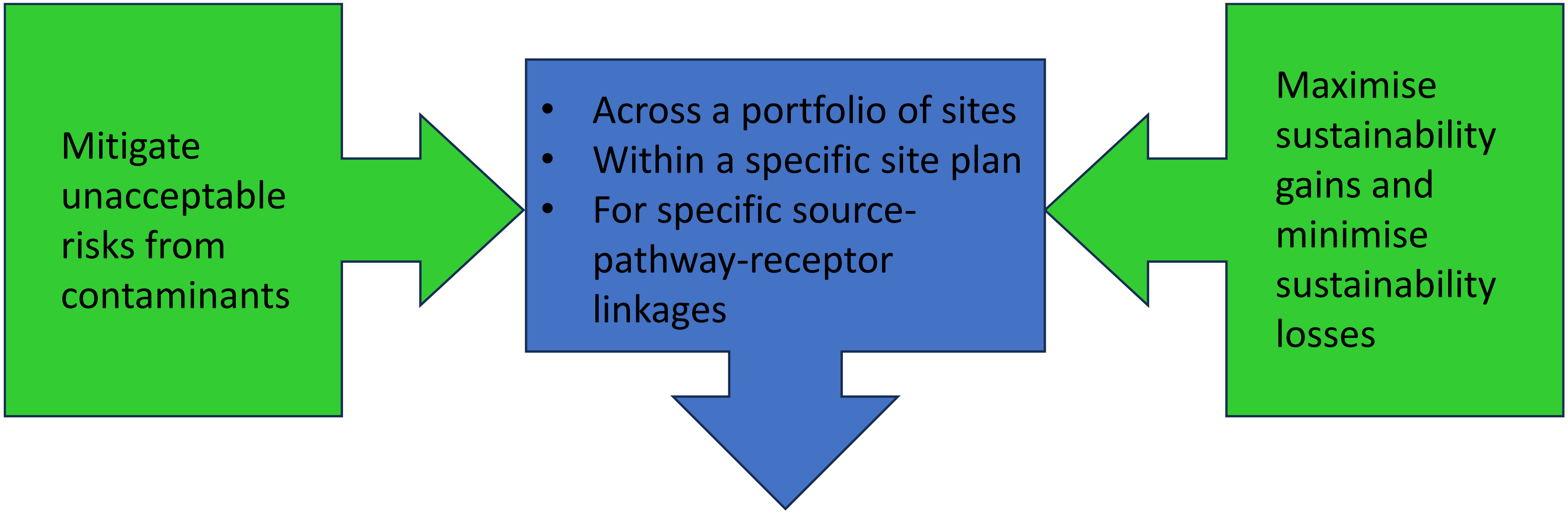
- Presented at: “Sustainable Remediation and Decommissioning in Practice”; November 5 2024; Seminar hosted by RemPlex in collaboration with IAEA ENVIRONET

Risk-based land management



Adapted from: Tack, F.M.G., and Bardos, P. (2020) Overview of soil and groundwater remediation, IN "Soil and groundwater remediation technologies- A practical guide", editors: Yong Sik Ok, Jörg Rinklebe, Deyi Hou, Daniel C W Tsang and Filip M G Tack, published by CRC Press, Taylor & Francis Group

Sustainable and risk-based land management

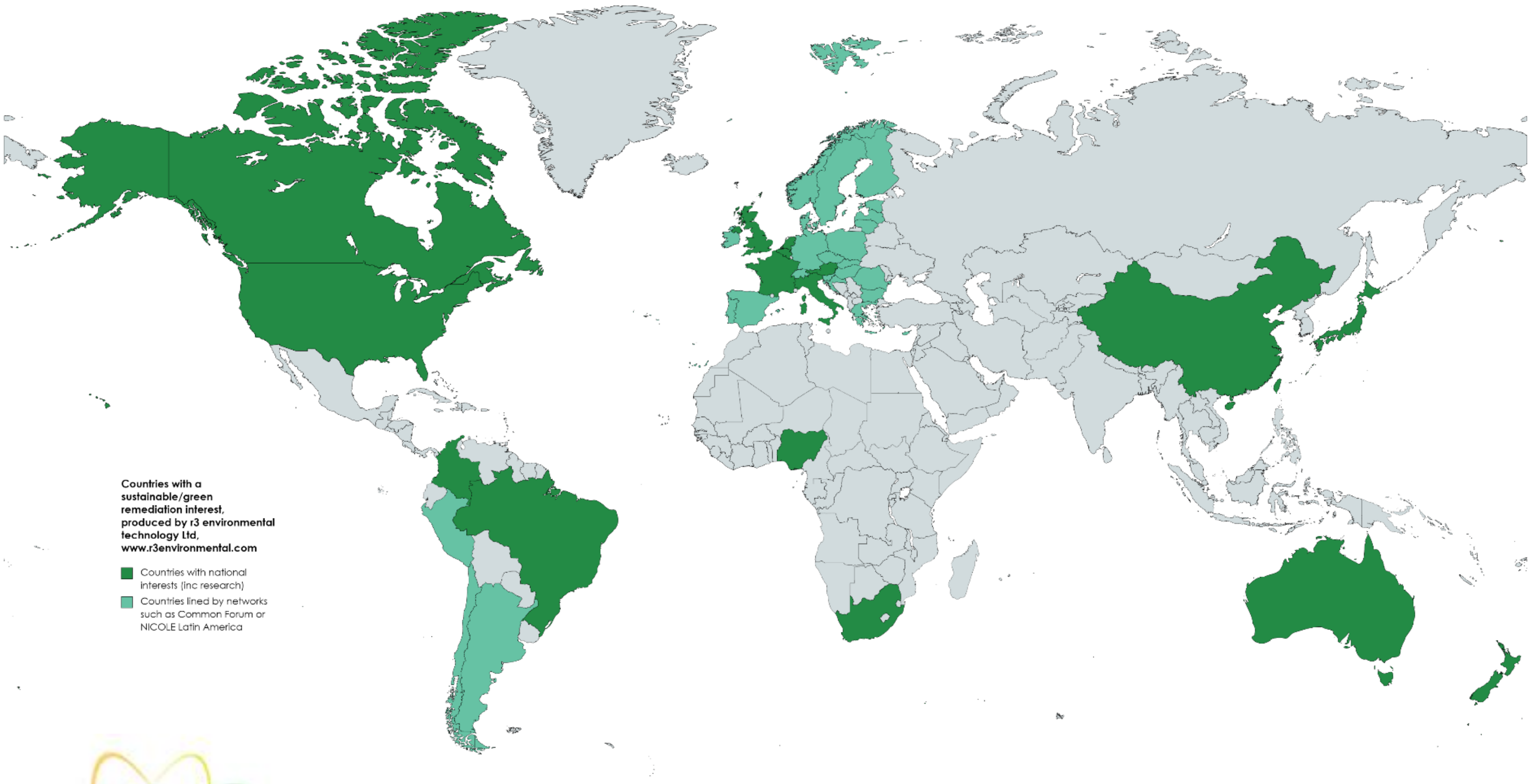


Finding an optimum remediation solution using a balanced decision-making process that mitigates unacceptable risks and maximises overall net benefit.

Benefits of SRBLM

Risk based	• Objective understanding of likely harm • Methodological framework and rationale for effective remediation • Ability to prioritise resources to the most significant / urgent problems
Sustainable	• Better optimised risk management (e.g. reduce secondary impacts) • Wider benefit and greater value • → Better cost effectiveness • Identifying and avoiding project risks • Clearer linkage to UN SDGs, & government and/or corporate policies and goals for sustainable development • Positive impact on reputation and public relations

Global interest in sustainable remediation



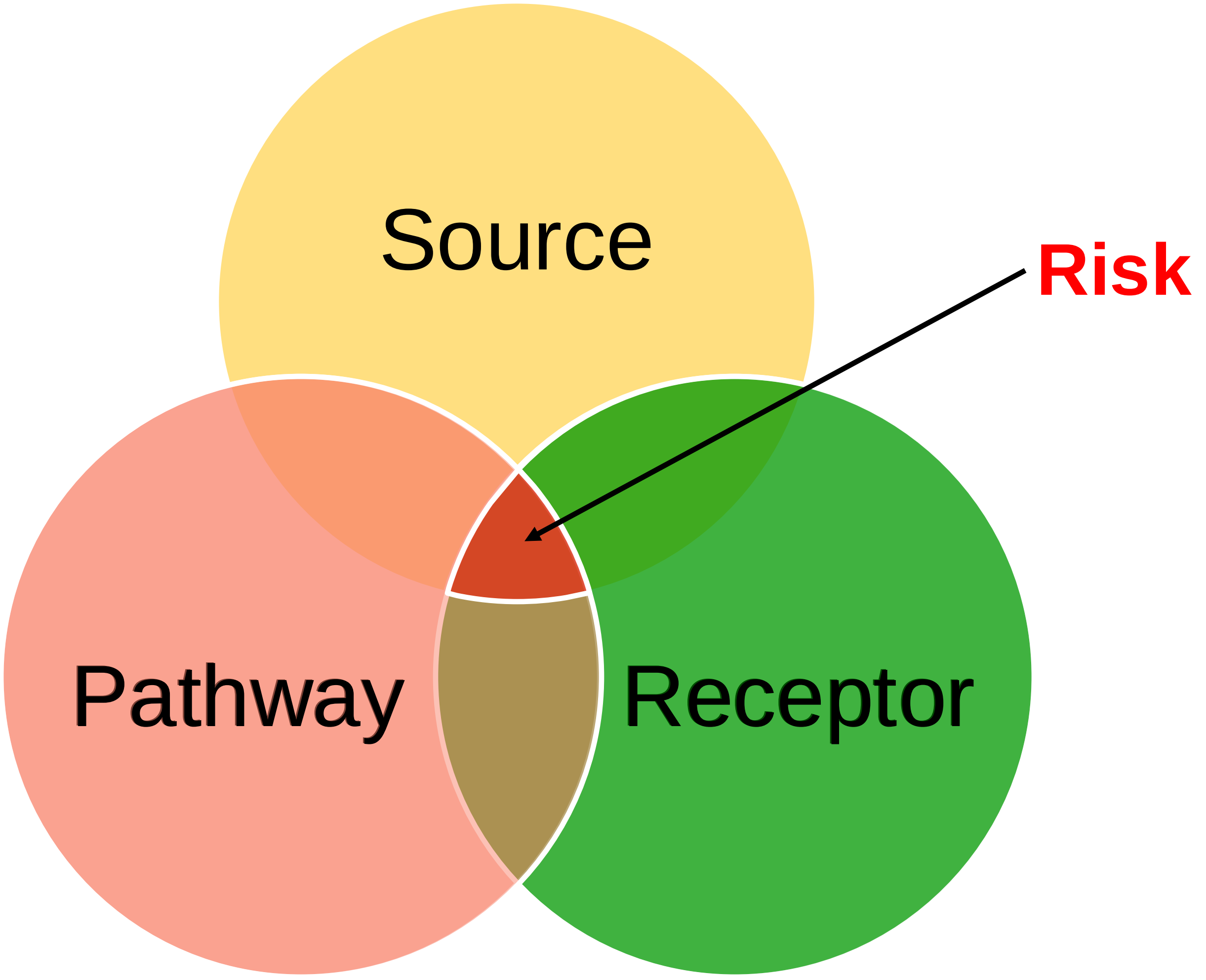
International Sustainable Remediation Alliance (ISRA), a network of networks open to all countries: https://www.claire.co.uk/projects-and-initiatives/isra-surf-int-l

Further information

Bardos P. : Sustainable and risk based land management for contaminated sites in practice.

3.1 Risk-based land management	*Describes the risk-based approach to contaminated sites management, which is widely adopted around the world. Risk assessment and risk management are described in more detail later in the book.*
3.2 Sustainable remediation	*Introduces the use of sustainability to optimise risk management, which is described in more detail later in the book.*
3.3 Sustainable & risk-based land management	*Introduces the linkage of risk-based and sustainability-based decision making in sustainable and risk-based land management and introduces the concept of resilience.*
3.4 Green remediation	*Describes green remediation and other concepts related to sustainable remediation.*

What creates a risk?



Sustainable remediation in a few minutes

- www.claire.co.uk/surfuk (short animation with multilingual subtitles)

Thank you

IS SUSTAINABLE MANAGEMENT OF SOILS AND MATERIALS; AN OPPORTUNITY OR A “WASTE” OF TIME?

November 2024

AtkinsRéalis

Introduction

Sarah Bullock
Associate Director
AtkinsRéalis

September 2023

AtkinsRéalis

Objectives

- Background
- What are Soils and Materials?
- Why do we care about Soils and Materials?
- What is the opportunity?
- Soils and Materials Strategy
- Conclusion
- Q&A

AtkinsRéalis

Background

The construction industry has always considered the use of Soils and Earthworks Materials atomistic, managed by different teams, specialists and specifications

Historically the re-use of soils and earthworks materials have not been effectively strategized or managed

It's been too easy to take materials to landfill

Cost has been the main driver to keep soils and materials on site

But to accomplish a sustainable construction, demolition and excavation (C,D&E) industry, driving NetZero, waste minimisation and circular economy, all materials used in the life cycle of a project need to be considered

What are Soils and Materials?

Dirt, Muck, Soil, Material, Earthworks Fill, Rock……

Soils:

- Principal substrate for life on Earth
- Reservoir and regulator for water, gases and nutrients
- Recycling system for nutrients and organic waste
- Cycling and store of carbon
- Regulator for atmospheric conditions
- Created through weathering
- Biologically active
- Continually changing by physical, chemical and biological processes
- Mixture of tiny particles of rock, dead plants, animals, air and water
- Support the life of plans and habitat for soils organisms
- Engineering medium

Materials

- Engineering medium
- Soils, earth, rock and other i.e. industrial by-products
- Can be processed and / or treated into a material suitable for construction

Why do we care about Soils and Materials?

- Enhances sustainability goals and NetZero objectives
- Preserves soil health and fertility
- Increases natural capital
- Contributes to biodiversity and habitat creation
- Supports the use of nature-based solutions
- Supports climate resilience
- Improves resource efficiency and drives circular economy
- Waste prevention, minimization and reduction
- Adherence to local legislation and regulations
- Cost efficiency
- Program risk
- Reputational damage
- Commercial liabilities

What is the Opportunity??

There is so much we still don’t know about soils, but we need them for life as we know it

- Management of a finite resource - soils take 1000 years for 1cm of soils to form – the type of soils and its production rate depends on the geology, relief, drainage, climate, vegetation and human impact

- Protection of Humans and Environment – re-use can drive “clean-up” of soils, groundwater, surface water

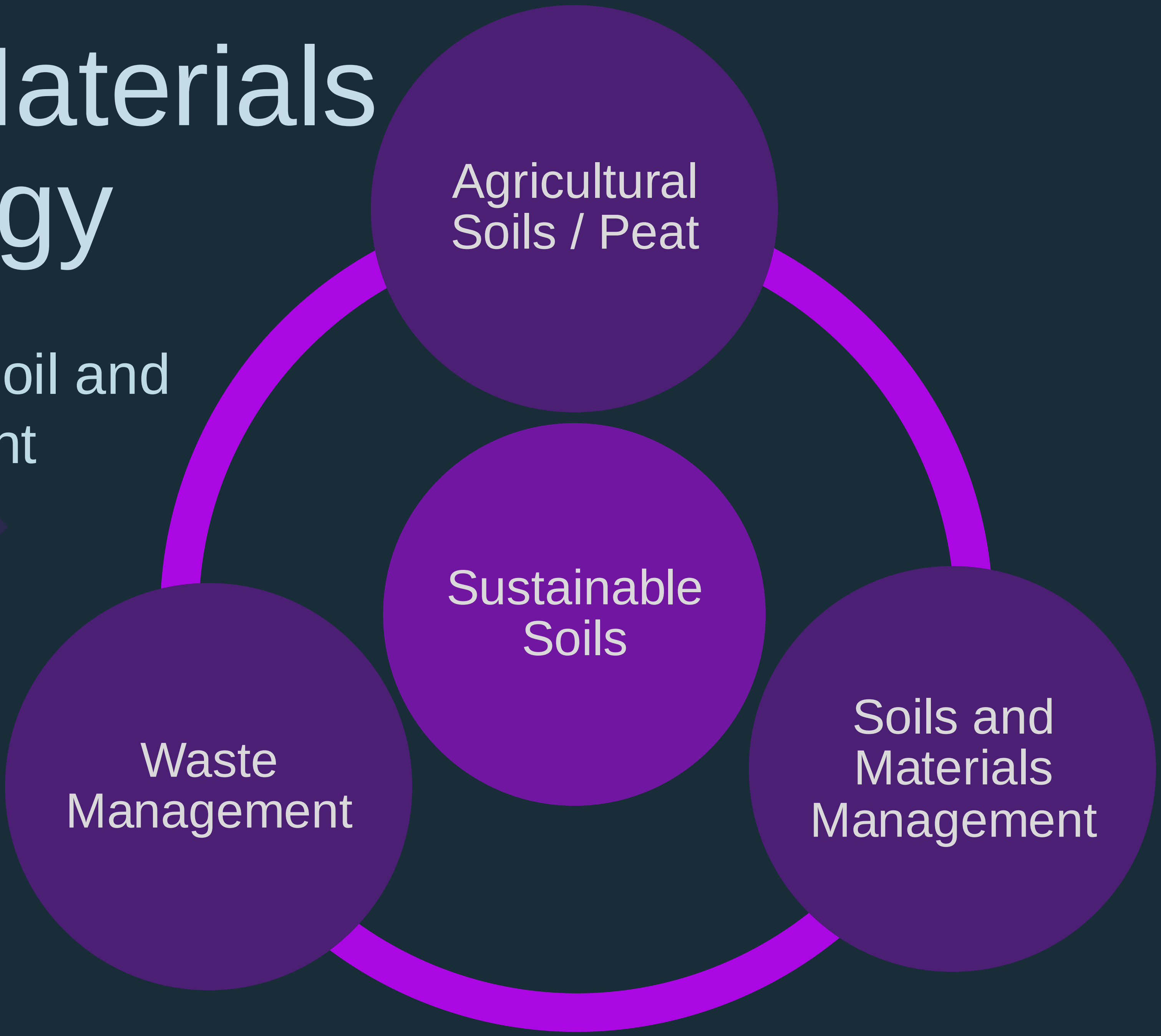
- Waste Reduction - significant volume of surplus / excess / discarded / unwanted Soils and Materials are disposed of each year. In the UK in 2022 62% of all materials considered a waste were mineral waste, soils and dredgings

- Protection of an important carbon sink – over half of carbon in a forest is being stored in roots, soil organisms and organic matter in soil

- Climate impact – re-use vs disposal

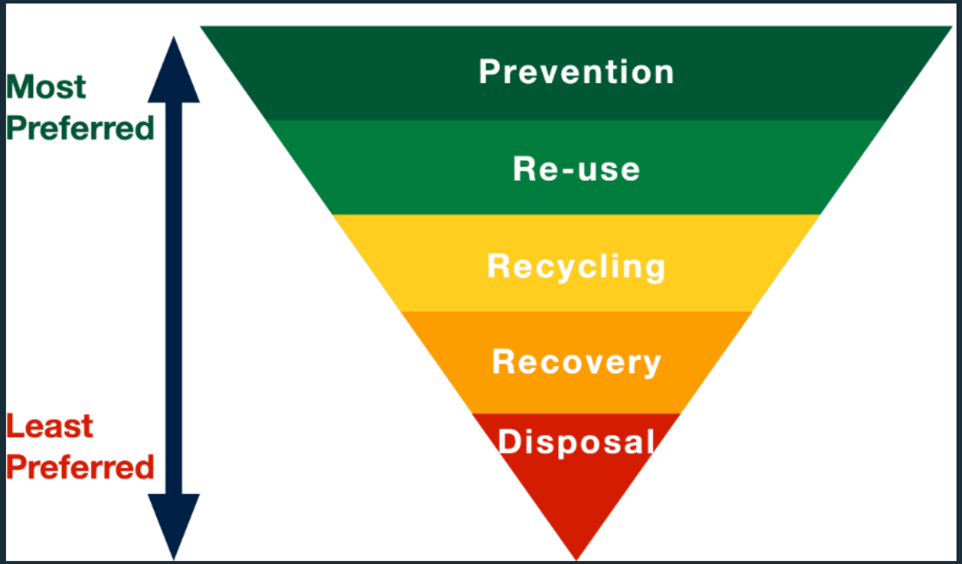
Soils and Materials Strategy

Holistic approach to soil and materials management



Soil and Materials Management Waste Hierarchy

- Prevention – design out waste
- Re-use
- Recycling – demolition materials
- Treatment – contamination, processing for achievement of earthworks specification
- Recovery
- Disposal



The Importance of a Strategy

Soils/materials management strategy:

- Drive decisions being made by project teams
- Acts as a reminder to the project team about what they aim to achieve
- Enables early consideration of your source of materials and supply chains
- Risks, opportunities & contingencies
- Timescales / programme
- Presents what success looks like for the project
- It should be a working document

All Specialists Working Together

- To enable the strategy to work, all specialists on a project need to work together
- There need to better collaborative working
- Someone driving the strategy
- List of specialists can include:
    - Carbon / sustainability
    - Civil Engineers
    - Structural Engineers
    - Geotechnical Engineers
    - Ecologists
    - Drainage Engineers
    - Landscape Architects
    - Contaminated Land
    - Waste

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Conclusion

Soils are fundamental to life on earth

Soils and Materials are needed to facilitate remediation and construction

To drive a sustainable C,D&E Industry; Soils and Material need to be managed, considered, strategized with a plan

This will require significant collaborative working between all specialists in a project team

But there is significant opportunities to be realized; certainly not a “waste” of time

Q&A

thank you

AtkinsRéalis

November 5, 2024

Ingenuity.
Imagination.
Insight.

Vysus Group

Nuclear Decommissioning in the Context of Sustainability and Circular Economy

Kristina Gillin
Principal Consultant

Introduction

- Current reactors generally designed without considering sustainability or a circular economy
- Reuse, repurposing and recycling gaining interest in decommissioning – but far from the norm

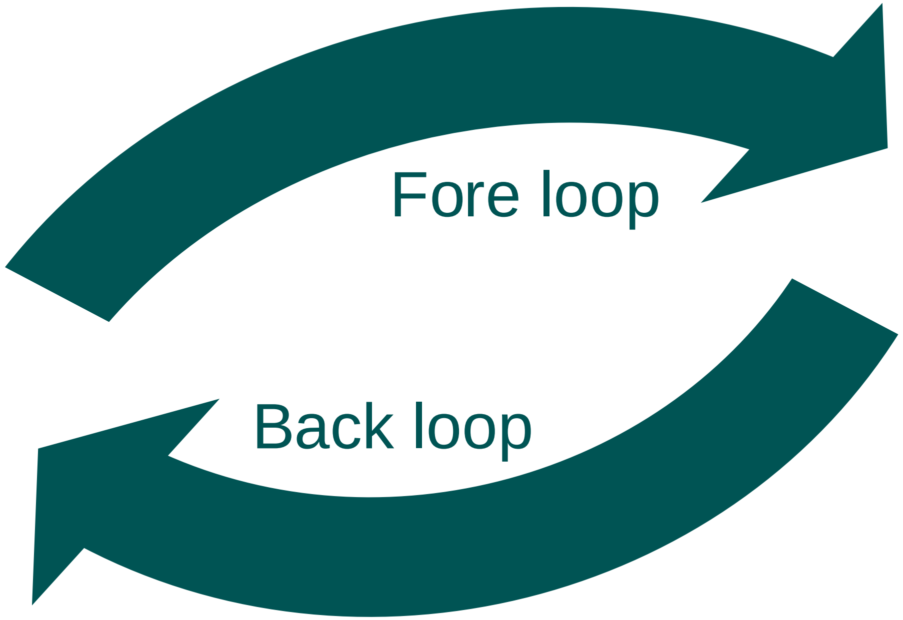
How to decommission a reactor in a way that is sustainable and circular?

Barsebäck, Sweden

Decommissioning using resilience thinking

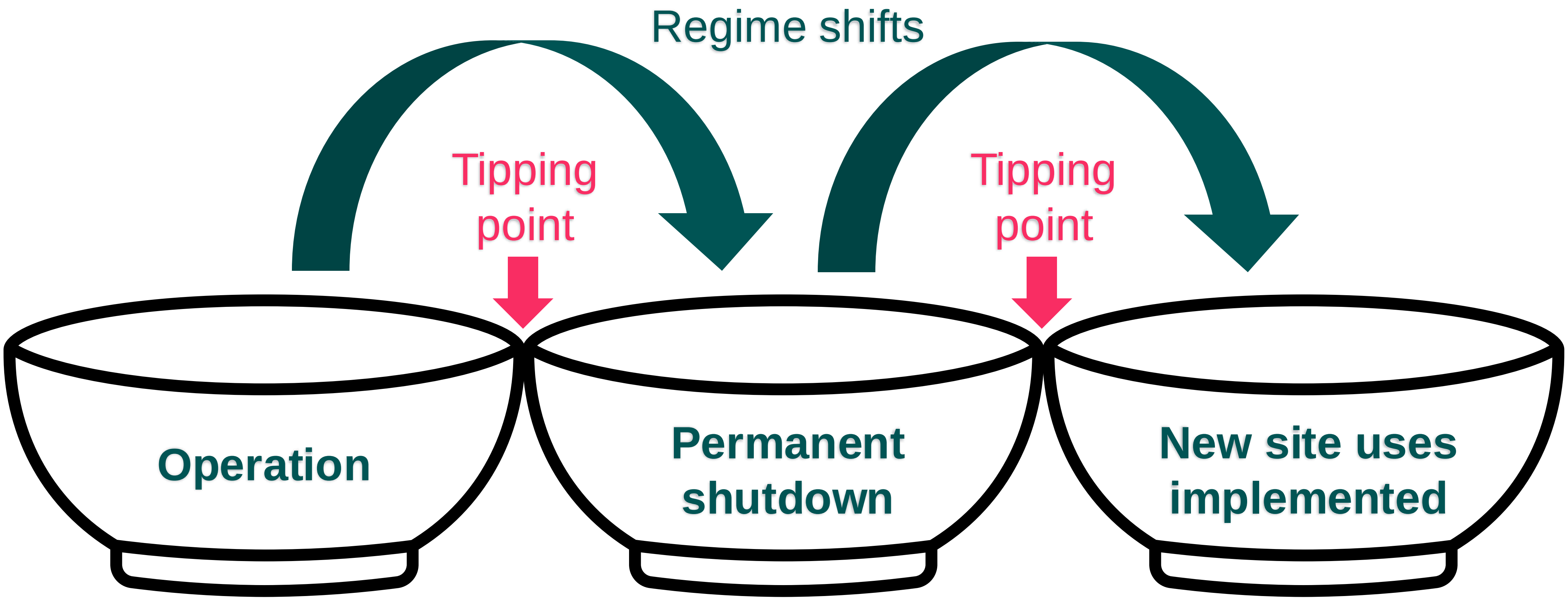
A complex adaptive system

The adaptive cycle



Source: Adapted from *Resilience Thinking, Sustaining Ecosystems and People in a Changing World,* Brian Walker and David Salt, 2006.

Regime shifts of a nuclear reactor site



Key features of a sustainable decommissioning approach

- Viewing all parts as potential assets
- Using holistic, integrated thinking
- Collaborating with local stakeholders and involving them in decision making
- Creating a vision post-decommissioning
- Implementing new uses and reuses on parts of the site as early as possible
- Expecting the unexpected
- Minimizing negative environmental, social and economic impacts

Decommissioning in a circular economy

- In a circular economy:
  - As little resources as possible are used
  - For as much and by as many as possible
  - For as long as possible
- Decommissioning corresponds with closing the resource loop after usage
- Cannot be achieved by one organization alone – hence requires circular supply chains

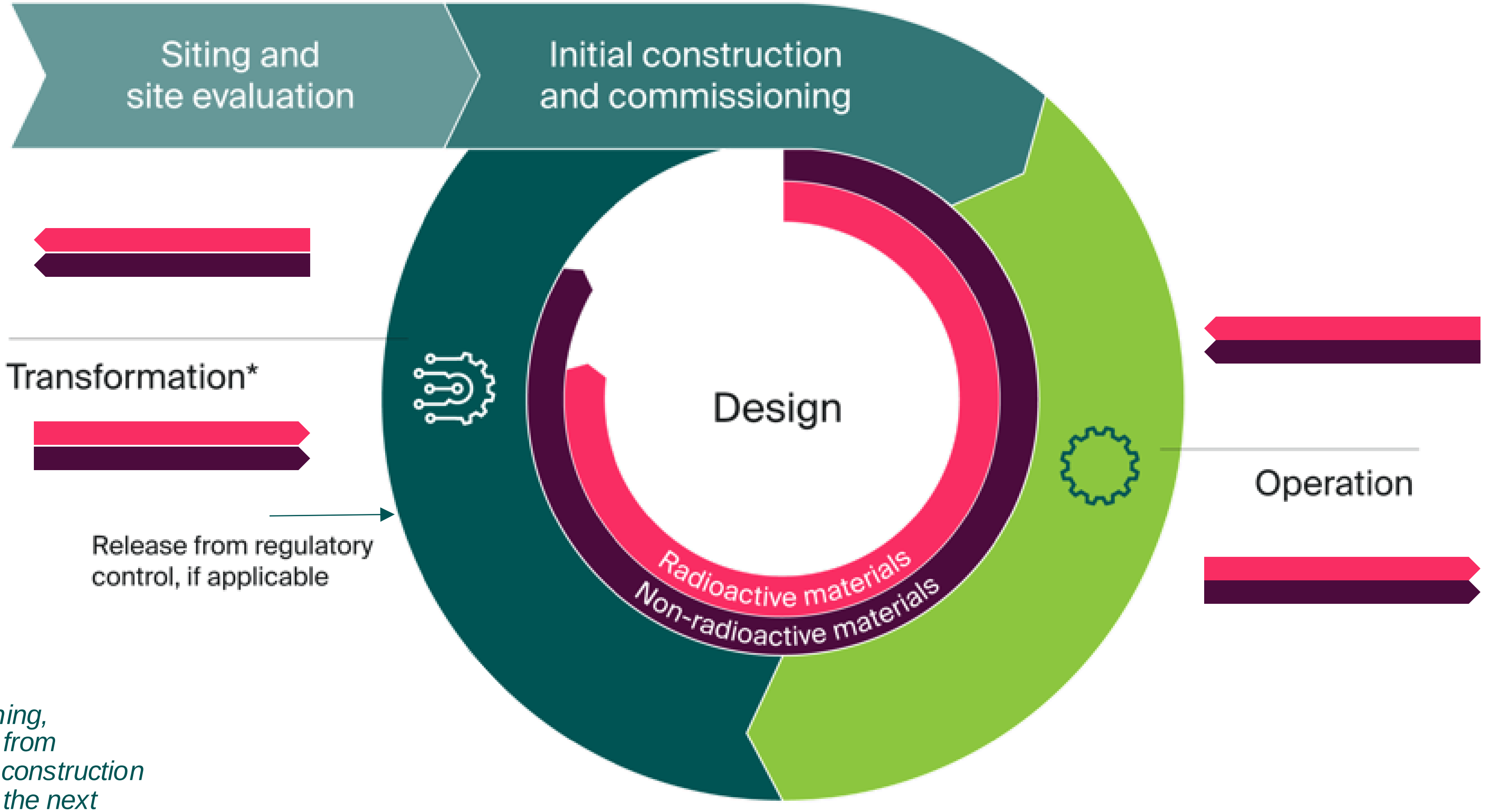
Current decommissioning practices consistent with circularity

- Repurposing of whole or part of site
- Interim uses while awaiting dismantling
- Reuse of systems and components
- Clearance and recycling of metals and other materials
- Use of demolished concrete structures as fill materials
- Reduction of power and water consumption
- Reprocessing of spent fuel?

R1 Reactor in Stockholm, Sweden

Photo: KTH Royal Institute of Technology

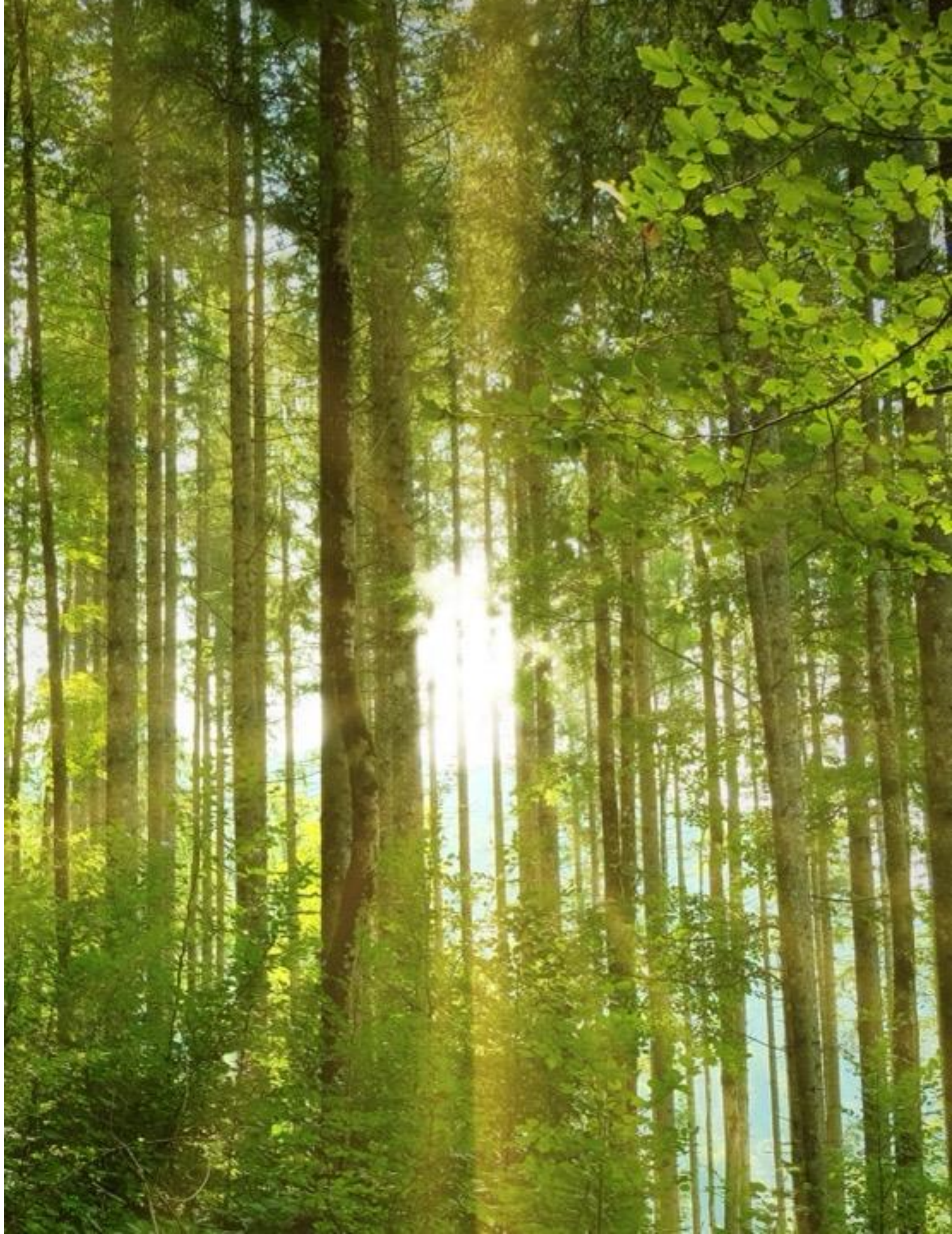
Conceptual model for circularity of a nuclear site



* *Includes decommissioning, preparation for release from regulatory control, and construction and commissioning for the next operation stage, as applicable.*

Conclusions

- Some current practices consistent with sustainability and circularity – but a lot more can be done
- Holistic thinking and local context key
- A sustainable decommissioning approach can reduce uncertainties, timelines, waste volumes and costs
- Window of opportunity to revisit and change the norm given increase in number of reactors that will:
    - Reach end of operation and require decommissioning
    - Begin construction



Thank you

Kristina Gillin,
Principal Consultant

Email: kristina.gillin@vysusgroup.com

Sustainable Remediation & Net Zero at the US DOE Hanford Site

Elaine Porcaro
DOE Hanford Chief Engineer

Sept 27,2024

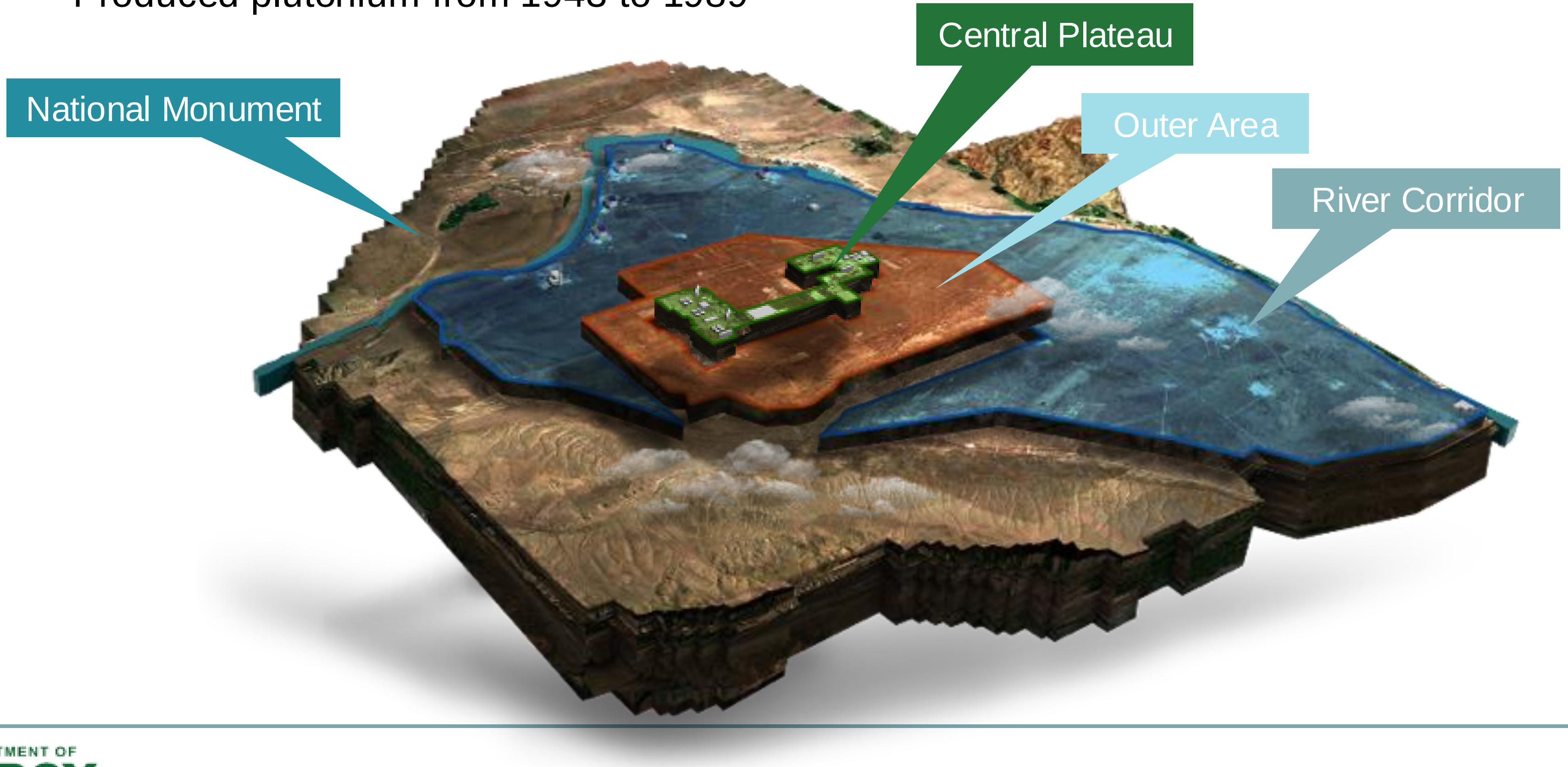
What is Hanford?

History

- One of the sites selected for the Manhattan Project during World War II
- Produced plutonium from 1943 to 1989

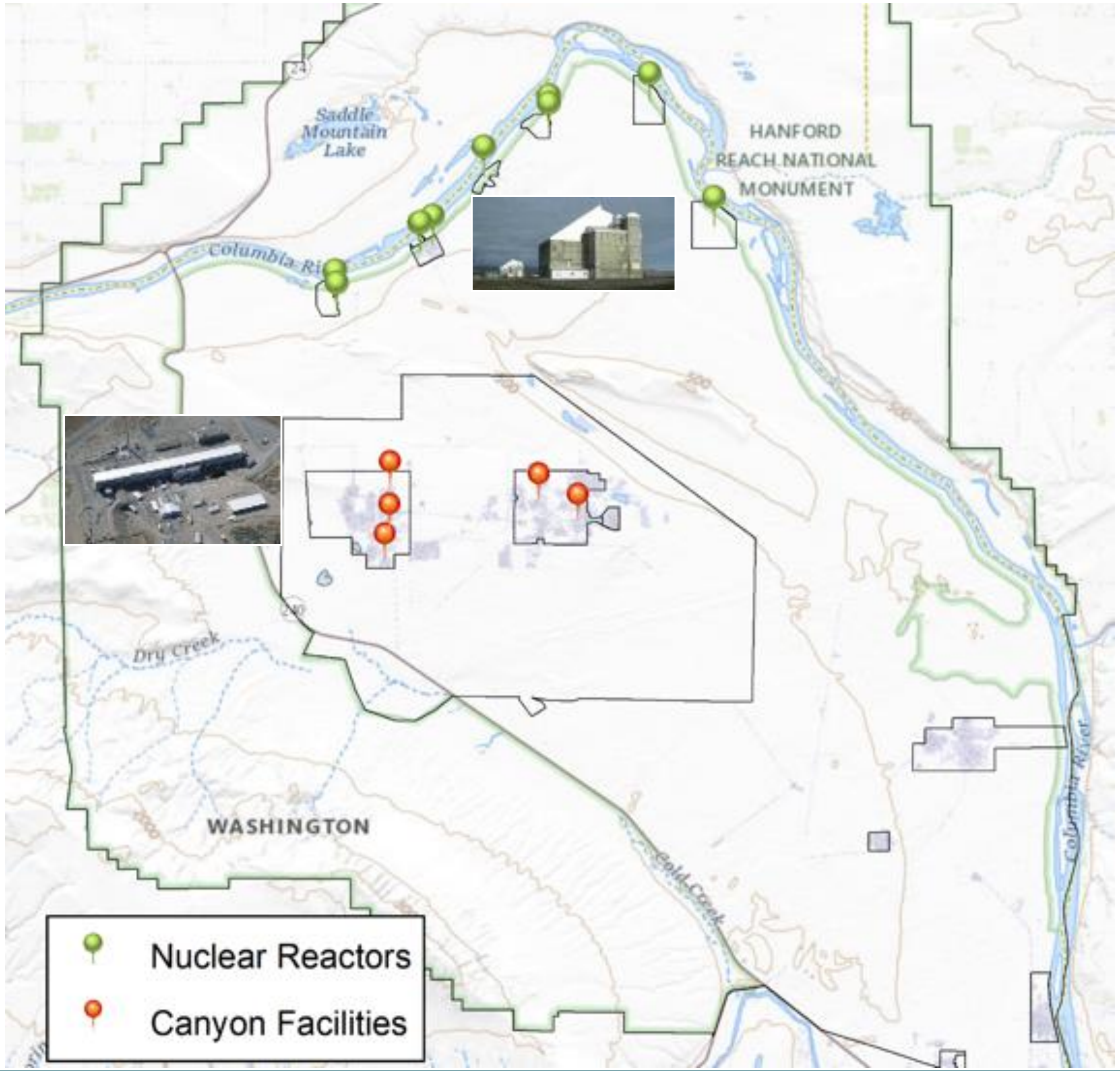
Today and since 1989…

- Largest nuclear cleanup project in the country



History

- During World War II and the Cold War era, the government built and operated nine nuclear reactors along the Columbia River to produce plutonium and other nuclear materials
- Large chemical processing facilities separated plutonium from spent fuel rods



THE HANFORD SITE

Hanford Timeline

1940s
Building Hanford

1944 – 1989
Plutonium Production

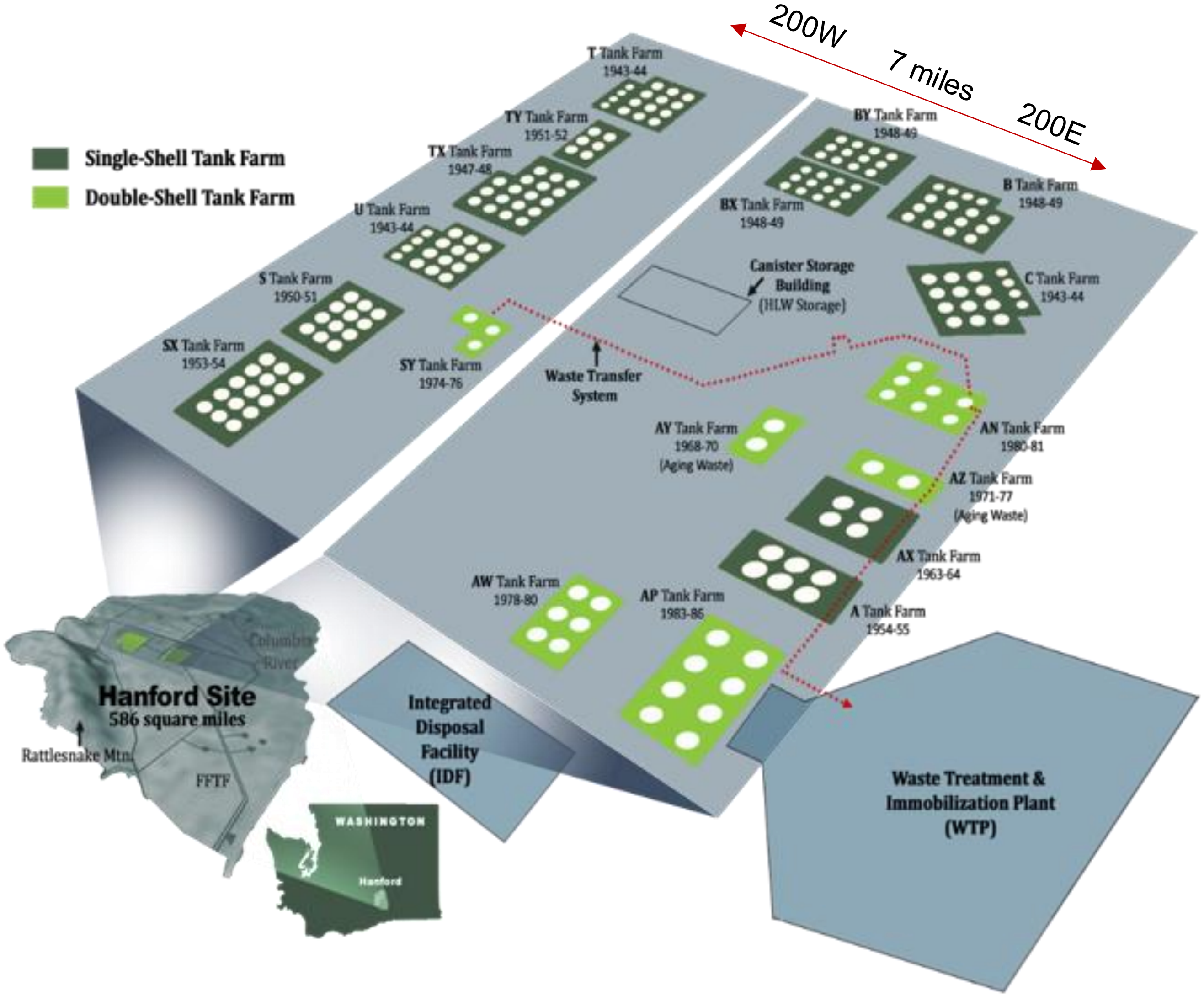
1990s – 2000s
Cleaning up near the Columbia River

Present
Shifting focus to the Central Plateau

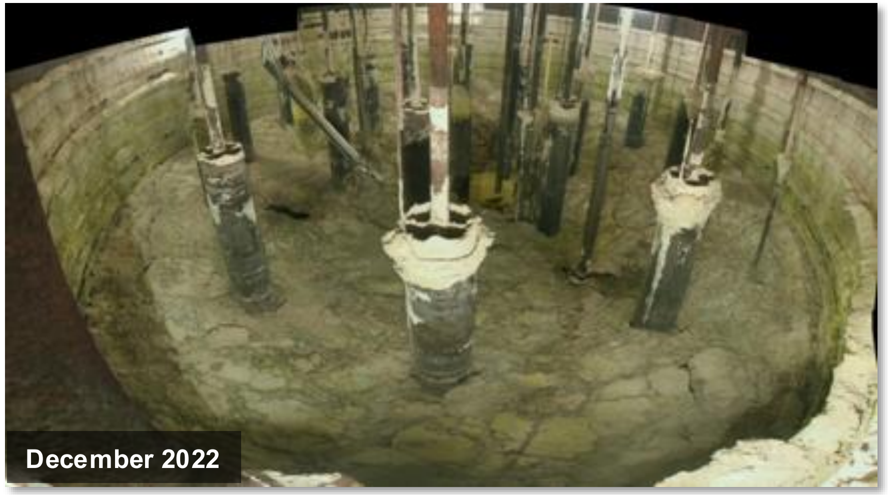
Tank Waste Mission

Single-shell tanks
- 149 built 1943-1965
- 20 retrieved
- 2 in retrieval/approval

Double-shell tanks
- 28 built 1968-1986
- 1 retrieved



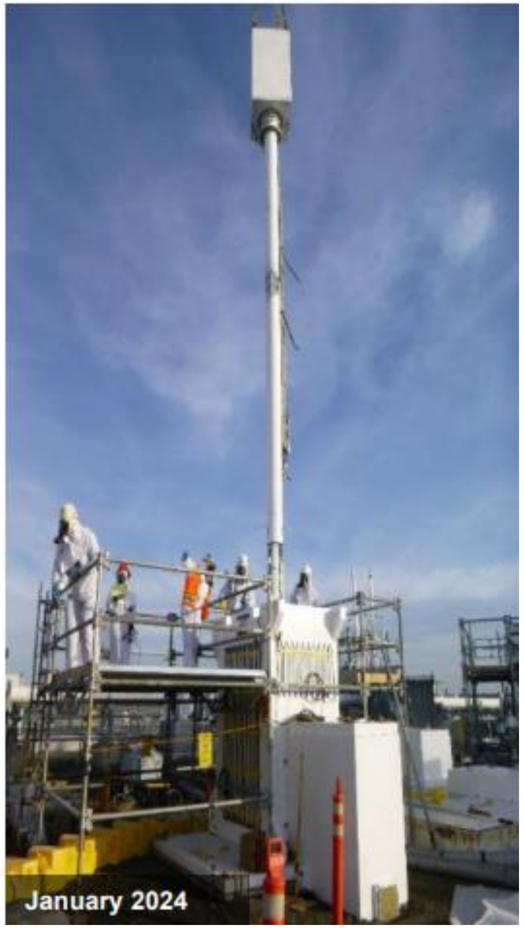
Tank Retrieval



Inside Tank AX-101 prior to waste retrieval

Modified sluicing inside Tank AX-101

Panorama of inside of Tank AX-101



Inserting ERSS into Tank A-101

What's next after retrieval?

EVAPORATION to reduce water volume, remove organics:

- 242-A evaporator – in restart, built 1976

PRE-TREATMENT to make Low Level Waste:

1. Filter out solids,
2. Ion Exchange to remove Cs-137 & soluble Sr-90
3. Sample to verify compliant feed

- Tank Side Cesium Removal (TSCR) - operating
- Advanced Modular Pretreatment System (AMPS) – in progress

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Pretreatment: Tank-Side Cesium Removal (TSCR), followed by AMPS

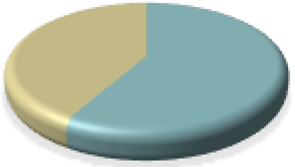
Tank-Side Cesium Removal and AP Tank Farm

TSCR unit showing ion exchange and filter units

Interior of Tank-Side Cesium Removal Process Enclosure

Modified Forklift to Safely Lift and Transport 27,000-pound Self-Shielded Ion Exchange Columns

Twelve Loaded Ion Exchange Columns on Storage Pad, 587,000 curies of cesium-137



Approximately 640,000 gallons treated

Tank AP-106 contents: Tank-side cesium removal (TSCR) treated Waste Treatment and Immobilization Plant (WTP) low-activity waste (LAW) feed

What’s next after pretreatment?

STABILIZATION to create a solid waste form for disposal:

- Vitrification:
  - Suspension in Glass
  - Waste Treatment Plant (WTP)
    - Direct-Feed Low Activity Waste (DFLAW) (Onsite disposal)
    - Direct-Feed High Level Waste (DFHLW) (Temporary storage onsite until an Offsite HLW National Repository is available)

- Alternative Treatment for SLAW? (LLW portion > DFLAW capacity)
  - Suspension in Grout for Offsite Disposal
    - Test Bed Initiative (TBI)
    - West Area Risk Mitigation (Depending on NEPA)

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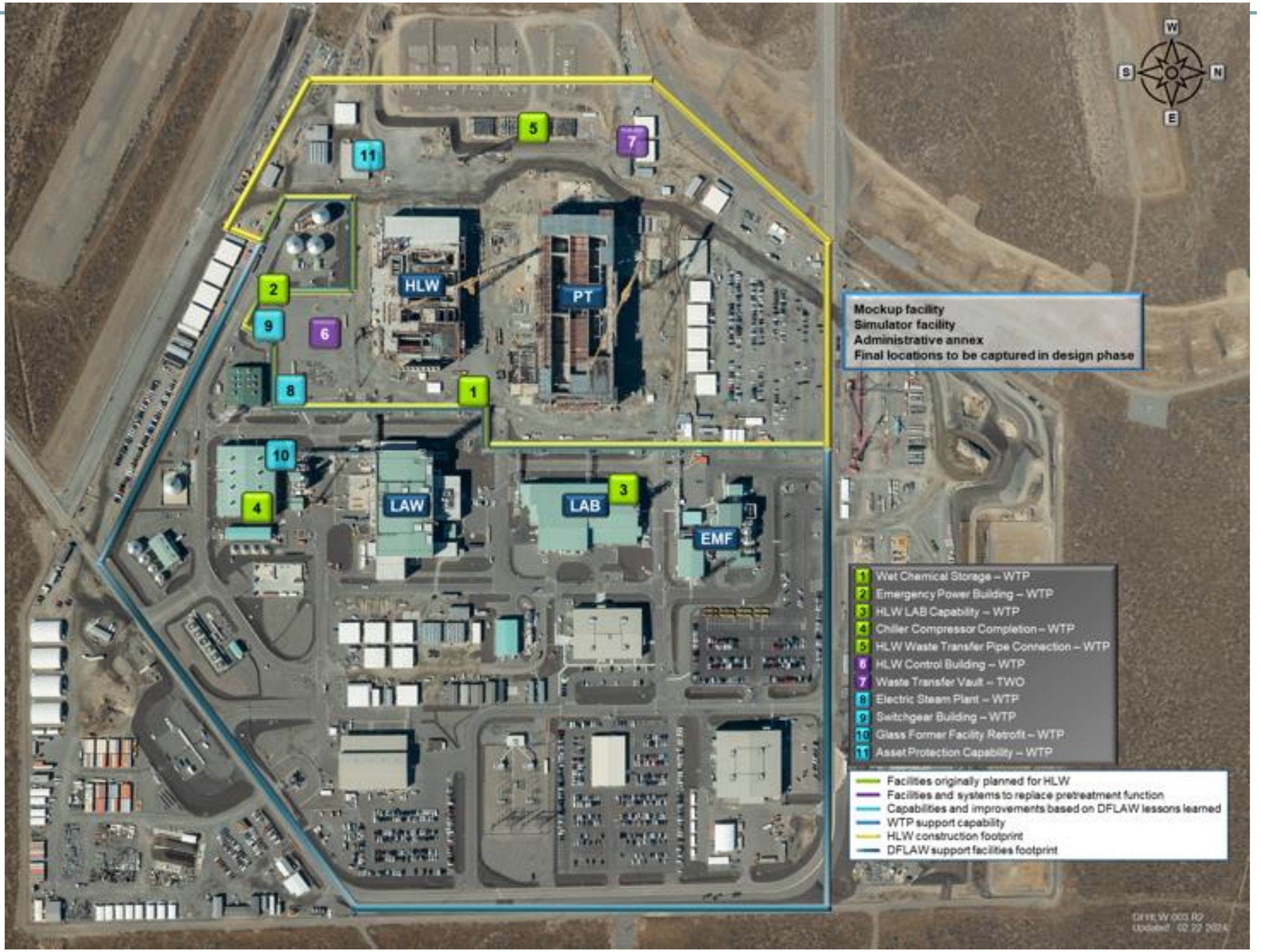
Waste Treatment and Immobilization Plant

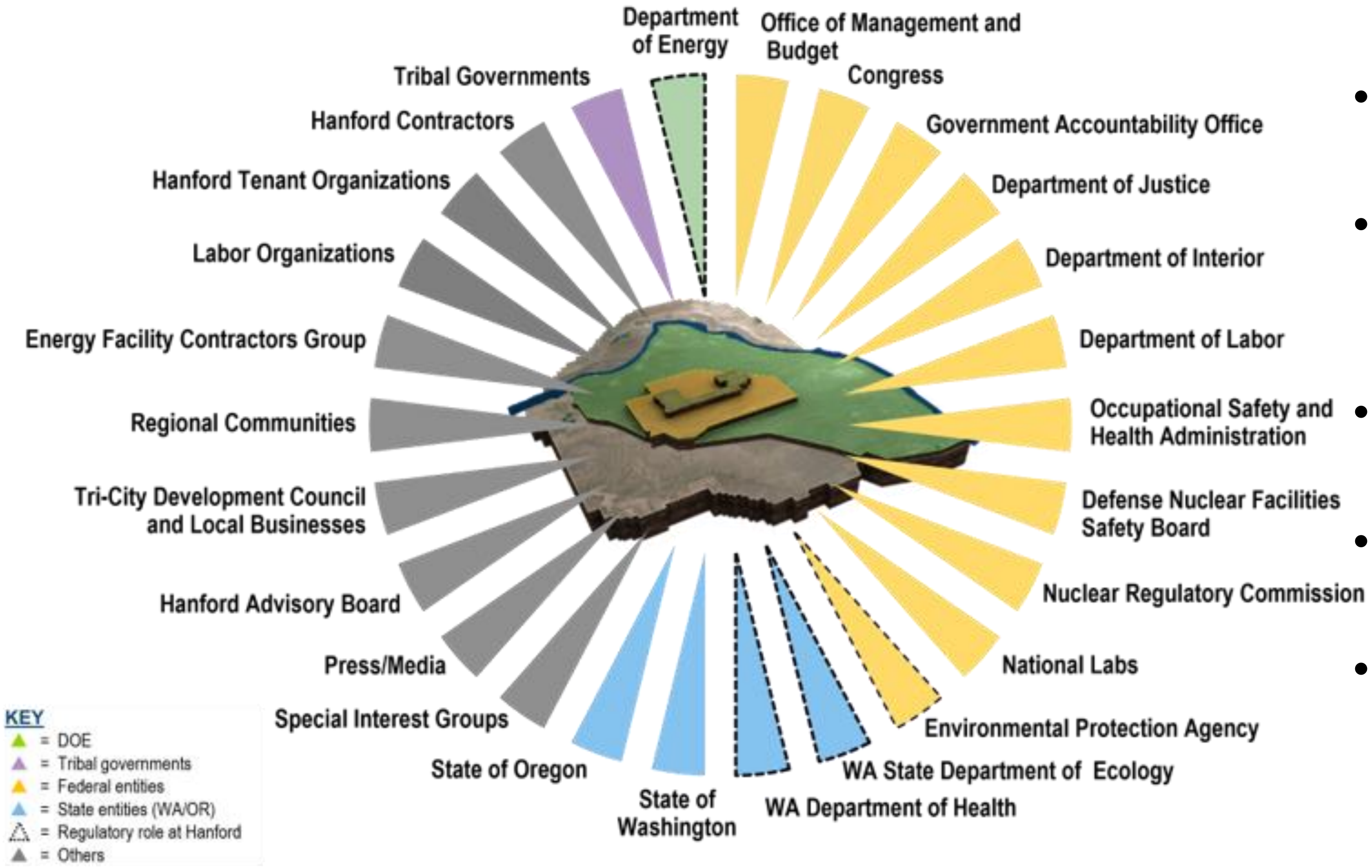
- WTP is a 65-acre site designed to encapsulate radioactive tank waste in glass via vitrification.
- The low-activity waste treatment portion is going through commissioning
- The high-level waste treatment effort is restarting design and limited construction activities.



U.S. DEPARTMENT OF ENERGY

ONE HANFORD

National Academy of Sciences Reviews: Engaging regulators, stakeholders, Tribal Governments



- Independent NAS review mandated by Congress, lasted 7 yrs
- Open public sessions to review technical information and results
- Regulators, Stakeholders, and Tribal Governments had access & input throughout reviews
- Independent scientific analysis & evidence shared openly
- Conclusion was broad acceptance of an Alternate Treatment path for LLW
- Accelerates cleanup mission and offers an opportunity for 70% of LLW long lived radionuclides disposed out of state at operating disposal sites with no path to potable water.

Taking a Whole Flowsheet look at Sustainable Remediation

- Calculations performed to support Federally Funded Research and Development Center (FFRDC) analysis for National Academies of Science, Engineering, and Medicine (NASEM) independent review of treatment technologies for the fraction of LLW beyond WTP LAW capacity…

  www.nationalacademies.org/our-work/review-of-the-continued-analysis-of-supplemental-treatment-of-low-activity-waste-at-the-hanford-nuclear-reservation
  - Inputs – power, clean water, fuel, process chemicals, waste formers
  - Outputs – stack emissions, liquid effluents, primary and secondary wastes
  - Worker hazards – chemical and physical hazards

- Numbers pulled from actual facility flowsheets
  - WTP LAW Vitrification Facility + Effluent Management Facility + Effluent Treatment Facility
  - Savannah River Site Saltstone Facility

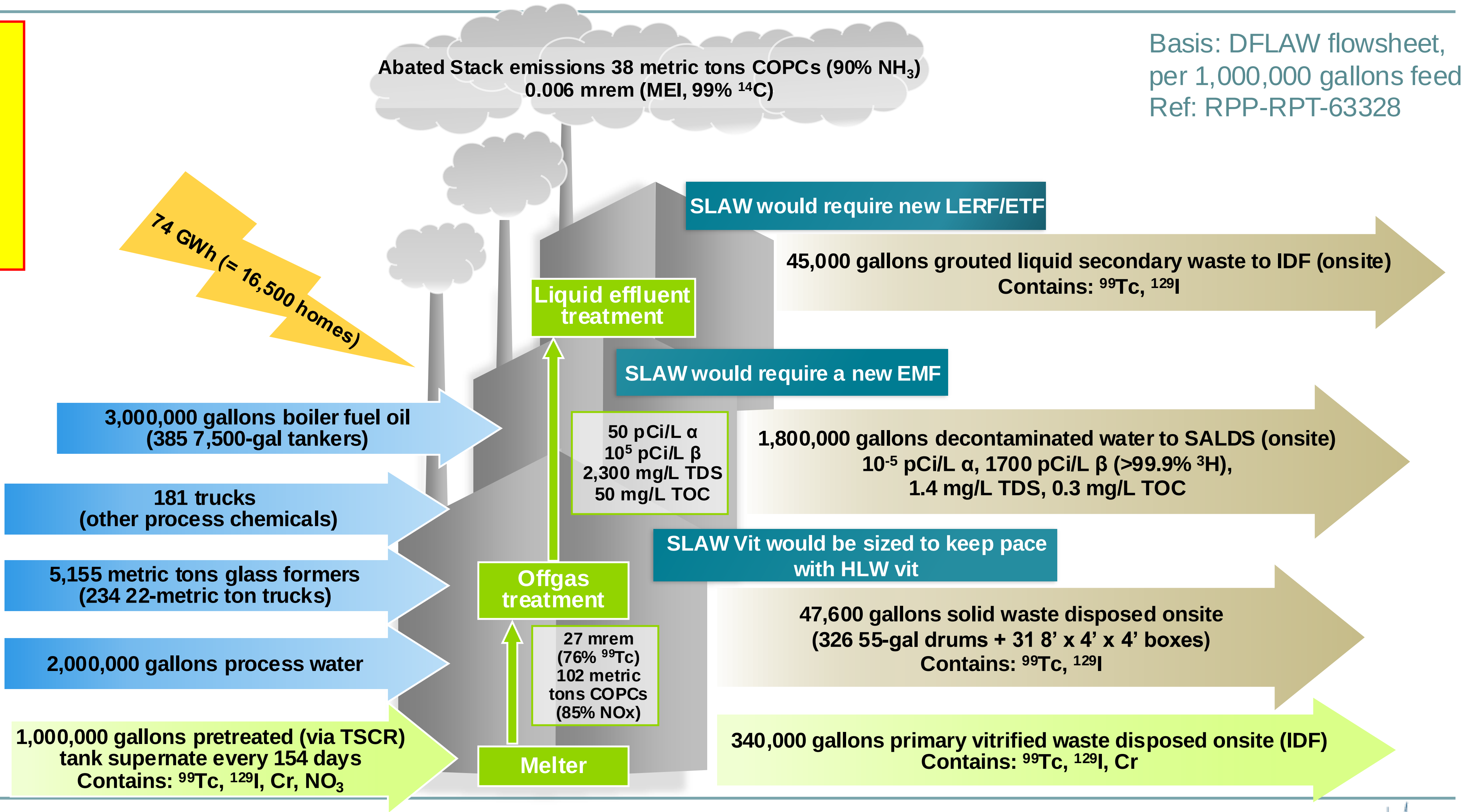
- Converted to same scale (per 1 million gallons pre-treated LLW feed)
- Tank waste mission has more than 100 million gallons of LLW feed

Glass Mass and Energy Flow

Safety Picture:
2 medium-consequence public hazards (anhydrous NH_3 vessels, spent carbon bed media)

38 high-consequence worker hazards (NO_x, NH_3, ACN, others)

Basis: DFLAW flowsheet, per 1,000,000 gallons feed
Ref: RPP-RPT-63328



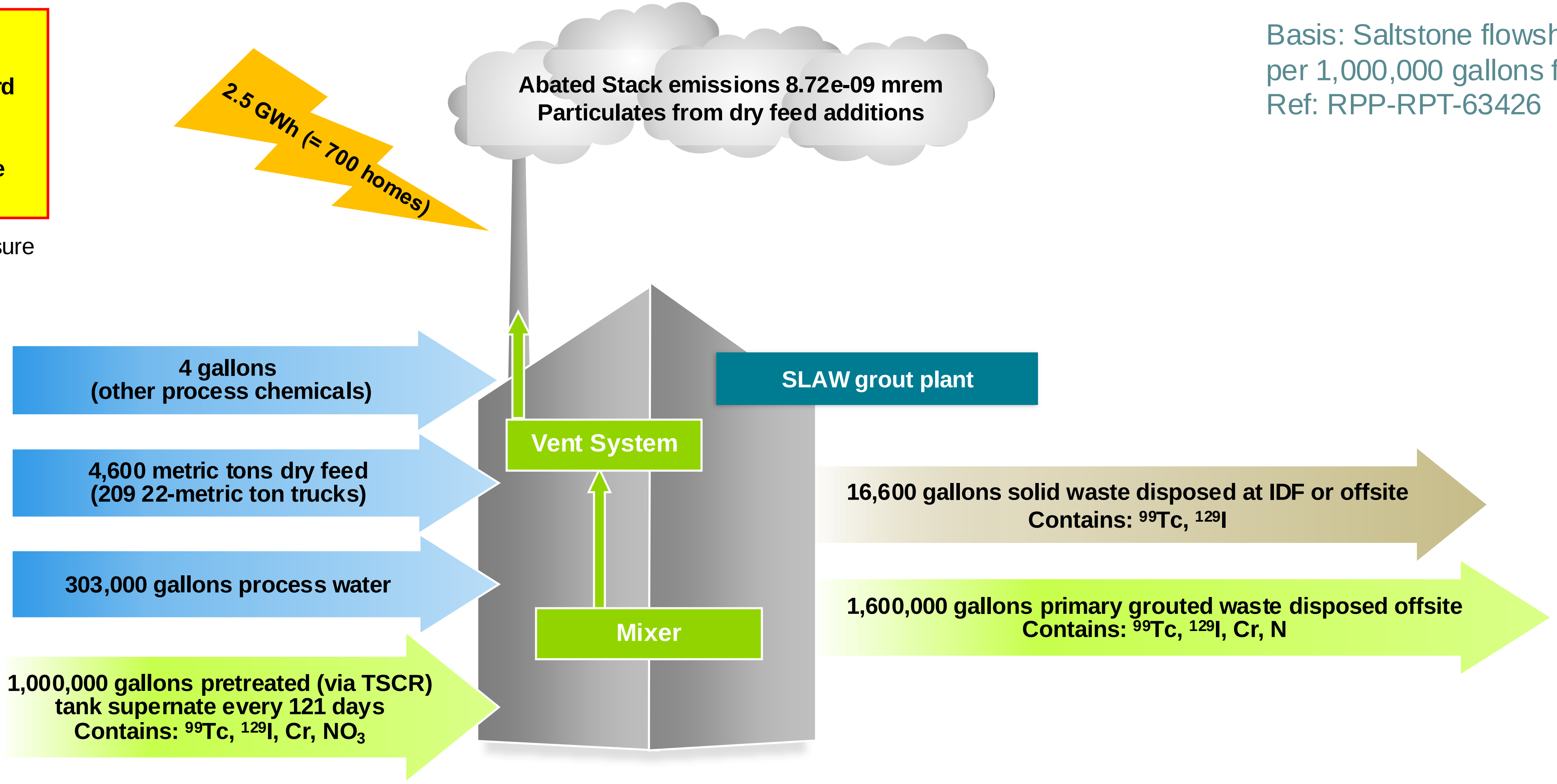
Grout Mass and Energy Flow

Safety Picture:
1 high-consequence worker and public[a] hazard (SDU explosion)

12 medium-consequence worker hazards

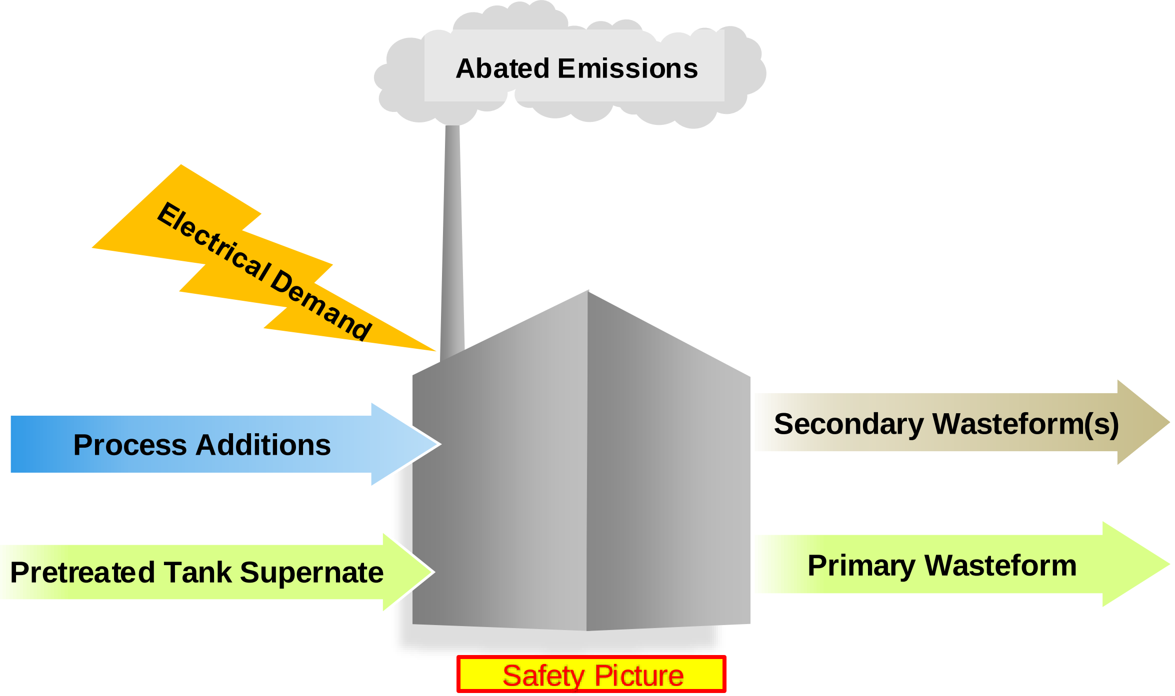
[a] Based on chemical exposure at the Savannah River Site boundary of ≈10 km.

Basis: Saltstone flowsheet, per 1,000,000 gallons feed
Ref: RPP-RPT-63426



Mission Impacts

	Vitrification	Grout
	per million gallons treated feed…	
Pretreated Tank Supernate (gallons)	1,000,000	1,000,000
Process Water (gallons)	2,000,000	303,000
Process Chemicals (trucks)	181	< 1
Process Additives (metric tons)	5,155	4,600
Fuel (gallons)	3,000,000	--
Electrical Demand (GWh)	74	2.5
Abated Emissions (metric tons COPCs)	38	Particulates
Abated Emissions (mrem)	0.006	8.72e-09
Estimated Carbon Footprint ($MTCO_2e$)	32,000	67
Grouted Liquid Secondary Waste (gallons)	45,000	--
Decontaminated Water (gallons)	1,800,000	--
Secondary Solid Waste (gallons)	47,600	16,600
Primary Wasteform (gallons)	340,000	1,600,000
Safety Picture – Public Hazards (consequence level, public, and worker)	2 med public	SDU only – 0 for packaged grout
Safety Picture – Worker Hazards	38 high worker	12 med worker

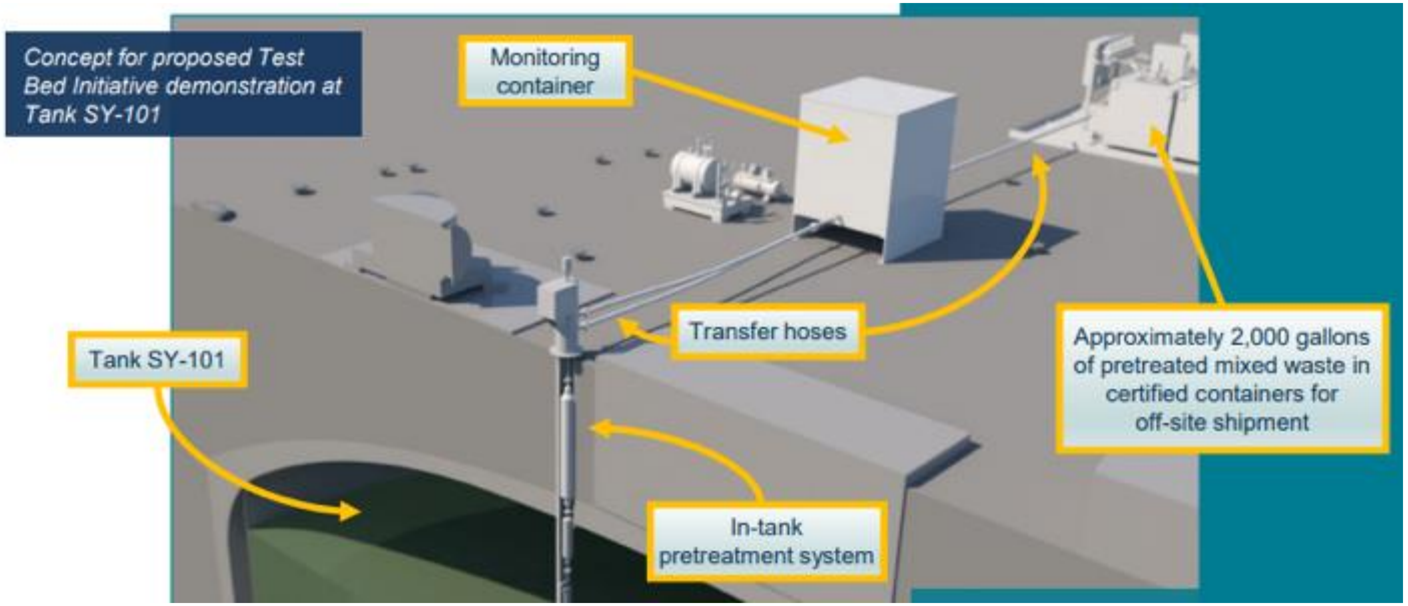


Conclusion:

A low temperature treatment alternative for SLAW has fewer associated hazards to workers and the public, lower energy and fuel demands, less effluent and secondary waste, and lower carbon footprint and emissions.

Tank Waste Stabilization by Grout: Test Bed Initiative, 2,000 Gallons, SY-101

Tank 241-SY-101
Field Deployment



Status

- Published Final Waste Incidental to Reprocessing (WIR) Evaluation (DOE/ORP-2022-02) and corresponding WIR Determination in support of requirements for DOE radioactive waste management
- Published Final Environmental Assessment (EA) of the TBI Demonstration (DOE/EA-2086) and corresponding Finding of No Significant Impact in support of requirements for the *National Environmental Policy Act*
- Transmitted a Research, Development, and Demonstration Permit application in support of regulatory requirements for the RCRA
- Published the final rule on the EPA Land Disposal Restriction treatment variance in the Federal Register
- Equipment was refurbished/fabricated and completed factory acceptance testing before delivery on-site

THE HANFORD SITE

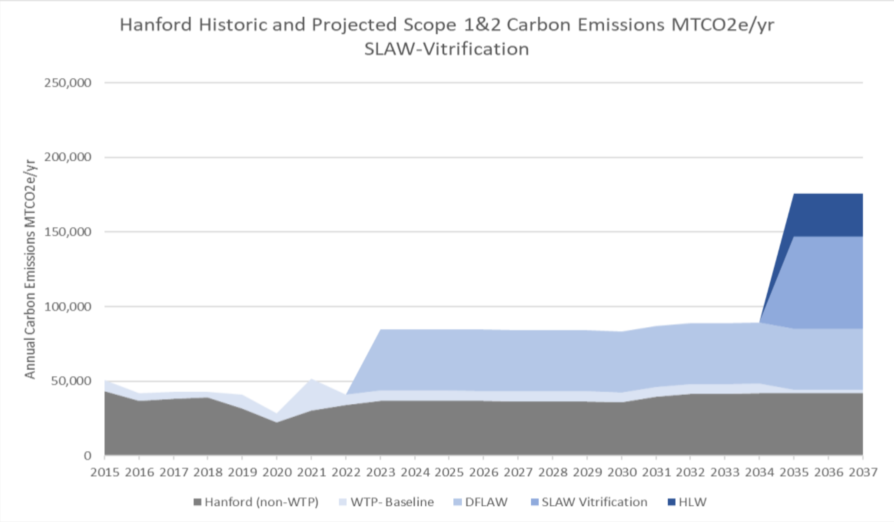
Proposed Tri-Party Agreement on Future Tank Waste Cleanup

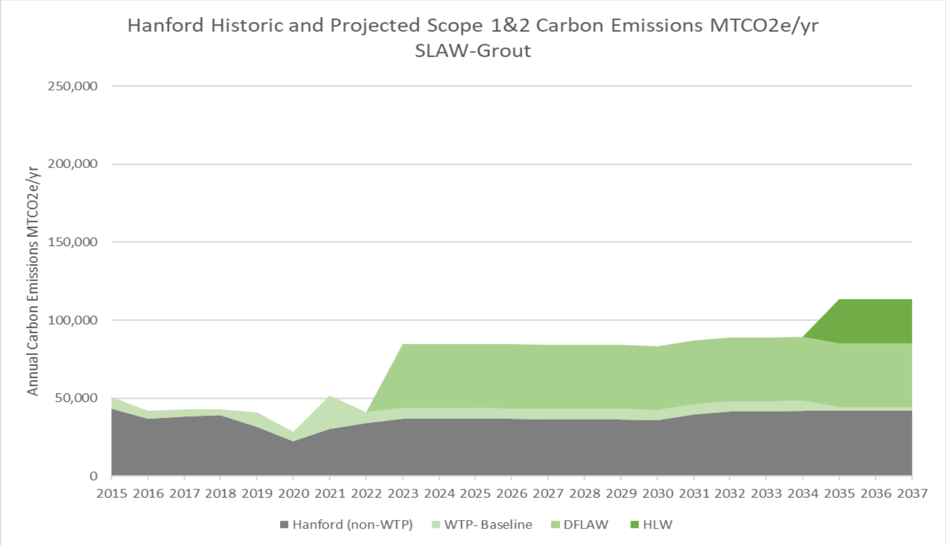
DOE, WA Dept of Ecology, and EPA signed a settlement agreement and proposed new and revised cleanup deadlines (Public comment period was May 30th, 2024 - Sept. 1st, 2024)

Proposed TPA Modifications:

- Maintaining existing timeframes for starting treatment of both low-activity and high-level waste by immobilizing it in glass via vitrification
- Using a direct-feed approach for immobilizing high-level waste (HLW) in glass, similar to the Direct-Feed Low-Activity Waste (DFLAW) Program
- Building a vault storage system and second effluent management facility to support treating HLW
- Designing and constructing 1-million gallons of additional capacity for multi-purpose storage of tank waste
- Evaluating and developing new technologies for retrieving waste from tanks
- Retrieving waste from 22 tanks in Hanford's 200 West Area by 2040, including grouting the low-activity portion of the waste for offsite disposal

Site Sustainability Goals Progress – Net Zero





NET ZERO Goal per Executive Order 14057:

Net-zero emissions building portfolio by 2045, including a 50% emissions reduction by 2032; a 65% reduction in scope 1 and 2 greenhouse gas emissions, from Federal operations by 2030 from 2008 levels…

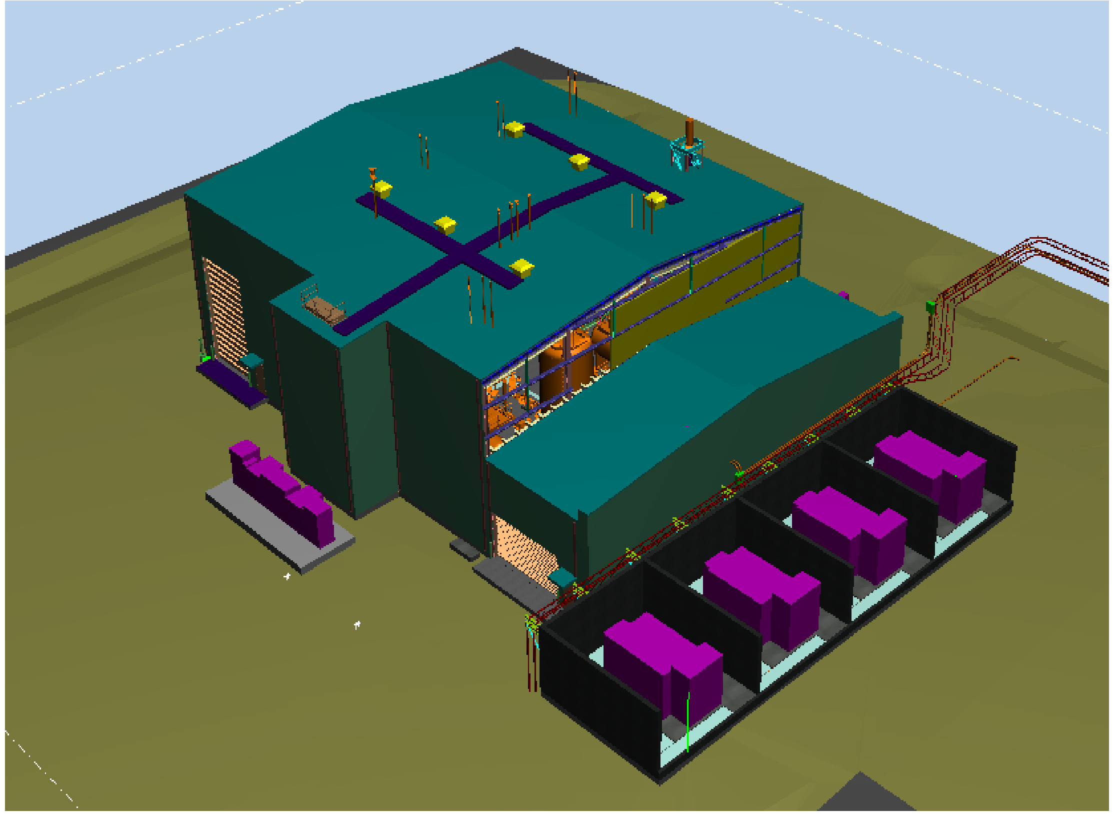
- *Hanford's 2022 Net Zero study quantified largest potential reductions*
- *Depending on NEPA, Alternative Treatment for SLAW has potential to avoid increasing site carbon emissions by 58,300 MTCO2e/year (also saves almost $9B in life cycle costs, completes SST retrievals 9 yrs sooner, per NAS/FFRDC review)*
- *Electrifying WTP boilers is included in DFHLW project, which will reduce carbon emissions significantly (winner of a DOE $5M clean energy grant)*

WTP Electrode Boiler plant…60% design

- To support the One Hanford Net-Zero effort WTP is preparing to transition from diesel fired steam generators to an electric steam plant.

- Requires a substantial upfront investment but represents a considerable greenhouse gas emission reduction and lifecycle savings.
  - Transitioning to an electrically powered steam plant will save millions in fuel costs annually.
  - Greenhouse gas emissions reduction by as much as 43,300 MTCO2e per year.

- WTP awarded DOE grant for electric steam plant effort.

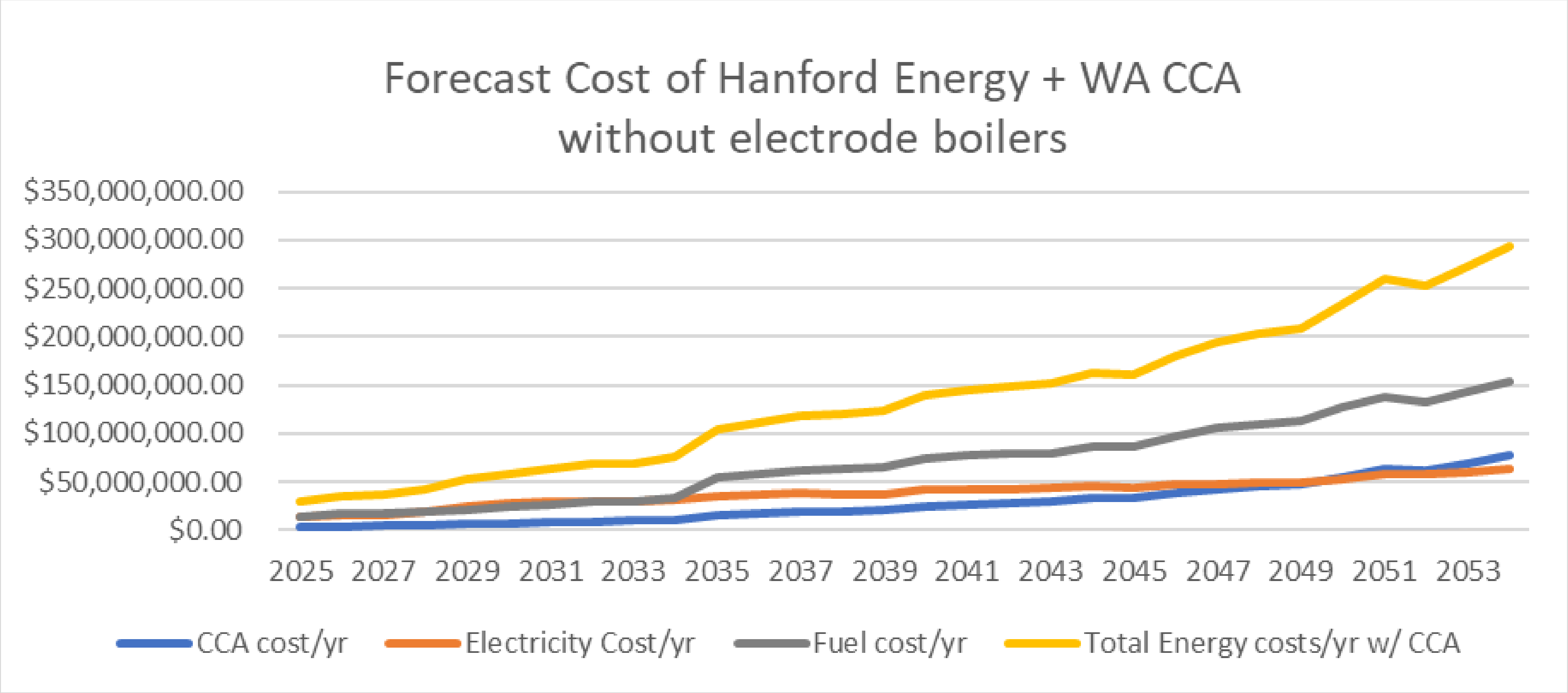


Benefits of Electric Steam Generators

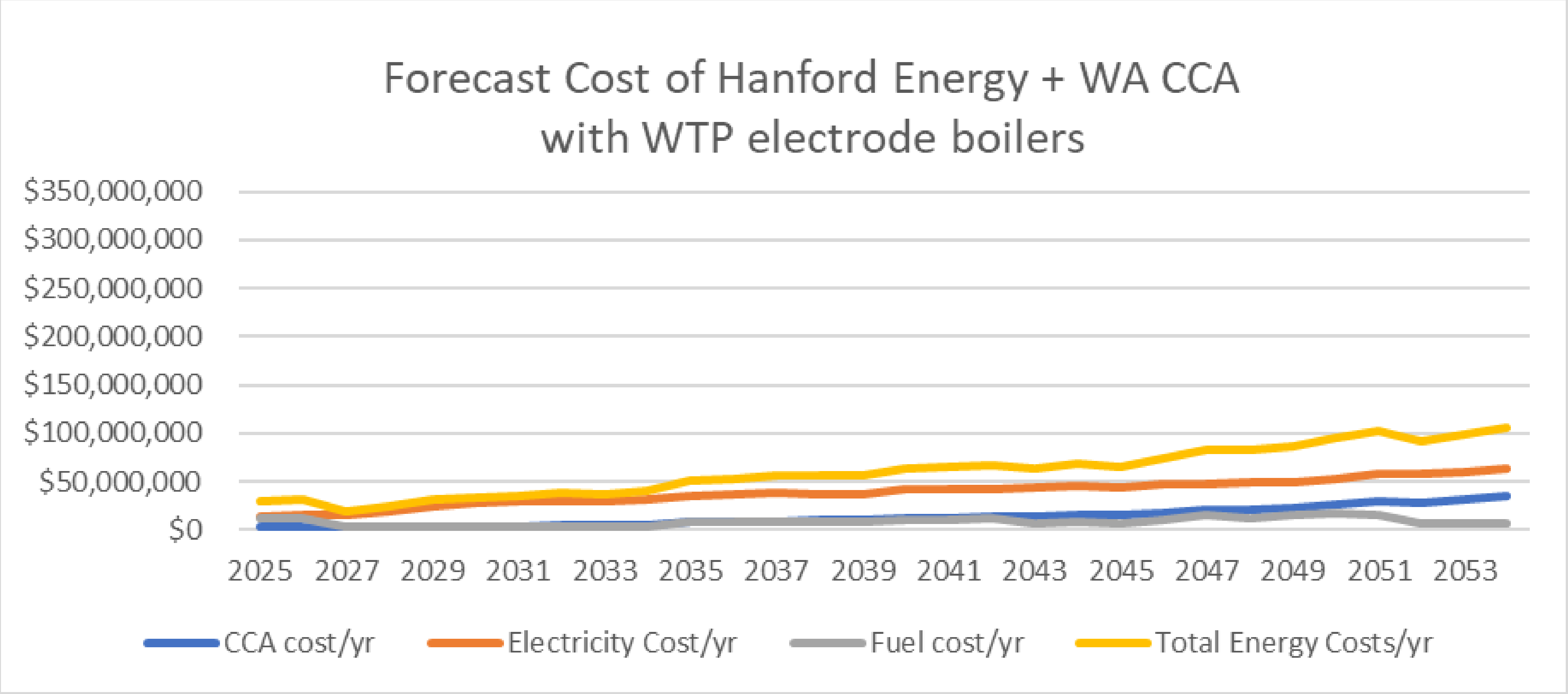
- **Zero Local Emissions** – 100% emission-free and well suited for decarbonization or site-emissions-reduction projects
- **No Combustion Equipment Required** – Reduces installation costs by eliminating the need for gas/oil piping, combustion air supply and exhaust stack.
- **Flexible Fuel Supply** – Electricity is readily available from several sources, including renewable sources such as wind, nuclear, and hydroelectric power.
- **High Efficiency** – Nearly 95-100% efficient at all operating points.
- **Flexible Turndown Capabilities** – Use only the amount of electrical energy required in response to system demand.
- **Does not need treated water** – Uses raw vs. sanitary water, reducing water treatment demand.

Picture courtesy of: Thermon Precision HVJ electrode boilers
HVJ High Voltage Jet Electrode Boiler - Precision Boilers

Energy Costs are Climbing...



Net Zero can help us reduce them...



THE HANFORD SITE

Advice for Sites

- Engage regulators & the community in remediation planning and evaluation of sustainable alternatives to build consensus
  - Frequently there is a win-win for all parties this process brings to light
- Take a whole site and cradle-to-grave flowsheet approach to carbon emissions, looking for the biggest reductions
  - Some of the biggest emissions reductions might be hiding in plain sight
  - LEED and GP are designed for new commercial buildings –
    - Industrial, chemical, and nuclear remediation processes aren’t always a good fit due to rigorous safety standards and requirements, and
    - Simply applying these standards can overlook the biggest emissions and energy cost saving opportunities
- Carefully consider future energy strategy
  - Electrification can trip limits in power contracts – CHWMs, NLSLs
  - Some providers limit renewable generation
  - Not electrifying can come with future carbon tax penalties by state or region

Questions?