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Roadmap for the Backend of the Fuel Cycle of HTR-SMRs

David Hambley

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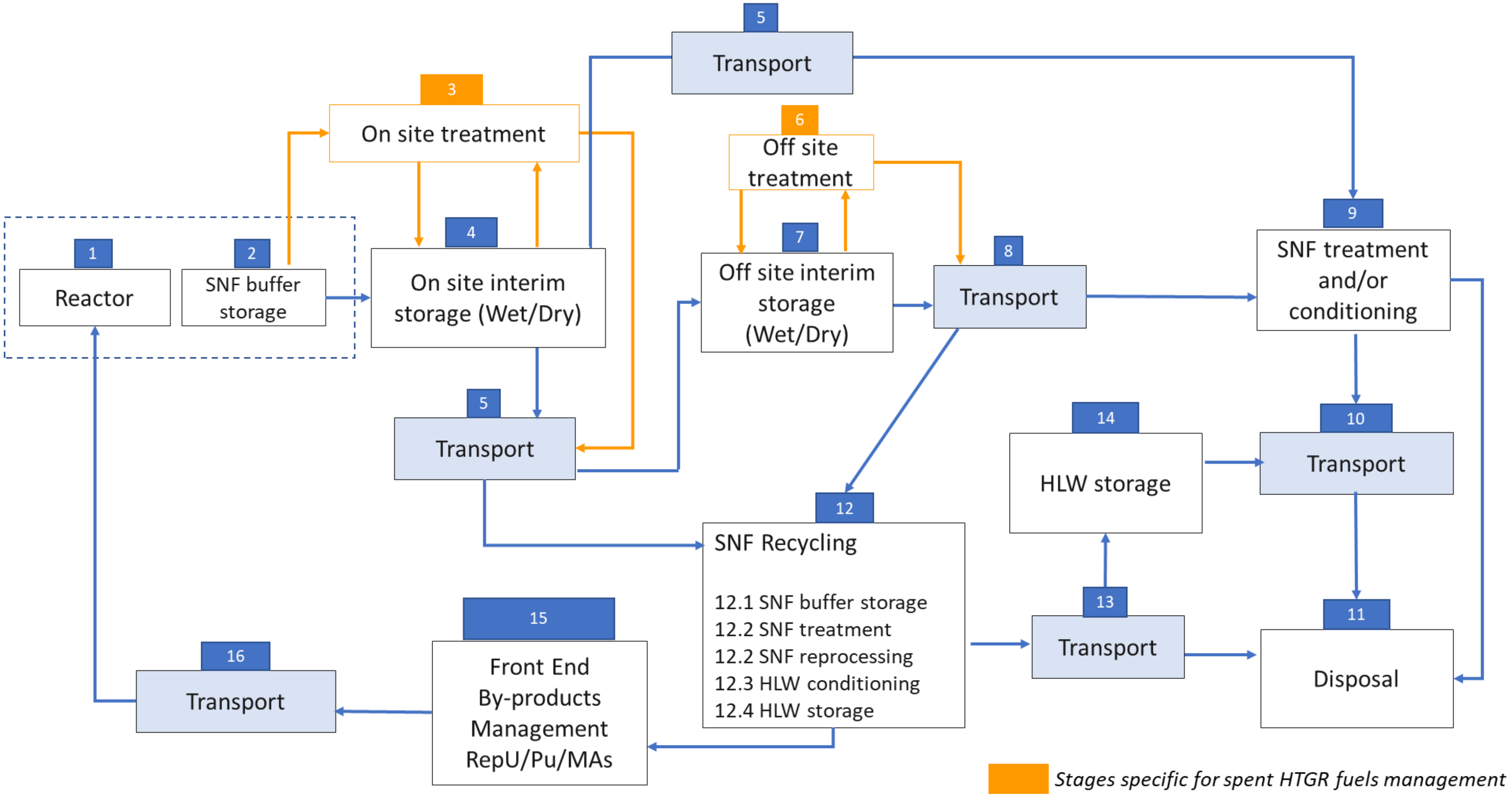
Challenges, Gaps and Opportunities for Managing Spent Fuel from Small Modular Reactors (T13021)



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The Roadmap

A key output of the CRP, built up from a comprehensive technology evaluation to

- Identify fuel cycle options
- Evaluate option maturity and key knowledge/technology gaps
- Define necessary R&DD activities and timescales

Its purpose is to provide a summary of the work required to fully implement each back-end solution

Technologies

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Reactor	Fuel Type	Scenario
LWR	Land based < 5%	A
	Marine based < 20%	B
HTGR	Pebble	C
	Prismatic	D
LMFR	Oxide (Hydroprocessing)	E
	Metal (Pyroprocessing)	F
	Nitride (Hydro/Pyroprocessing)	G
MSR	Thermal Reactor	H
	Fast Reactor	I
	Th	J

Assessment Topics

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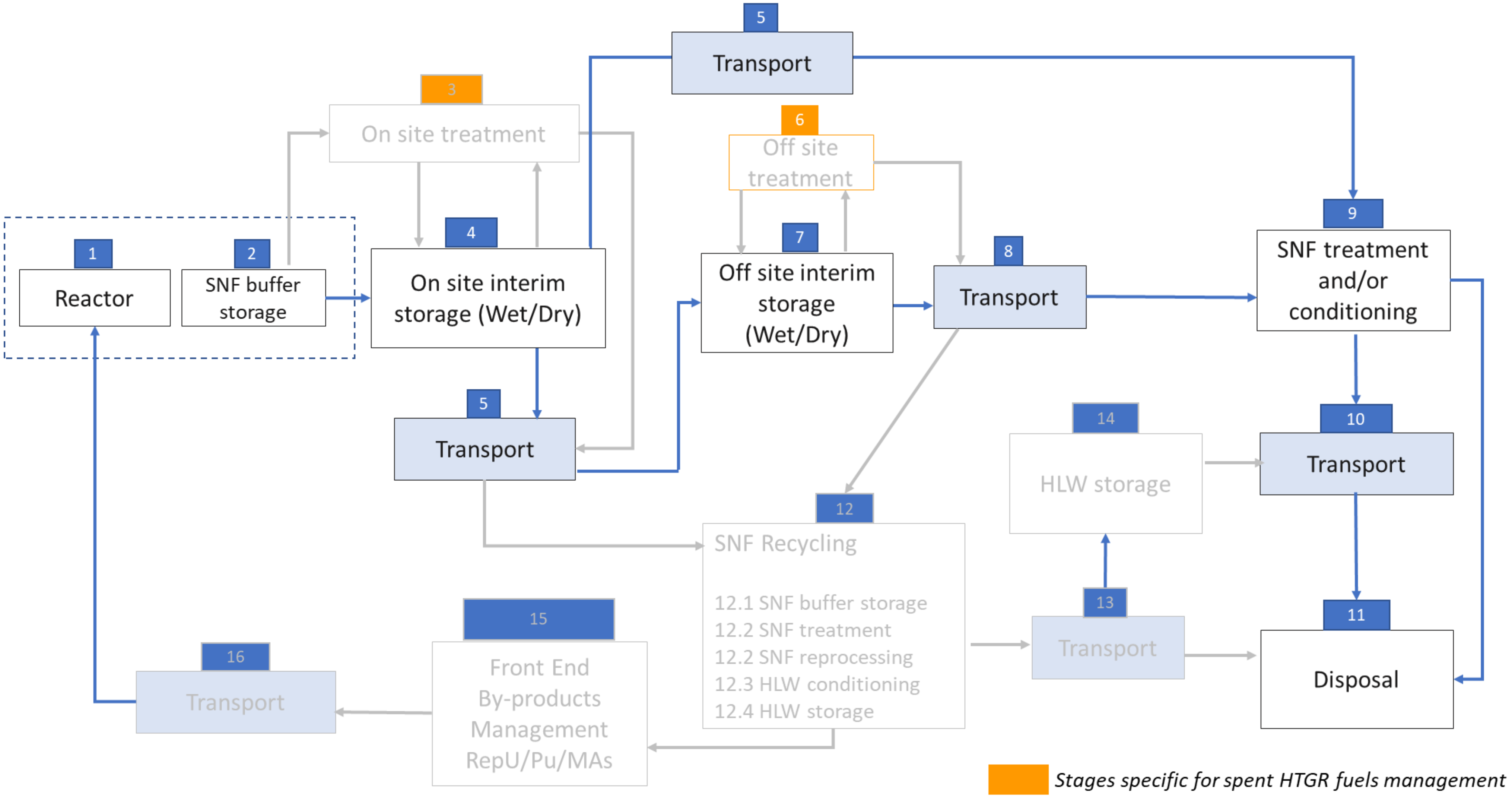
Characteristics	Notes
Differences in SNF Characteristics	Significant differences from 5% LWR UOX spent fuel
Nuclear Facilities needed	Storage, reprocessing, processing, etc… facilities plus immediate supporting infrastructure, e.g. LWR reprocessing plant needs evaporation and vitrification facilities
Radioactive Waste Streams	Significant waste streams from all of the above, in particular high volume and high activity wastes. Routine operational wastes can be omitted unless they had unusual and challenging characteristics
Nuclear Materials Involved	Materials and forms present in normal and abnormal conditions
Infrastructure Needs	Packages, roads, rail, transporters, legal framework, licensing, skills, workforce numbers, safeguards
Enablers	Availability of relevant knowledge, experience or technology in nuclear or other industries that will facilitate implementation, sharing infrastructure, available services (adaptation of existing systems to new fuel cycles)
Gaps	Any known knowledge gaps or areas of high uncertainty in the characteristics of materials in this stage and their evolution. Includes inputs, outputs and intermediates. Also, absence of necessary technologies and relevant operational experience.
Opportunities	Options for minimizing dependency on or need for other stages Ability to integrate into existing or planned energy systems and fuel cycle infrastructures, flexibility to accommodate changes in policies and technology availability
Challenges	Material characteristics, process conditions and performance requirements that are (a) substantially outside current technological envelope or operational experience. (b) known from experience to be challenging in terms of engineering or cost Significant dependency on other stages with high uncertainties
R&D needs	Research, development and demonstration activities required to provide underpinning for engineering design and safety justification/licensing for each unit operation

LWR LEU Open Cycle



LWR HALEU Closed Cycle

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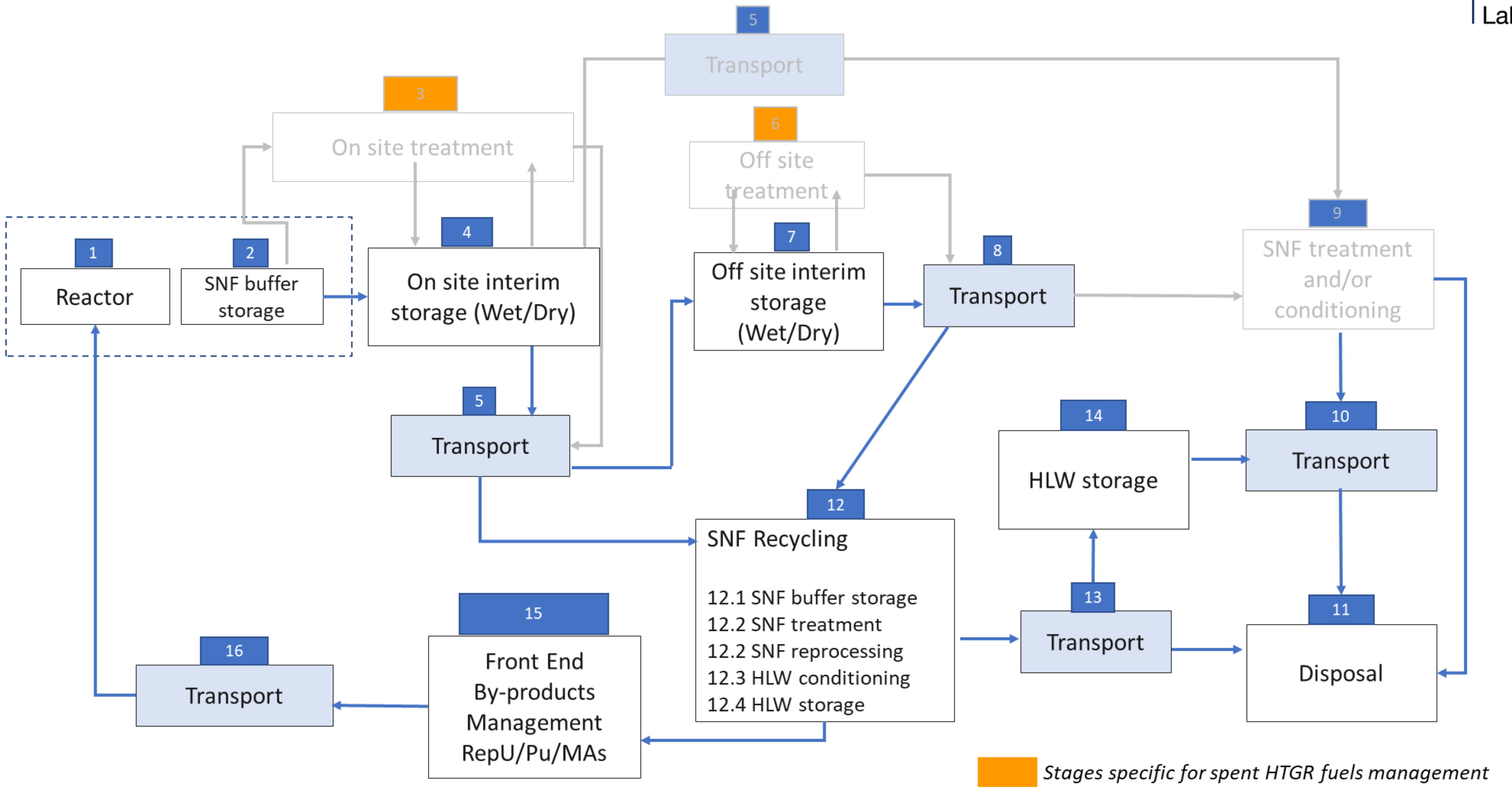

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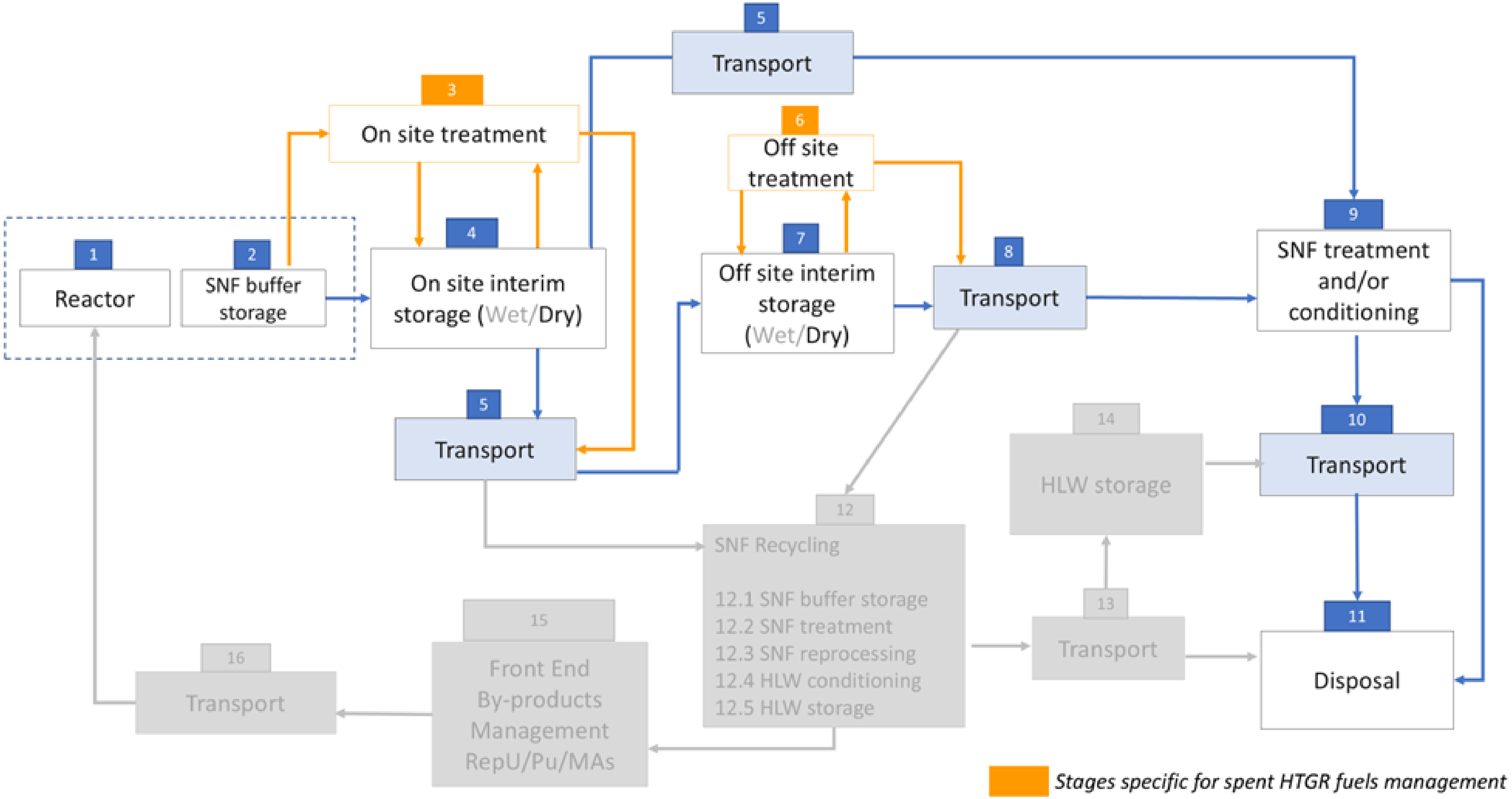
HTGR Prismatic



HTGR Recycle

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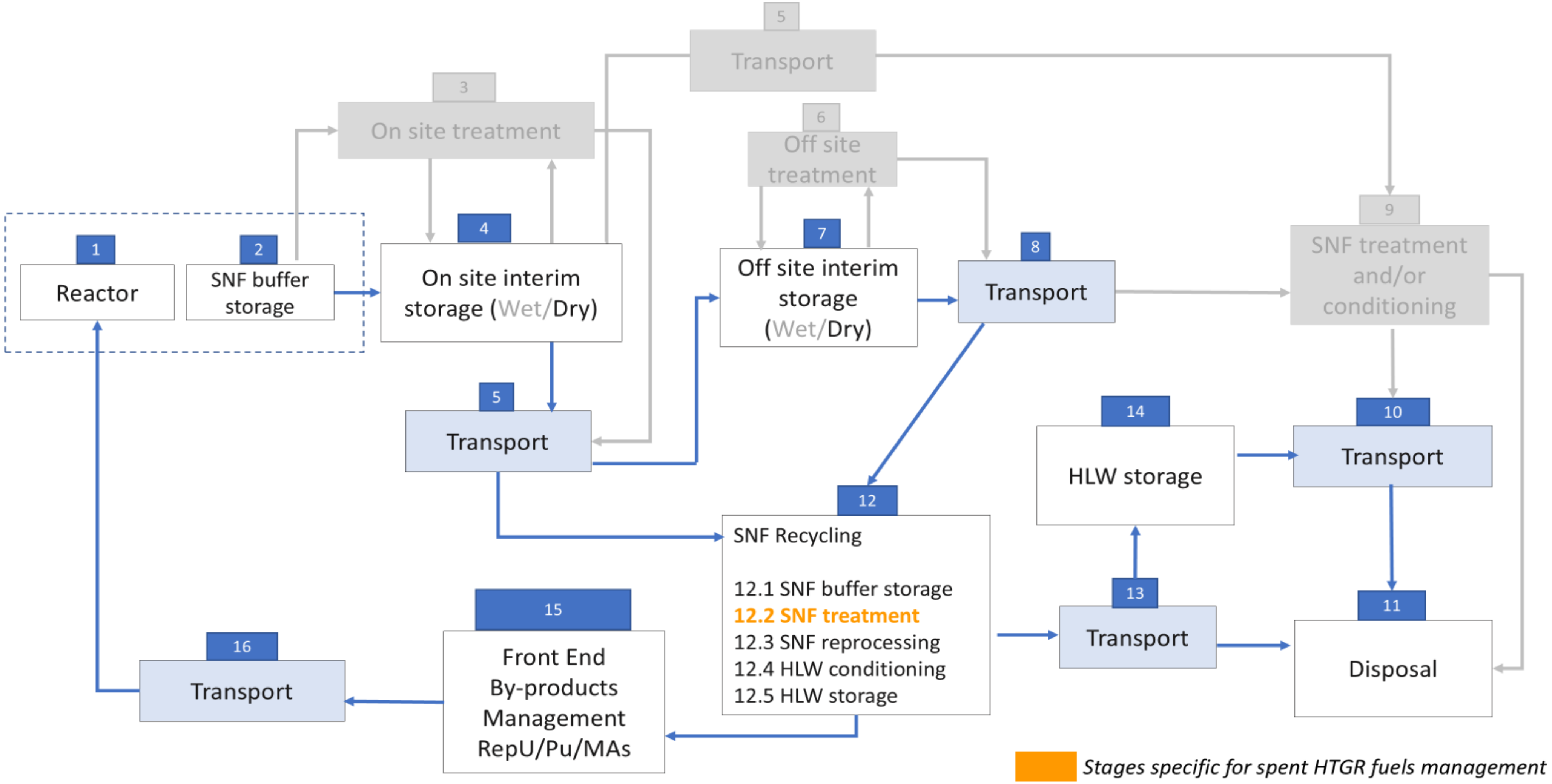

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HTGR Prismatic Open Cycle Assessment

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HTGR Prismatic - Open Fuel Cycle	SNF characteristics	Nuclear Facilities needed	Radioactive Waste Streams	Nuclear Materials Involved	Infrastructure (roads, legal framework, Licensing, etc…)	Enablers	Opportunities	Challenges	Gaps	R&D needs
2. SNF buffer storage	Higher volume, graphite, Higher enrichment, higher burnup, different nuclide composition, lower volumetric heat load. UCO common form, as well as UO2.	Potentially needed for short term heat management (not required for some reactor designs) Forced or convecion		Blocks (with some failed kernels) damaged blocks.Irradiated UCO /O2.	Potentiall forces air if needed. Transpot links and loading facilities	Prior experience in similar operations and would be similar to fuel handling	Opprtunity to avoid need by direct discharge to canisters	none	none	Design of specific storage configurations
3. On site treatment:										
3. On site treatment: seggregation of damaged blocks		Ability to load to contained for damaaged blocks	Irradiated graphite rubbles/parrticulate	damaged blocks	management of special containers and import ruotes	Prior experience with LWR and fuel cycle facilites	-	Wide range of potential particle sizes to be considered and managed	detectionlinspections methods for failed blocks and definitions of failed/waste streams	
4. On site interim storage (Dry)		Similar to existng dry storage technologues (adapted to fuel geometry/heatload): cask and vaults, pads/buildings	minimal	Blocks (with some failed kernels) damaged blocks.Irradiated UCO /O2.	adapted existing technologies.	Prior experience in similar operations and would be similar to fuel handling.	Low volumetric heat load enables early transer to storage	Higher numbers of packages/larger storage requiremen	Ageing effects not fully understood, especially for UCO. In some regulatory environments limits related to storage may have to be changed.	Ageing effects in HTGR /TRISO fuel
5. Transportation		Similar to existng dry storage technologues (adapted to fuel geometry/heatload): cask and vaults, pads/buildings	minimal	Blocks (with some failed kernels) damaged blocks.Irradiated UCO /O2.	numbers of packages, transporters, transport link integrity, maintenance facilities, intermodal facilities and locgistics.	Well established design and operational methods and expertise	Block geometry allows greater optimisation of package characteristics. Graphite blocks have significant moderation and low volume	higher number of shipments higher enrichment fuel	Criticality for water intrusion Criticality benchmarks to validated design measure for criticality saftey	Benchmarks
6. Off site treatment: removal of compacts (rods)		Processing facility (remote handling), with import and export interfaces suporting fuel and waste streams. Treatment of damaged compacts. Buffer storage and export capacity	Graphite blocks, degraded graphite Operationals waste from processing facility. Decommissioning wstes.	Separated compacts (rods), damaged damaged compacts	transport interfaces (see transport), secondary waste management infrastruture	HTTR fuel designs, experimental work on this operation in addition to HTTR rod adaption	Significnt reduction in fuel stream volume with potential const savings	Cost, secondary wastes, dose to workforce. Damage to compacts / kernels during processing. Potetial to need wasteform development.	Workforce experience lacking	Process dvelopment and demonstration. Impact on disposal performance
6. Off site treatment: removal of particles from compacts (rods)		Processing facility for high temperature removal of graphite 1(pyroprocessing discarded because of ability to attached pyC and Sic). CO2 liquification	graphite rubble contaminatinated and radioactive gas, waste from (some) volatile RNs	Separated compacts (rods), damaged damaged compacts, Then separated TRISO particles	Infrastructure to transport CO2 and dispose of it in geological formations	CCS (Carbon capture and storage) for CO2 sequestration	May be able to use CCS facilities for disposal of contaminated CO2. reduction in fuel stream volume	Cost, secondary wastes, dose to workforce. Damag. o kernels during processing. FPs mainly Cl-36. How high efficieny carbon rcapture will be required and how. Handling and packaging of separated particles criticality management of particles	Damage rate	testing for process development and product quality (damage rate)
7. Off site interim storage (Dry)		Similar to existng dry storage technologues (adapted to fuel geometry/heatload): cask and vaults, pads/buildings	minimal	Blocks (with some failed kernels) damaged blocks.Irradiated UCO /O2.	adapted existing technologies.	Prior experienece in similar operations and would be similar to fuel handling.	Low volumetric heat load enables early transer to storage	Higher numbers of packages/larger storage requiremen	Ageing effects not fully understood, especially for UCO. In some regulatory environments limits related to storage may have to be changed.	Ageing effects in HTGR /TRISO fuel
8. SNF Reprocessing										
8.1 SNF Buffer Storage										
8. SNF Reprocessing										
8.2 HLW Conditioning										
9. Transportation	as transport above								Does agring of blocks/particles affect behaviour in subsequent storage?	
10. SNF conditioning		Inspectio and maintenance/repair of packages Inventory characterisatio to meet disposal Waste Acceptance Criteria	minimal	Blocks, compacts in packages or particles in packages	transport interfaces (see transport), secondary waste management infrastruture	Ageing management provides	Opportunity to characterise sufficiently at discharge if disposal WAC are known	May need new techniques for requirememts that are not anticipated	Disposal acceptance criteria	
		potential repackaging facility	used storage systems and operatinonal wastes from repackaging facility	Blocks, compacts or particles		concept designs exist and handling systems are existing technolgy. Packagng is designed to allow retireval				
11. HLW storage										
12. Transportation	as transport (9)									
13. Disposal - mined		Mined facility and surface facilities, Underground research laboratory	minimal	Packaged fuel	same as LWR	precedent set by existing oxide fuel disposal systems TRISO containement- higher containement than existing fuels	Credit TRISO containment to simplify other barriers (e.g. package requiremets) Low voluemtric heat from as discharged fuel, may reduce spacing)	Higher enrichment impact on criticality (burnup gredit may be necessary)	Typ and evolution of radiation defects on PyC and Sic layers Protective eefcts of PyC for Sic TRISO source term model for repository RN diffuction through saturated graphite Radiolysis effects at TRISO surface RN speciation in particle - imact on dissolution and transport (UCO v UO2) Failure time distribution for particles galvanic coupling with waste container	degradation mechanism of TRISO layers in geochemistries Sorption and desorption reactions diferebces arising from local materix and compostional differeces Dissolutions rate of fuels and speciation at relevant burnups for relevant temperature ranges
13. Disposal - borehole		Drilling rig and transfer systems	minimal	Packaged fuel	similar connection infrastructures, less need if located on-site	seal development and site characterisation from CCS	Opportunity to reduced off-site impacts and transport by on-site disposal via borehole	Maturity of safety case and regulatory acceptance with lower reliance on barriers and less detailed site characterisation Boreholes less economically viable for high volme wastes. Retrievability is a significant canister design and demonstration challenge	Lower sensitivity to dissolution behaviours	Degradation and disoslution rates at higher temperatures Technology demonstration for larger borehole sizes Emplacement operations demonstration canister design maturation site characterisation plans need to be established
14. Front end By-products Management RepU/Pu/MAs										
15. Transportation										

Synergies

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1	Failed fuel definitions (establish consistency)
2	Verification of methods for calculations of different SF (e.g. gamma, neutronics, calorimetry)
3	Benchmarking outputs from different calculation codes and users
4	Needs for codes development (validation with data from existing fuels and verification) to address specificities from SMRs' fuels performance in the core (e.g. validation of existing codes)
5	Isotopic calculations (analysis/modeling) especially for higher burnups and isotopes such as Cf-252/254 that are spontaneous neutron sources that make SFM more challenge. This topic seems to overlap with (4) end (6) - suggest we delete this but put key aspects into relevant lines.
6	Nuclear Data Libraries (e.g. identify data gaps that could be common for all technologies)
7	Canisters for storage, transport, and disposal of multiple fuel types (e.g. standardization of containers) Rod to make some reports from USA available to the group if possible
8	Backflow of requirements from disposal (e.g. define a kind of generic acceptance criteria for disposal, compatibility of mining repositories with DBD). Rod to make some reports from USA available to the group if possible
9	End User and stakeholder requirements that are not technical (e.g. co-location of reactors in industrial areas, etc)
10	Transportation envelope (e.g. ensure transportability of spent fuel)
11	Reprocessing of multiple fuel types at the same facility
12	Non-fuel radioactive wastes resulting from recycling and treatment including fuel hardware (and associated component) management (e.g. after reprocessing or treatment, storage, transport, and disposal)
13	Recycling input/output connections (recycling fuel from one reactor type to produce fuel for a different reactor type)
14	Isotope customers (e.g. medical isotopes)
15	Safety case development, commonalities to meet existing regulatory requirements. The IAEA will share the link on "Mapping gaps on safety standards" publication

Assessment Output Example

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HTGR – Prismatic Fuel

Buffer Storage

(2) Spent fuel buffer storage: This stage consists of storage of fuel at the reactor, analogous to storage of fuel in spent fuel pools in an LWR. Storage of quantities greater than that necessary to manage refuelling may not be necessary for HTGR fuels and export of spent fuel direct to cask storage is likely to be credible.	
Nuclear characteristics	Higher volume per kgU than current oxide fuels, higher enrichment, higher burnup, different nuclide composition, lower volumetric heat load. UCO and UO_2 are common forms. Large quantity of graphite associated with fuel.
Nuclear facilities needed	Potentially forced or natural convection system needed for short term heat management.
Radioactive waste streams	Coolant systems are likely to generate some secondary wastes.
Nuclear materials Involved	Blocks (with some failed kernels), damaged blocks, Irradiated UCO/UO_2
Infrastructure (roads, legal framework, licensing, etc.)	Coolant supply, back-up power and coolant supply if required for loss of power conditions Transport links and loading facilities Transport infrastructure will affect the size of containers for storage and transport
Enablers	Prior experience in similar operations. Operations would be similar to fuel handling associated with refuelling
Opportunities	Opportunity to avoid need by direct discharge to canisters, for small prismatic cores.
Challenges	No fundamental technical challenges, although specific storage configurations would need to be designed and verified using existing engineering methods.
Gaps	Adequacy of available criticality benchmarks
Research and development needs	The need for critical benchmarks in HALEU enrichment in the presence on large quantities of graphite (common issue for all operations) Validation of cooling effectiveness for store design.

On-site Treatment

(3) On-site treatment: This is applicable to prismatic HTGR fuel and in this assessment covers segregation and mitigation of damaged blocks or failed fuel to meet downstream performance requirements	
Nuclear characteristics	Blocks with significant degradation affecting handling or subsequent management Blocks with particle failures fractions that do not meet acceptance criteria for downstream activities
Nuclear facilities needed	Facilities to load damaged blocks to container compatible with subsequent operations and/or provide additional containment for ‘failed fuel’
Radioactive waste streams	Irradiated graphite rubble/particulate and contaminated operational equipment
Nuclear materials Involved	Degraded/failed blocks
Infrastructure (roads, legal framework, licensing, etc.)	Management of special containers. On-site transport routes
Enablers	Prior experience with management of current fuels at reactors and fuel cycle facilities
Opportunities	Potential for this to be required only for exceptional events.
Challenges	Wide range of potential particle sizes to be considered and managed Packages for damaged block may be incompatible with normal block storage systems on-site and downstream
Gaps	Detection and inspections methods for failed blocks Definitions of failed/waste streams
Research and development needs	Develop definition of failed fuel that is consistent across fuel types (*synergy*) Development of reliable inspection and retrieval methods for degraded blocks

On- or Off-site Dry Interim Storage

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(4) On-site interim storage (dry) Storage of intact and degraded blocks in sealed, dry, inert conditions.	
Nuclear characteristics	Intact and degraded blocks
Nuclear facilities needed	Similar to existing dry storage technologies (adapted to HTGR fuel geometry/heat load): cask or vaults, pads/buildings with cask handling facilities.
Radioactive waste streams	None
Nuclear materials Involved	Intact blocks (with some failed kernels), damaged blocks. Fuel containing irradiated UCO/UO_2.
Infrastructure (roads, legal framework, licensing, etc.)	Storage systems and facilities: licensing of adapted storage systems. Transport infrastructure of on-site imports and for final exports to an off-site facility. There may need to be contingency infrastructure to recover and repackage fuel.
Enablers	Adapted existing technologies: initial assessment indicates casks/packages will be no greater than current system size and weights. Established engineering methods should be adequate for adaptions
Opportunities	Prior experience in similar operations at a range of storage technologies and fuel handling operations at reactors/fuel cycle facilities. Low volumetric heat load enables early transfer to storage and less demanding heat transfer requirements TRISO fuel has multiple barriers, may reduce engineering requirements
Challenges	Higher numbers of packages/larger storage requirements than current reactor of similar output If fuel is to be treated, transport and storage system choice may be different from storage only
Gaps	Ageing effects not fully understood, especially for UCO In some regulatory environments limits and detailed guidance related to storage may have to be changed.
Research and development needs	Ageing effects in HTGR /TRISO fuel Validation of cooling system designs for lower intensity sources Confirmation of lower temperature threshold for fuel degradation on loss of inert conditions

Transport

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(5) Transportation This transport operation is from a reactor site to an off-site facility for long-term storage, recycling or treatment and conditioning prior to disposal.	
Nuclear characteristics	Casks and transporters licensed for public domain containing prismatic fuel. This may include international transfers, e.g. for recycling options.
Nuclear facilities needed	Similar to existing dry storage technologies (adapted to fuel geometry/heat load): cask and transporters
Radioactive waste streams	Minimal
Nuclear materials Involved	Blocks (with some failed kernels). Damaged blocks Irradiated UCO/UO_2
Infrastructure (roads, legal framework, licensing, etc.)	Transport packages, transporters, maintenance facilities, intermodal facilities. Transport planning and emergency arrangements. Adequate transport infrastructure for selected packages.
Enablers	Well established design and operational methods and operational expertise of road, rail and shipping operations, nationally and internationally.
Opportunities	Prismatic fuel is smaller than current LWR assemblies increasing range of package sizes that could be used. Graphite blocks have significant moderation and low free volume. Risk of degradation under normal conditions minimal due to compact fuel forms
Challenges	Higher number of shipments
Gaps	Criticality benchmarks to validated design measures for criticality safety during normal and accident conditions, e.g. flooding.
Research and development needs	Criticality benchmarks Performance of irradiated fuels under accident conditions

Off-Site Treatment

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(6.1) Off-site treatment: removal of compacts from the blocks This operation applies only for prismatic fuel. The treatment consists of mechanical separation of fuel rods/compacts from prismatic blocks to reduce the volume of the spent fuel inventory.	
Nuclear characteristics	Mechanical removal of fuel rods/compacts Repacking of compacts (or rods) for onward management Repacking of graphite for storage pending disposal Treatment and packaging of damaged compacts & damaged fuel blocks
Nuclear facilities needed	Processing facility (remote handling), with import and export interfaces supporting fuel and waste streams May include buffer storage for import and export
Radioactive waste streams	Graphite blocks, degraded graphite, operational waste from processing facility Some parts of block storage system may become waste Decommissioning waste
Nuclear materials Involved	Input: intact and damaged prismatic blocks Output: Separated compacts (rods), damaged compacts
Infrastructure (roads, legal framework, licensing, etc.)	Transport interfaces (see transport), Secondary waste management infrastructure, e.g. storage facilities Management of packages for output materials
Enablers	Japanese HTTR fuel design has compacts in graphite sleeve (rod) for ease of removal Previous experimental work on defueling provides insights to options and remaining development needs AGR fuel dismantling provides operational experience
Opportunities	Significant reduction in fuel stream volume with potential cost savings. Potential to recycle graphite blocks (may require annealing) Crushed graphite could be recycled as feedstock
Challenges	Cost, secondary wastes, dose to workforce Damage to compacts / kernels during processing May need wasteform development.
Gaps	Verified data on compact/block clearance at high irradiation Optimised design for block design to ensure reliable compact removal
Research and development needs	Process and packaging development and demonstration Proportion of removed fuel that is damaged/requires additional treatment Impact on disposal performance

Spent Fuel Conditioning

(9.1) Spent fuel conditioning (without repackaging) Monitoring and inspection of received packages to confirm compliance with disposal facility. It may include activities to repair defects.	
Nuclear characteristics	Intact and processed fuel items packaged in a form suitable for transfer to disposal facility for emplacement.
Nuclear facilities needed	Inspection and maintenance/repair of packages to demonstrate that they meet waste acceptance criteria (and transport requirements) after (long-term) storage Inventory characterisation to meet disposal Waste Acceptance Criteria (WAC)
Radioactive waste streams	Minimal
Nuclear materials Involved	Intact or processed damaged blocks after a period of aging. If blocks have been volume reduced, contents for transfer to conditioning could be aged, packaged intact and degraded compacts (after 6(a)) or aged, packaged intact and degraded TRISO particles (after 6(b))
Infrastructure (roads, legal framework, licensing, etc.)	Transport interfaces (see transport), secondary waste management infrastructure (expected to be minimal) Data recording will need to meet disposal requirements
Enablers	Ageing management of current fuels provides useful data on potential degradation and development of inspection techniques and equipment
Opportunities	Opportunity to characterise fuel sufficiently at discharge fromreactor, if disposal WAC are known, which avoids additional costs/dose/delays prior to disposal
Challenges	May need new techniques to be developed and qualified for requirements that are not currently anticipated.
Gaps	In the absence of disposal package designs and disposal acceptance criteria, it is unclear what specific gaps exist, however it is likely that detailed understanding of the impact of long term storage on package and content characteristics will be required to demonstrate compliance with WACs (when available)
Research and development needs	Currently unspecified, but will be informed by content of ‘challenges’ and ‘gaps’.

Reprocessing

(12) Recycling (combined)	
Nuclear characteristics	Receipt, buffer storage, and preparation of prismatic blocks and pebbles. Separation of fuel from non-fuel components, dissolution of fuel, separation of reusable components from high level waste. Concentration, storage and conversion of high level fission products wastes to a durable wasteform. Packaging for storage and transfer.
Nuclear facilities needed	Cask receipt maintenance facilities, fuel buffer storage facility, reprocessing plants, effluent plants, waste treatment plants, solid waste storage
Radioactive waste streams	Multiple: deconsolidated graphite, residual SiC, TRISO rubble from crushing, recovered thermal process particulate and gaseous FP, separation liquors, separated FP&TRU. Used transfer and storage containers etc.
Nuclear materials Involved	Prismatic blocks and pebbles. Dissolved fuel Separated U/Pu/MA products High activity wastes with significant missile material content
Infrastructure (roads, legal framework, licensing, etc.)	Large scale transport infrastructure Large technological support organisation Security and safeguards organisation Environmental monitoring Regulatory management Contracting and contract management
Enablers	Experience in recycling out of spec unirradiated fuel. Existing oxide fuel reprocessing technology should be compatible with acidic stream from TRISO, subject to low organic carryover
Opportunities	Recycling of LEU/LEU+ material along with Pu and Minor Actinides (isotopes of Np, Am, Cm, etc.). Reduce mass and volume of radioactive waste to be sent to a GDF/DGR (only fission products and non-actinide activation products)
Challenges	Degrading TRISO particles removed most of the fuel attributes that make ~~is~~ it a durable and reliable fuel/waste form. A number of techniques to explore the fuel kernel have been demonstrated at laboratory scale, but remain at TRL2. Technologies for abatement of Volatile releases from head end operations need to be demonstrated and upscaled.
Gaps	
Research and development needs	Scale up and active material testing to support plant design and licensing

Disposal

(11.1) Disposal – mined Receiving of packaged fuel, transfer underground, emplacement, backfilling and long term evolution and migration to surface	
Nuclear characteristics	Packaged fuel will be transported to it's disposal position and emplaced. Local environment will transition from initial operational conditions to post closure conditions.
Nuclear facilities needed	Mined facility and surface facilities, underground research laboratory
Radioactive waste streams	Minimal during operation.
Nuclear materials Involved	Blocks, compacts in packages, or particles in packages Also packaged degraded blocks/compacts/particles.
Infrastructure (roads, legal framework, licensing, etc.)	Similar to current repository designs and concepts
Enablers	Precedent set by existing oxide fuel disposal systems provides reference for an adequate engineering system and system requirements
Opportunities	TRISO fuel has higher containment durability than existing fuels, which may reduce packaging performance requirements. Low volumetric heat load associated with fuel blocks should enable lower spacing requirements for disposal Where significant quantities of moderator exist in fuel matrix, effect of water ingress will be lower than for current fuels. Graphite is highly durable in deep repositories, providing long term geometric stability
Challenges	Higher enrichment impact on criticality (burnup credit may be necessary) Additional benchmarks may be required for TRISO containing fuel at HALEU enrichments
Gaps	Leaching behaviour of high burnup TRISO particles Durability of TRISO particles if additional claims on containment are to be claimed Solution conditions within compacts/wasteful matrix Failure time distribution for particles
Research and development needs	Short term: demonstrate fuel behaviour is bounded by existing oxide fuel *or* provide reasonable confidence of durability for optimised concepts Long term: provide reliable data to enable performance assessments and back end facility licensing.

Activity to Come

Review assessment outputs to validate or amend assessment conclusions

Target inputs to:

- Operating experience of HTGR fuel management
- Knowledge gaps and data requirements for new fuels
- R&D and implementation timescales

Generate option specific diagrams and notes on decisions that drive adoption of each option

HTGR Bulletin

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Bulletin

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Interim summary of the broad conclusions of fuel cycle assessments.

Proposed format for HTGR assessment:

- Introduction (purpose and importance)
- Assessment context and criteria
- Key characteristics of HTGR Fuel
- Once-Through Management of Irradiated Prismatic Blocks
- Once-Through Management of Irradiated Pebbles
- Closed Cycles for Irradiated Prismatic and Pebble Fuel
- Synergies
- Assessment Output for HTGR closed fuel cycles (assessment tables)

6 pages

Bulletin Plan

Reactor Technology	Fuel Cycle Scenarios	Milestone	Due Date	Deliverable	Group Leader
LWR	LEU (< 5%) (Open Cycle) LEU (< 5%) (Closed Cycle) LEU+ (5 -10%) (Open Cycle) LEU+ (5 -10%) (Closed Cycle) HALEU (10- 20%) (Open Cycle) HALEU (10 - 20%) (Closed Cycle)	Strawman to group: Finalise LEU+ and HALEU scenarios learning fom HTGR Group (sent proposal to IAEA when ready)	January to June 2025	Booklet 1 on LWR-SMRs	Luis Moreno Pombo (Spain)
		Consultancy Meeting on LWR (virtual) other Group's Leads Attending	September 2025		
		IAEA Technical Meeting on Spent eATF Management (To review the Draft of the Booklet)	10 - 14 November 2025		
		Issuance of the Booklet on LWR-SMRs	May to June 2026		
HTGR	Pebble (Open Cycle) Prismatic (Open Cycle) Pebble/Prismatic (Closed Cycle)	Strawman to group (First Outline Proposed) other Group's Leads Attending	January 2025	Booklet 2 on HTGR-SMRs	David Hambley (UK)
		Consultancy Meeting (virtual)	March 2025		
		IAEA Technical Meeting on Spent HTGR Management (To review the Draft of the Booklet)	7 - 11 July 2025		
		TWG review of bulletin	September 2025		
		Issuance of the Booklet on HTGR-SMRs	December 2025		
LMFR	Oxide/Metal/Nitride (Open Cycle) Oxide (Closed Cycle, Hydroprocessing) Metal (Closed Cycle, Pyroprocessing) Nitride (Closed Cycle, Hydro/Pyroprocessing)	IAEA will discuss with potential lead countries depending on received proposals	December 2024	Booklet 3 on LMFR-SMRs	To be discussed with France
MSR	Thermal/Fast Reactor (Open Cycle) Thermal Reactor (Closed Cycle) Fast Reactor (Closed Cycle) TRISO (Open Cycle) Th (Open Cycle) Th (Closed Cycle)	IAEA will discuss with potential lead countries depending on received proposals	December 2024	Booklet 4 on MSR-SMRs	To be discussed with France

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Thank you

United Kingdom
National Nuclear Laboratory
5th Floor, Chadwick House
Warrington Road, Birchwood Park
Warrington WA3 6AE
T. +44 (0) 1925 933 744
E. engagement@uknnl.com

www.uknnl.com