Moltex technology

An overview for the National Academies of Sciences, Engineering, and Medicine committee on fuel cycles and waste aspects of advanced nuclear reactors

February 23, 2021

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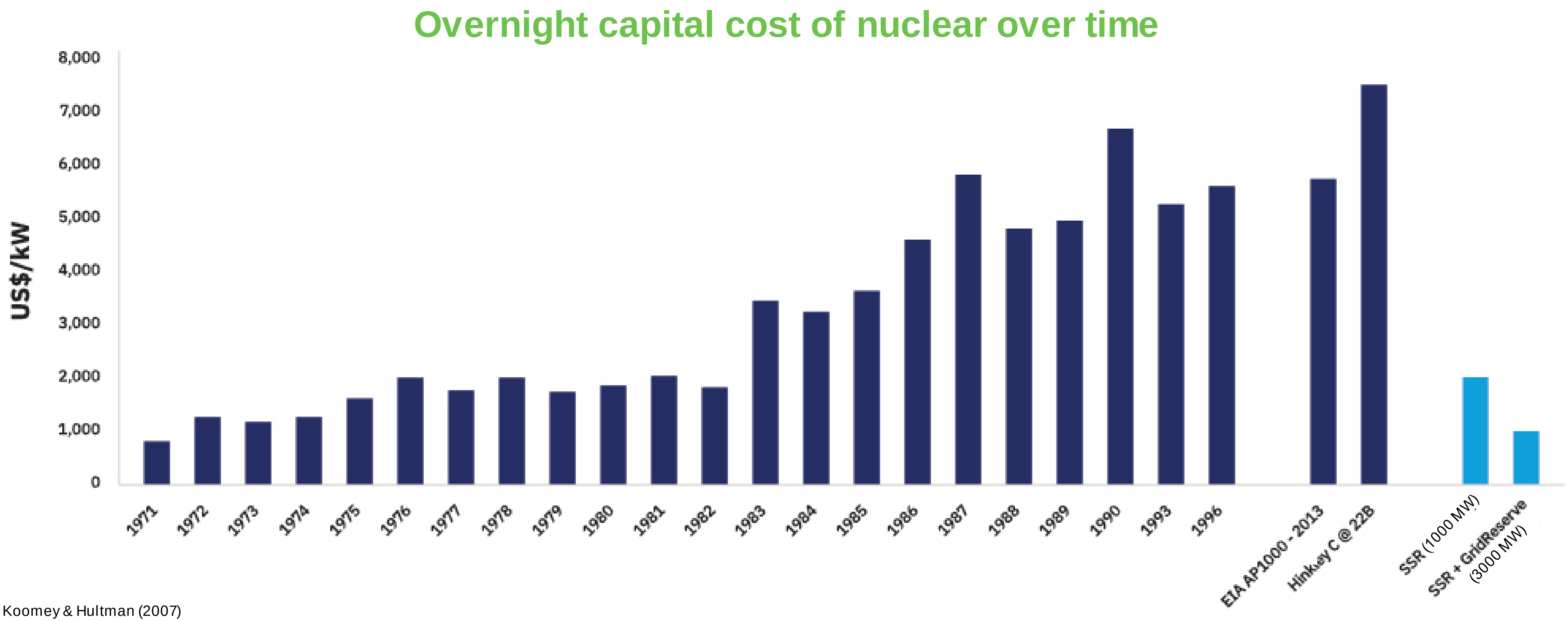
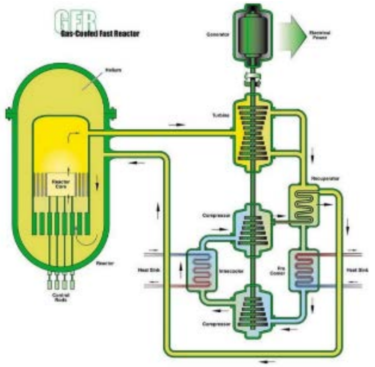
Why Moltex was founded



Koomey & Hultman (2007)

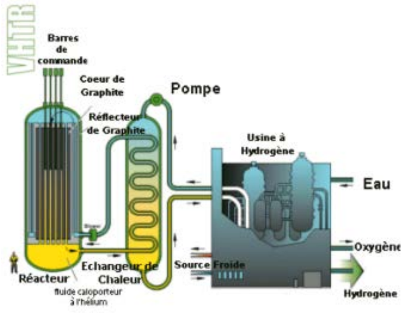
What are the options for low-cost nuclear?

Gas cooled fast reactor



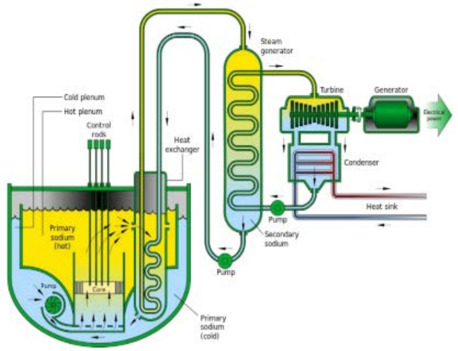
Costly high pressure system and expensive new solid fuel system

TRISO fuelled reactors



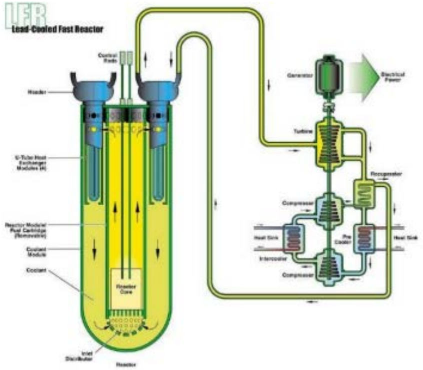
Excellent safety but published fuel cost estimates show cannot compete with gas/coal

Sodium fast reactor



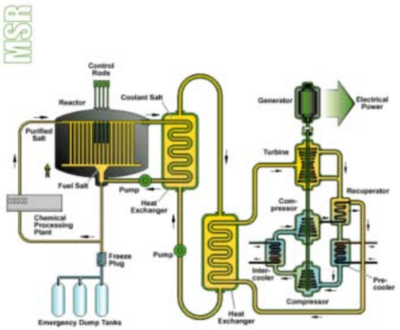
Highly dependent on engineered safety

Lead cooled fast reactors



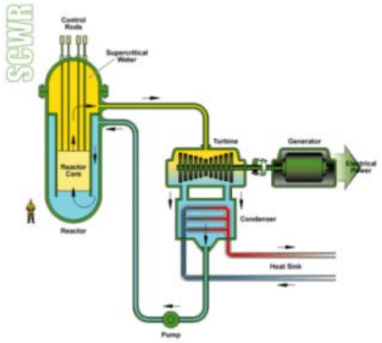
Better than sodium, but new materials needed

Molten salt reactor



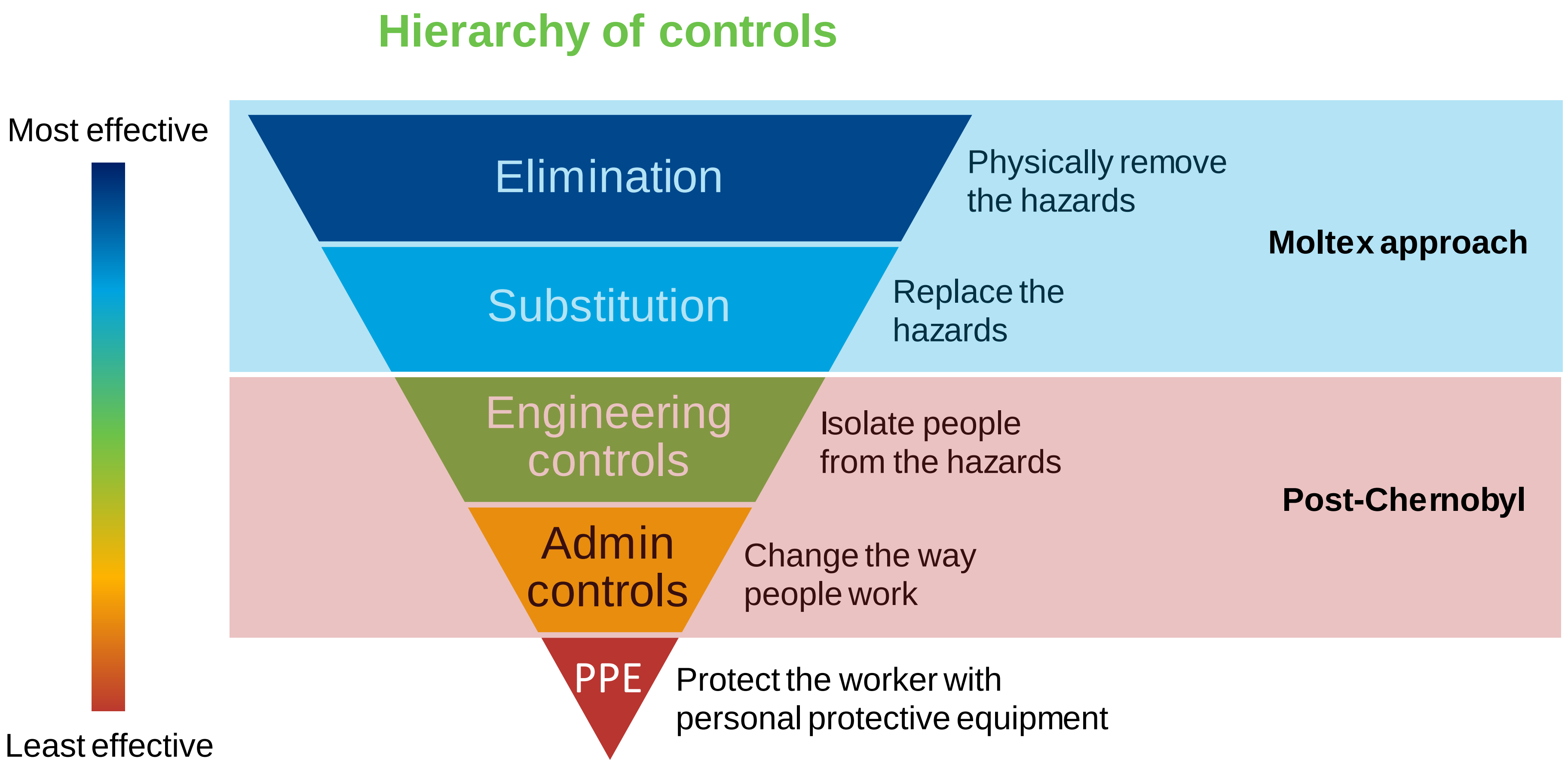
MAYBE?
Step change in intrinsic safety at lower cost than TRISO

Supercritical water



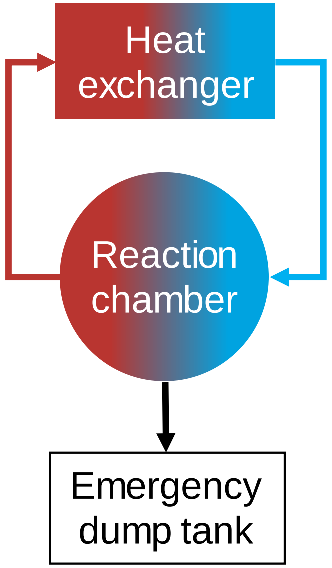
Not credibly cheaper

Reducing risk



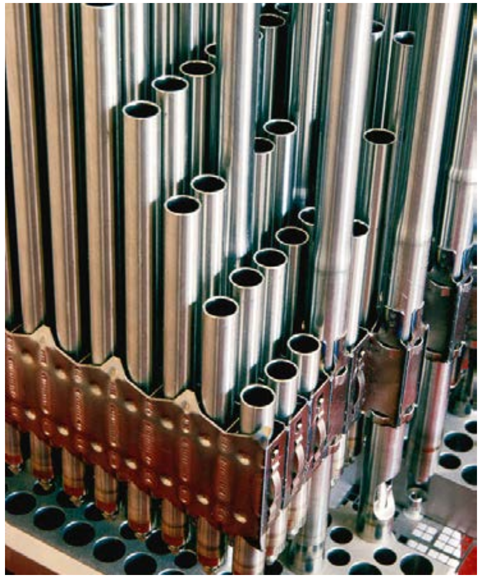
Two ways to use molten salt fuel

Conventional MSRs



- **Intensely radioactive fuel salt pumped at pressure round an engineered system which can never be approached by a human being**

Stable Salt Reactor platform



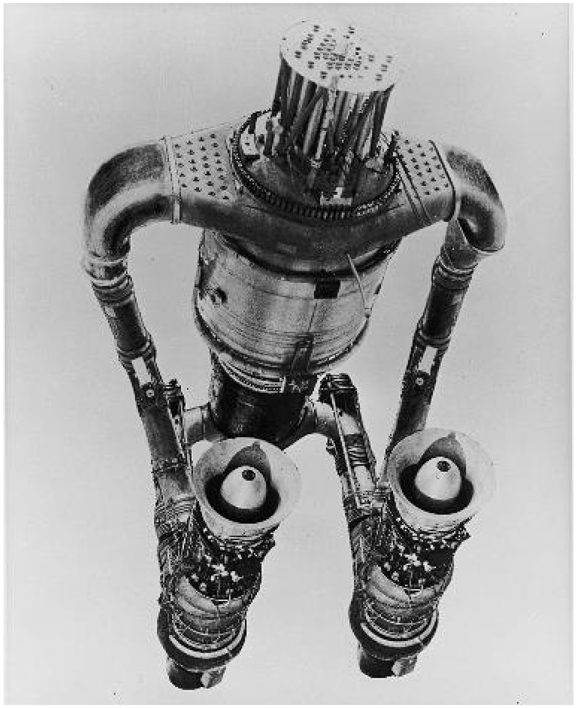
- **Fuel salt placed in fuel assemblies**
- **New concept, patent now granted worldwide**

Why is this a new idea?

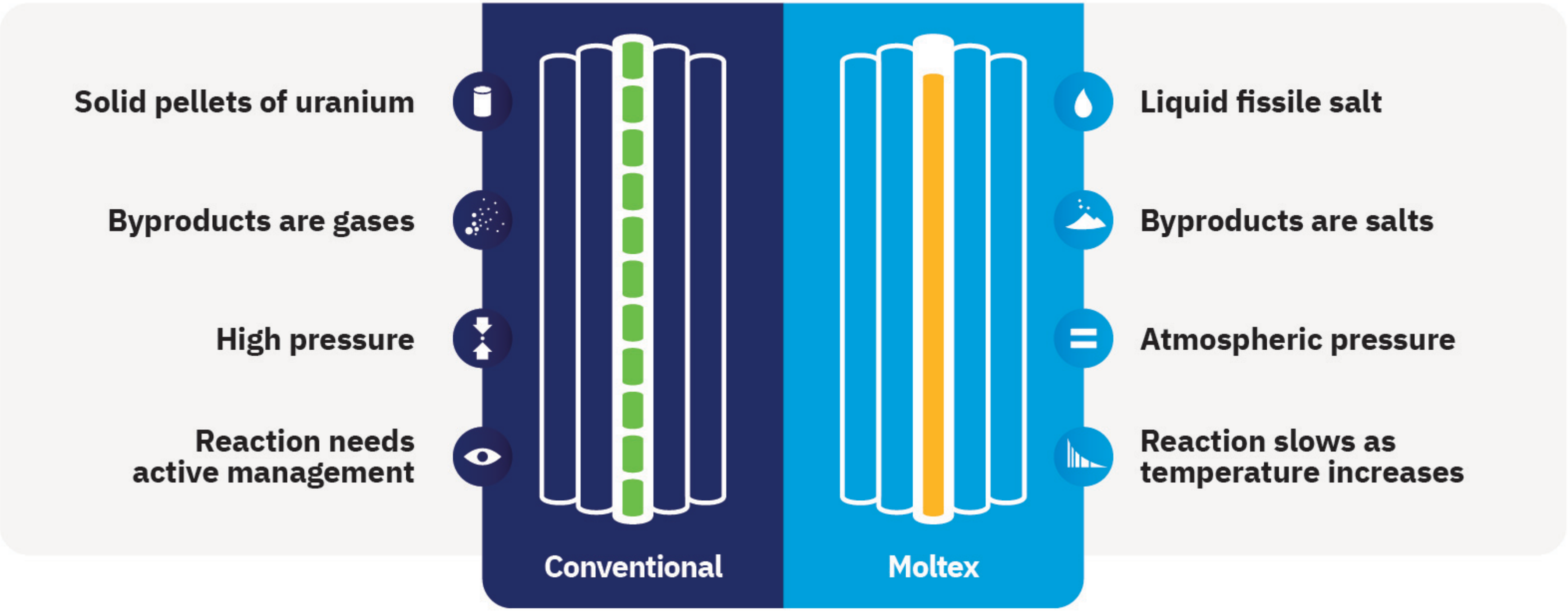
- "Static" molten salts in fuel pins rejected by ORNL because convection of fluids would be unreliable in an aircraft – but convection is essential for heat transfer in unpumped fluids

- **Decision not revisited for ground-based reactors**

Aircraft reactor experiment which led to molten salt reactor experiment



Fuel pin comparison



Technology benefits

1. Costs less

Moltex's design is smaller, simpler and inherently safe, making it low-cost to build and operate

2. Reduces waste

Moltex recycles waste from existing nuclear power stations, and uses it to produce more clean energy

3. Enables renewables

Moltex can store energy and supply it to the grid as needed, enabling intermittent renewables

4. Cogeneration

Moltex can produce heat for heavy industry and hydrogen production

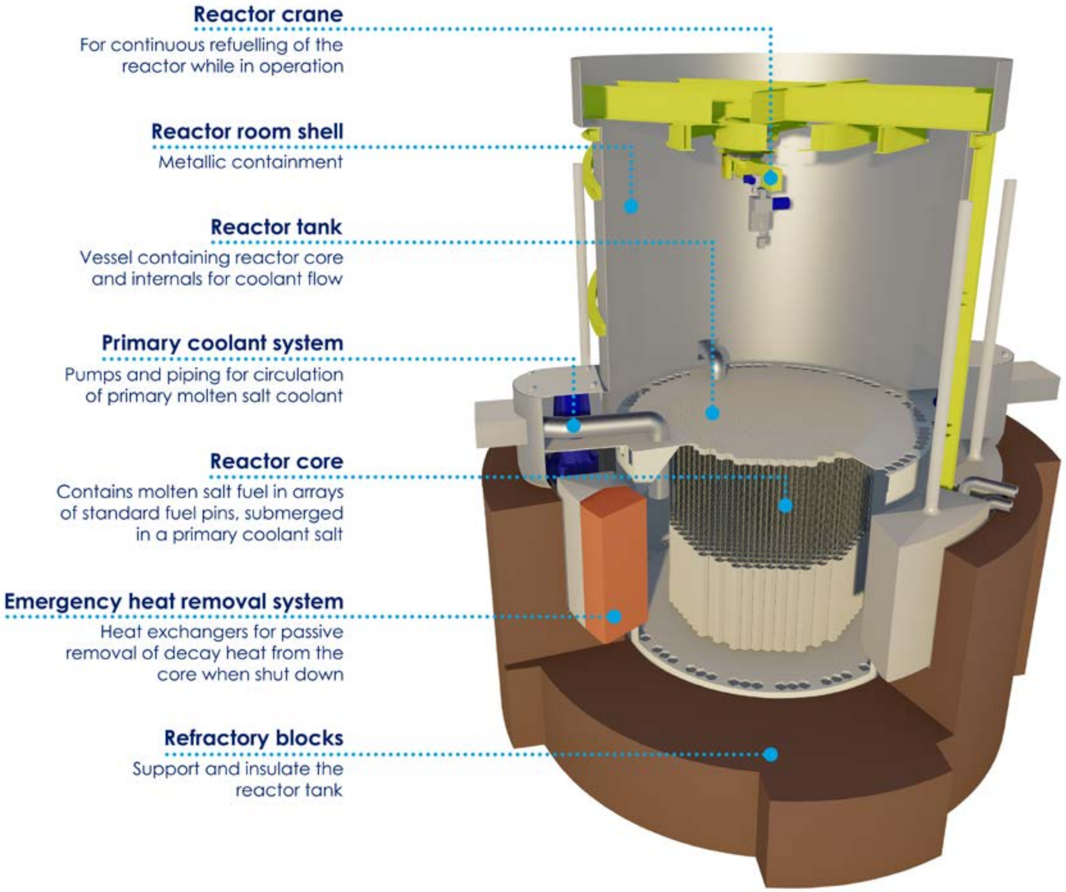
Advanced reactor design

REACTOR CORE	
Thermal power	750 MWth
Refueing cycle	Online refueling
Thermal or fast neutrons	Fast

FUEL	
Chemical composition	55%XCl3 : 45%KCl where X = Pu-U-An-Ln
Physical form	Stable molten salt in pins

CLADDING	
Material	Stainless steel
Physical form	Each fuel assembly has hexagonal pins inside a hexagonal wrapper

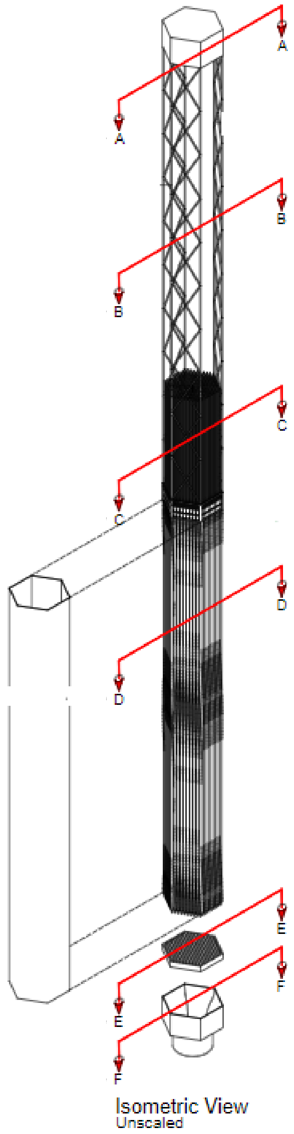
COOLANT	
Chemical composition	$MgCl_2$ / NaCl
Physical form	Molten salt flowing through rector core



Refueling

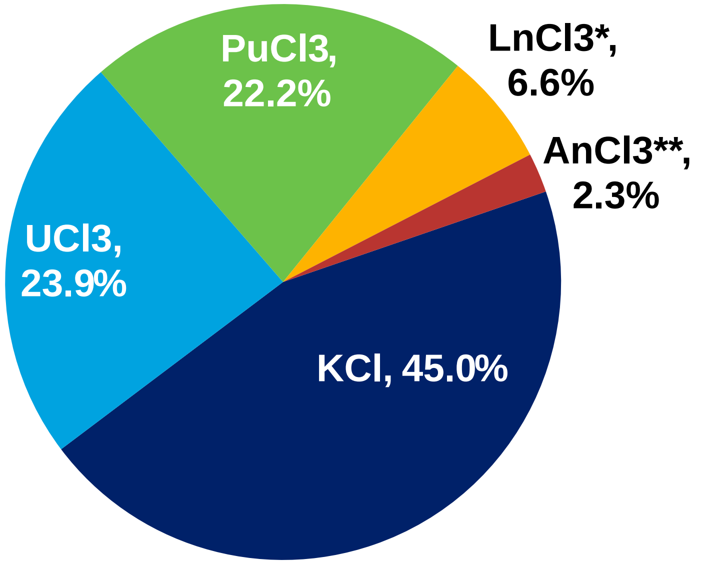
Cross between SFR and CANDU

- Online refuelling
- Hex fuel assemblies with channel like BWR
- Vertical lift like PWR/SFR
- Cycle duration (between refuelling) – 6-12 days
- Assembly average residence time – 6.3 years



SSR-W fuel

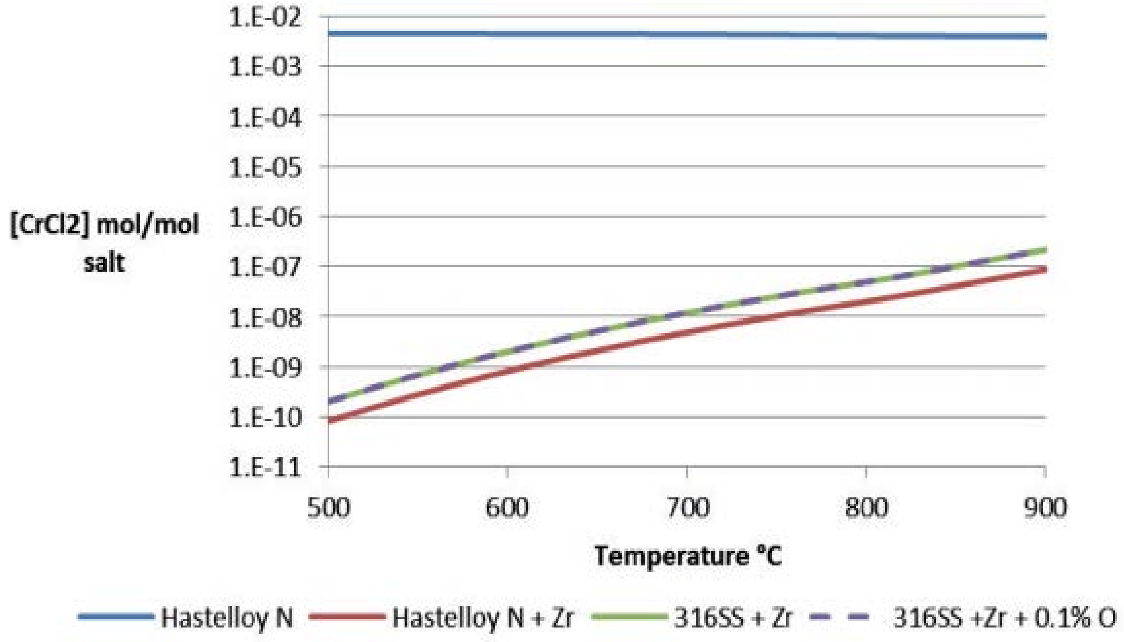
Chloride fuel with high impurity level



Pu vector is approximately 2/3 fissile based on CANDU spent fuel composition. U vector is below natural enrichment levels.

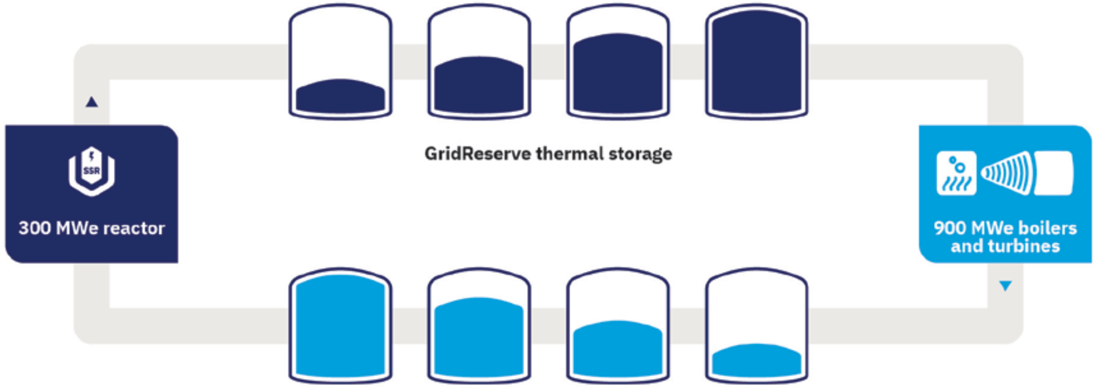
*Ln=Lanthanides; **An=Actinides

Corrosion control in fuel pins by addition of Zr metal



Low-cost thermal energy storage at grid scale from solar industry

Crescent Dunes solar power station, Nevada

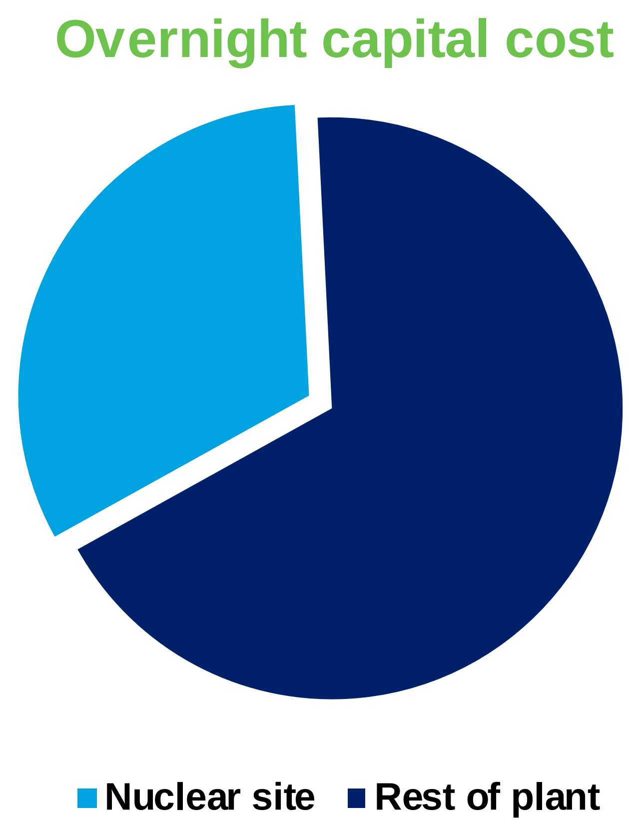


Molten salt thermal energy storage

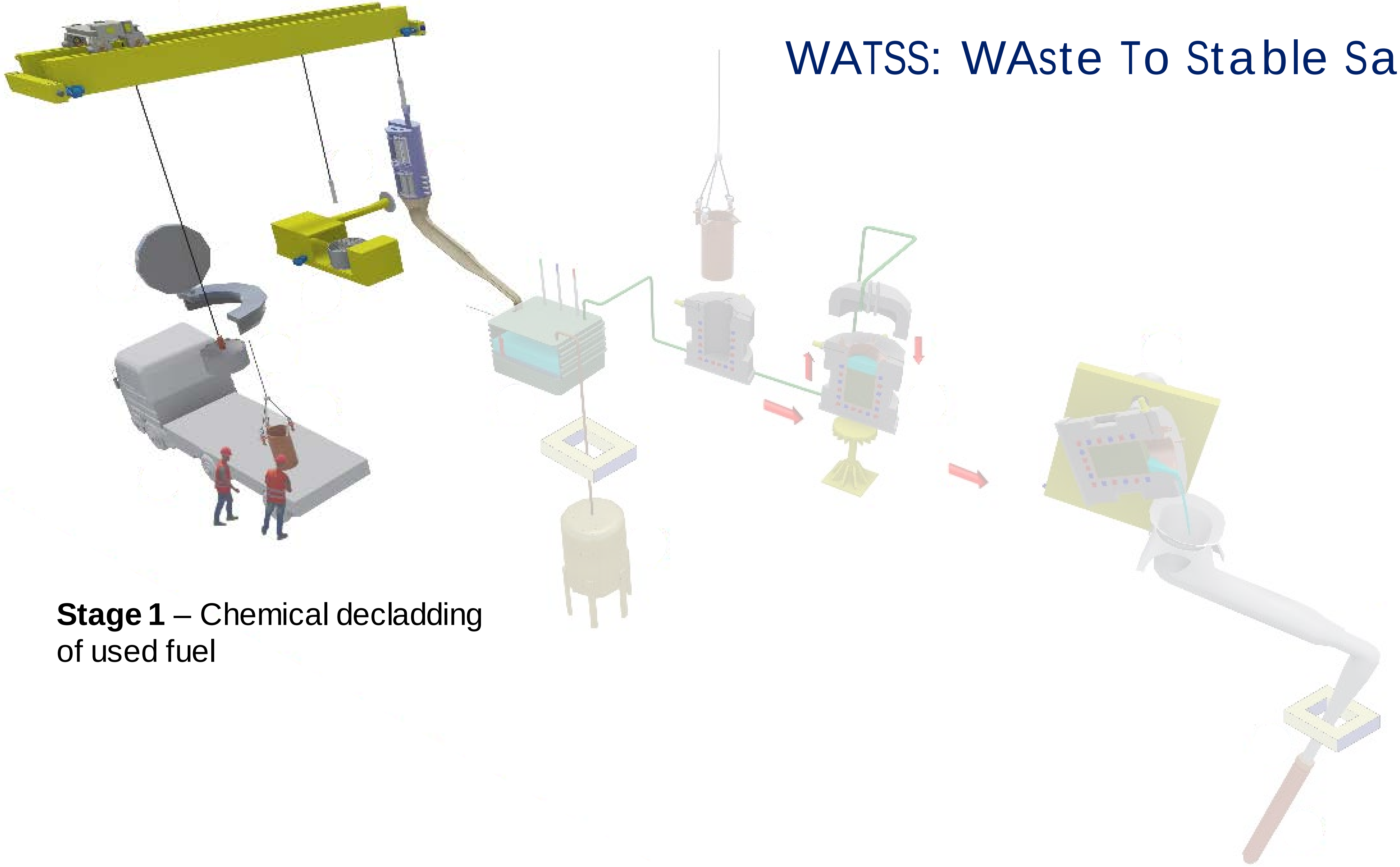
www.moltexenergy.com

Impact of GridReserve on capital cost

- Rest of plant costs are **high confidence** as similar to CCGT and CSP plants and not subject to nuclear regulation. Errors, optimism bias, etc. in nuclear island costs have relatively little impact on total cost.
- GridReserve triples the capacity for double the cost
- GridReserve is a fraction of the cost of lowest future battery cost
- Only possible with high temperature reactors

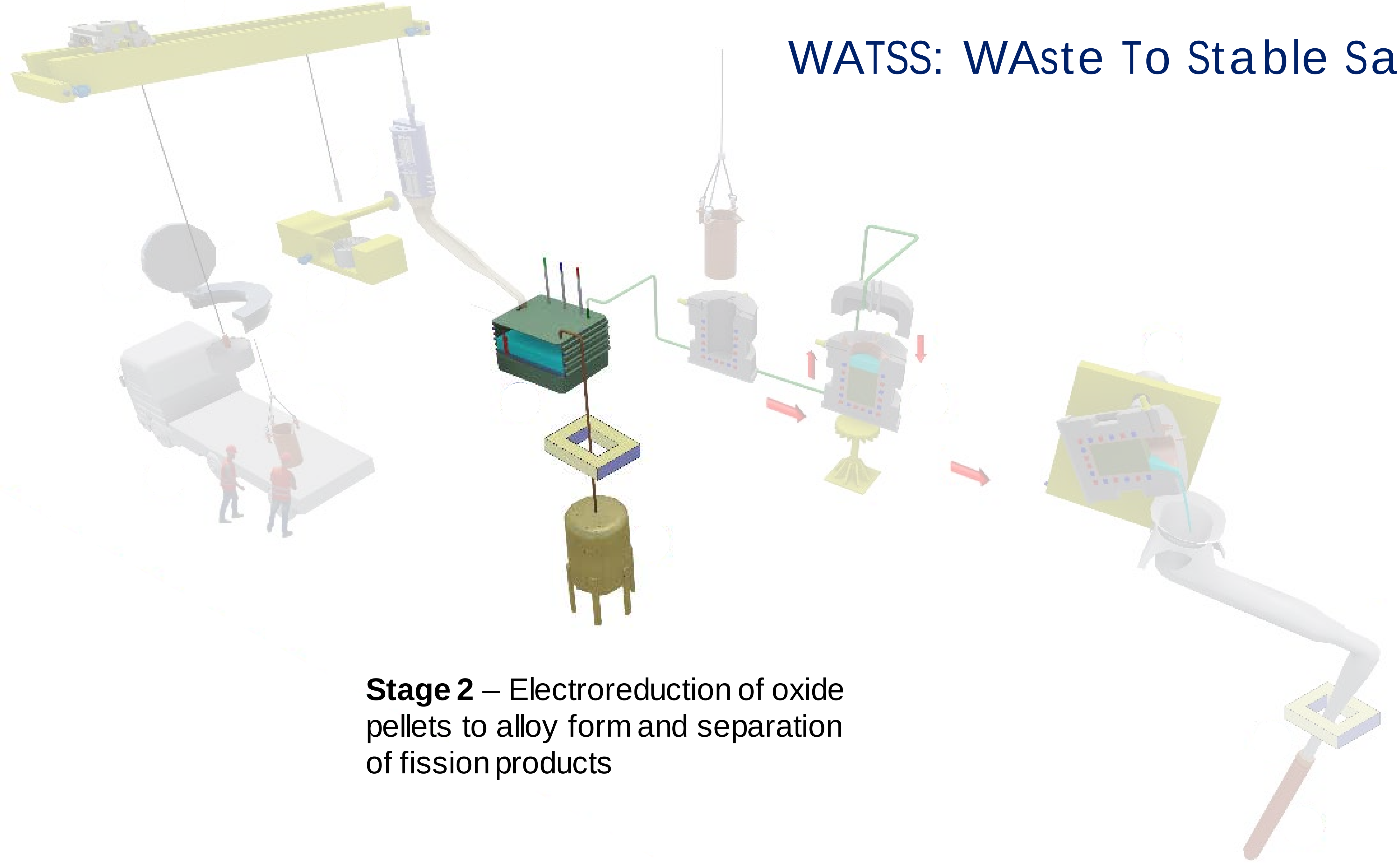


WATSS: WAste To Stable Salt



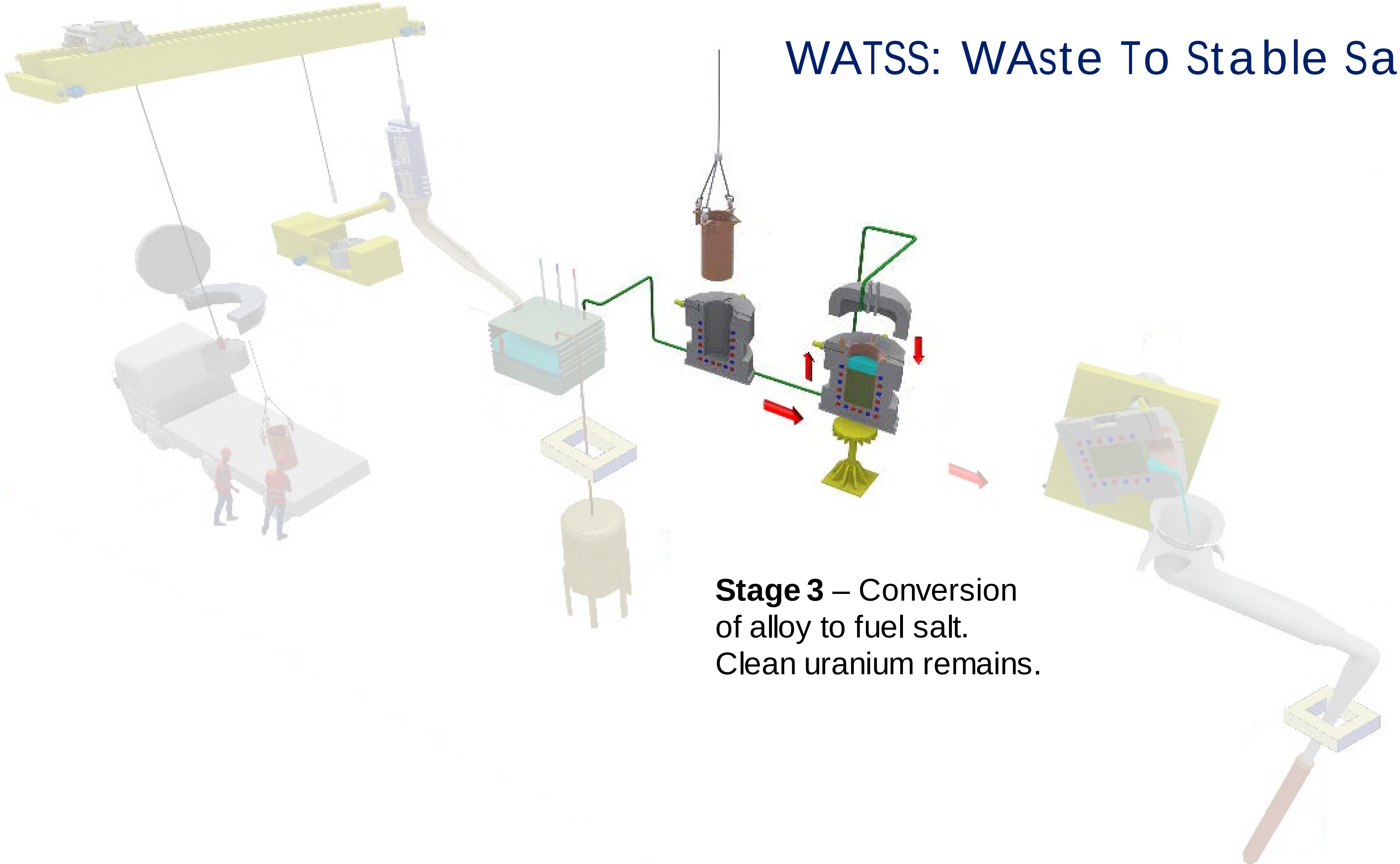
Stage 1 – Chemical decladding of used fuel

WATSS: WAste To Stable Salt



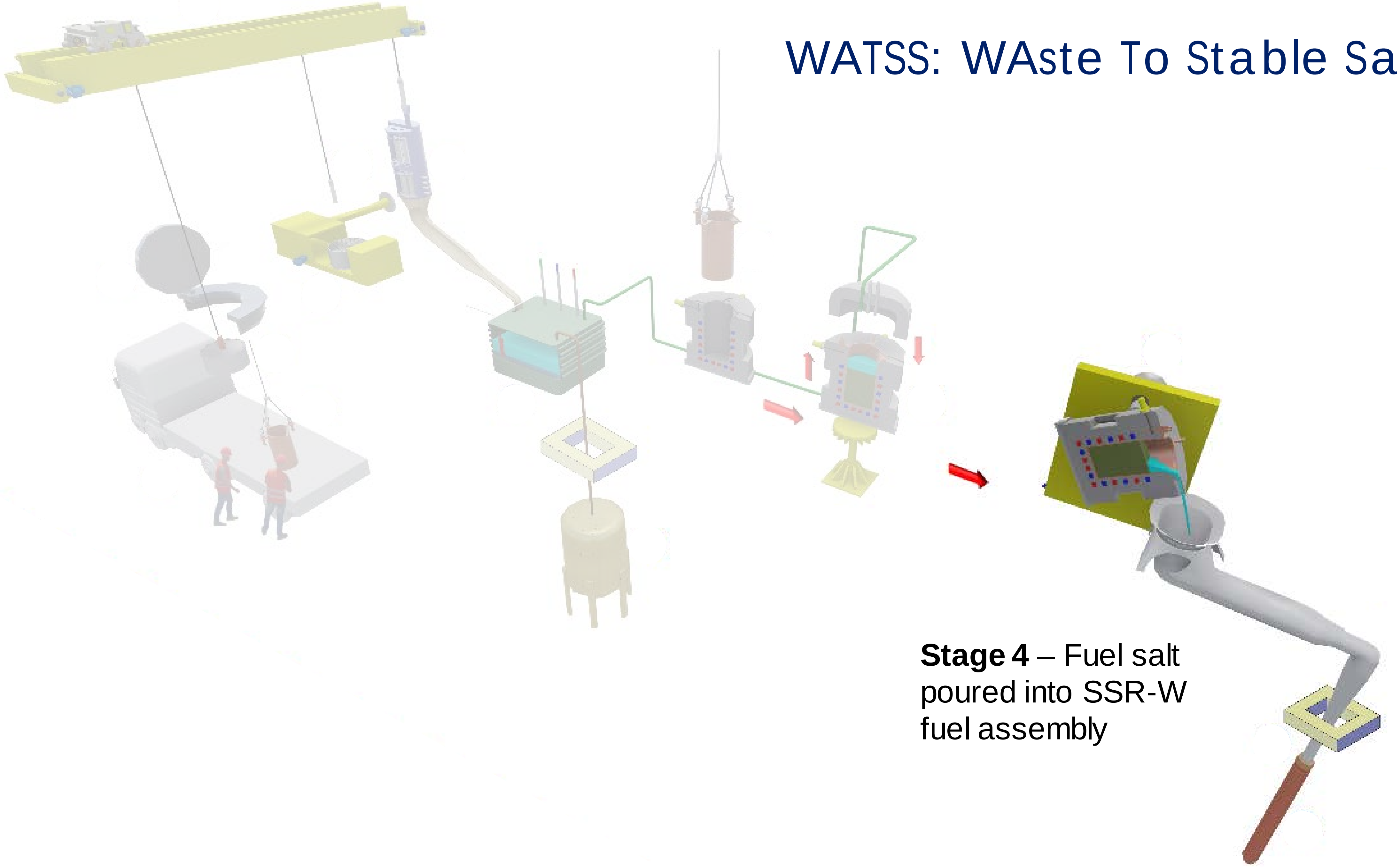
Stage 2 – Electroreduction of oxide pellets to alloy form and separation of fission products

WATSS: WAste To Stable Salt



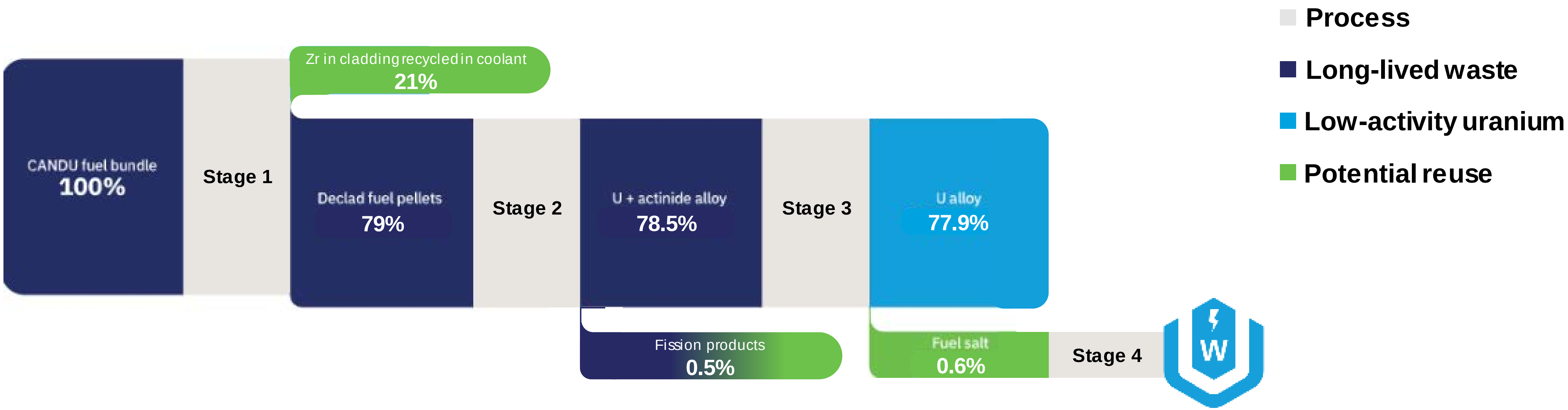
Stage 3 – Conversion
of alloy to fuel salt.
Clean uranium remains.

WATSS: WAste To Stable Salt



Stage 4 – Fuel salt poured into SSR-W fuel assembly

WATSS waste streams for first fuel load



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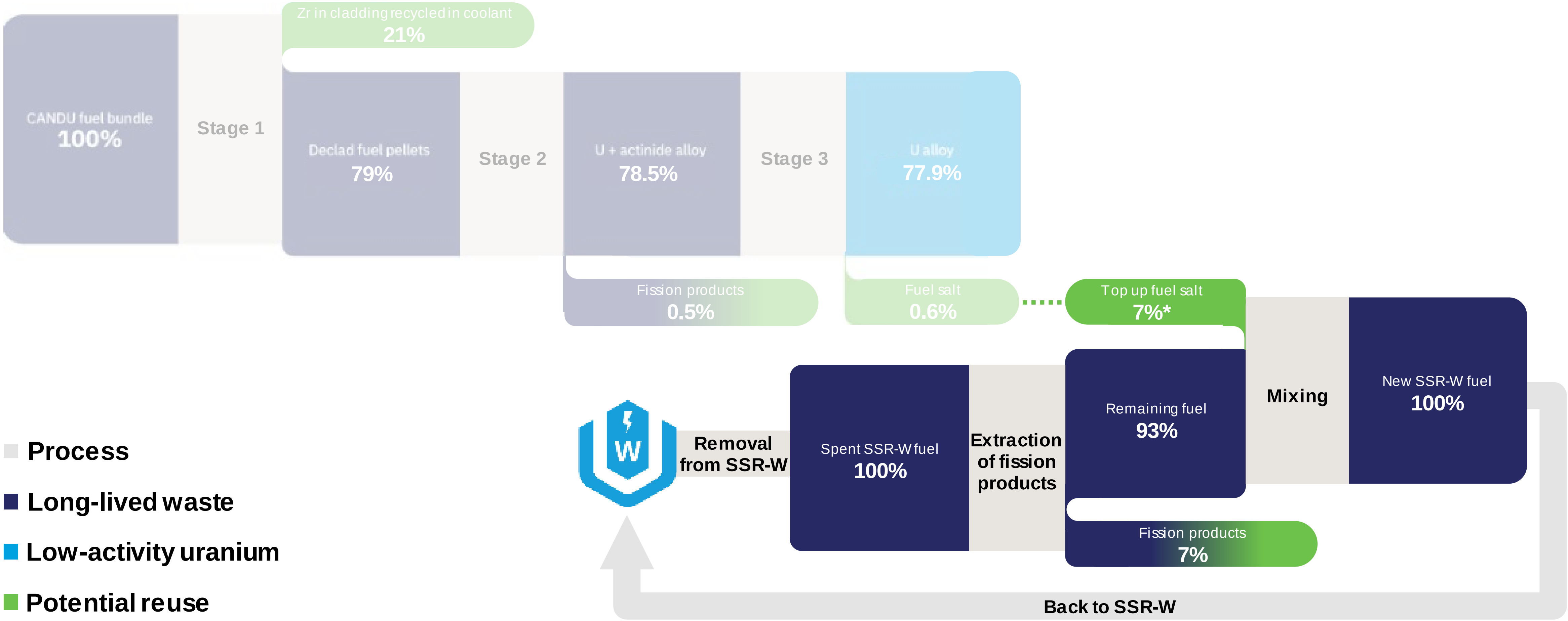
WATSS waste streams during SSR-W operation

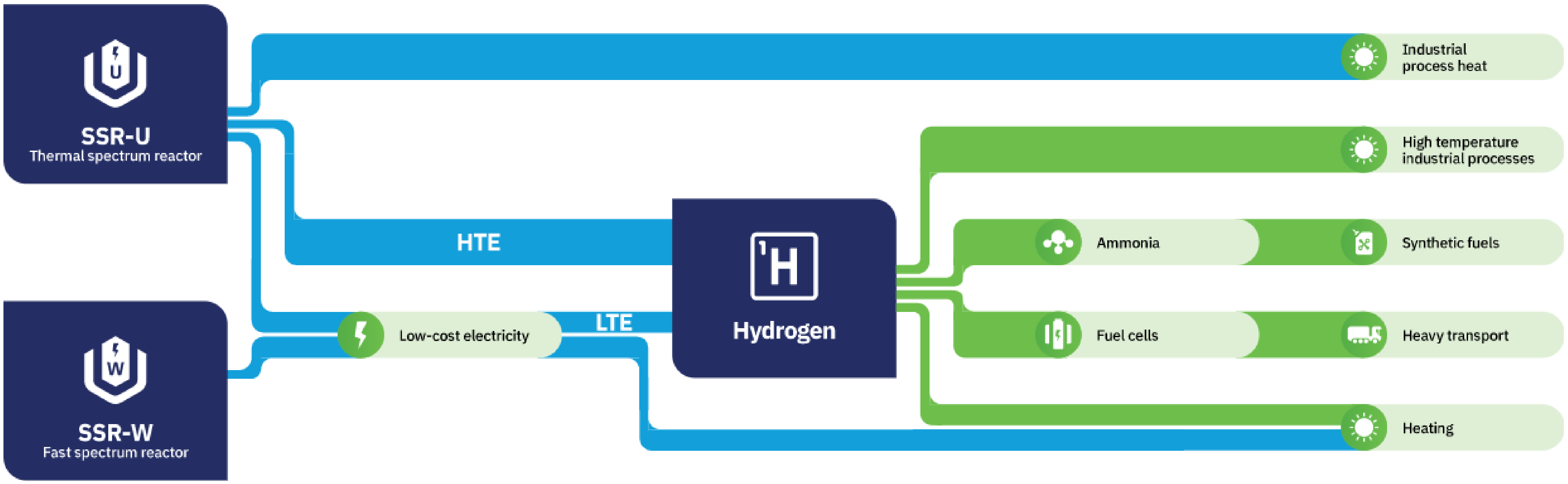


WATSS: Key advantages

- SSR-W reactor burns Pu and higher actinides
- Much of the cost of traditional pyro-processing is in separating Pu from other chemically similar actinides and lanthanides (rare earth elements)
  - This high purity separation is required for any oxide or metal fuel fabrication
  - The WATSS recycling process is therefore simpler and cheaper
- Residual waste streams contain no higher actinides
  - Makes storage/disposal easier and cheaper

US spent fuel disposition

Cogeneration



Challenging licensing issues

Regulatory challenges associated with waste management

- Lack of standards and regulations around nuclear fuel recycling
- US export controls around reprocessing make international collaboration extremely challenging

Moltex implementation plan for commercializing nuclear energy system

- Step 1: Perform laboratory scale tests to obtain critical parameters for the operation, process design and reactors design
- Step 2: Perform real tests at hot cell scale
- Step 3: Commission and operation of industrial scale as part of the FOAK facility in Point Lepreau nuclear site

Current US activities

Rapid construction studies with c.U$4M grant from ARPA-E

- Accelerated construction methods by Purdue University
- Hazard and operability study with EPRI
  - Expert working groups identifying all fault scenarios and failure modes (expanded PIRT)
- Fast reactor physics with Argonne National Laboratory
  - Transient and static analysis of all major fault groups
- Oak Ridge salt studies
  - Fission product vapor and from salts
  - Dose release for severe accidents
  - Molten salt / concrete interactions in severe accidents

SSR-W milestones

2021-2024

- Laboratory scale tests conducted and engineering design completed
- CNSC Vendor Design Review phase 2 completed

2025-2027

- Hot cell tests performed and detailed design completed
- Licences to prepare site and construct obtained

2028-2031

- FOAK facility at Point Lepreau commissioned and constructed
- First SSR-W core ready for commercial operation

moltex clean energy

Summary of key points

- Molten salt fuel in essentially conventional fuel assemblies is a genuinely new concept that eliminates many of the novel challenges of an MSR.
- Eliminates conventional nuclear hazard which radically simplifies safety case
- GridReserve enables lower cost renewables
- The SSR-W can reduce legacy waste from the first nuclear era
- Canada, UK and US governments aligned on nuclear policy
- Moltex has a utility partner and is progressing demonstration, planning expansion into US market

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Thank you

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