

Partitioning of Fission Products and Waste Salt Minimization during Pyroprocess

2008. 10. 8.

Eung Ho Kim, G-I Park, I-T Kim, H.Lee
and S-W.Park

KAERI



Backgrounds

❖ Next generation nuclear fuel cycles

- Reduction of environmental hazard by selectively recovering a long-lived nuclide and transmuting it
- Minimization of the waste volume to be eventually disposed of

❖ Basic strategy for partitioning

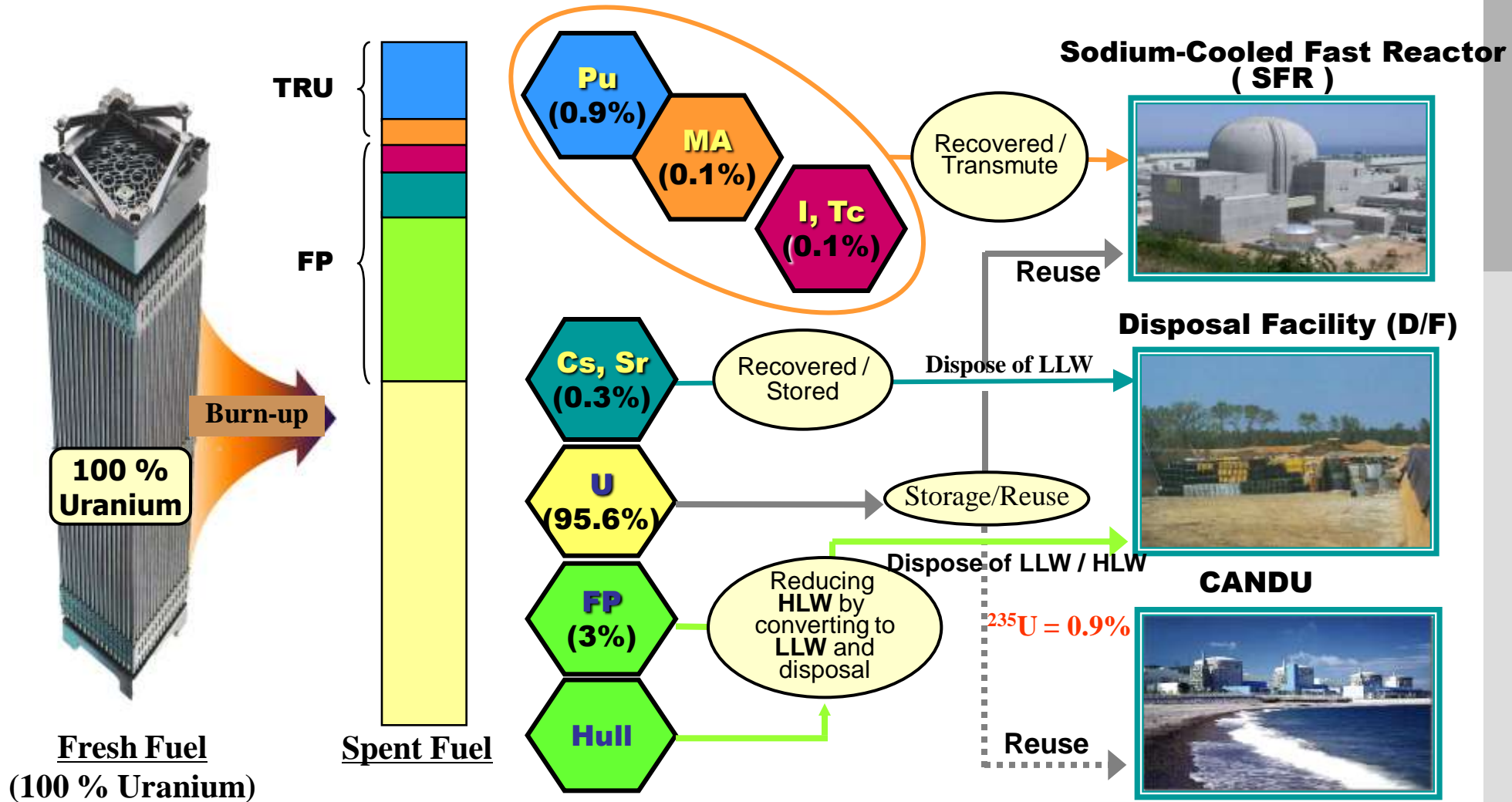
- Classify and optimize waste streams arising when treating spent fuel
- Minimize waste volumes resulting from each waste stream

Little information on a strategy for waste minimization in pyroprocess

❖ Strategy for optimization of waste streams and waste minimization

- Pyro-partitioning of fission products being performed in KAERI
- Strategy requested for optimizing waste streams and minimizing waste amounts
- Reduction of **HLW** generating from each waste stream
 - Converting **HLW** to **LLW** through an increase of **DF** or **SF**
- Candidate wasteforms for consolidation of waste salts from a pyroprocess

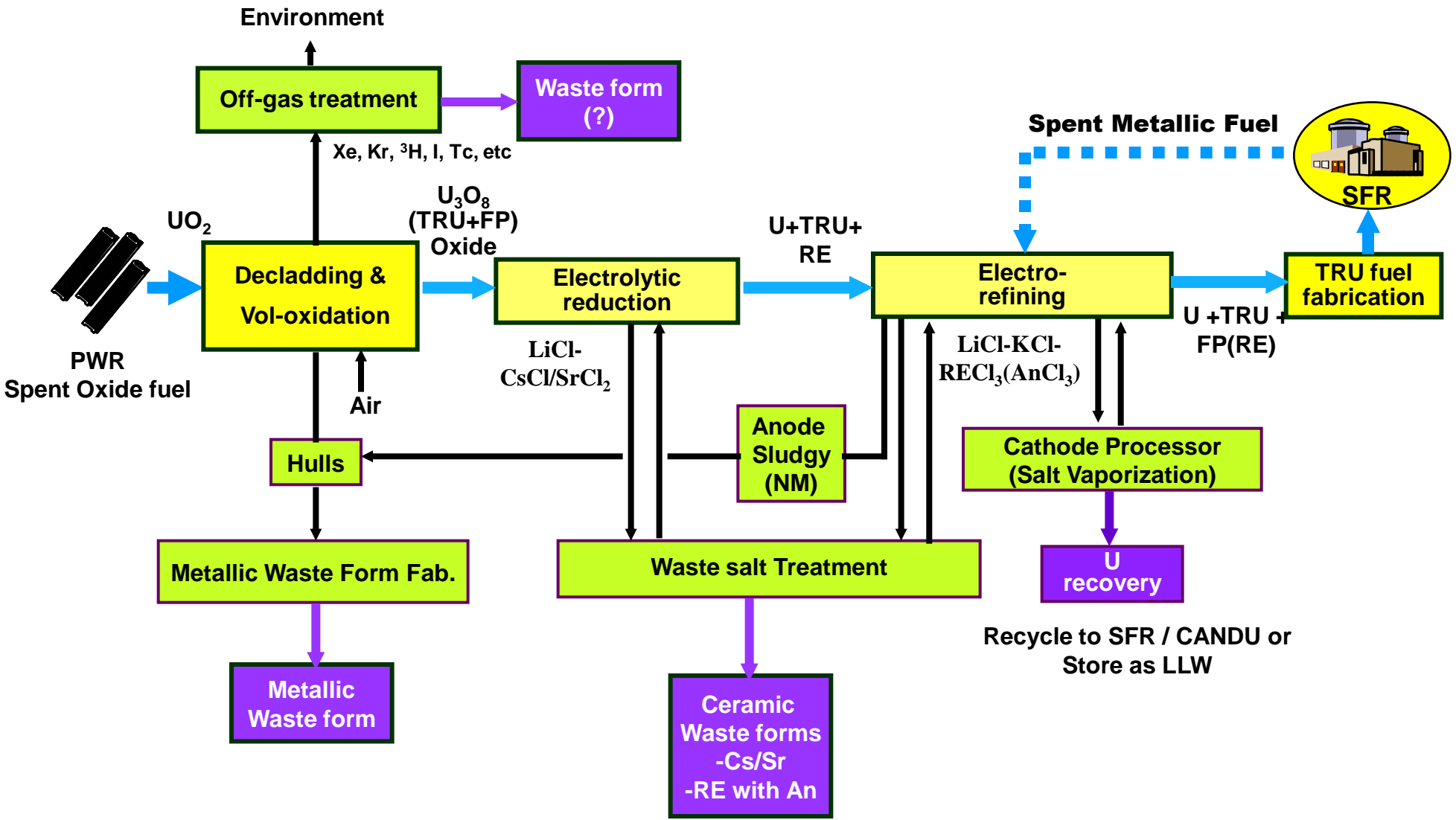
A Strategy for Efficient Management of Spent Fuel in Korea



FP: Rare earth, Noble metal, Volatile / Semi-volatile Fission Products
 KAERI's waste management strategy: directed to minimize HLW amounts

A Flow Diagram of Pyroprocess being Developed by KAERI

Optimizing waste streams and evaluating a strategy for minimization of wastes



Fission Products Release with Voloxidation Conditions

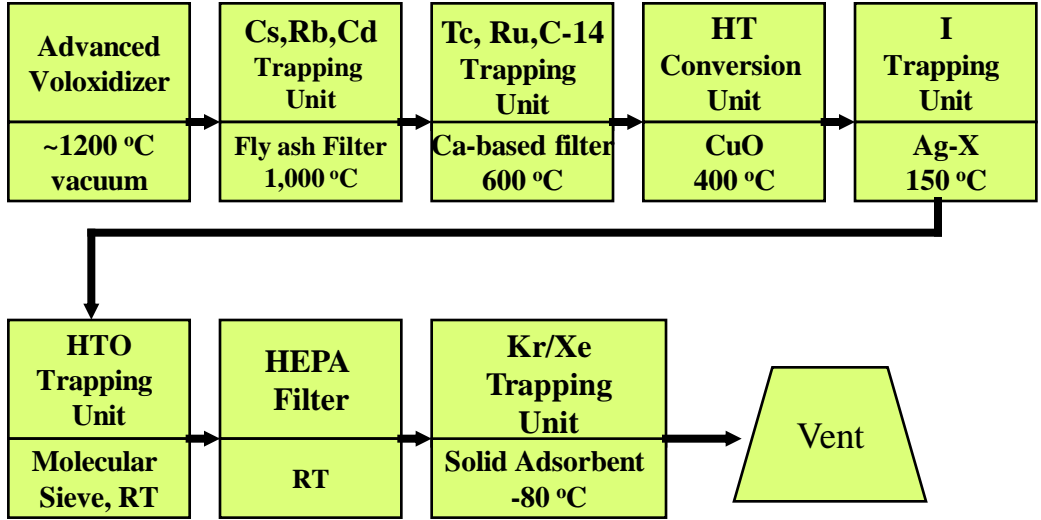
Nuclides	Standard voloxidation (500°C)	Advanced voloxidation* (1200°C)	Remarks
Kr / Xe	<30%	100%	
H	100%	100%	
I	<10%	100%	I-129: long-lived nuclide
Tc	<1%	92%	Tc-99: long-lived nuclide
C	<10%	100%	C-14: long-lived nuclide
Cs	<1%	98%	Highly radioactive, high decay heat nuclide
Ru	<1%	98%	Noble metal
Mo	<1%	62%	Noble metal
Rh	<1%	83%	Noble metal
Rb	<1%	96%	

* INL hot experimental data in I-NERI program of INL-KAERI

Advantages

- ✓ Minimize influence of fission products on the **down-stream** process conditions
- ✓ Recover and store fission products separately

Flow sheet for capturing fission gases



Challenges

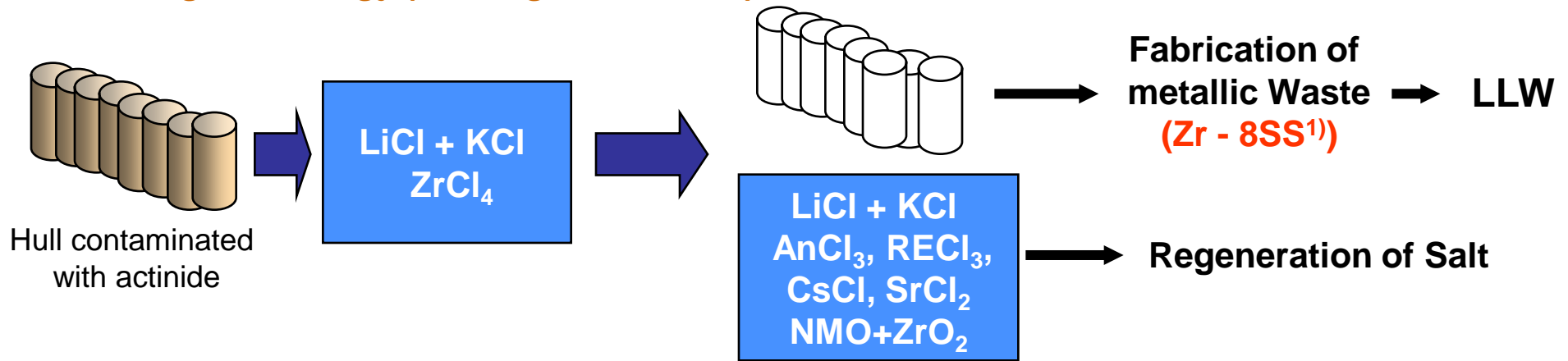
- ✓ DF > 10⁴ to minimize the impact to the environment
Further development of trapping technologies and conditions
- ✓ Optimization of waste forms for consolidation of several absorbents
- ✓ Minimization of waste amounts issued from capturing fission gases

Treatment of Hull

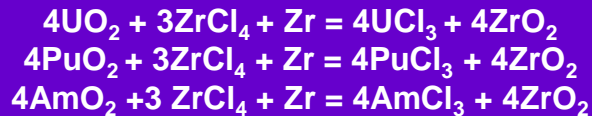
Objective:

- Experimentally recover higher than 99% fissile material during air-oxidation process
- Look for a promising way enabling a conversion of hull to LLW
- Strip residual fissile materials from the contaminated hull
- Classify the hull as LLW → **Challenge !!**

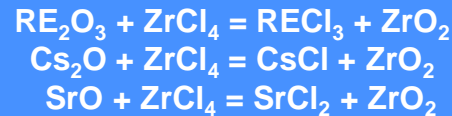
Promising technology (Rinsing Mechanism)



Actinides



Rare earth and I/II groups



Noble metals

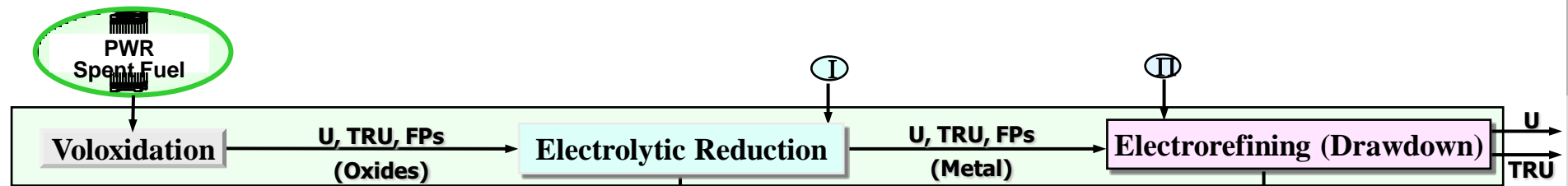
- Not chlorinated
- Co-precipitated with ZrO_2

Waste Salt Treatment Technologies

❖ Developing technologies to recycle waste salts to process units, not by releasing to repository

-Salt cooling technologies: Czochlarski, **Zone freezing**, Layer crystallization

-Precipitation technology: **oxidation-precipitation** using air



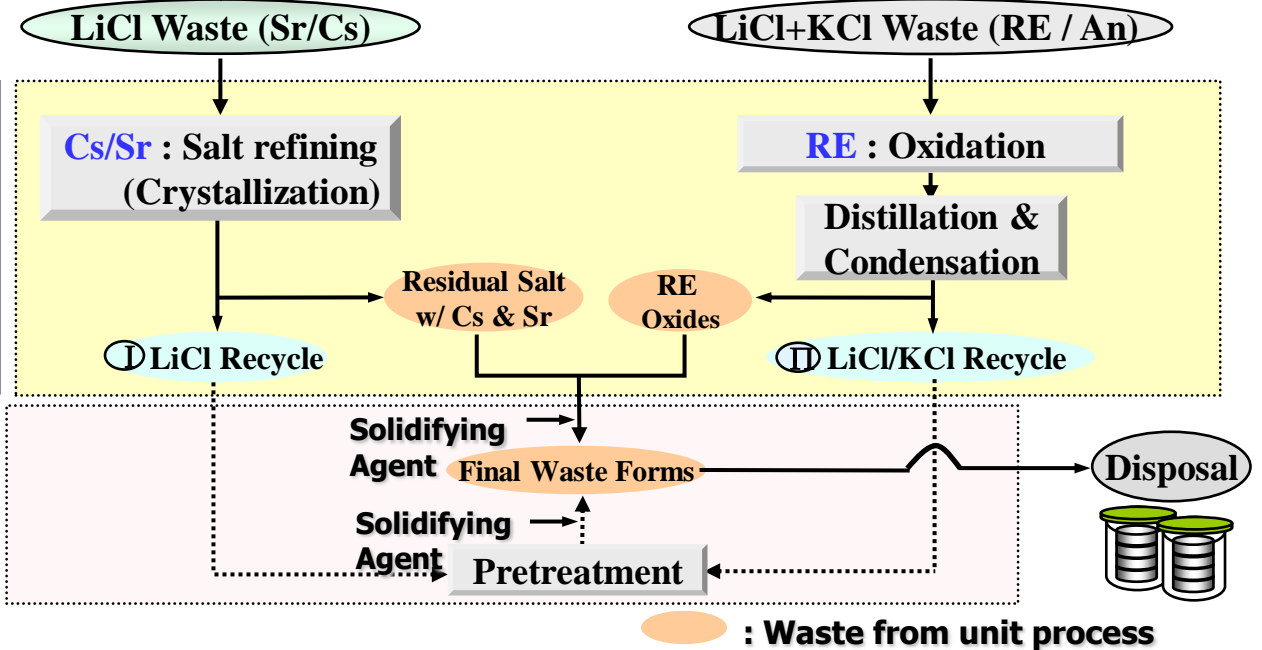
Strategy

■ Minimize waste salt by adopting a recycling technology

Salt Regeneration
(FPs Removal & Salt Recycle)

■ Develop high-integrity wasteforms

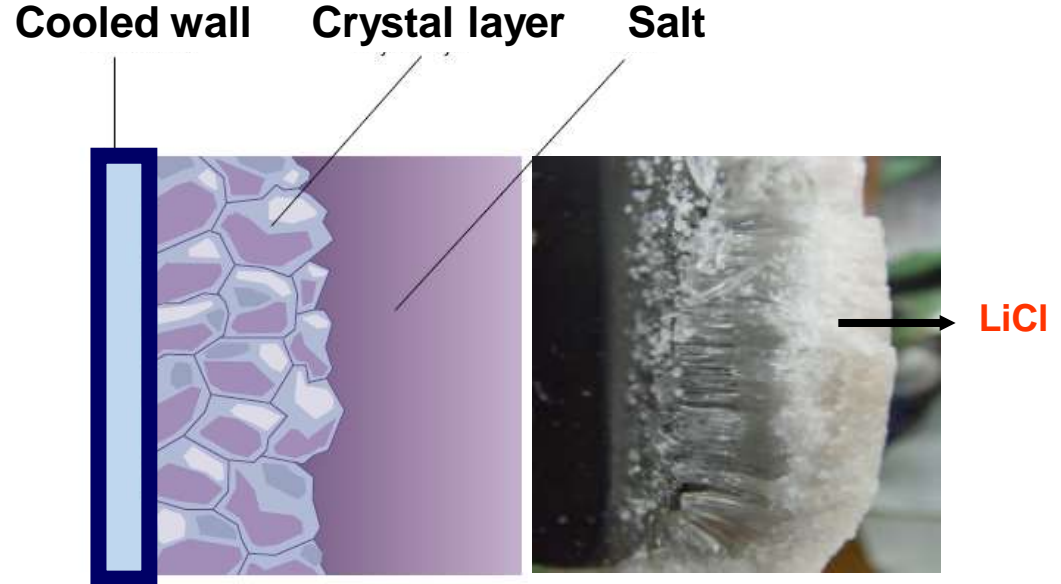
High-integrity Solidification



Recovery of Purified LiCl Salt from a Waste Salt



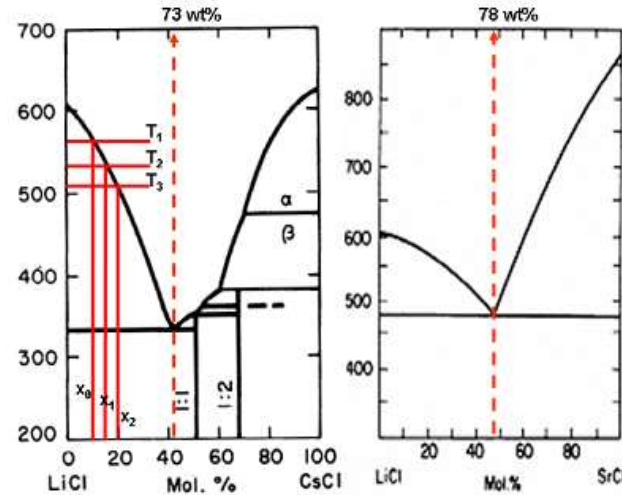
Czochlarski



Layer Crystallization

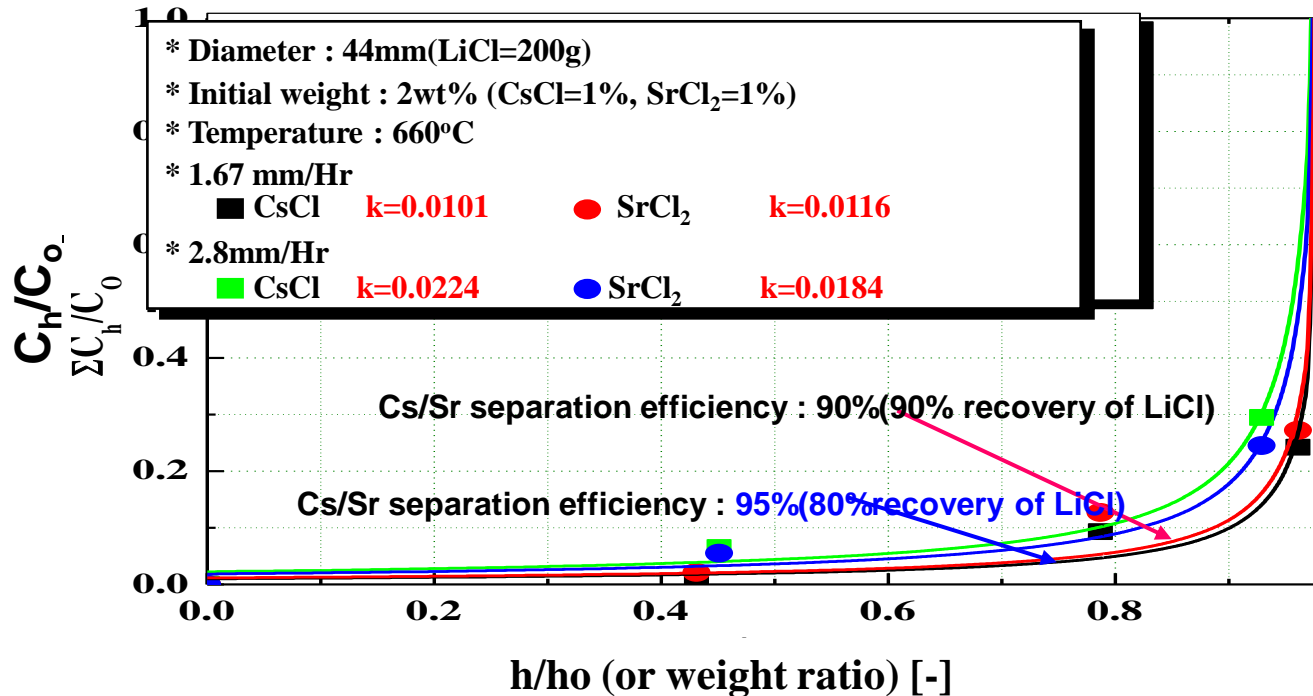
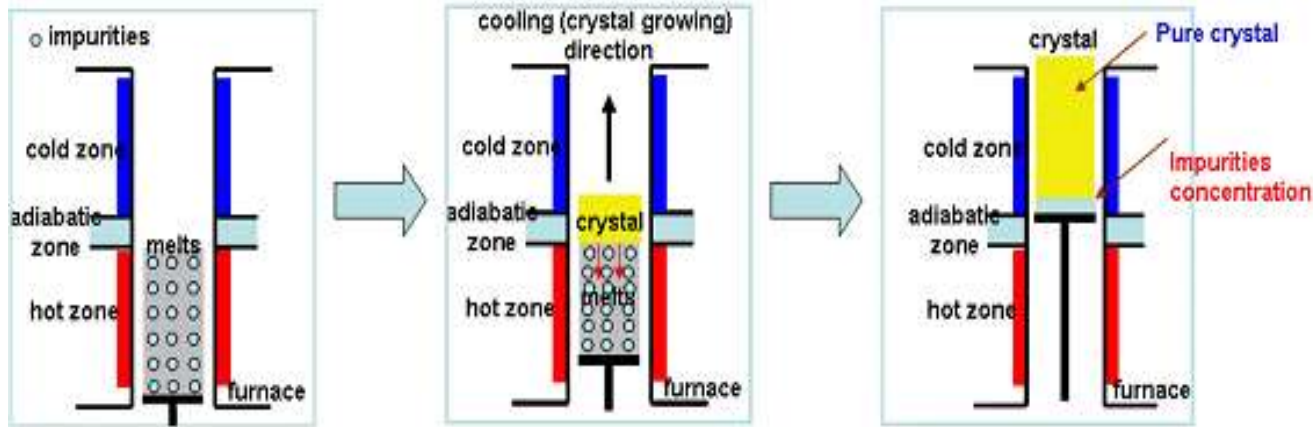


Zone Freezing



- To concentrate Cs and Sr to eutectic point by cooling method
- To theoretically recover 99wt% of LiCl from a waste salt
- To evaluate and select which technology is more preferable and effective for scale-up and practical use.

Zone Freezing Technology for Recovery of LiCl Salt



Experimentally
 recycle 90% of LiCl
 (contaminated with
 a small amount of
 impurity)

90%

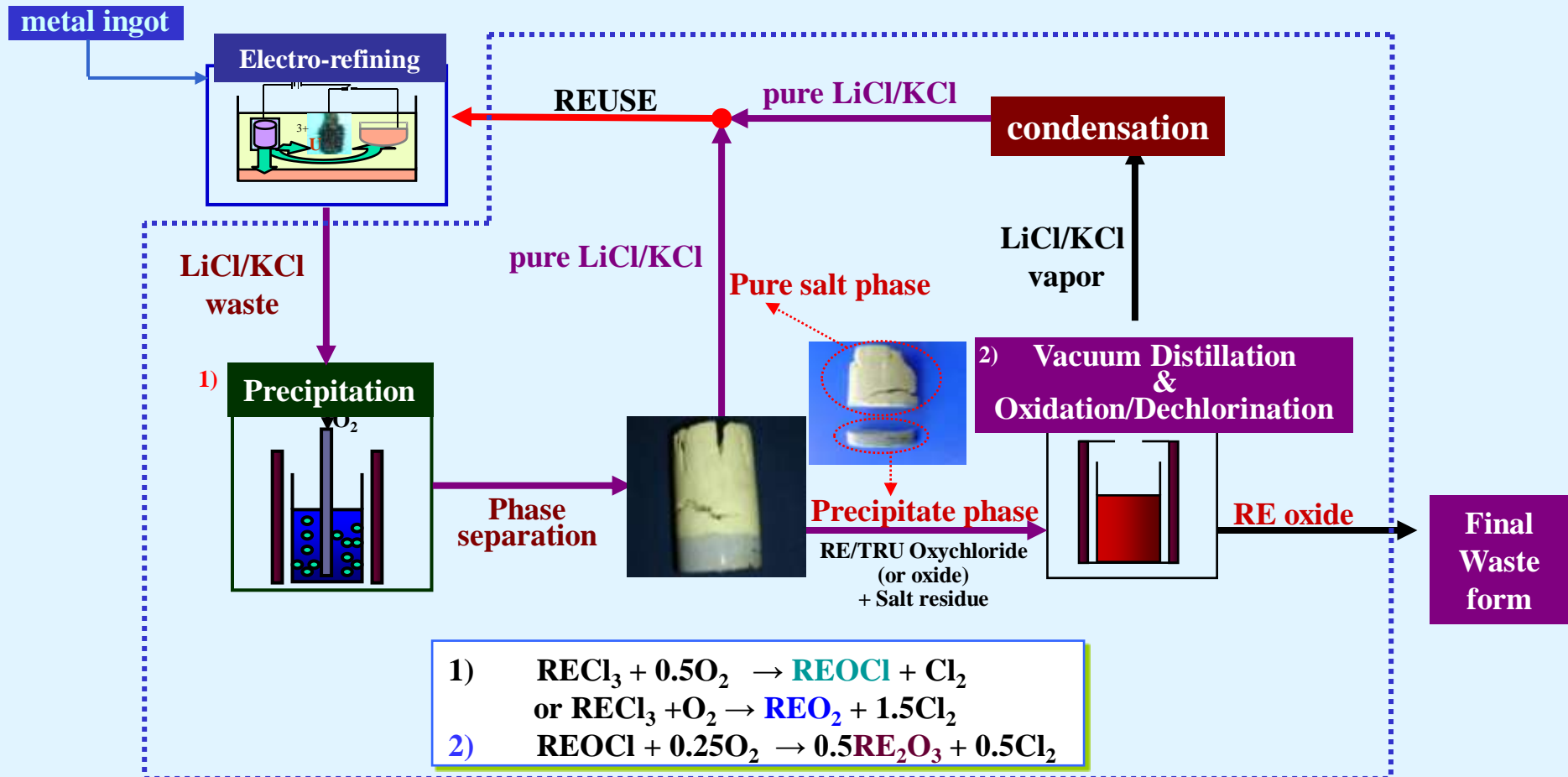
Fabricated to a final
 wasteform
 (contaminated with
 90% of initial impurity
 amount)

10%

LiCl-KCl Waste Salt Recycle

Possible to recycle all most of eutectic salts to electrorefiner and to minimize waste salt to be disposed of

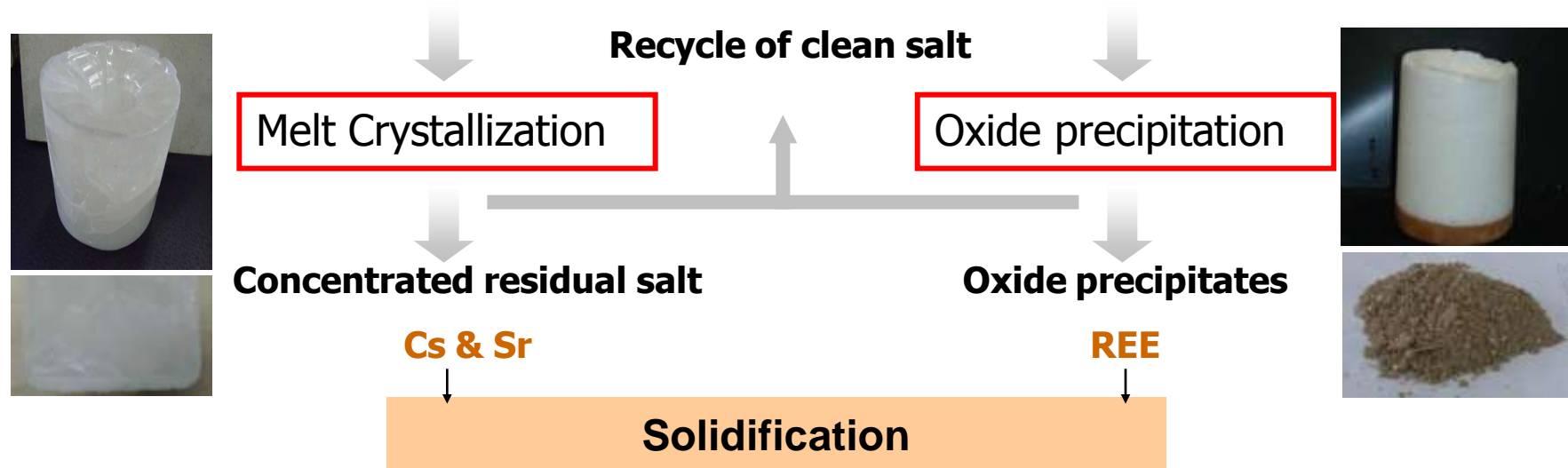
- REE are precipitated as oxide or oxychloride forms



Wasteforms

Waste LiCl from Electro-reduction

Waste LiCl-KCl from Electro-refining



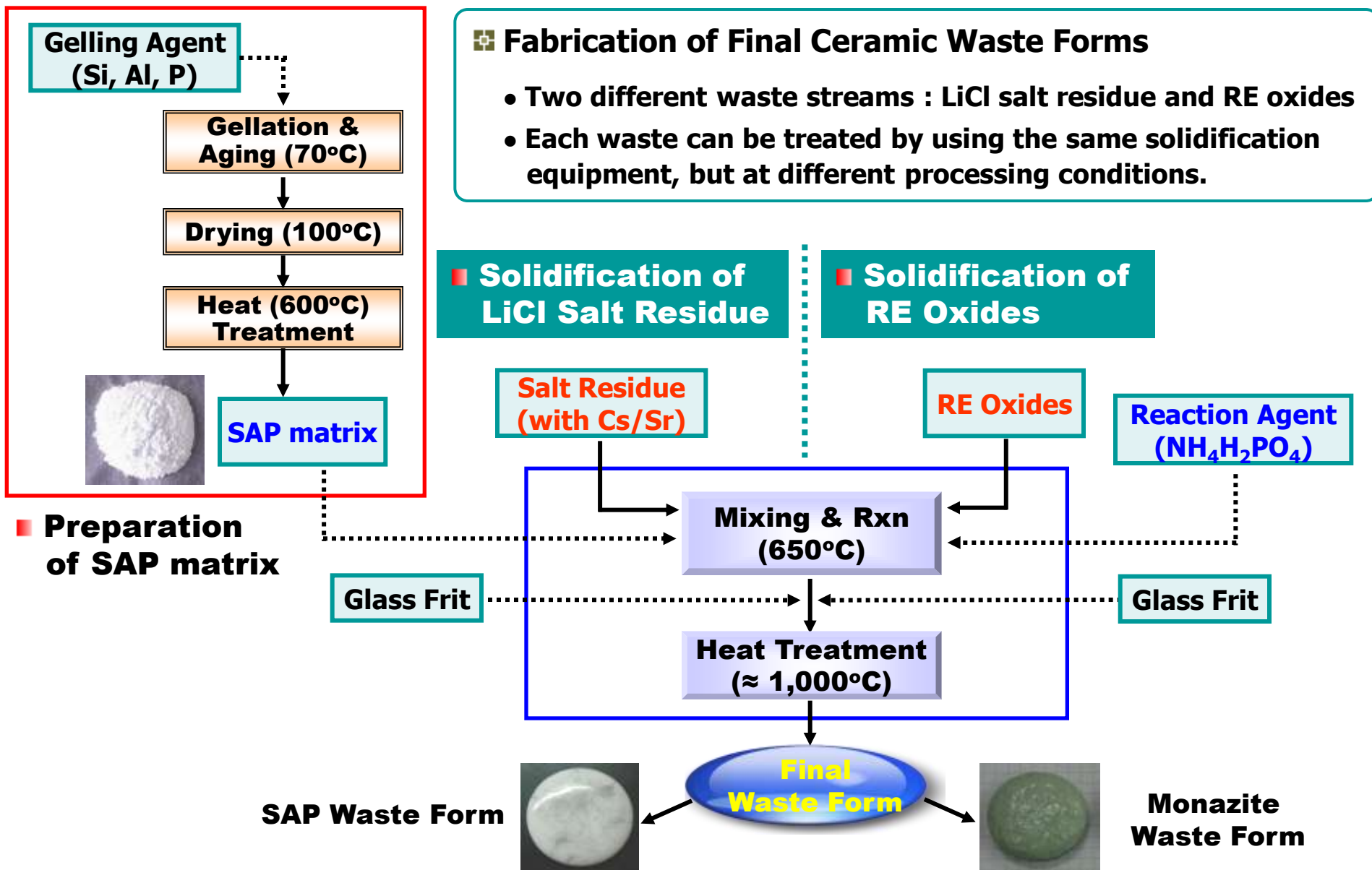
Candidate wasteform for consolidation of waste salt [LiCl residual salt]

- Incorporation of Cl into a wasteform
 - Mineral-based wasteform
 - sodalite, apatite, spodiosite, wadalite
 - phosphate-based glass
- Not incorporation of Cl [KAERI]
 - **SAP-based wasteform**
[SAP: $x\text{SiO}_2\text{-}y\text{Al}_2\text{O}_3\text{-}z\text{P}_2\text{O}_5$]

Candidate wasteform for REE / An oxides

- BSG, SynRoc, Pyrochlore and etc
- **Monazite-based wasteform [KAERI]**
 - Reliable host matrix for α -radionuclide
 - Reasonable processing condition
 - Waste loading & Chemical durability
 - Radiation stability

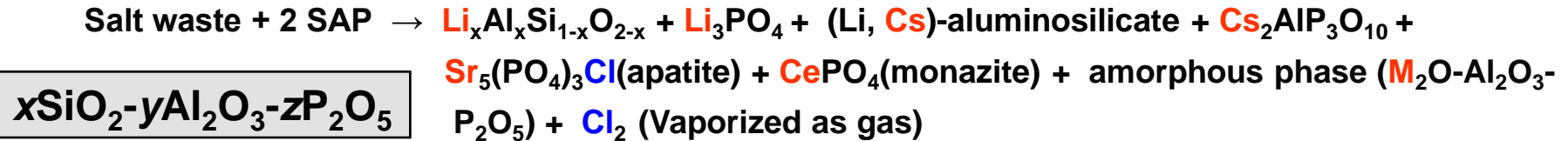
A Flowsheet for Wasteforms Fabrication



Chemical route and Qualification of Waste forms

❖ Chemical route for the immobilization of each waste

For LiCl waste



For REE oxide waste



❖ Waste loading factor of waste forms

LiCl waste salt : SAP material : Glass frit = 1 : 2 : 1 [waste loading : 25 wt%] for SAP

RE oxide : Chemical additive(NH₄H₂PO₄) : Glass frit = 1 : 0.52 : 3.48 [waste loading: 20wt%] for Monazite

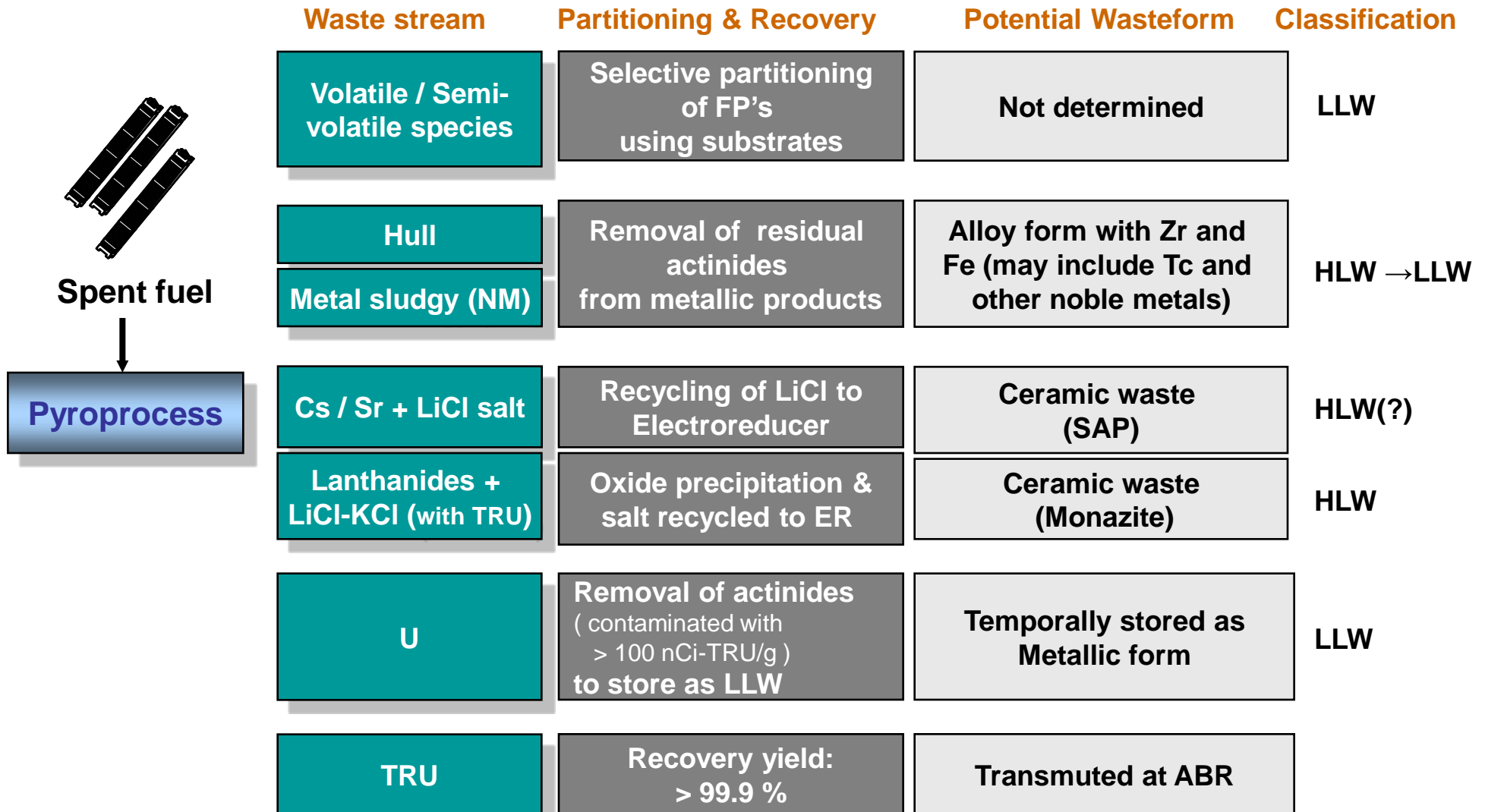
❖ Chemical durability of waste forms

PCT-7days,

(unit : g/m²)

	SAP for LiCl waste	Monazite for REE oxides	Conventional BSG	Sodalite for LiCl-KCl
Cs	~ 10 ⁻²	-	~ 10 ⁻¹	~10 ⁻²
Sr	~ 10 ⁻²	-	~ 10 ⁻²	~10 ⁻²
RE	-	< 10 ⁻³	< 10 ⁻³	-

Partitioning-Waste Streams



Conclusion

❖ **Classify into 4 waste streams**

- Volatile and semi-volatile species waste stream
- Metallic form waste stream
- Uranium metal waste stream
- Salt waste stream-ceramic composite wasteform

❖ **KAERI' strategy for waste minimization is focused on**

-Reduction of HLW by converting to LLW

- ☞ Removal of actinide residual from hull
- ☞ Removal of actinides from an electrorefined uranium metal product
- ☞ Increase of decontamination factor of actinide from waste LiCl salt

-Reduction of LLW: waste arising from voloxidation

- ☞ Simplification of wasteforms applicable to several absorbents
- ☞ Reduction of waste amounts

❖ **Comparison of wasteform volume with and without a salt recycle**

- Possible to reduce HLW amounts by 30 times
- Predictable to reduce HLW by 80 times if converting LiCl waste to LLW

❖ **Eng.-scale demonstration for waste salt recovery and wasteform fabrication**

- Establishment of Eng.-scale facility(10 t-HM/yr) for an inactive test by 2011 at KAERI



Environmentally-Friendly Nuclear Energy for Next Generation



풍부한 에너지, 깨끗한 환경, 건강한 **사람**을 제공하자