High Temperature Blanket and Its Socio-Economic Issues

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- Fast track and Development Strategy in Japan
- Power plant design
- Hydrogen production
- Safety and environmental impact

Fast Track : the next step

Fusion study is in the phase to show a concrete plan for Energy.
-Power plant design and strategy following ITER are required.

Common understanding

- Resource constraint (Energy)
- Global warming problem (Environment)
- Growth in developing countries (Economy)

Energy Demonstration in 2030?	Technical feasibility
Combined Demo-Proto steps	Social feasibility

Strategy varies in each Parties due to different social requirements.

Fast Track Discussion in Japan

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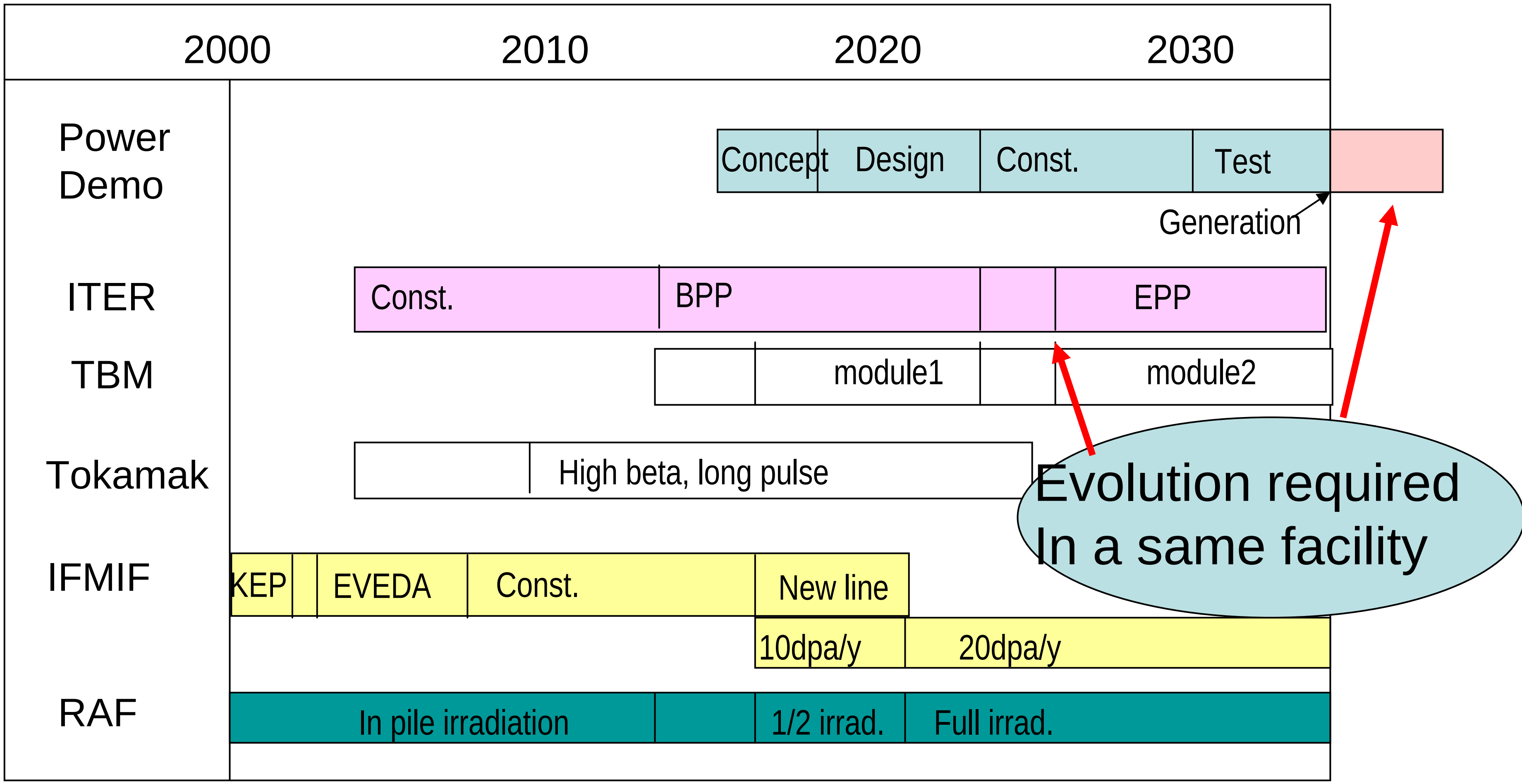

Drawn from Fast track working group in Japan, 2002,Dec.

Socio-Economic Aspect of Fusion

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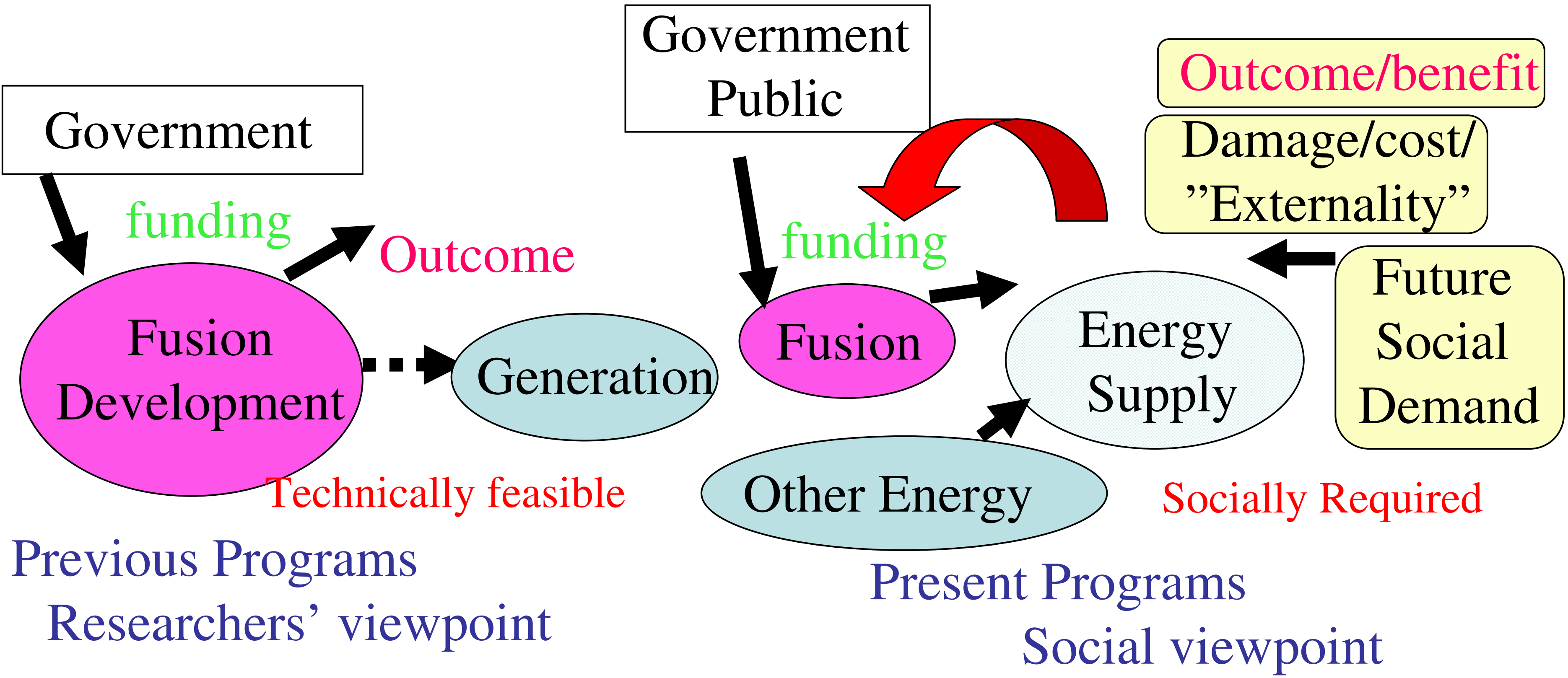
- Future energy must respond to the demand of the society.
- Social and Economical feasibility of fusion depends on high temperature blanket and its feature.



Near Future Plants

-Reduced Activation Ferritic steels (RAFs) are expected as blanket material candidates.
-Considering temperature range for RAFs, 500 C range is maximum, and desirable for efficiency.

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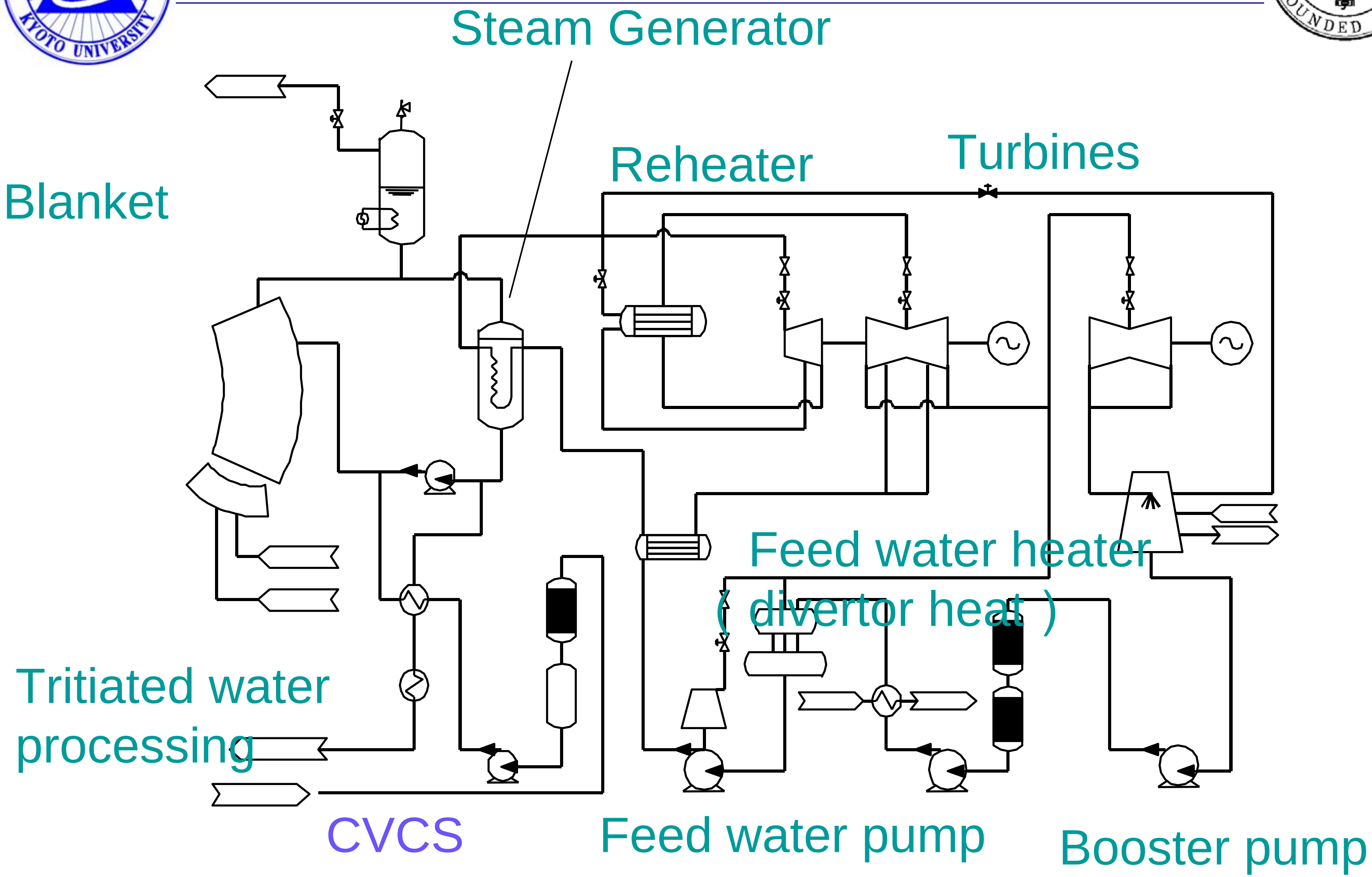
-From the aspect of thermal plant design,
ONLY supercritical water turbine is the available option
From fire-powered plant technology.

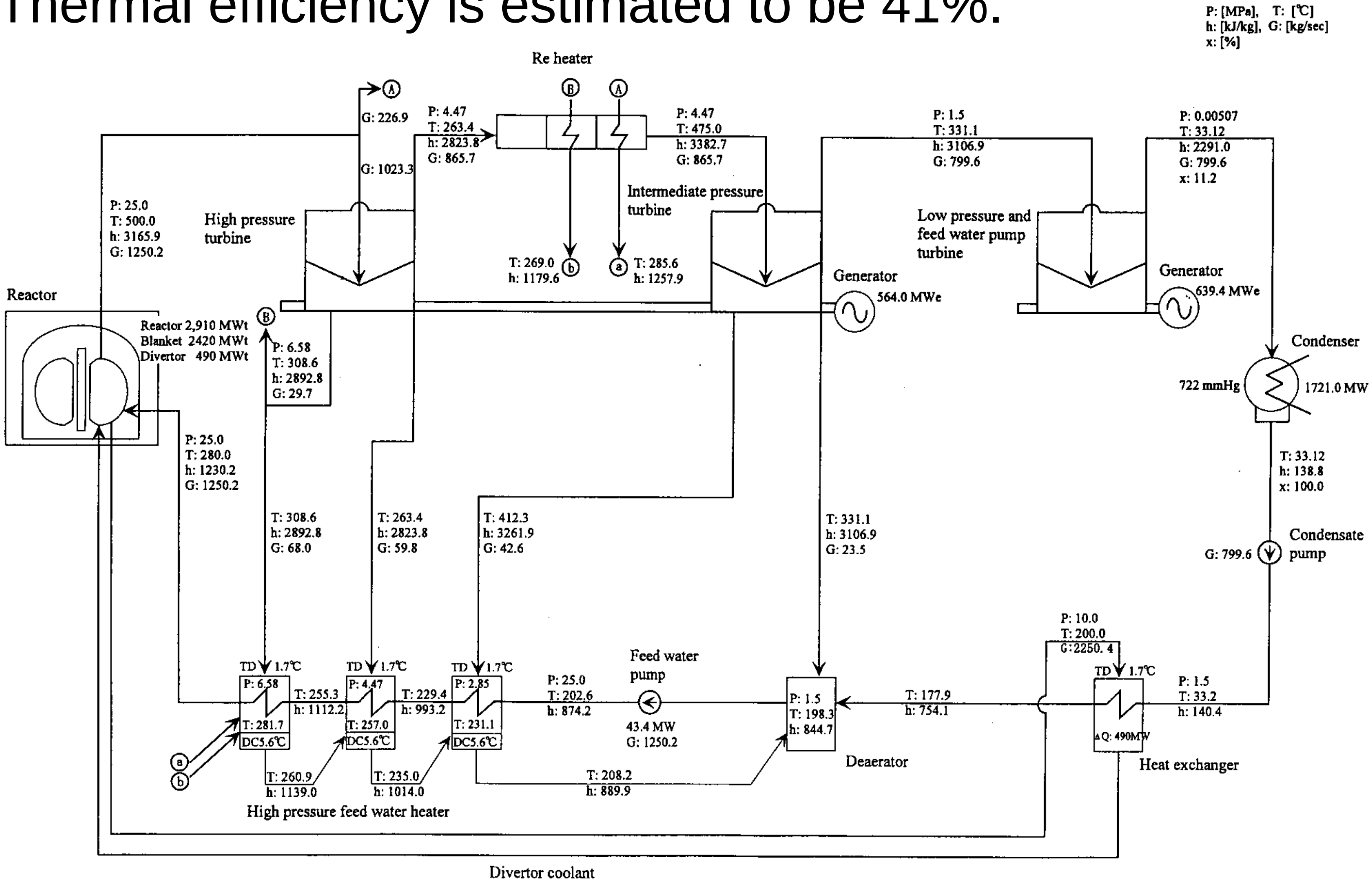
-No steam plants available above 650 degree C.

Flow diagram of indirect cycle



Thermal plant efficiency

Direct cycle turbine train generates 1160MW of electricity.
Thermal efficiency is estimated to be 41%.



Comparison of Generation Cycles

	direct	indirect	He gas
Main steam pressure	25MPa	16.3MPa	10MPa
Turbine temp.	500℃	480℃	500 ℃
Coolant flow rate	1250kg/s	1260kg/s	1865kg/s
Vapor flow rate	1250kg/s	1037kg/s	908kg/s
Total generation	1200MW	1090MW	1028MW
Thermal efficiency	41.4%	38.5%	35.3%
Technical issues	tritium in coolant	steam generator	expansion volume

Other thermal Plants:

BWRs – 33% PWRs – 34%

Supercritical Fire – 47%

Combined gas turbine - >60%

Findings

-Supercritical water cycles is desirable and possible (technically difficult).

- No gas turbine system is effective in temperature ~500 C.
- With steam generator, gas cooled is less effective than water.
- Plant design limited above 650 C.

High temperature material does not guarantee economy.
Improvements may be required in the DEMO generation.

Possible Advanced Plant Options

-High temperature cycle can be planned with He gas turbine at ~900 C.

-Only dual coolant LiPb blanket has possibility for high temperature in ITER/TBM.

-At high temperature, use of heat for hydrogen production may be an attractive choice.

Fusion Contribution with hydrogen

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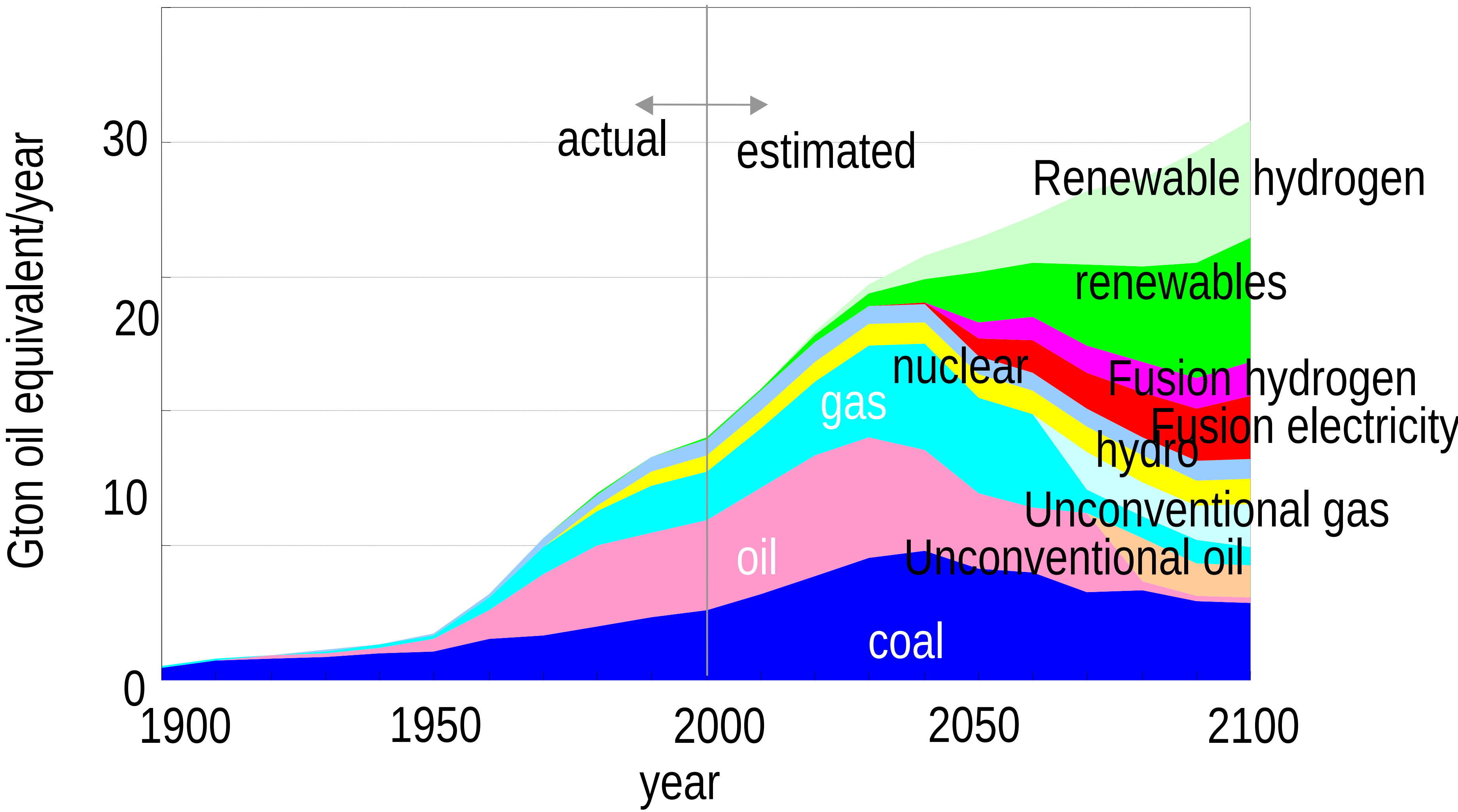

Hydrogen Production by Fusion

Fusion can provide both high temperature heat and electricity
- Applicable for most of hydrogen production processes

As Electricity
- -water electrolysis, SPE electrolysis : renewables, LWR
- -Vapor electrolysis : HTGR

As heat
- -Steam reforming:HTGR(800C),
- -membrane reactor:FBR(600C)
- -IS process :HTGR(950C)
- -biomass decomposition: HTGR

Energy Eficiency

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○amount of produced hydrogen from unit heat

- low temperature（３００℃）generation
  → conventional electrolysis
- high temperature（９００℃）generation
  → vapor electrolysis
- high temperature（９００℃）→ thermochemical production

From 3GW heat	efficiency	electricity	Energy consumption	Hydrogen production
300C-electrolysis	33%	1GW	286kJ/ mol	25t/ h
900C-electrolysis	50%	1.5GW	231kJ/ mol	44t /h
900C-vapor electrolysis	50%	1.5GW	181kJ/ mol	56t /h
900C-biomass	—	—	60kJ/ mol	340t / h

Use of Heat for Hydrogen Production

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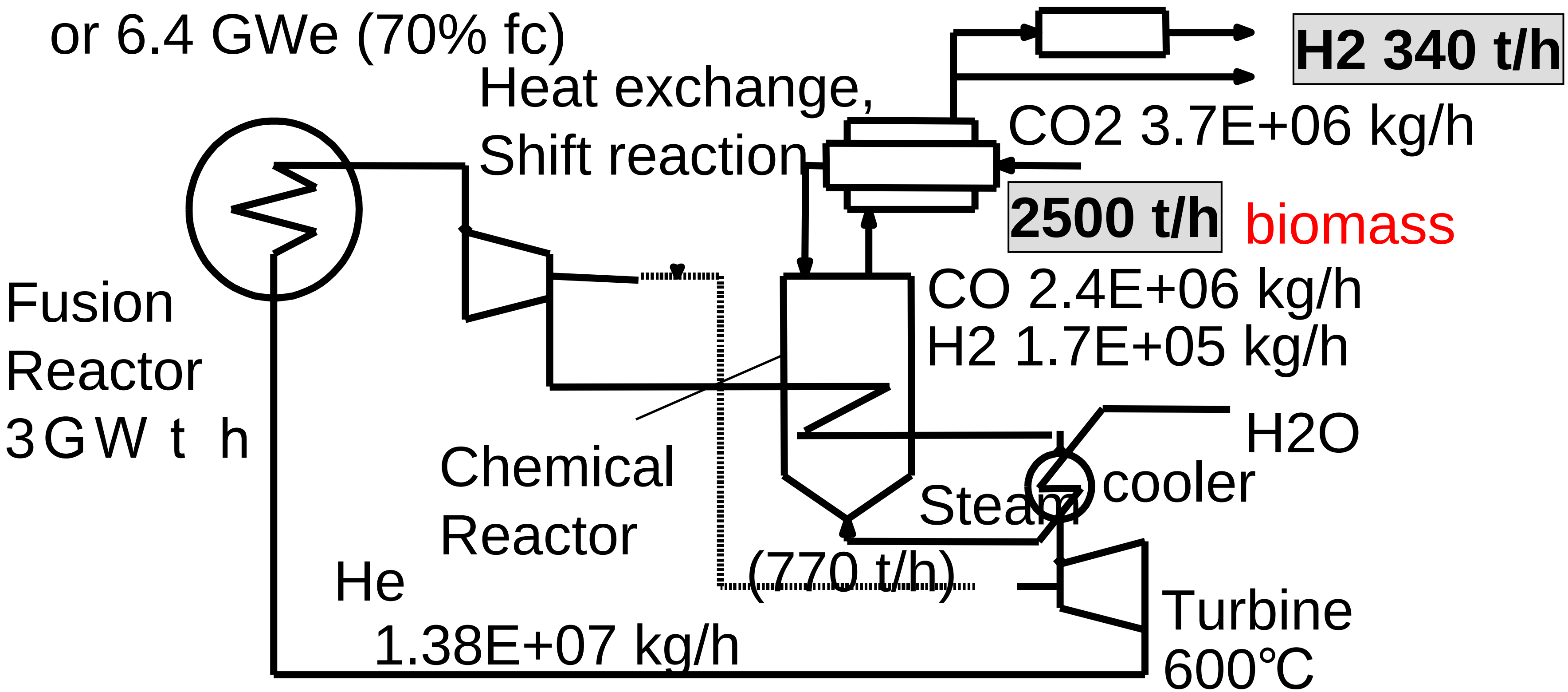
○Processing capacity: 3GWt

- 2500t / h waste → 340t of H_2

1.3x10^{6} fuel cell vehicles (6kg/day)
or 6.4 GWe (70% fc)



Hydrogen from biomass and heat

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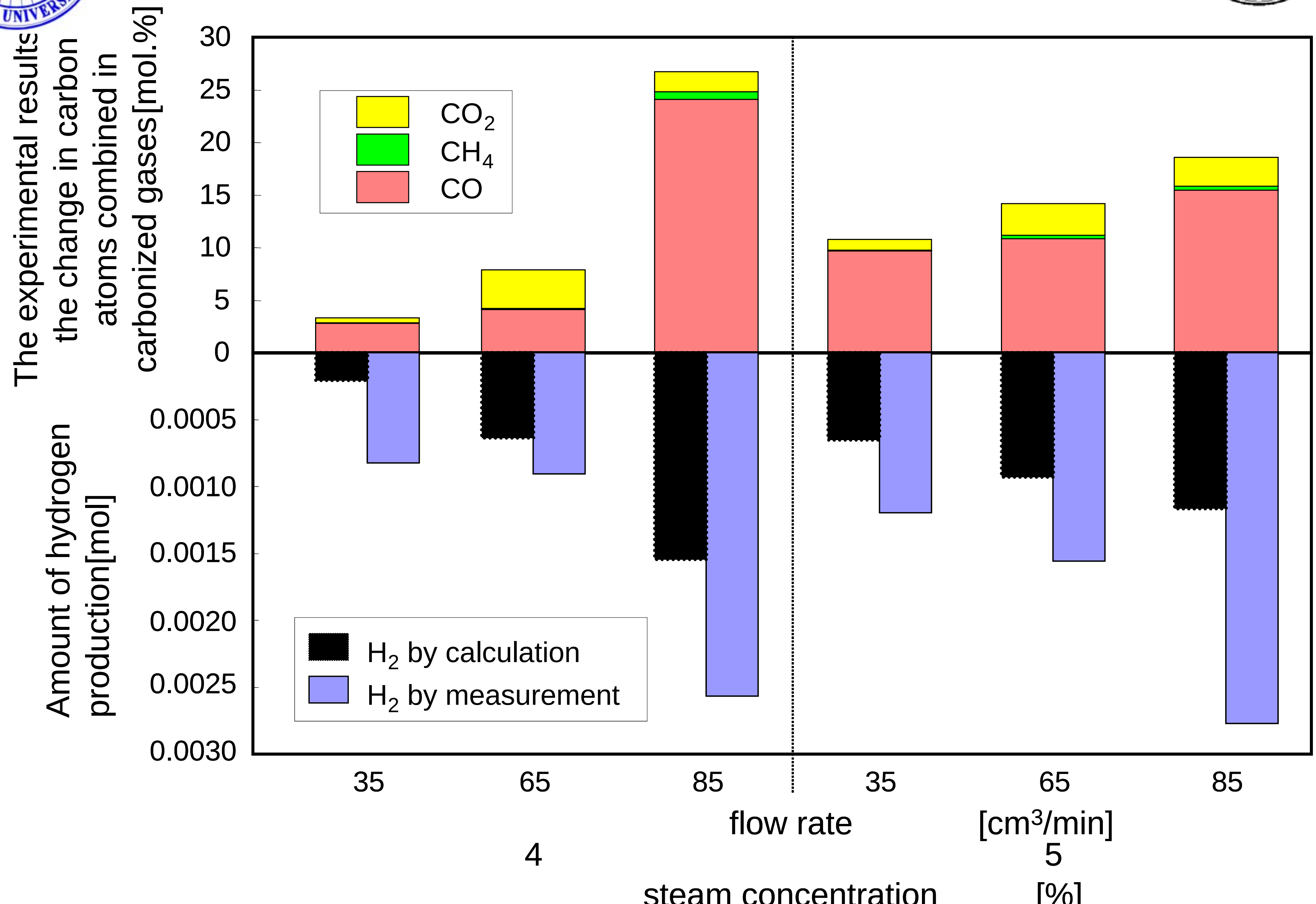

Fusion safety and environmental impact

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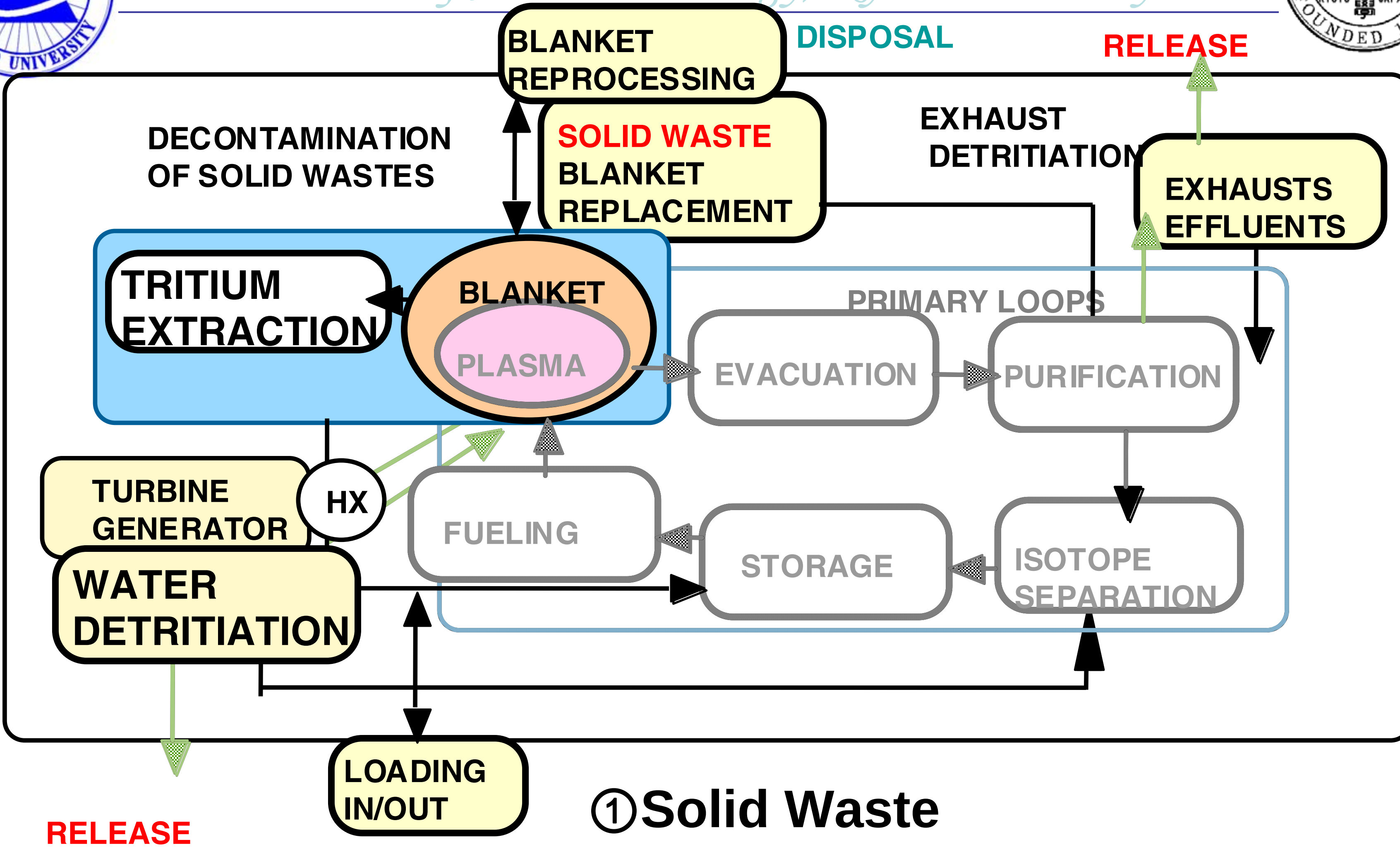


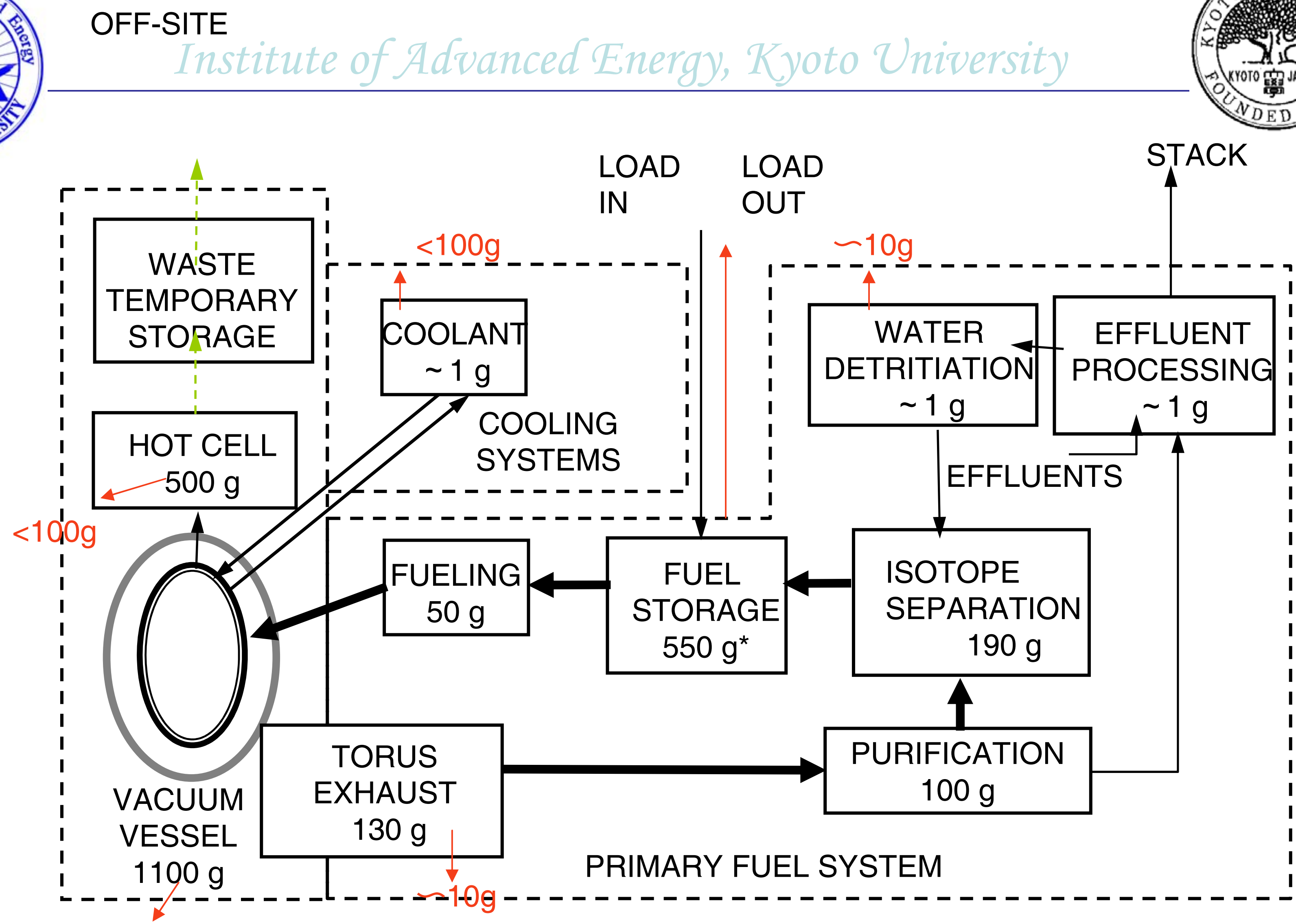
Impact pathway

①Solid Waste

②Tritium Release from Coolant

③Fuel Processing exhaust

Inventory distribution compared with ITER



ITER SITE INVENTORY : 2800 g → POWER REACTOR : probably less

POWER BLANKET (example)

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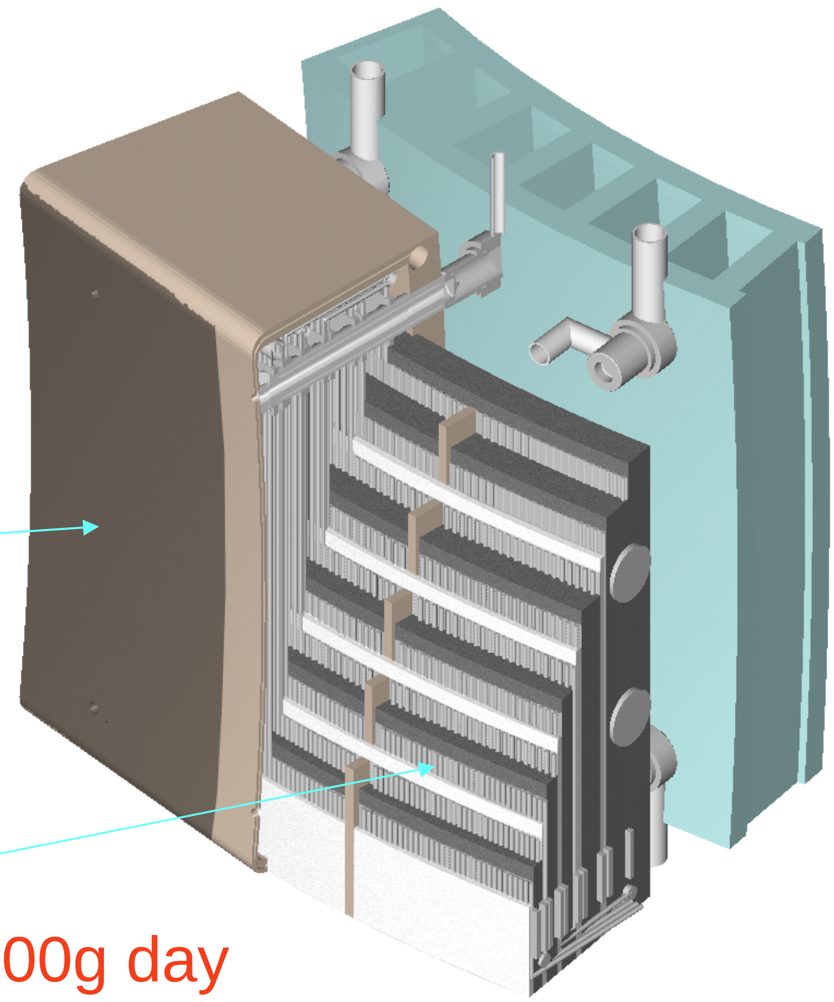
780K supercritical water
Li ceramic pebbles
He/H2 sweep for tritium recovery



High Temperature
High Pressure
Fine tubings
Tritium Production

1st wall

Cooling tubes

Tritium Permeation could be ~100g day

Normal release from Fusion Facility

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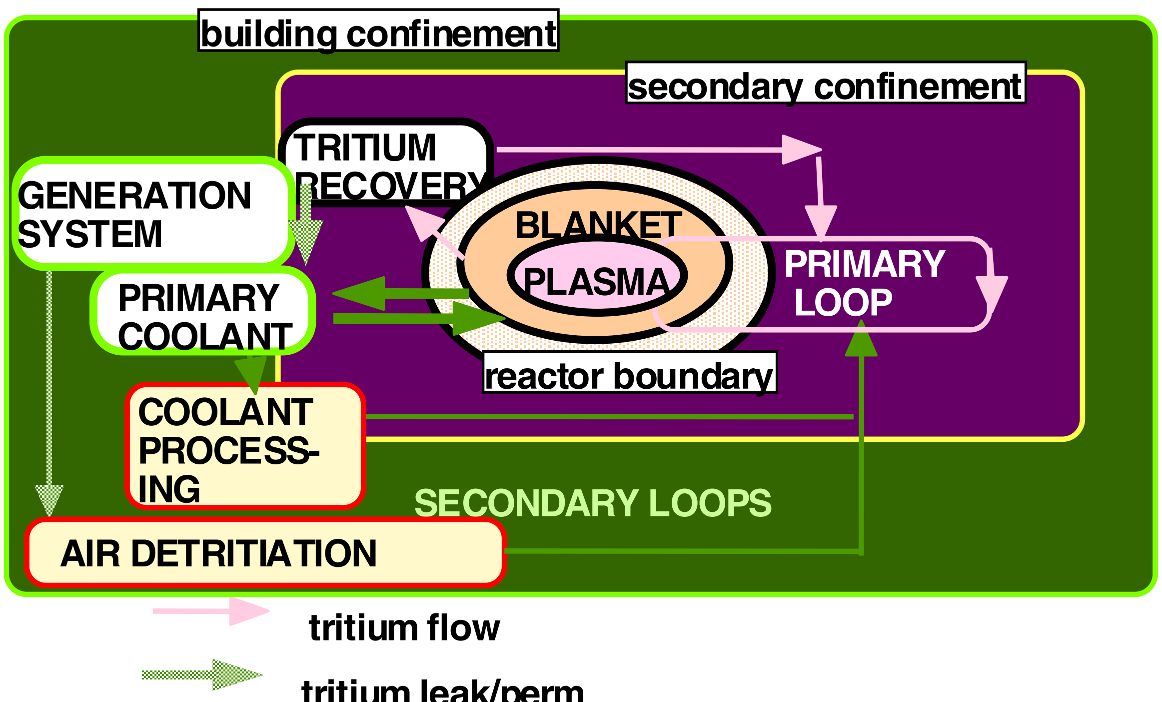
- Normal tritium will be dominated by release from coolant
- Largest detritiation system will be for coolant
- Fusion safety depends on ACTIVE system.

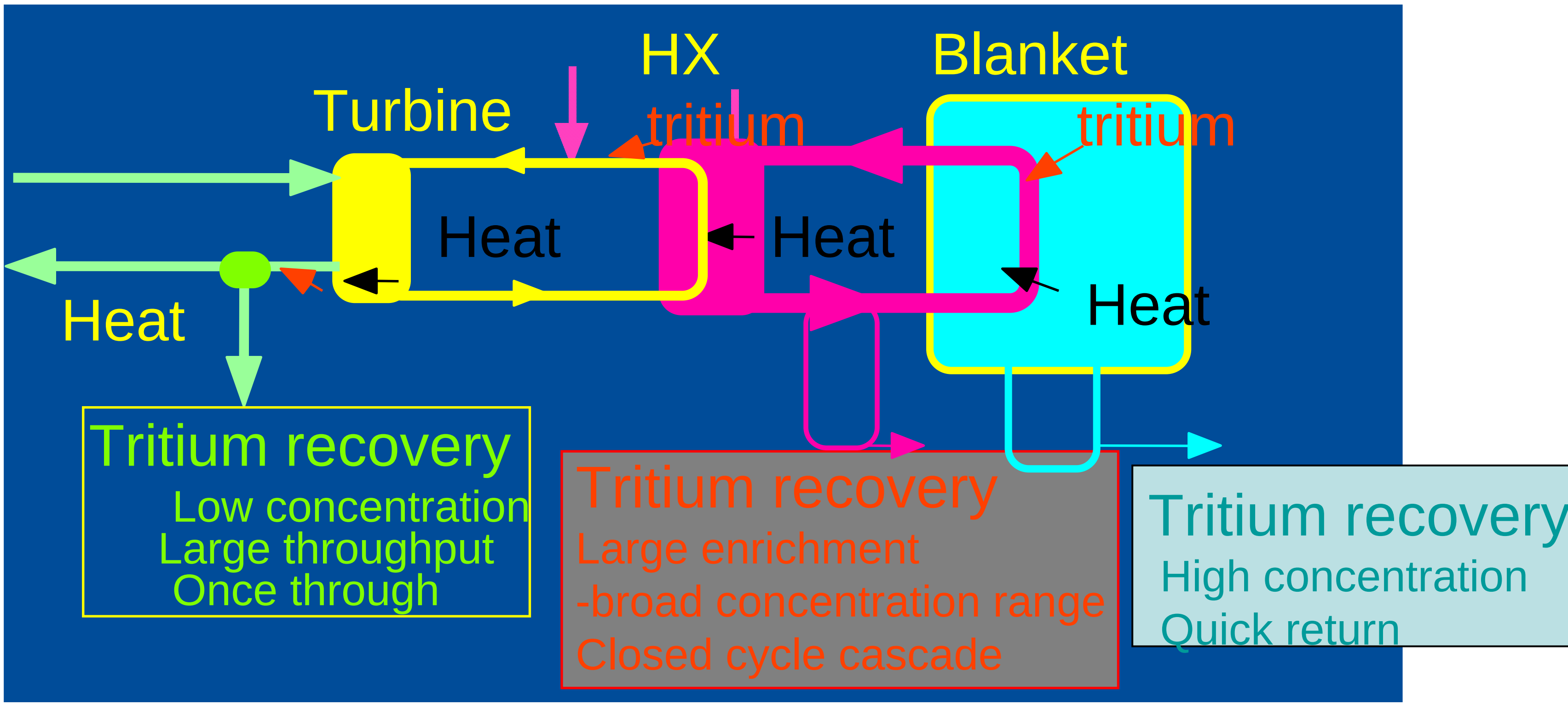
Generalized fusion plant



	PRIMARY LOOP	COOLANT PROCESS
TRITIUM INVENTORY (kg)	1	0.5
TRITIUM THROUGHPUT (kg/day)	30	0.5
TOTAL THROUGHPUT (kg/day)	60	50000

Generalized detritiation system

- Detritiation for power train will depends on blanket types.
- Normal detritiation for coolant will handle emergency spill.
- Safety control with active system is not site specific.



Detritiation systems of Plant

Processes large throughput, lower concentration
Controls environmental release
Operational continuously (including maintenance)

Air Detritiation :

- 1000 m^3 / hour, possibly ci/m^3 level
- leak from generator, secondary loops, hot cell

Water Detritiation : (isotope separation)

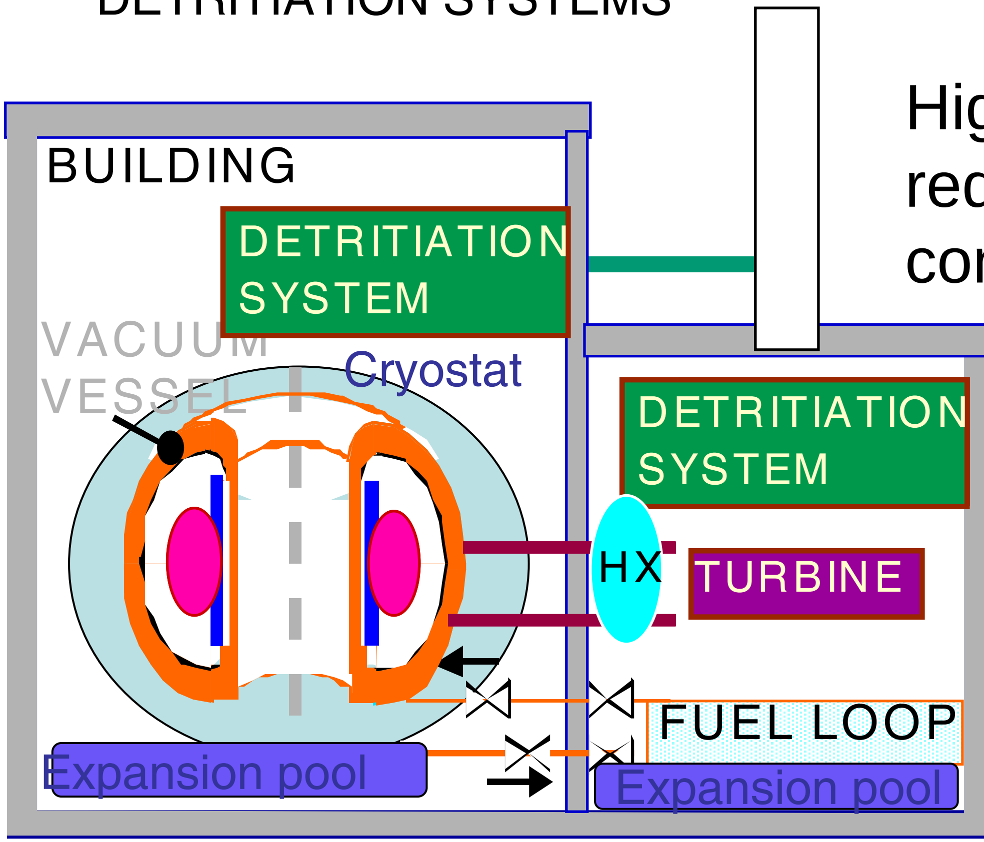
- 100 m^3 / day, possibly 1000 ci/m^3 level, 100g/day?
- driving turbine

Solid Waste Detritiation :

- 1 ton / day, possibly g / piece?
- materials (lithium, berylium, Steel) recycle
- needed both for resource and waste aspects.

Tritium confinement

TRITIUM IS CONFINED WITHIN ENCLOSURES AND DETRITIATION SYSTEMS



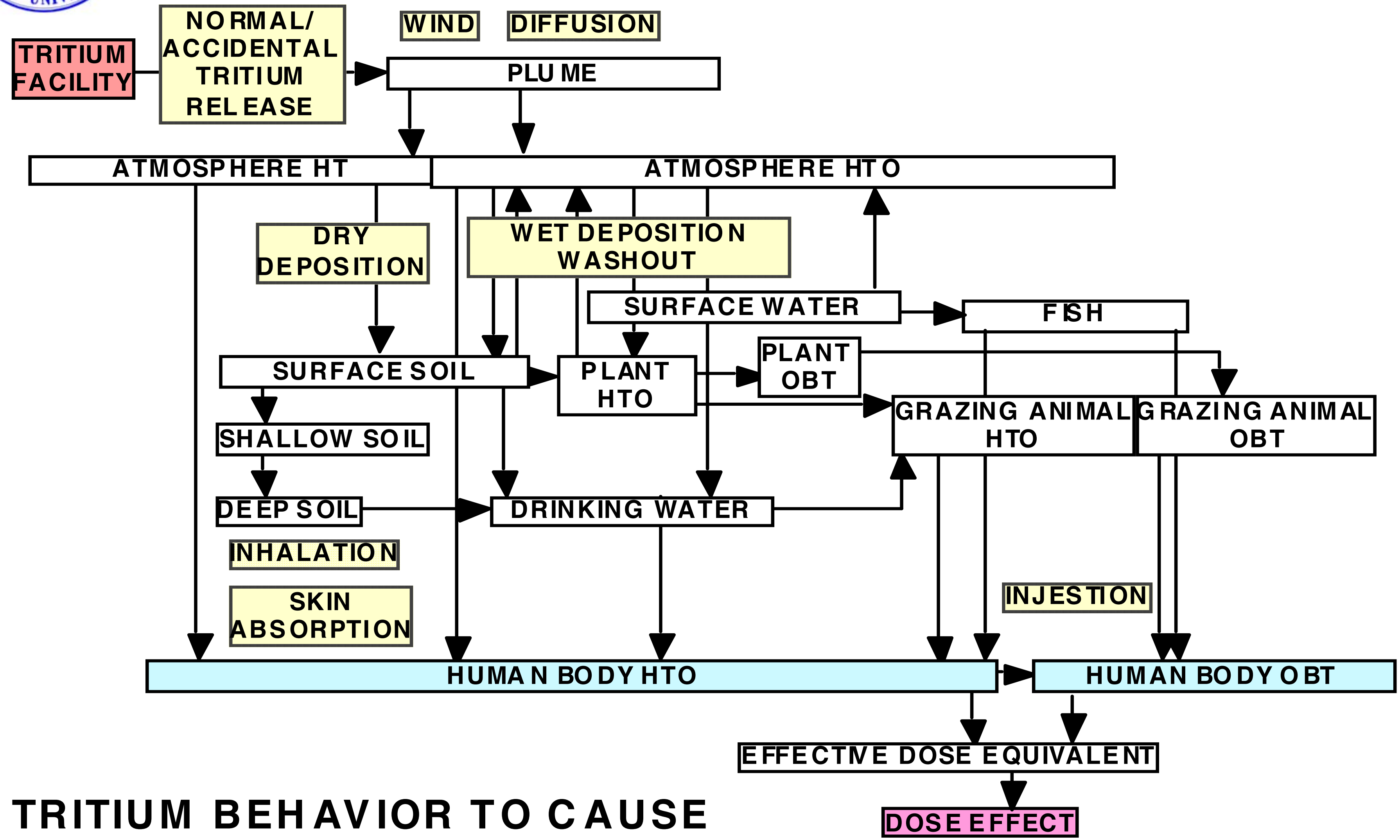
Power train will be driven with tritium containing medium.

High temperature blanket will require improved permeation control.

Pressurized gas may require additional expansion volume.

For gas driven system, large Expanson volume may be needed.

Emission from Fusion and Dose



TRITIUM BEHAVIOR TO CAUSE HUMAN DOSE

Impact pathway of tritium suggests ingestion will be dominant.

Findings

-Fusion plant detritiation will be dominated by power plant configuration.
- Normal tritium release will be controlled actively.
- Off-normal spill can be recovered with normal detritiation.
- High temperature plant will require improved tritium system.

-Measurable tritium will be released in airborne form.
-Tritium accumulates in environment (far smaller natural BG).
-Ingestion dose will be dominant.
-For long run, C-14 may be a concern.

Conclusion

Fusion development is in the phase to study market

- Fusion must find customers and meet their requests.
- Fusion must satisfy environmental and social issues.

Development of advanced blanket is a key issue for fusion

- Economy - not just temperature, but to maximize market
- Environment - not just low activation, but best total cost and social value / least risk(Externality)

Development strategy (road map) for blanket is needed.

- ITER and DEMO require 2 or more generations of blankets.
- staged improvement of blanket is planned with water-PB, and LiPb dual coolant concepts.

Conclusion 2

Possible blanket improvement

- Independent from large increment of plasma
- Continuous improvement can be reflected in blanket change.

(Improvement in DEMO phase)

- Multiple paths to meet various needs are possible.
- Flexibility in development of entire fusion program is provided by blanket development.