Thorium Energy Alliance Conference
March 29-30, 2010, Mountain View, CA, USA:

-What is "Thorium Molten-Salt Nuclear Energy Synergetic System: *THORIMS-NES* " ?

(Establishing *SIMPLEST* Breeding Nuclear-Fuel Cycle)

Dr. Kazuo FURUKAWA

President of the International Thorium Molten-Salt Forum

e-mail:QYT00127@nifty.ne.jp

Agenda

International Thorium Molten-Salt Forum

A) Basic Principle of Fission Energy Industry Technologies
B) Selection of specific Fuel-Cycle System
C) Path to realize the Th–U Breeding Fuel-Cycle
D) Development strategy for realizing the “Simplest” Th-U Breeding Fuel-Cycle

Conclusions:

Ref) "A road map for the realization of global-scale thorium breeding fuel cycle by single molten-fluoride flow", K. Furukawa, et al, Energy Conversion and Management 49 (2008)

International Thorium Molten-Salt Forum

"International Thorium Molten-Salt Forum" is a Non-Profit-Organization, which was registered to the local government of Japan in October, 2008.

The members are researchers and engineers besides citizens, who are interested in the Molten Salt Reactor and related thorium cycles.
At this moment, 20 domestic members and 10 foreign members from USA, France, Russia, Ukraine, Czech and so on.
There are other 50 domestic people who are supporting occasionally.

We will proceed research and design besides education, in order to promote Molten Salt Reactor and related thorium cycles.

Dr. Kazuo Furukawa

(President of the Forum)

Activity of our Forum

1) So far, we held 3 seminars in 2009, inviting the above people.

2) Also, we provided lectures to the public/university.

3) We issued an Annual report.

A) Basic Principle of Fission Energy Industry Technologies

(1) "Establishment of Breeding Nuclear-Fuel Cycle" is essential.

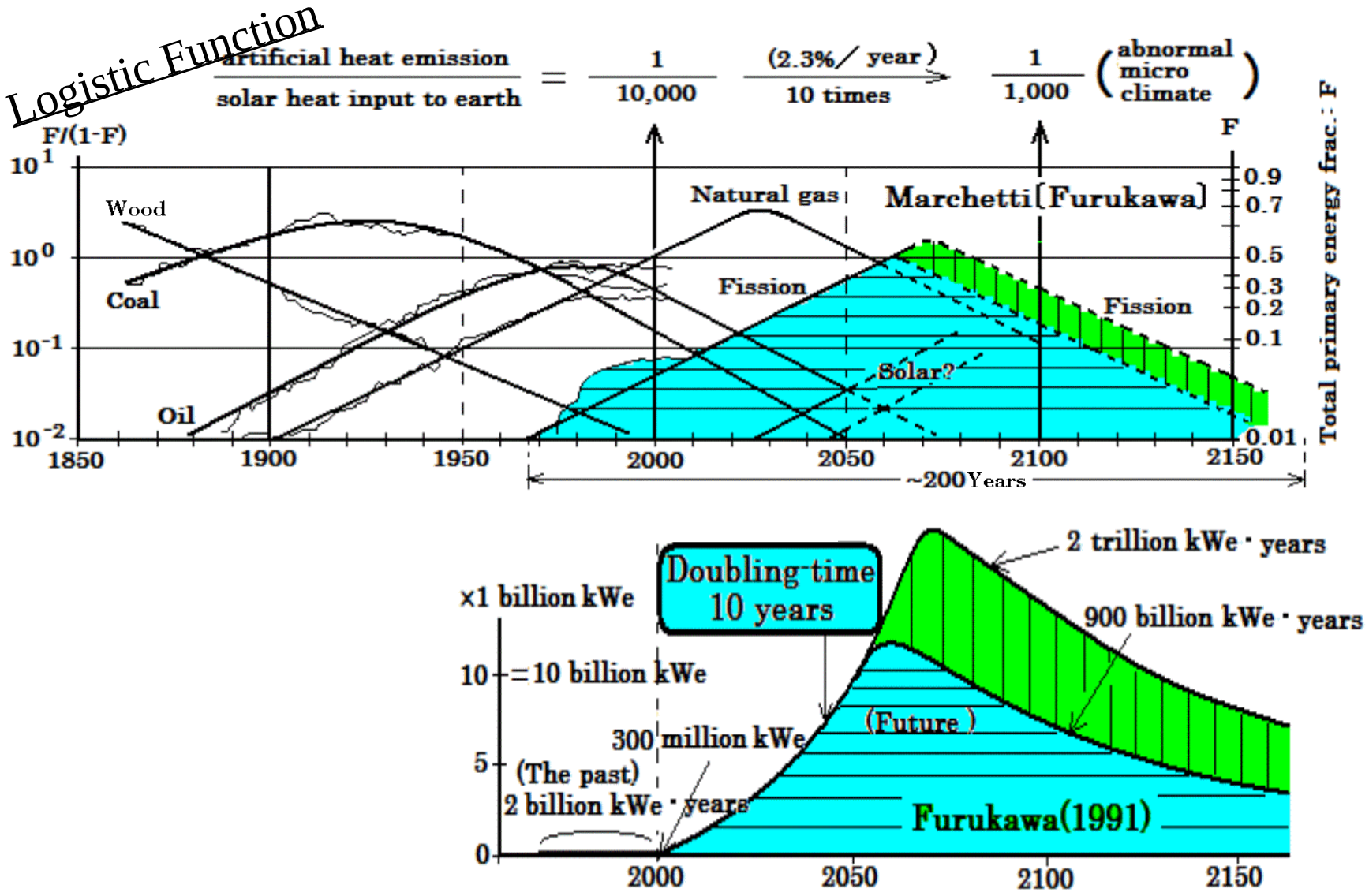
- **Doubling Time (DT)** for fissile material is required as **about 10 years**
  (cf. the next Figure)

-Necessary for Global Survival-

- 10,000 tons of fissile material per year is required
  for 10-T(10 billion kilo)We.

“Global Future Energy Prediction”

The basic problem: ***disordering of major energy technology***,
Application of **solar-based technology**: Needs more 100 years



B) Selection of specific Fuel-Cycle System

(1) U-Pu breeding fuel-cycle is not completed, and previous breeder reactor is too slow on Doubling Time

- Disadvantages of **SOLID-FUEL U-Pu Breeding Fuel-Cycle**
  - nuclear proliferation
  - nuclear waste
  - severe accident (core melt-down)possibility
  - economical difficulties
    due to “fuel-assembly fabrication & handling”,
    “complex reprocessing”, “necessity of huge-size”, etc.:

- Huge investment in the past 60 years, but **effective Breeding Fuel-Cycle** is not established.
  ("Why commercialization of FBR failed" by Von Hippel, IPFM2010)
  .

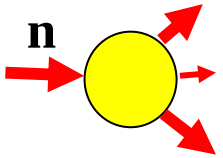
B) Selection of specific Fuel-Cycle System

(2) Thorium - Uranium (Th–U) breeding fuel-cycle is the most promising approach

- Breeding Cycle should be achieved by Synergetic system:

  (1) FISSION process : **Energy rich,** but Neutron poor

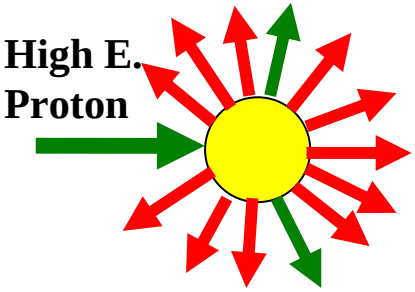
  Fission Breeding Power Reactor : insufficient



  (2) SPALLATION process: Energy poor, but **Neutron rich**

- Synergetic system coupling :

  Good converter of Fission Power Reactors with
  Good fissile producing Spallation system



20-30 neutrons & protons

- "**Near Breeder**" ("Self-sustaining nuclear fuel system"):

  -Most simple, stable and very high safety one,

  ➔**ideal NUCLEAR POWER STATION**

C) Path to realize the Th–U Breeding Fuel-Cycle

(1) Establishment of the Nuclear-Fuel Cycle as ”Chemical Engineering Devices”

- What Dr. Eugene WIGNER predicted in 1940s was that:
  - Reactor should be ”Chemical Engineering Devices”

    Its working medium should be **“FLUID”** as nuclear fuel and coolant.

  - An ideal nuclear power reactor would be probably

    “the molten-fluoride salt fuel reactor”

    later developed by ORNL under his successor, Dr. Alvin Weinberg

C) Path to realize the Th–U Breeding Fuel-Cycle

(2) Previous Th-U study on solid-fuel reactor

- Thorium utilization in "SOLID-FUEL REACTORS":

  High Temperature Gas-cooled Reactors(HTGR) and
  Light- or Heavy-Water Reactors (LWR or HWR) etc.

  not suitable for practical "Th-U" cycle development
  due to the **strong gamma rays associated with U232:**

Difficulties of Chemical-Processing and Fuel-Fabrication

C) Path to realize the Th–U Breeding Fuel-Cycle

(3) Fissile material procurement

- Thorium is a **fertile material** which has no fissile.
  So, we need **fissile material** for the start-up of Thorium Reactors.

- 1) **Plutonium** from spent fuel of LWRs by dry-processing (FREGAT) system in molten-salt form.

- 2) **Enriched uranium** can be used for the initial fuel.
  (Plutonium production will be of relatively low concentration.)

- 3) For large-scale breeding fuel cycle..... (see next page)

C) Path to realize the Th–U Breeding Fuel-Cycle

(4) Realization of Breeding Fuel-Cycle by selecting the synergetic system

- For large-scale breeding fuel-cycle:

  ➔Implementing

  "Accelerator Breeding System"

  (SPALLATOR)

- Successful development of

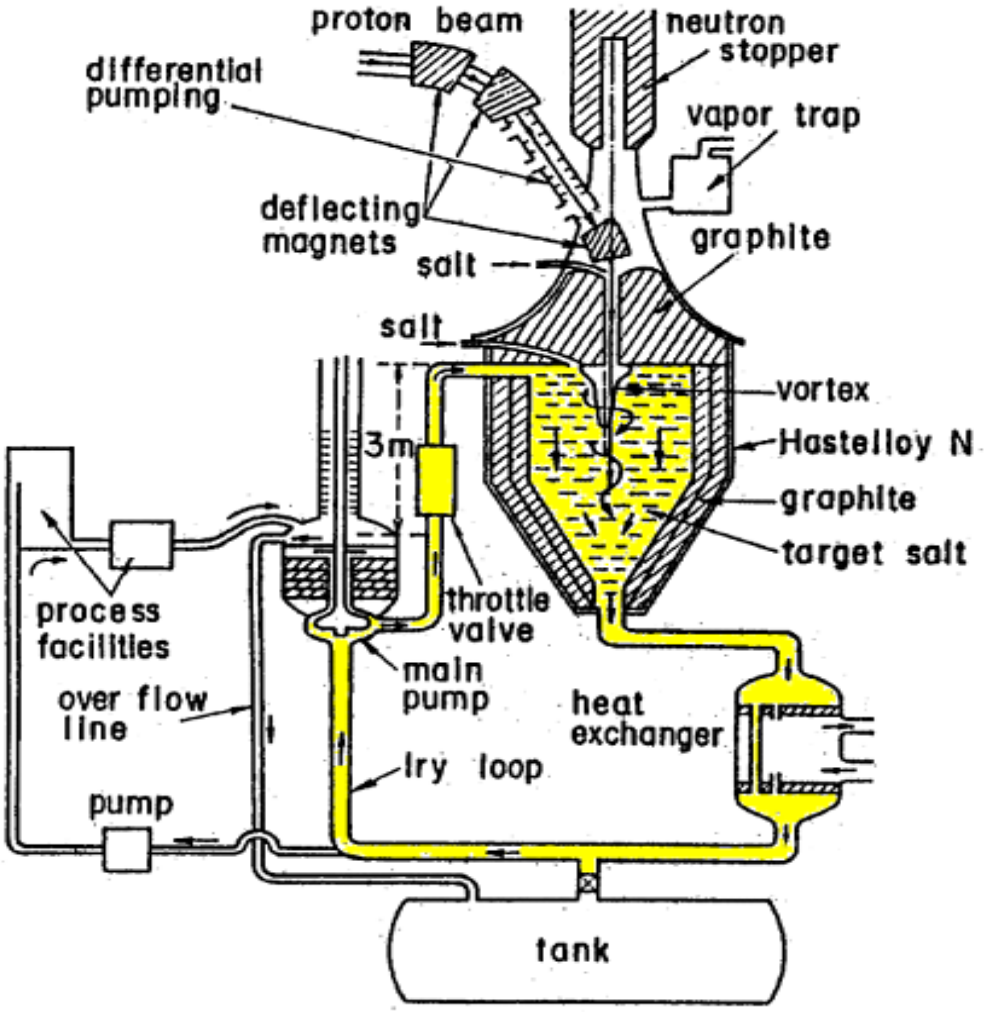
  the "Accelerator Molten-Salt Breeder(AMSB)"

  invented by Furukawa et al. in 1980 (cf. the next Figure)

  ➔Solving the technical difficulties of intensive radiation-damage & localized intense heat generation etc.:

Accelerator Molten-Salt Breeding Facility (AMSB)

* Composed of three parts:
* 1GeV and 200-300 mA **proton accelerator**
* Single-fluid molten fluoride **target/blanket** system
* Heat transfer and electric **power recovery** system



sub-critical
no radiation damage
easy heat removal
no target/blanket shuffling
Gas-curtain window
multi-beam funneling available
simpler chemical aspects

D) Development strategy for realizing the "Simplest" Th-U Breeding Fuel-Cycle

(1) Basic principle was in 1950s

- CANADIAN PLAN in realizing the "Th-U Breeding Fuel-Cycle":

  Solid-fuel high conversion "**CANDU**" + "**Accelerator Breeder**" was considered by Dr.W.B.Lewis (1950's)

  ➔Not succeeded to achieve simple breeding cycle system.

- THORIMS-NES concept is to be implemented.

D) Development strategy for realizing the "Simplest" Th-U Breeding Fuel-Cycle

(2) Ideal "Thorium - Molten Salt Reactor" system

- Proposed Thorium-Molten Salt Reactor,
  "FUJI": **near breeder** (cf. the next Figure)

- **Simplified Structure**, easy to operate and maintain:
  - Almost **fuel self-sustaining** ,
  - Even small power size150-300 MWe
    without continuous chemical processing & core-graphite replacement

- **Simple Reactor Vessel:**
  with no big-flange, only few control-rods, and no fuel-handling:

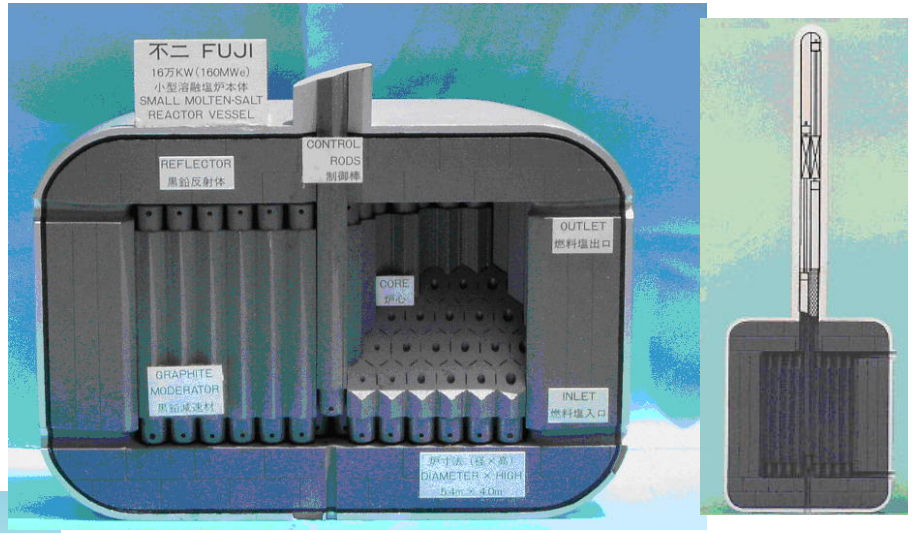
- **Factory manufactured:** a smaller size & modular arrangement:

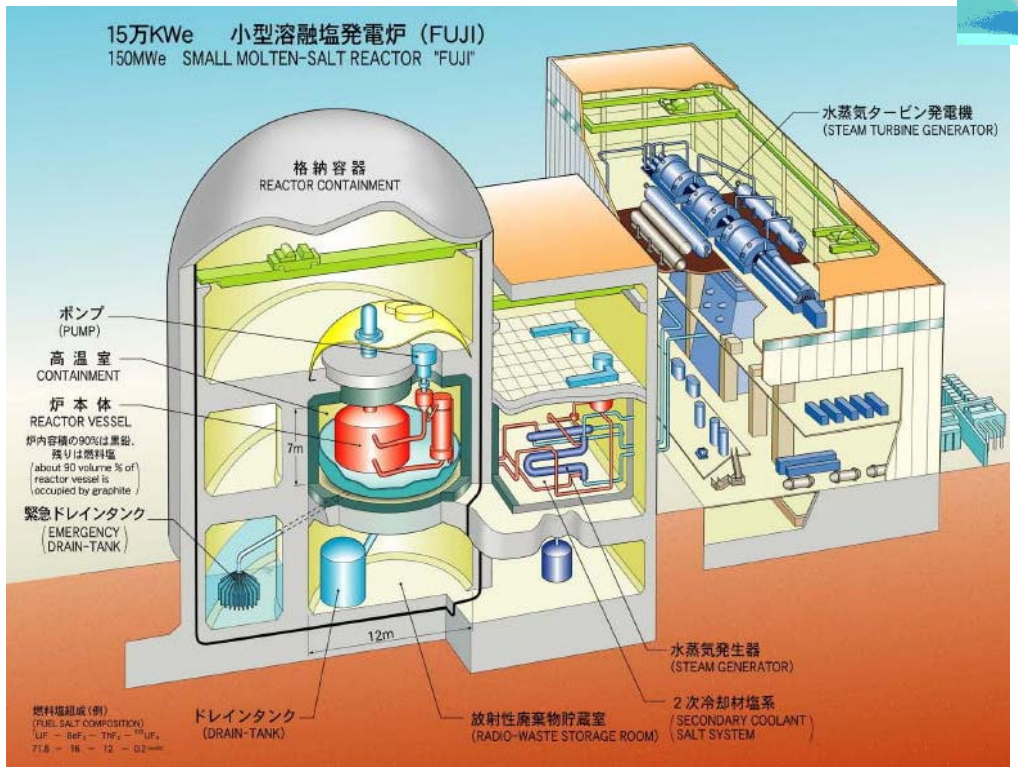
Excellent economical advantages

(Continued)

Molten-Salt Power Reactor :FUJI

Cut-model of **FUJI** and **miniFUJI**
Reactor Vessel





Bird-eye view of FUJI
power station

D) Development strategy for realizing the "Simplest" Th-U Breeding Fuel-Cycle

(3) Configuration of THORIMS-NES

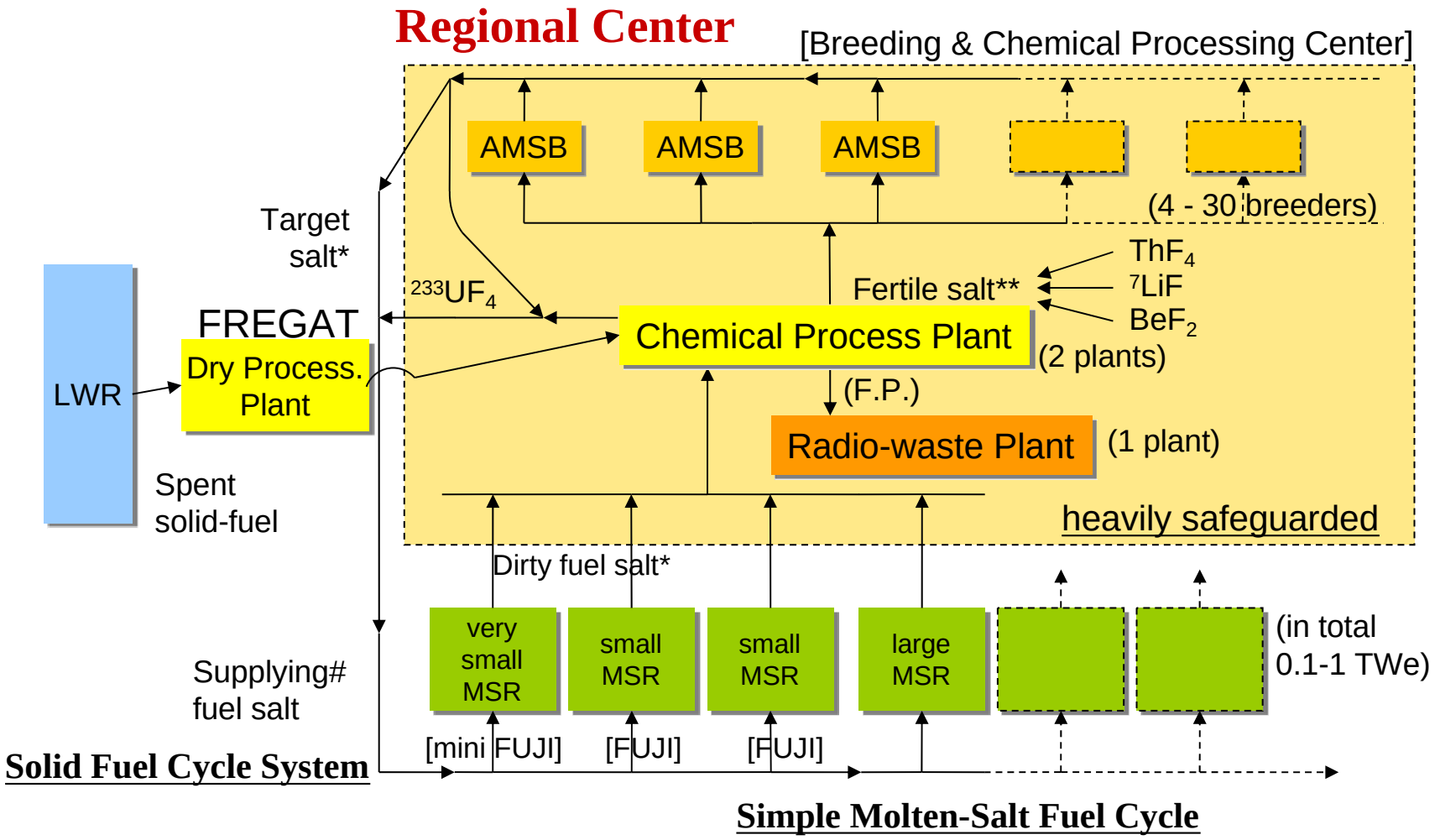
- For the 1st stage fuel:
  Plutonium from existing uranium solid-fuel reactors
  aiming at the reduction and eventual elimination of plutonium

- For the 2nd stage fuel:
  Building many "**AMSB**"s after about 30 years, and
  producing **U233** for more new reactors: **FUJI.**.

- "**Regional Centers**" : 20-30 locations in the world (cf. next Fig.)
  to handle the "chemical processing" of the spent fuel salts.

➔"U233 producing AMSB" and "Nuclear Waste Plants"

Thorium Molten-Salt Breeding Fuel-Cycle System



(*) ^{7}LiF-BeF_2-ThF_4-$^{233}UF_4$ (**) ^{7}LiF-BeF_2-ThF_4 (#) target salt* + additive $^{233}UF_4$

D) Development strategy for realizing the "Simplest" Th-U Breeding Fuel-Cycle

(4) THORIMS-NES is feasible in the Shortest Period with Minimum Development Cost:

- Concept based on the review of R&D results for past 60 years:
- "Small-sized nuclear power station: in minimum investment
  - by using the past excellent R&D results
  - by international cooperative partnership
  - by the support of liquid-sodium technology experience
- MSRE operation at ORNL for 4 years:
  - equivalent to the fuel burning for 10 years at "FUJI" already
- Investment estimated:
  - $1.5B for "FUJI" reactor for the next 12 years:
  - $20B for AMSB development at "Regional Centers" worldwide for 25 years (starting 10 years later) from now

Conclusions

- Excellent advantages of THORIMS-NES:
  - **Safety** (No “core meltdown” accident in principle)
  - **Radioactive-waste** is minimized
  - **Nuclear proliferation** protection
  - **Economy**

    which will result in a conclusive public acceptance

- Simple design....."Simplest is the best.”
- Promising huge-sized nuclear industry throughout the world.
- Co-existence with LWRs is possible.

Thank you for your attention!