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The Japanese Industrial Activities on Non-Electrical Applications of Nuclear Energy, mainly related to HTGR Plant

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1. Introduction (1/3)

- **"*Japanese Industry*" or "*The Industry*" has long been executing a series of "*Activities*" on Commercial Feasibility of "*Non-Electrical Applications of Nuclear Energy*", mainly by "*HTGRs*"**
- ***"Japanese Industry"* or *"The Industry"* means ;**
  - **Members from Industry**
    - **Electric Power Companies, Nuclear Power Plant or Nuclear Fuel Makers, Gas Suppliers, Car Makers, Steel Makers, Engineering, Trading Houses, etc.**
  - **Members from R&D Organizations and Academia**
    - **JAEA (ex. JAERI), Universities**
- ***"Activities"* means ;**
  - **Participating in HTGR Development Programs (Japan and abroad), Studying, Grasping, Evaluating, Appealing, Proposing, etc.**
- ***"HTGRs"* means ;**
  - **HTGR and/or VHTR Plants**

1. Introduction (2/3)

- ***"Non-Electric Nuclear Heat Applications"*** **means ;**
  - **Heat Uses, mainly by means of HTGRs**
  - **Then, Heat Uses, mainly of High Temp.s (800-1,000 deg.C) such as ;**
    - **H_2 production**
    - **Coal gasification / Liquefaction (Synthetic Fuel Production for Transportation)**
    - **Process Heat (for Chemistries, etc.)**
- **Since 1960's ;**
  - **Studying, Developing and Grasping on ;**
    - **Multi-Purpose Nuclear Heat Uses (like "Nuclear Steel Making")**
    - **H_2 Production Technology, High Temp. Materials**
    - **Feasibility of High Temp. Heat Applications**
    - **R&D Status and Commercialization Trend in the World**
  - **Participating in ;**
    - **HTGR Development Program, such as HTTR (Japan), PBMR (S.Africa), GT-MHR (US/Russia), and/or NGNP (US)**

1. Introduction (3/3)

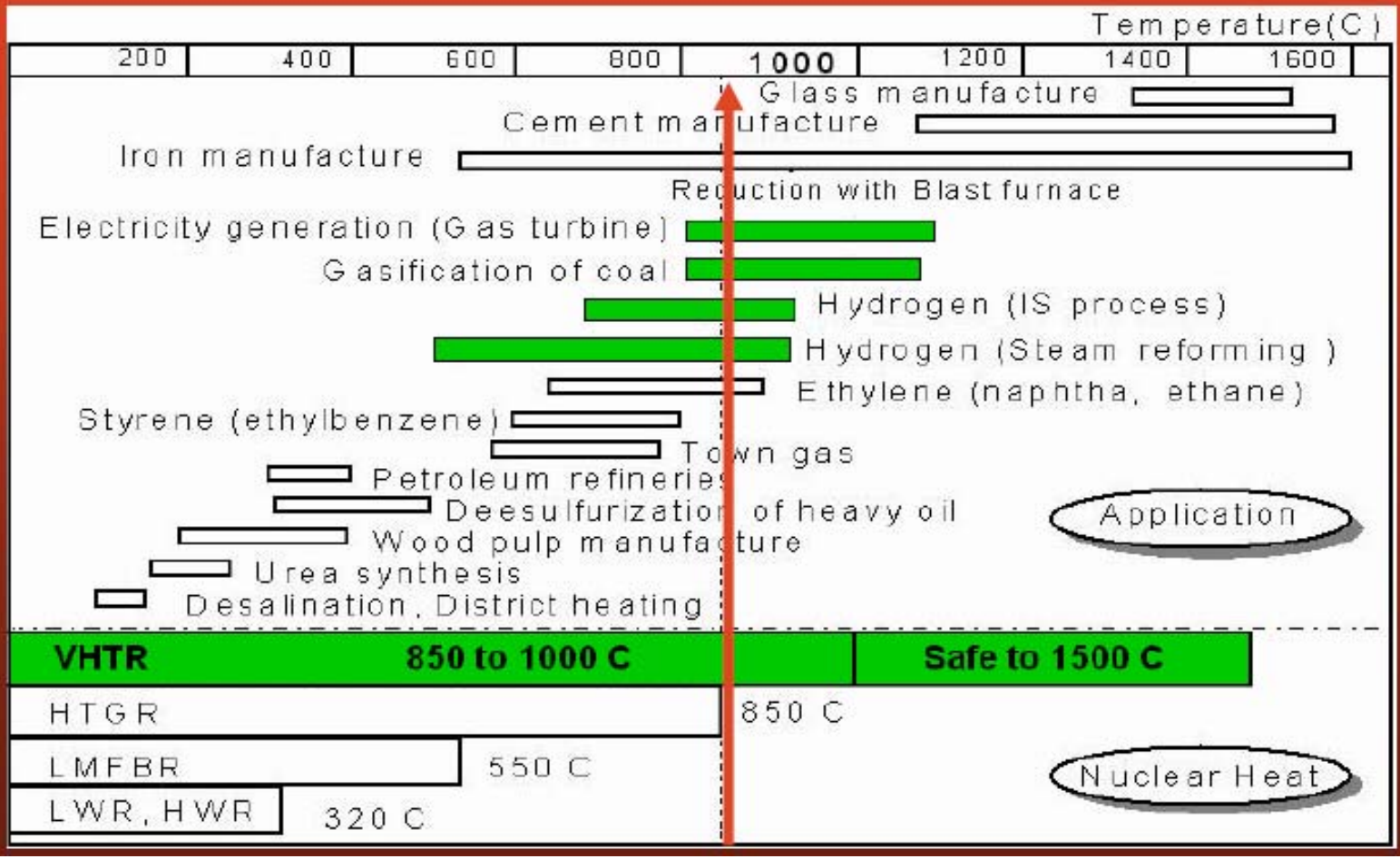
- **Since 2000's;**
  - **Appealing/Proposing to Japanese Government (and the Industry) on ;**
    - **Evaluation and Establishment of the National Energy Development Strategies and Programs**
    - **Evaluation and Strategic Positioning of HTGR Plant and Nuclear Heat Applications in the Programs**
- **Currently ;**
  - **Exemplifying of "*Introductory Scenario*"on HTGR in Japan**
    - **"*Fuel Cell Vehicles*" Scenario**
    - **"*Industrial Complexes (Kombinates)*" Scenario**
    - **"*Hydrogen Towns*" Scenario**
  - **Exemplifying of "*Commercialization Roadmap*" on HTGR in Japan**
- **Main Results of those Activities are given below ;**

2. Characteristics and Applications of HTGR Plant (1/2)

- **HTGR Plant Systems have unique Characteristics, such as ;**
  - **Very Wide Applications, then, the World Marketability**

    (in Forms of Electricity, Heat, Hydrogen, Oxygen, Steam)
    - **Electrical Production**
    - **Wide Range of Heat Uses (from High Temp.s to Mid/Low Temp.s)**
      - **Massive Hydrogen Production**
        - » **Fuel Gas (for Car, Ship, Aircraft, etc.)**
        - » **Fuel Cell Vehicle (FCV)**
        - » **Stationary Fuel Cell**
      - **Coal Gasification / Liquefaction (Synthetic Fuel Production for Transportation)**
      - **Oil (and/or Oil Sand) Recovery & Refinery**
      - **Steel Making**
      - **Process Chemistry**
      - **(District Heating, Seawater Desalination, etc.)**

Why High Temperature? Process Heat Applications



(UT Systems (UTPB)/GA/Permian Basin, HTTTR (HT^3R), 2006)

2. Characteristics and Applications of HTGR Plant (2/2)

- **Safety**
  - **Fuels and In-core Materials made of Refractory Ceramics**
  - **Enhanced Safety (by means of Suppressed Power Density Design)**
    - **Ensured "Inherent Safety"**
    - **Plant Siting near Demand Areas**
- **Economy**
  - **Modularized or Standardized Design**
  - **Components/ Equipment Fabrication in Factory under stable QC/QA**
  - **Plant Siting near Demand Areas**
    - **Low Cost for Electricity / Heat Transportation**
- **Global Environment**
  - **No Emission of Global Warming Gases (CO_2 Gas, etc.)**
  - **High Heat Use Efficiency**

3. Development Status of HTGR and High Temp. Nuclear Heat Applications in the World

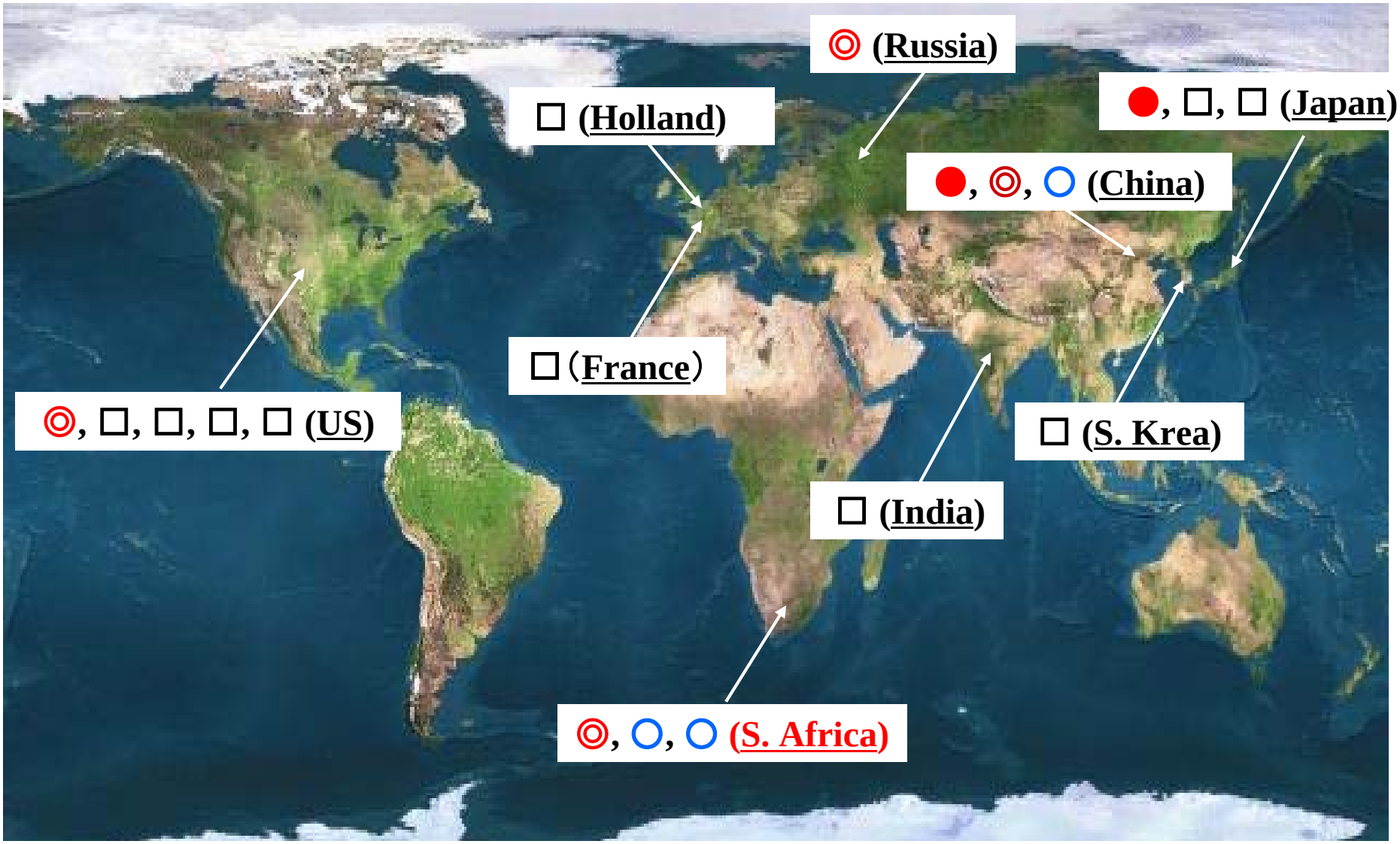
- **In the World, many R&D and Demonstration / Commercialization Programs are under way ;**
  - **on "High Temperature Heat Uses"(, as well as Electrical Production) towards Commercialization in ;**
    - **2010's in case of HTGRs ; PBMR, PHP (S. Africa), HTR-PM (China), etc.**
    - **2020's in case of VHTRs ; NGNP (US), etc.**
  - **Mostly on National (or Governmental) Program Basis**
- **In Japan, however ;**
  - **No Commercialization Program, as of now, although R&D has been executed on national basis and taking an International Leadership, so far**

"HTR" Development Programs in the World

(Ref.; TWG-GCR-2005, HTR-2006, Internet, etc.)

("HTR"s = HTGR, VHTR, AHTR, etc.)

(Country) Program	Applications	Development Status (Operational Start)
(Japan) HTTR	Test/R&D	In Ope. ('98-)
(Japan) GTHTR300	Elec	Concept. Design
(Japan) GTHTR300-H,-C	H_2 or Elec/H_2, etc.	Concept. Design
(S.Africa) PBMR	Elec	Demo Reactor ('13)
(S.Africa) PBMR	Elec	Commercial Reactor (24Modules,-'20)
(S.Africa) PHP	H_2/Heat	Commercial Reactor ('16-)
(US) GT-MHR	Pu Burn/Elec	Concept. Design
(US) H_2-MHR	H_2	Concept. Design
(US) NGNP	Elec/H_2	Demo Reactor ('21)
(US) HT^3R	Test/R&D/Training	Concept. Design
(US) AHTR	H_2/Heat	Concept. Design
(Russia) GT-MHR	Elec/Heat	Demo Reactor ('20)
(France) ANTARES	Elec/H_2/Heat	Concept. Design
(Holland) ACACIA	Elec/Heat	Concept. Design
(China) HTR-10	Test/R&D	In Ope. ('00-)
(China) HTR-PM	Elec	Demo Reactor ('10)
(China) HTR-PM	Elec	Commercial Reactor (18Modules,-'20))
(India) CHR	Elec/H_2/Heat	Concept. Design
(S.Korea) NHDD	H_2	Concept. Design



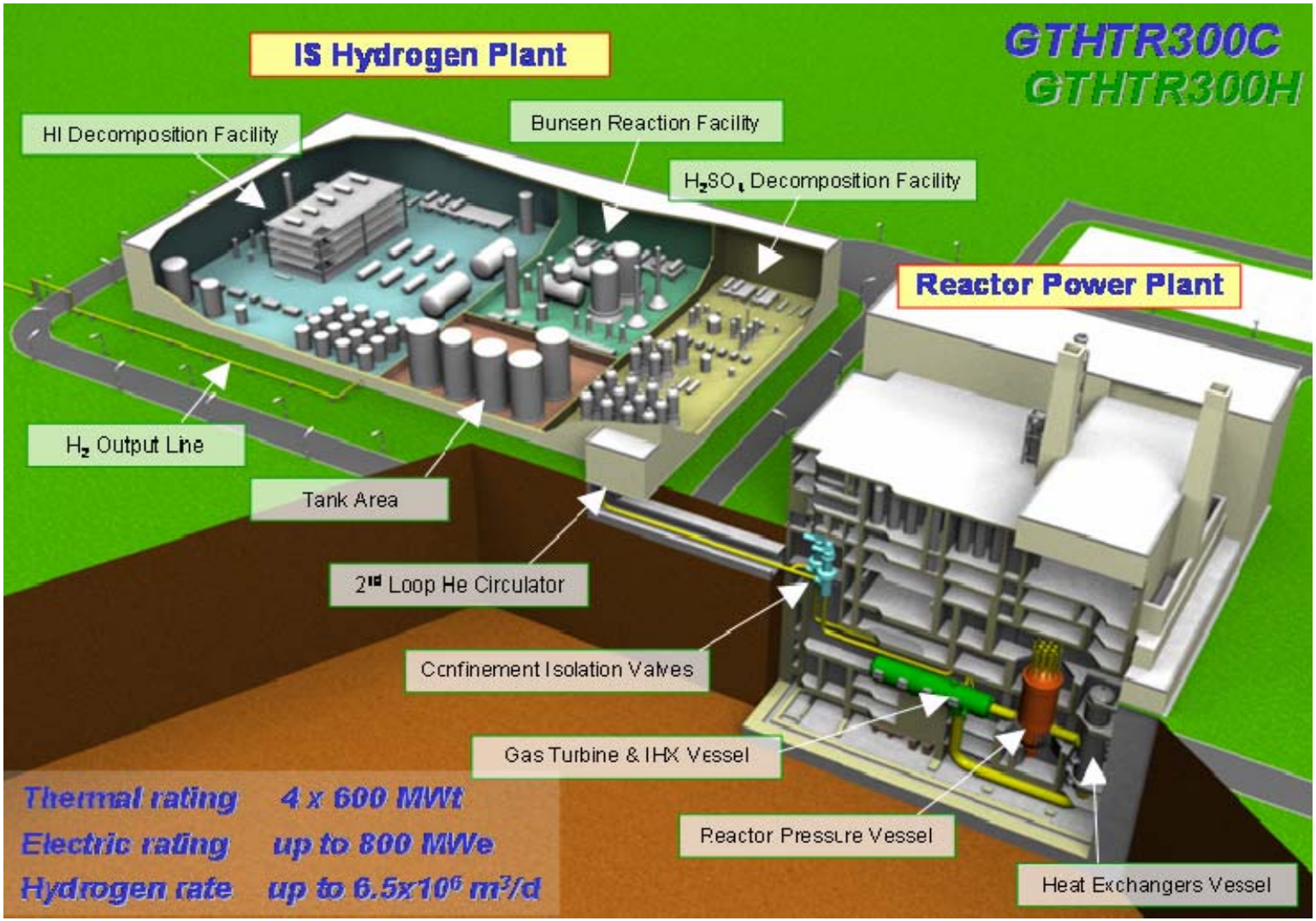
HTR (HTGR, VHTR, AHTR, etc.) Development in the World

● : Test Reactor in operation, ◎ : Demonstration Reactor Program,
○ : Commercial Reactor Program, □ : Conceptual Design Study

Nuc. H't Application Programs or Proposals using HTRs

(Ref.; HTR-2006, Johannesburg, COE-INES THEN-2, 2006, Tokyo)

(Country) Organ	Program	Applications
(Japan) JAEA	GTHTR300 -H,-C (HTGR)	H_2, Co-generation (such as Elec./H_2 Production)
(Japan) JGC	HTGR	Oil Sand Reforming
(Japan) ARTECH	HTGR	Process Heat
(S.Africa) PBMR	PHP (HTGR/VHTR)	Coal Gasification/Liquefaction, N. Gas Reforming, H_2 Production, --
(US) GA	H_2-MHR (VHTR)	H_2 Production
(US) DOE	NGNP (VHTR)	Elec/H_2 Production
(US) ORNL	AHTR	Oil Sand Reforming, H_2 Production, Others
(Holland) NRG-Petten	ACACIA (HTGR)	Process Heat (Co-Generation)
(India) Indira Gandhi Res.Inst.	CHR	H_2 Production, Others (Coal Gasification/Liquefaction)



HTGR Plant for Hydrogen Production or Co-generation; (GTHTR 300H or 300C)

(X. Yan（JAEA）; HTTR H_2 Workshop, Oct.5-7, 2005, Oarai, Japan)

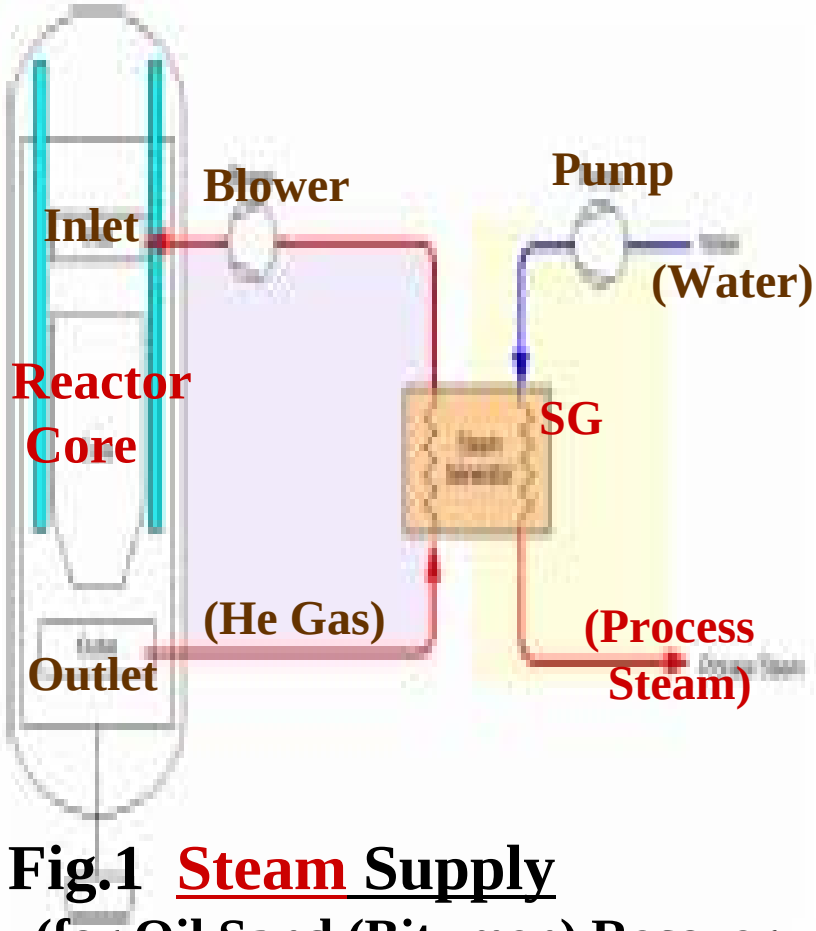


Fig.1 Steam Supply
(for Oil Sand (Bitumen) Recovery /Reforming Industry)

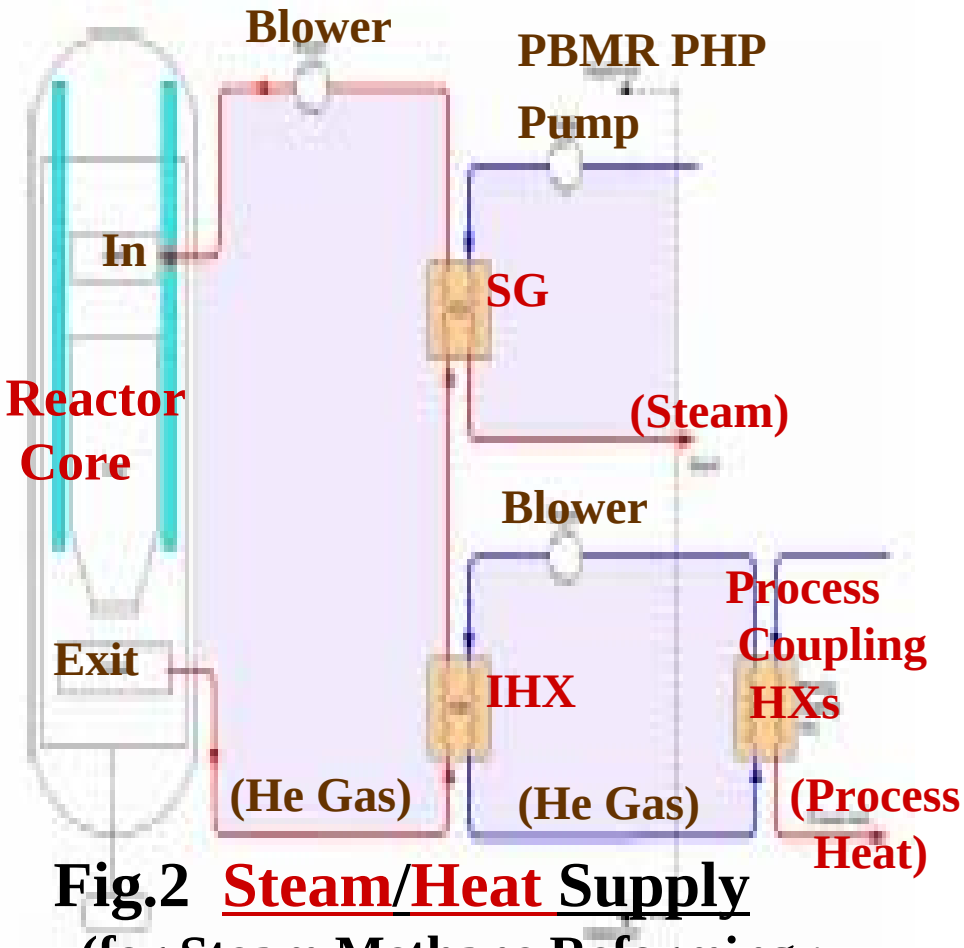


Fig.2 Steam/Heat Supply
(for Steam Methane Reforming ; Syngas (Hydrogen, Ammonia, Methanol) Production)

Various Heat Applications by HTGR (ex; PHP)（1/2）

(W. Kriel, et al (PBMR-US), HTR-2006, Johannesburg, S. Africa)

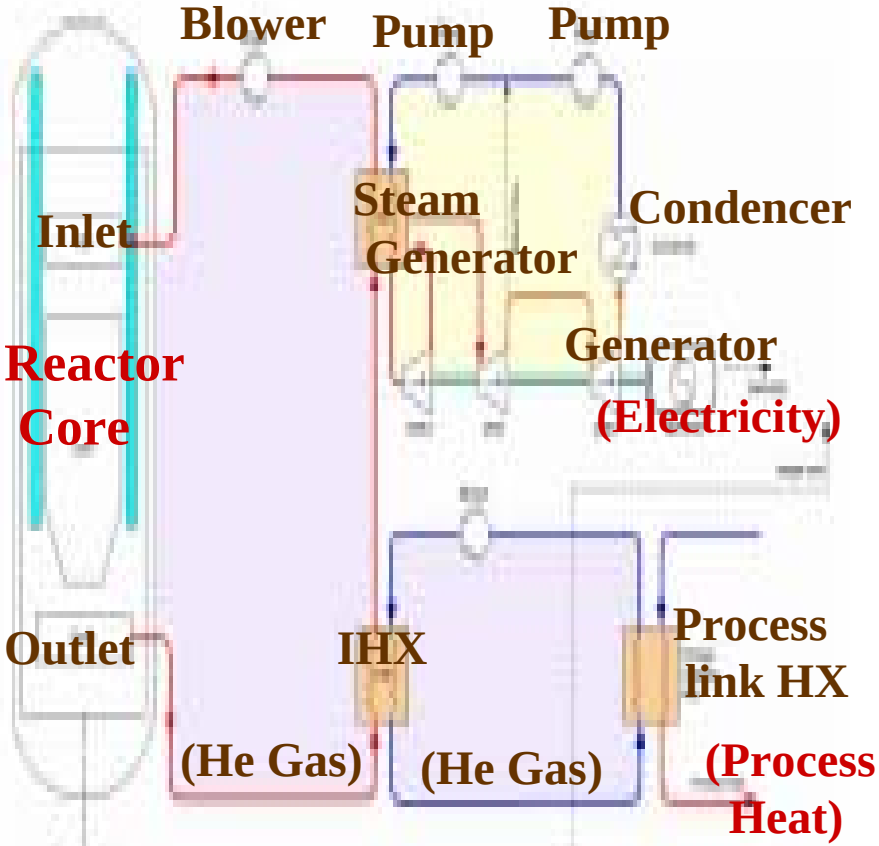


Fig.3 Electricity/Heat Supply

(for HyS Process Water Splitting ; Hydrogen/Oxygen Production ; Coal Gasification/Liquefaction)

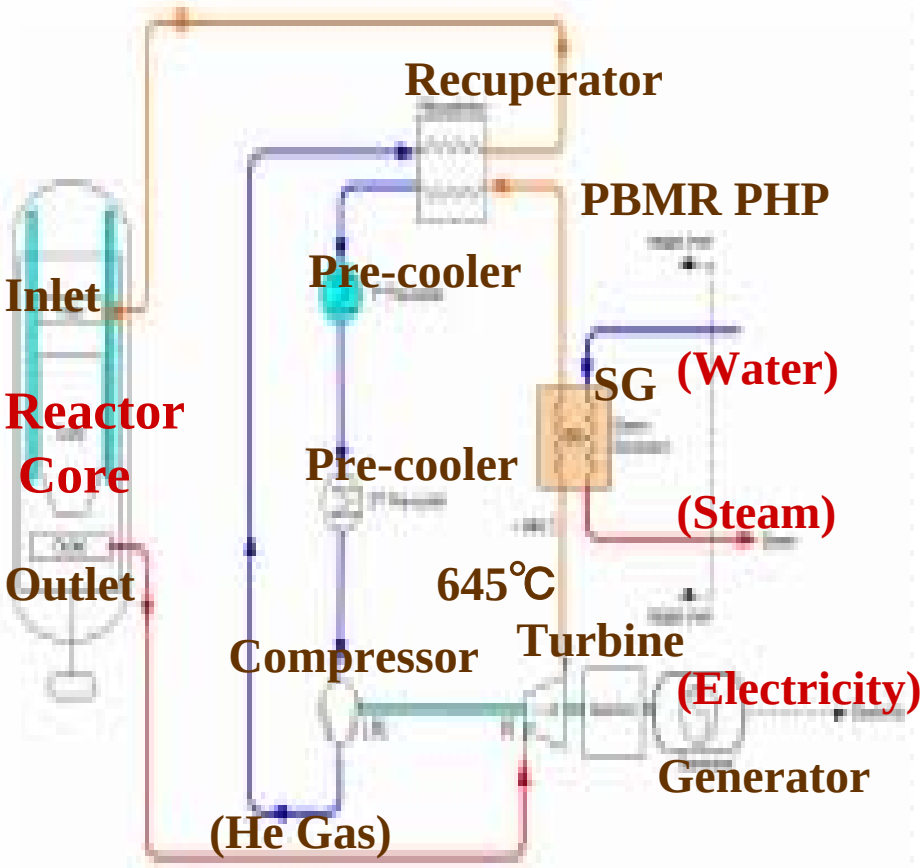


Fig.4 Electricity/Steam Supply

(for Petrochemistry, Oil Sand Industry)

Various Heat Applications by HTGR (ex; PHP)(2/2)

(W. Kriel, et al (PBMR-US), HTR-2006, Johannesburg, S. Africa)

FCV: **Honda FCX（FCV）**

Trailer: **Honda FCX（FCV）**

Jet Plane: **A310 Airbus（H_2 Fuel）**

Rocket: **2nd Stage Saturn 5（H_2 Fuel）**

Hydrogen Powered Vehicles

(file:///C:/Documents%20and520Settings;
A magazine article about the Ford P2000, etc.)

4. Economy

- **Economy of Nuclear Heat Applications by HTGR**
  - **based on the economy of HTGRs for Electricity Production**
- **Targets of PBMR (S.Africa) and GT-MHR (US/Russia);**
  - **less than 1,000 $/kWe and 1-2 cents/kWh on N-th Module**
- **User's Requirements (Japanese Industry);**
  - **less than 2,000 $/kWe and 4 cents/kWh on N-th Module**
- **Estimates of GTHTR300 (JAEA)**
  - **less than 2,000 $/kWe and 4 cents/kWh on N-th Module**
- **Depends on Heat Application System ;**
  - **Hydrogen Production, Coal Liquefaction, or Steam Supply, -- ?**
  - **Performance and Cost of Key Components**
    - **Heat Exchanger for Process Heat Supply, for example**
- **The higher the costs of Coal, Oil and Natural Gas, and the greater the number of HTGR modules in Production, the lower the cost of HTGRs and Nuclear Heat Applications**

5. Positioning of Hydrogen by HTGR in "Hydrogen Society"

- **RAHP committed a Research Study on "Adaptability of Hydrogen by HTGR to Hydrogen Society" to Hydrogen Specialists of The Institute of Applied Energy (IAE), for independent Review (2006)**
- **Reviewed on ;**
  - **Very Long Term（up to 2100）Energy Technology Vision**
  - **Roadmap of Hydrogen Commercialization in Japan**
  - **Costs of Nuclear Hydrogen (Production, Refining, Transportation, and Service Station)**
- **Main Results obtained ;**
  - **HTGR Plant can supply Hydrogen to Fuel Cell Vehicles (FCVs) competitively with Current Gasoline Fuel, and the Hydrogen can become cheaper, due to its Environmental / Taxation Effect in Future**

6. Recognition by the Industry

- **The Industry is very interested in and watching on Development Status or Trend of HTGRs and Heat Uses**
- **Certain Part of the Industry is recognizing, in general, that ;**
  - **Such HTGR Plants are desirable to be commercialized world wide, from View Points of Energy Security, Economy and Global Environment ;**
    - **Expansion of Nuclear Energy Applications**
    - **Remarkably Enhanced Energy Utilization Efficiency**
    - **Clean Energy Supply, and "Hydrogen Society" in Future**
      - **Electricity, Hydrogen, Oxygen, Heat and/or Steam**
    - **"*Synergy*" between "*Nuclear*" and "*Fossil*" Fuels (Coal, etc.)**
    - **Plant Exportation**
    - **Japan's Role (Current and Future)**
  - **Such HTGRs should be positioned and developed towards Commercialization on "*National*" Basis, as seen in US, France, S.Africa, China, etc. , at least during the early Stage of Commercialization**

7. Proposals to the Government

- **The Industry have been made proposals to the Government on HTGR Commercialization, in 2000, 2001 and 2004, on ;**
  - **Review and Establishment of Strategic National Energy Program**
  - **Evaluation of "*HTGR Plant*" and "*Nuclear Heat Utilization*", and**
  - **Their Clear Positioning in the National Energy Program**
- **The Governmental Current Position (Framework for Nuclear Power Policy, Oct. 2003) is, nevertheless, that ;**
  - **Nuclear Energy is positioned as Main Source of "Electricity"**
  - **R&D of Innovative Technologies such as Nuclear Hydrogen Production is to be promoted from Long Term View Point**
- **Then, the Industry is preparing an Introductory Scenario or Commercialization Roadmap for Japan, for Exemplification and Acceleration**

8. Potentials of Hi. Temp. Nuc. Heat Applications in Japan

- **Recently, the Industry has exemplified several Potentials or Candidates of *"Future High Temperature Nuclear Heat Applications in Japan"*, as "*Introductory Scenarios*", as shown below ;**
  - **(1) "*Fuel Cell Vehicles (FCVs)*" Scenario**
  - **(2) "*Industrial Complexes (Kombinates)*" Scenario**
  - **(3) "*Hydrogen Towns*" Scenario**
- **They are considered to be newly arising from Global and Local Needs or Thinking for Improvement of Economy and Environment in Japan**
- **Based on their Needs, their Realizations are considered to be in 2020's-2030's**
- **Appearance of those Candidates or Needs in Japan will make above-mentioned Proposals as more practical and persuading ones in Near Future**

(1) "*Fuel Cell Vehicle (FCVs)*" Scenario

(Ref.; HTGR Future Deployment Study Committee Report, Mar. 2007)

- **Concepts**
  - **A Quantity of *Hydrogen* Production by *HTGR* Plant**
  - **Hydrogen Supply for Fuel Cell Vehicles (FCVs)**
- **Background & Needs**
  - **FCVs are under Development by the Government and the Industry**
  - **FCVs use a Quantity of Hydrogen**
  - **The Hydrogen can be produced in large scale by Nuclear, like HTGR Plant**
  - **The Government assumes that the Cars are to be "Electrified (EVs)" or "Hydrogenized (FCVs)" by 100% by 2100**
- **Timing of Introduction considered**
  - **In about 2020 in Small Scale**
  - **(2030 in Mid Scale, and 2050 in Large Scale)**

(2) "*Industrial Complexes (Kombinates)*" Scenario

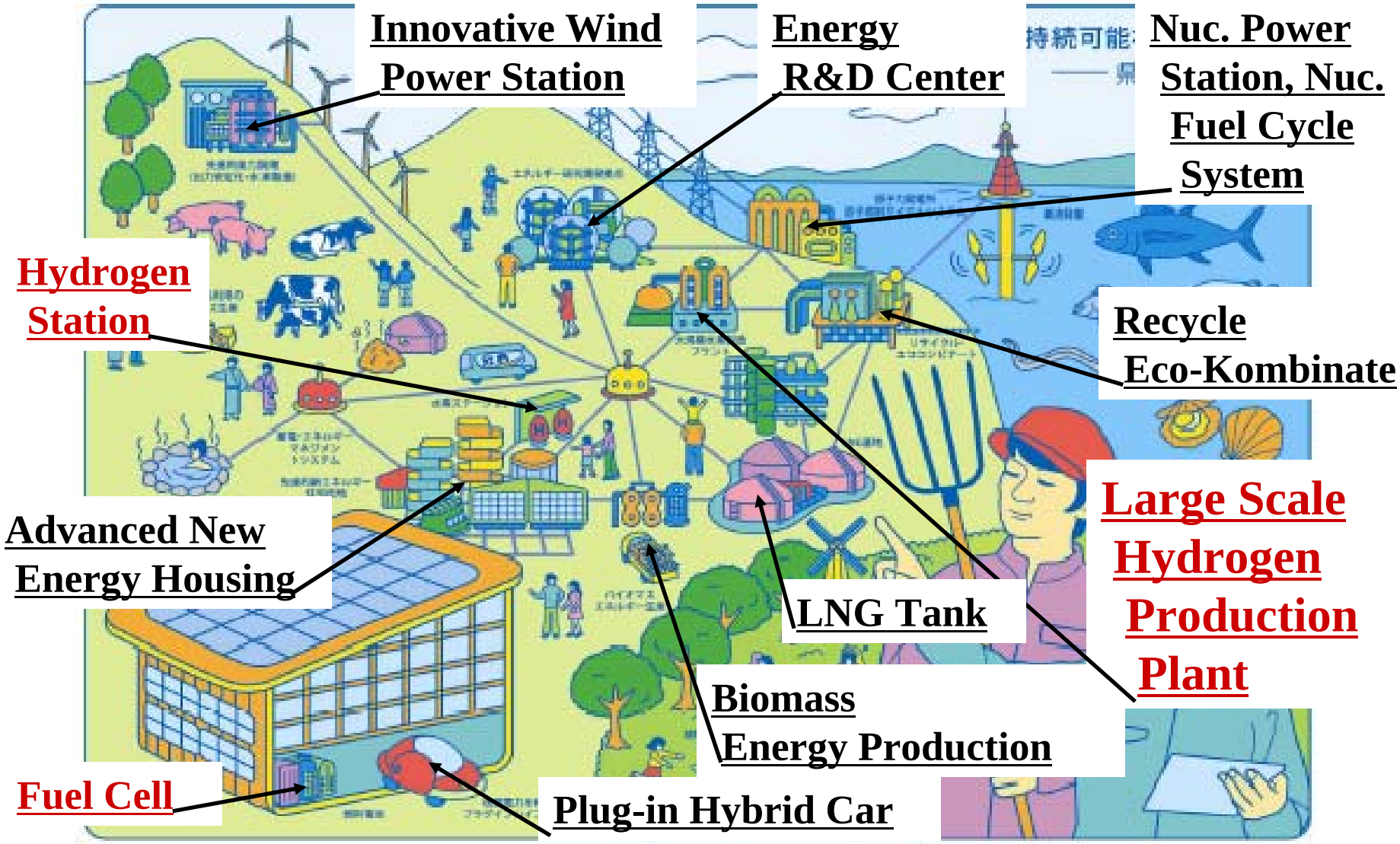
(Ref.; HTGR Future Deployment Study Committee Report, Mar. 2007)

- **Concept**
  - ***Replacement of Old Coal Fire Power Plants*** **by** ***HTGR*** **Plants**
  - ***Electricity***, ***Heat*** **and/or** ***Hydrogen***/***Oxygen*** **Production by** ***HTGR***
  - **Their Supplies to the Facilities in the Company or in the Kombinates, according to the Kind, Quality and Quantity of Demands**
- **Background & Needs**
  - **Coal Fire Plants in Industrial Kombinates in Japan, as shown below, are becoming old, and needed to be renewed one by one**
    - **Ibaragi, Tokyo/Chiba/Kanagawa, Osaka, Yamaguchi Pref., etc.**
  - **Strict Environmental Regulation by the Government**
  - **Electricity, Hi.Temp. Steam, and/or Hydrogen, etc. are needed in each single Facility or Facilities in the Kombinate**
- **Timing of such Renewal**
  - **In about 2020's in Small Scale, and 2030'S-2050's in Larger Scale**

(3) "*Hydrogen Town*" Scenario

(Ref.; HTGR Future Deployment Study Committee Report, Mar. 2007)

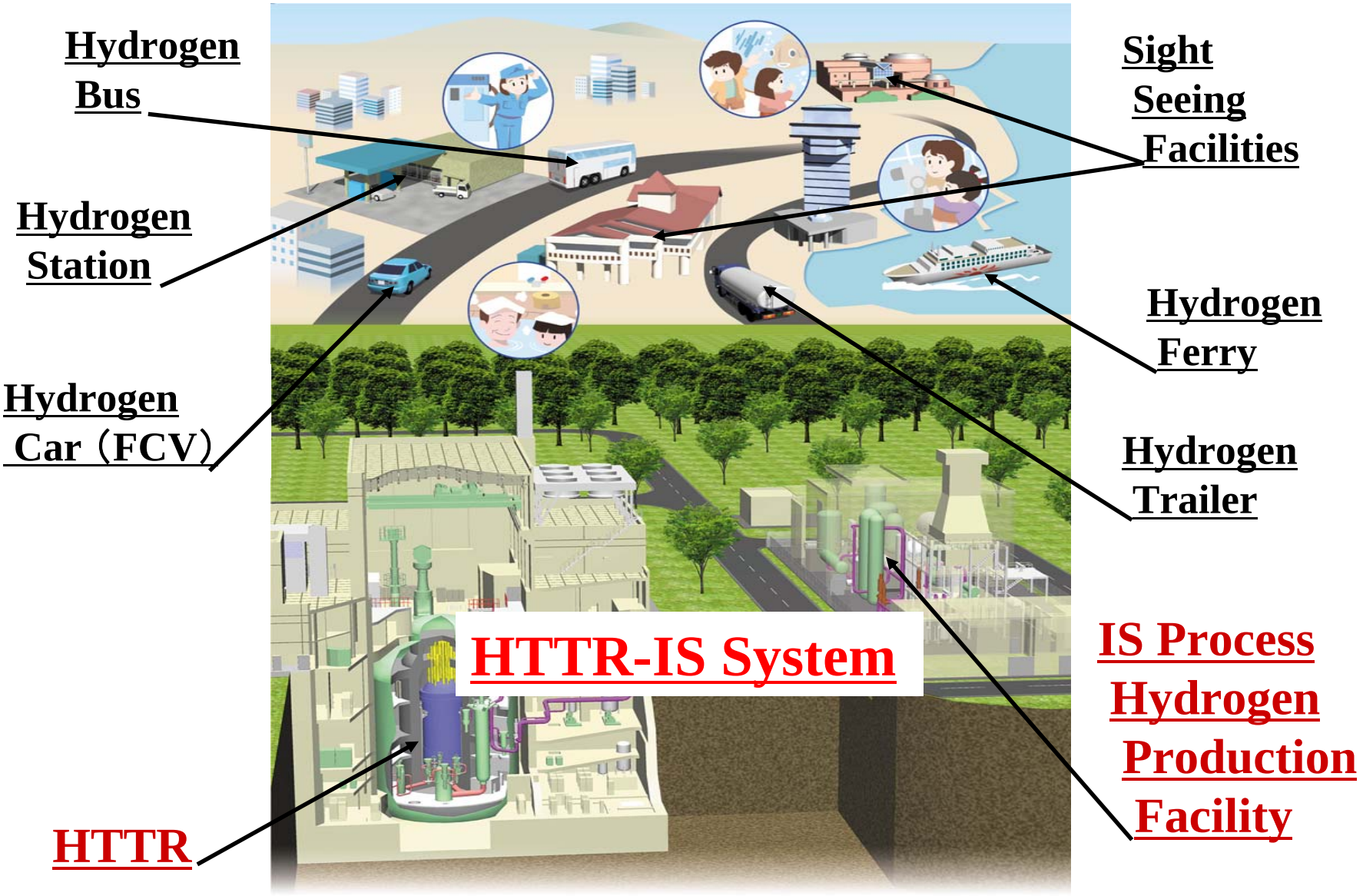
- **Concept**
  - ***Hydrogen*** **Production by "Wind", "Solar", "Geothermal"and/or "Biomass" (in near term), and by "*Nuclear*" (like *HTGR* Plant) (in longer term)**
  - **Hydrogen Supply to "Hydrogen Towns"**
- **Background and Needs**
  - **"Hydrogen Towns", "Eco-Towns"or "Industrial and Innovative Special Regions" are being proposed and planned to be established in Local Areas, such as;**
    - **Aomori, Ibaragi, Yamaguchi Prefectures, etc.**
  - **Aiming at Development and Establishment of Energy-independent, Environmentally Friendly and Re-vitalized Towns or Prefectures**
  - **Hydrogen is to be used for Transportation (Cars, Buses, Ferries, etc.), Housings, etc.**
- **Timing of Introduction considered**
  - **In about 2020 in Small Scale, and 2030-2050 in Larger Scale**



Hydrogen Town (Image 1)

(One of Images of Aomori Type Sustainable Society)

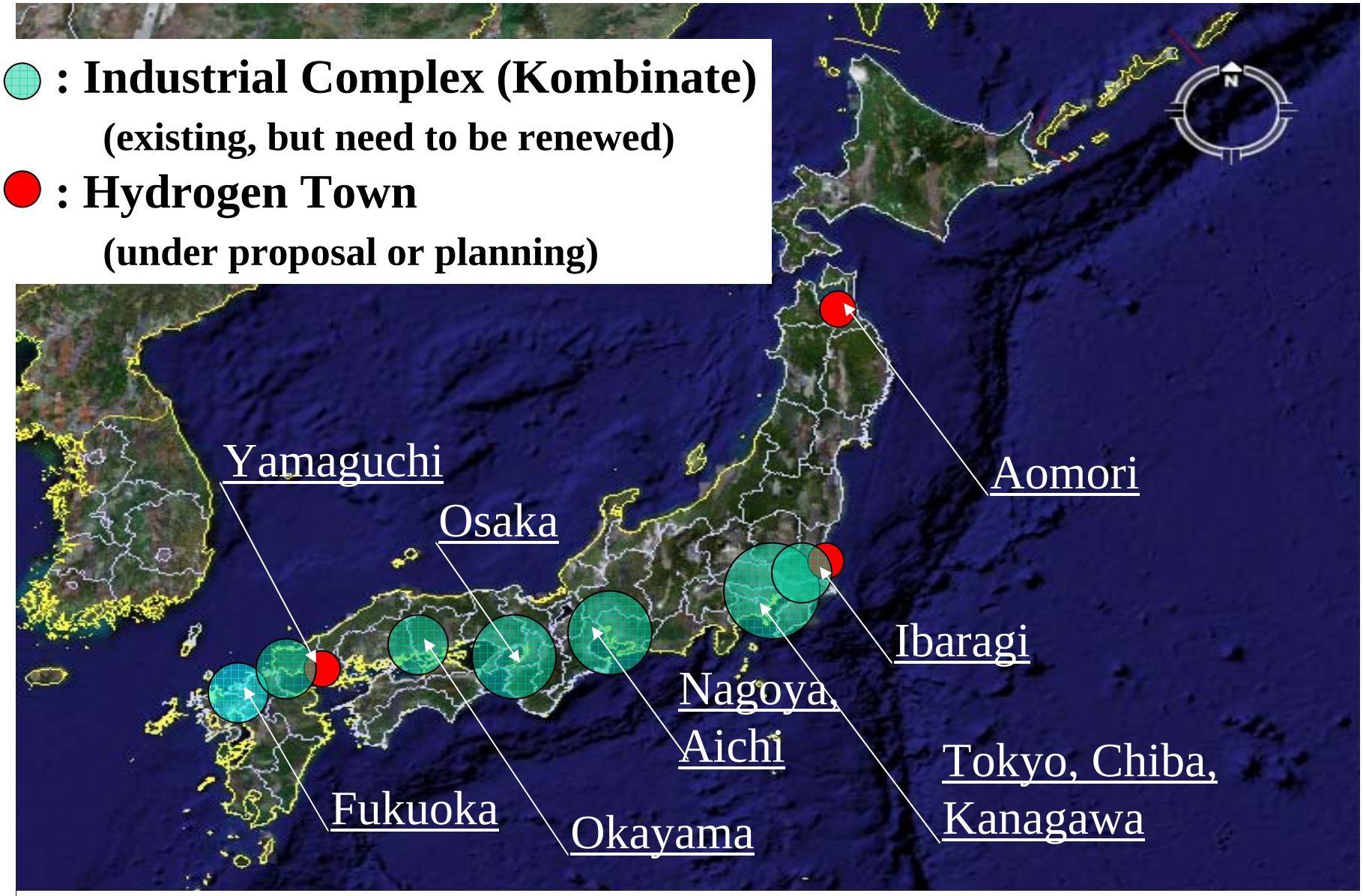
(S. Mimura; "Aomori Pref. Mutsu-Ogawara Energy Industry Promotion Forum", Feb.23, 2007, Tokyo)



Hydrogen Town (Image 2)

(Model ; Oarai Town, Ibaragi Pref.)

（Monthly “Energy”, Vol. 39, No.6, 2006 (in Japanese))



Potential Sites for Hi.Temp.Nuclear Heat Applications in Japan (Heat, hydrogen, oxygen, steam and/or electricity)

9. Summary and Conclusion

- **Japanese Industry has long been studying, investigating, evaluating, developing, participating and/or proposing on the Nuclear Heat Applications, of Hi. Temp.s in particular**
- **HTGR Plants are considered very suited for such Applications, and many R&Ds and/or Commercialization Programs are in Progress in the World towards 2010's-2020's**
- **In Japan, R&D has long been executed so far, but as of now, No Commercialization Programs**
- **The Industry, however, has recently exemplified several Possibilities or Candidates for such Applications in Japan**
- **For solving the Problems of Energy Security and Global Environment, Cooperative and Strategic Efforts should be pursued, Locally, Nationally and Internationally**
- ***Japanese Government* and *the Industry* have Key Roles in this Field**

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