Fuel Cell and Hydrogen for the Sustainable Future

Market and Application For PGM Potential

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CEO HyWealth CO.

Invited Prof. International Institute for Carbon Neutral Energy Research, Kyushu University

Dr. Prof. Katsuhiko Hirose

Lucky Engineer involved two big innovations of automotive technologies

- 39year worked as an engineer and planner at Toyota Motor Corporation Japan
- Developed innovative power trains and initiated several government- Private infrastructure partnerships such as German H2Mobilty, Uk and US.
- Initiated Hydrogen Council and was responsible for the many study report.
- Still promoting the hydrogen toward the sustainable low carbon society

- Currently CEO& Chief Consultant HyWealth CO.
- WPI Visiting Professor International Institute for Carbon Neutral Energy Research Kyushu University

- HyWealth CO. helping company to move ahead with hydrogen

What is my role in this conference

Talking about future role of PGM in the Hydrogen society and update of hydrogen society

Any influence for PGM application

15 years ago at Kyoto

- Soon or later diesel will be an issue in term of environmental

- VW diesel gate terminate the ICE diesel future and accelerate BE

- **5year ago at SFA**
  - Decrease of ICE
  - ZEV need both BEV and FCV
  - PGM role will be important for FCV and electrolyzer and electro-chemical process
  - BEVs gaining against FCVs (Passenger Cars)
  - FCV is gaining expectations for Commercial vehicle

Today

- 100 % BEV solution is doubtful
- Electrification and hydrogen are both necessary
- Huge role of PGM remains for the both automobile and energy production such as electrolyzer
- FCVs increase after hydrogen energy implements into the society
- ICE remains some roles in heavy duty together with synthetic fuel and hydrogen
- Electro Chemical Synthesize is getting more role of PGM

Is Hydrogen dead for the future mobility race ?

Hydrogen is dead

1. BEV is already occupying the market no space for late comer
2. Battery is getting cheaper FCV is more expensive
3. Hydrogen efficiency is not better than BEV

No It is alive and comes a bit later

1. Delaying due to the lack of infrastructure for mobility
2. Performance such as range charging Speed, and conveniency is superior than BEV
3. Commercial us is fur better than the BEV (Heavy , less cargo capacity)

BEV and Hydrogen need infrastructure
Low carbon society need both soon or later

Only a matter of time
BEV adaptation can be earlier, and Hydrogen comes a bit later
We need both

ICE elimination

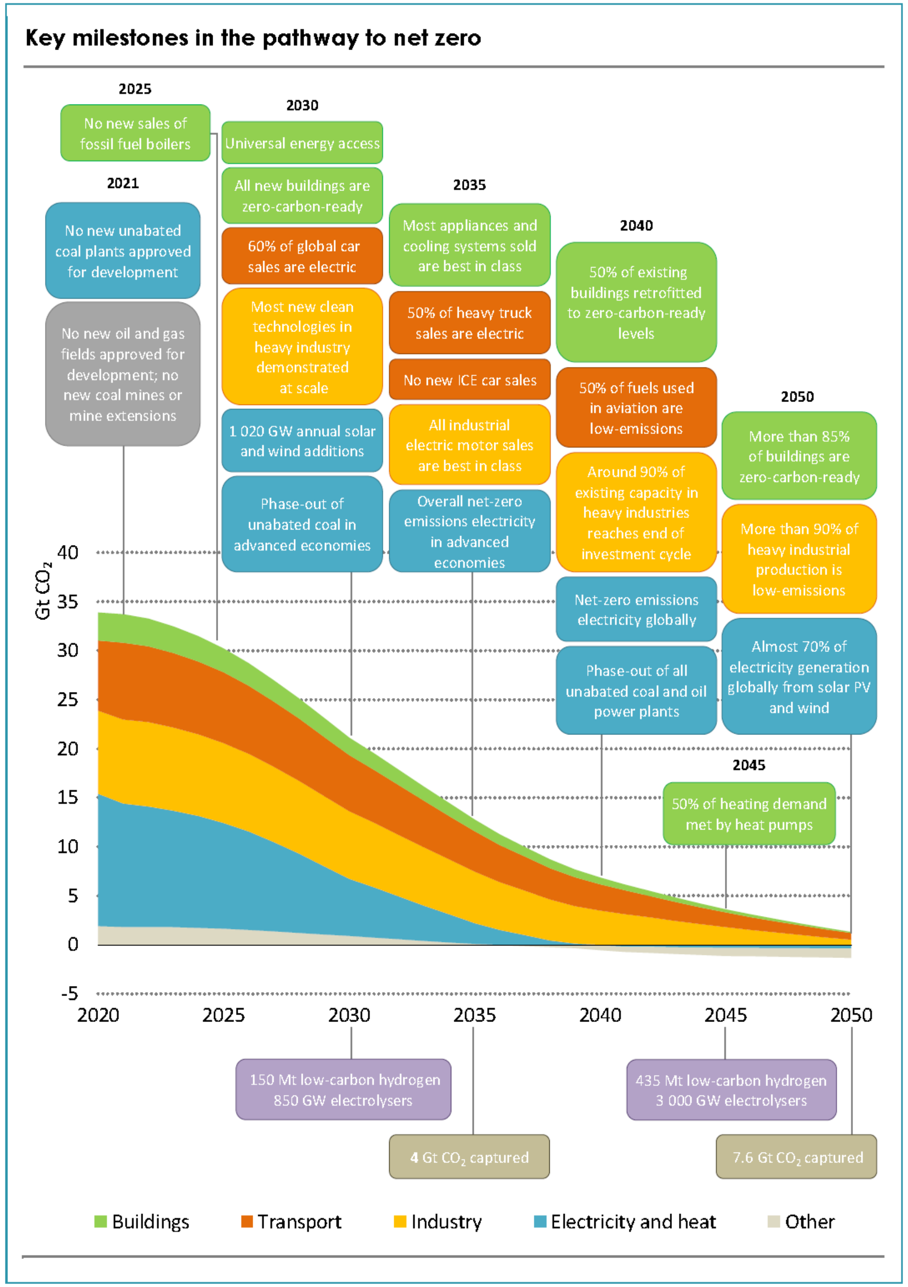
Came from IEA back casting from 2050 goal

Are there any solutions?

2035 no new ICE car

Because of average life of use in the market is 15years

Time line may be delays
But no other solution yet



Our Goal

Objective of hydrogen society

- De-carbonization X
- Net Zero Society X

- Sustainable society
- Sustainable economy
- Sustainable JOBs
- Sustainable Energy System

- With RE and Electricity, Hydrogen

Hydrogen contributes to energy, the environment, and economic activities

Slide changed the world

Estimated impact in 2050

1 Value add of fuel cells

SOURCES: Hydrogen Council, IEA ETP Hydrogen and Fuel Cells CBS, National Energy Outlook 2016

Hydrogen Infrastructure Worldwide

Exhibit 14

Hydrogen refueling infrastructure deployment continues to accelerate in China and South Korea, but appears to be stagnating in Europe and North America

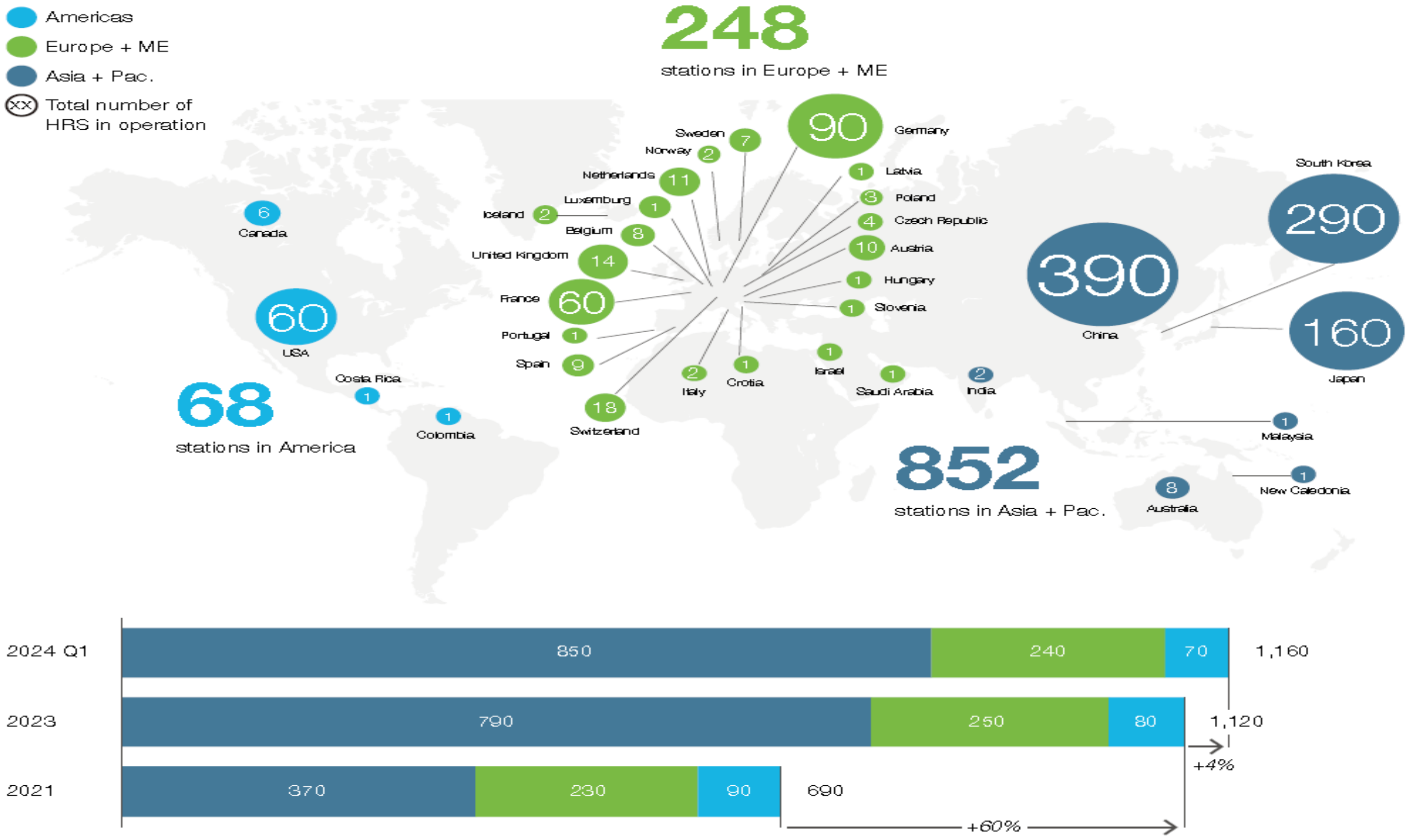
More than 1,150 hydrogen refueling stations are now operational globally, with deployment growing by 65% from 2021. China, Japan, and South Korea are the largest markets exceeding 850 stations in total, followed by Europe with around 250 stations. In Europe and North America, there has been a downward trend for hydrogen refueling stations the previous year, with a decline in number of operational hydrogen refueling stations of about 10% and 40% respectively.

The number of hydrogen refueling stations could grow if ambitious government targets are realized. South Korea and Japan plan to expand their networks to more than 600 stations each through 2030, which could double the number of stations in Asia. In the EU, the recently adopted Alternative Fuels Infrastructure Regulation (AFIR) will require the deployment of a hydrogen refueling station every 200 km along the Trans-European Transport Network (TEN-T), corresponding to more than 400 stations through 2030.

Sales of hydrogen-powered vehicles correlate geographically with the roll-out of hydrogen refueling infrastructure. South Korea and Japan continue to lead in light hydrogen-fueled vehicles (about 65% of current light vehicle fleet), and China in the global hydrogen truck and bus market (about 95% and 85% of each respective market). Heavy hydrogen-fueled vehicles, especially trucks, are gaining momentum. This is reflected in the number of hydrogen-fueled bus and truck models exceeding 130. As the hydrogen-fueled vehicle park could potentially transition toward heavier vehicles, requiring higher refueling station capacities, existing stations might require expansion and adaptation. Additional hydrogen refueling infrastructure might be needed for off-road mobility such as rail and inland shipping.

While most hydrogen-fueled vehicles continue to be fuel cell electric vehicles (FCEVs), there is ongoing development in hydrogen combustion powertrains.

Hydrogen refueling stations



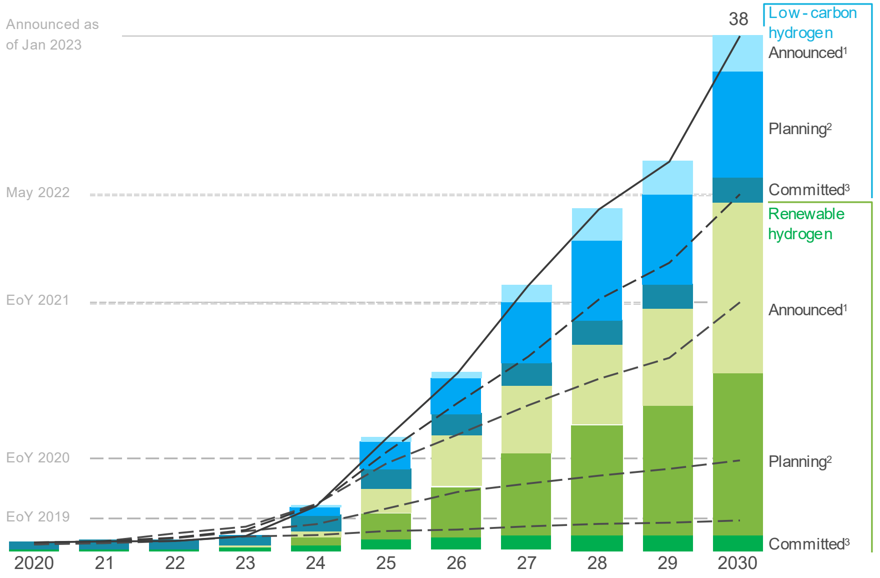
Source: h2stations.org; iphe.net, Press research announced, Mt p.a.

Hydrogen Hype around the world

Hype

Accelerated

green Hydrogen



>70%
share of capacity in top 3 markets (Europe, North America, Latin America)

+16 Mt
additional capacity (low-carbon and renewable) announced for post-2030

1. Preliminary studies or at press announcement stage
2. Feasibility studies or at front-end engineering and design stage
3. Final investment decision has been made, under construction, commissioned or operational

Source: Project & Investment tracker, as of Jan 31, 2023

Hydrogen in the Transport

Zero Emission Vehicles　Trend in the world

Passenger

- Small passenger
- Midsize-large size passenger

Commercial Vehicles

- Light Duty
- Heavy Duty

Other

- Bus
- Train
- Marine
- Aviation

- BEV
- BEV＋FCEV

- BEV＋FCEV
- FCEV

- BEV+ Hydrogen FCEV
- E-Train＋Hydrogen　FCEV
- Hydrogen＋Ammonia (LH2 for cruise ship)
- E-Fuel（DAC＋H2）、Hydrogen

Notice
Above are trend in northern countries
We need to design the transport for
Relatively Hot region such as Malaysia, India, Indonesia and　GCC

Zero Emission Transport

Source Airbus

Source Alakai-Technologies-Corporation

Source Toyota Motor

Source Nikola Motor

Movement　Collaboration for Hydrogen Society

Toyota Motor Corporation and BMW Group Strengthen Collaboration Towards the Advancement of a Hydrogen Society
Aiming to expand the lineup of fuel cell passenger cars, Toyota and BMW are jointly developing third-generation fuel cell system and working on infrastructure development co-creation

1.
The two companies will provide a wider range of options to customers by equipping more passenger cars with fuel cell systems.

2.
Establishing sustainable hydrogen supply networks

From Toyota/BMW press release

Heavy Duty Truck FUEL CELL Powered

TOYOTA HINO

Hyundai

DAIMLER TRUCK

Bosch

Picture From Press Release of each company

New Scheme

600 FCV Taxi in Tokyo

TOKYO H2

Hydrogen ICE Solution or Gimmick?

- **Passenger Car**
- =>   Limited Efficiency and limited Tank space
- Limited Range and Exhaust Emission

Not very practical => Fuel Cell preferable

- **Heavy Duty Commercial Truck**
- Marine
- Aviation

New Technologies Necessary
such as Liquefied Hydrogen Tank
LH2 refueling
Light Weight Tank

Big Potential

- Many projects are stand still
- Despite of strong swing back from Hype to reality

- Hydrogen and electrification with Renewable Energy are the still only solutions for the sustainable future

Surroundings about hydrogen

Before

- Cost Competitive
- Demand High
- Projects huge number

Now

- Cost Expensive
- Demand weak
- Projects Few FID

Construction of new infrastructure is a heavy obstacle for the cost of new energy such as hydrogen

Hesitation of investment due to the high cost of construction
Demand side are also hesitated to promise the amount of use

Delay of standard and holistic incentive

Japan

1. Government implemented (Hydrogen Society Promotion Law)
2. Gov. will fill in the gap between the hydrogen and fossil fuel for 15-year span
3. Hydrogen implementation is slower than expected vehicles, power generation,
4. Many projects are about to finalize to bring foreign hydrogen and ammonia to Japan
5. Some new ideas such as use of Northern wind to generate hydrogen and bring by pipeline are under discussion

General

Government is steadily pushing forward, and industry are moving but cost is getting more serious issue since production cost in Australia, Middle east are getting very high.

World

USA

- IRA attracted most of the resources about hydrogen because of the 3$/kg incentive is so strong
- Trump adm. is killing many projects except already starting implementation

Europe

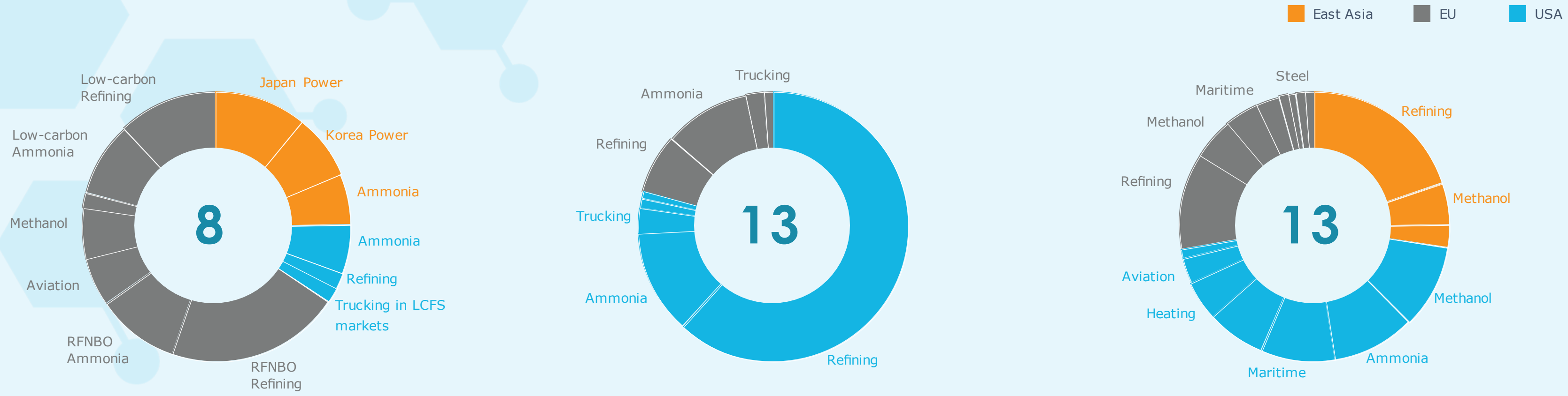
- Europe targeted dreaming figure of 40GW hydrogen at 2030
- Delaying due to the budgetary struggle with the military expense increase
- Steady progress for building infrastructure

Current status of Hydrogen projects around the world (from the Hydrogen Council report)

Executive summary (2/2)

Three segments comprise 34 Mt p.a. of total potential 2030 hydrogen demand in the EU, US and East Asia[6]

Hydrogen demand split by end-use, segmented by current viability of adopting clean hydrogen, 2030, Mt p.a. H_2e



Seizing Low-Hanging Fruit: Clean demand supported by current policies

Existing policy initiatives in these regions could enable the uptake of

(8MT hydrogen projects will be proceed under the current regulation and cost progress)

co-firing of clean ammonia in the power sector.

Bridging the Gap: Clean demand enabled by feasible infra-structure scale-up

Some ~13 Mt p.a. of clean demand, largely in existing industry, could be

(13MT hydrogen projects will be accelerated under the IRA)

for end uses in this segment.

High Stakes, High Rewards: Clean demand where few alternatives exist

(13MT hydrogen projects will be proceed with the progress of infrastructure prepared)

some of the largest demand segments long term.

6. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8°C warming scenario)
7. Including capture equipment, transportation pipelines, and storage infrastructure

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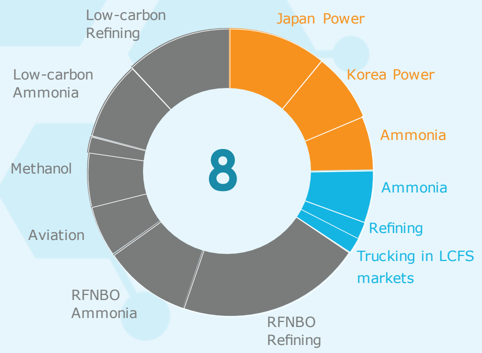

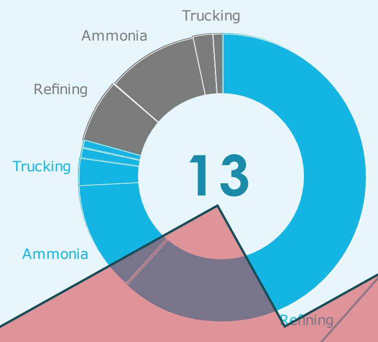

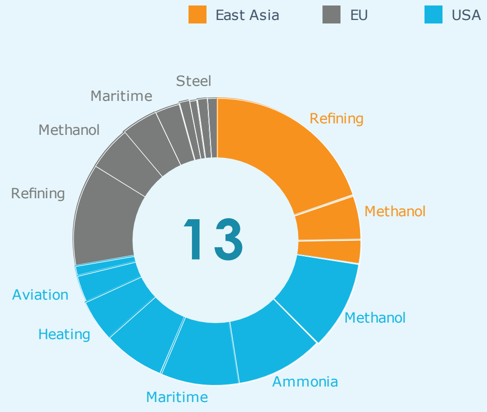

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Energy Transition

- **Climate Change**

- **Energy Security**

- **Actions**
- **to prevent the Unfavorable future**
- **Investment create Favorable Future**

Lessons from the past

Successful examples of the energy transition

Introduction of LNG in Japan

項目	Japan	US	Europe
Pre oil shock reliance for oil	77%	45%	60%
1973 Oil shock policy	Increase LNG、Energy saving	Stock release Price control	Coal and Atomic Stagflation
1979 Second Oil shock	Minimum influence(Due to increase LNG)	High Gas price Economic damage	Slowing economic growth 、Rising unemployment rate
1990 Oil reliance	50%（LNG・Nuclear shift）	40%	45%

- **Energy situation in Japan**
- Large-scale introduction of LNG since the 1970s
- Relatively mitigating the impact of oil shocks
- Energy situation in the U.S. and Europe
- High dependence on oil
- The economy was hit hard

Successful energy shift in Japan

From oil to LNG

Made the Japan's miracle through thr oil shock

year	Main Topic	LNG Import (Mt)	LNG Price ($/MMBtu)	Oil price (WTI, $/BBl)	LNG-Oil ratio (LNG/Oil Price)
1969	First import from Alaska	0.5	0.50	1.80	0.28
1973	First oil shock	3.1	1.00	11.65	0.09
1980	Second Oil Shock	14.4	4.00	37.42	0.11
1990	Expansion of LNG power generation	31.8	3.50	23.73	0.15
2000	Liberalization of natural gas	50.2	5.00	30.38	0.16
2011	Nuclear power plant shutdown → the Great East Japan Earthquake	78.5	16.50	94.88	0.17
2014	LNG Imports Peak	89.1	18.00	93.26	0.19
2020	Decarbonization policy, Corona disaster	74.4	9.00	39.68	0.23
2023	Energy Crisis (War in Ukraine)	71.9	20.00	77.58	0.26

Why Japan’s energy transition/shift was successfully done through oil shock 1960-80

1. Strong will to prevent war, based on the experience Japan was force to start war because of oil embargo in 1939

-> need self controllable energy source

Share the Common philosophy

2. Common view of long-term steady energy toward the more expensive energy
3. LNG was 4-5times more expensive than oil

=> Utility total cost system cover the difference later oil shock accelerated transition (Time followed)

Systematic incentive

4. Strong leadership both politics and industry lead this decision

Narrative for the people

Energy Transition

Preparation to Prevent the unhappy future (War, Climate change ,,,,)

Investment to create the favorable future

Discussion

Who pays for the infrastructure of the future?

- **Clarification of why hydrogen is added**
  - Global Warming Countermeasures: Environmental Costs?
  - The energy transition will be an asset of the future: an investment for the future wealth, not an expense
  - ## Preparing for a future that you don't want to happen
  - Global warming is progressing, and disasters are increasing
  - Soaring import prices make life difficult
  - (There is a possibility that exports will decrease, so in that case, import prices will rise even more, putting pressure on people's lives.)
  - The next generation will continue to use 1/3 of trade for energy imports (negative legacy to children)
  - ## Investing in the future we want to happen
  - Incorporation of the energy economy (a society in which the more energy is used, the better the economy)
  - Stabilization of energy costs and domestic industrialization

Who should pay

The economic effects of infrastructure construction will be felt by the current generation

→ the more expensive infrastructure you build, the better the economy will be.

The high cost of hydrogenation should be paid by the current generation

The next generation will be able to use inexpensive hydrogen with the convenience of infrastructure utilization, and at the same time receive employment and economic benefits.

Idea: Decarbonization fund: Hydrogen pipeline, bought by the current generation with government bonds, etc., and given to the next generation

Lesson Learned from successful fuel shift from Gas to HEV

Successful Incentive " Money or Non - Monetary"

- BEV incentive success or fail — money — **Fail**
  - US Europe money incentive decrease -> BEV sale decrease
- HEV incentives in California — NON money — **Success**
  - Nonmonetary HOV lane drivable Huge SUCCESS
- BEV incentive in China
  - Big monetary incentive for Manufacturers Create strong hype to collect finance sector to push development — money — **Success**
  - Number plate selection for BEV Create huge market especially rich metropolitan area user — NON money — **Success**
  - Money incentive for passenger cars => decrease sale after incentive decrease — money — **Fail?**
- ZEVE Mandate regulation
  - CA ZEVE mandate success both regulation and money flow creation — NON money — **Success**

Success related to the long-term registration and funding mechanism rather than immediate money incentives

PGM’s role

Passive (Catalyst for after treatment) to Proactive Role to produce material and function

Effective conversion
and produce material

PtX

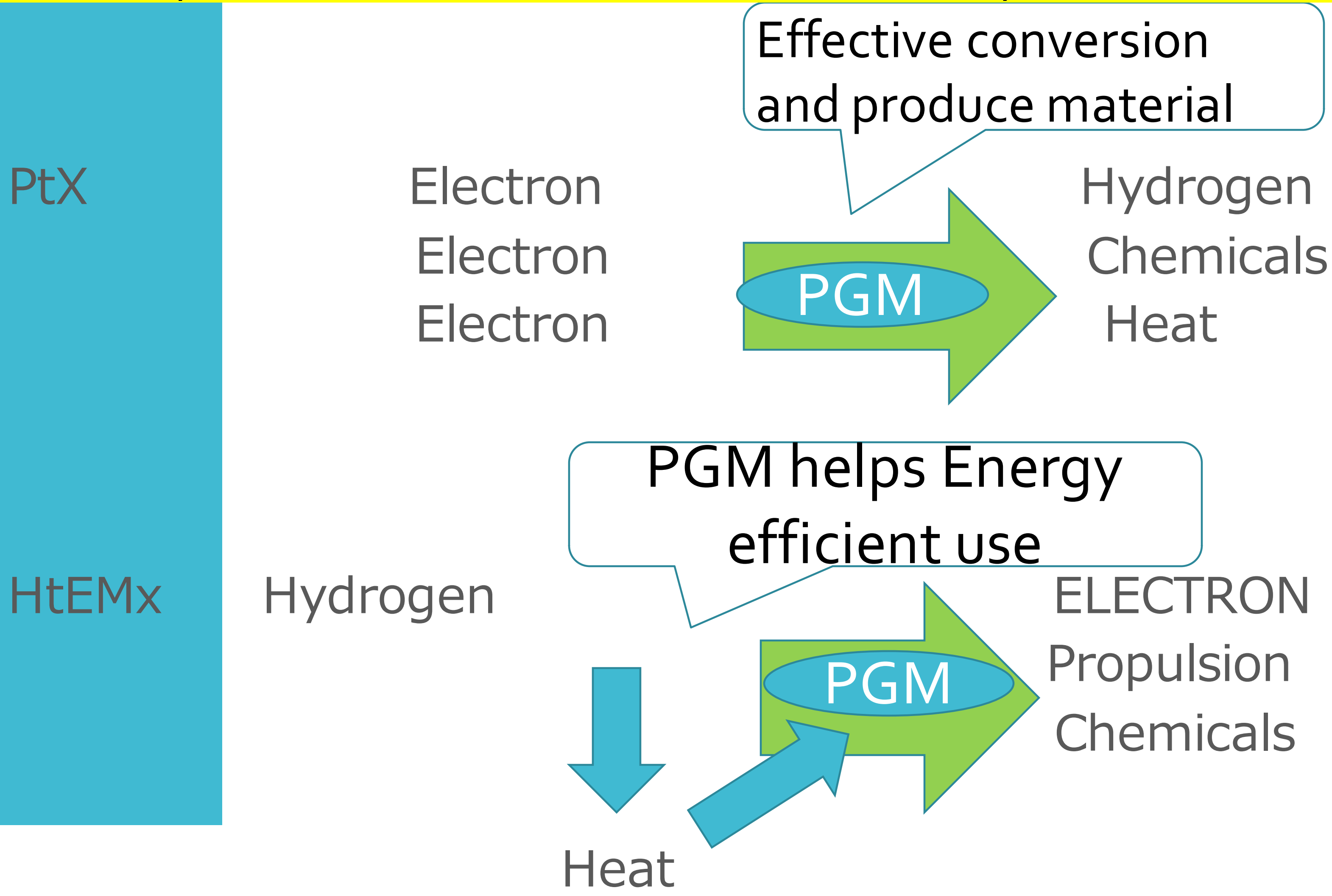
Electron
Electron
Electron

PGM

Hydrogen
Chemicals
Heat

PGM's role

Passive (Catalyst for after treatment) to Proactive Role to produce material and function



Conclusion

- **Environment**
  - Hydrogen is facing the serious implementation barrier in cost and huge investment for the infrastructure
  - Green hydrogen is getting more expensive due to the inflation and infrastructure building cost
  - Europe is steadily investing infrastructure such as hydrogen pipeline and logistics
  - US is losing big advantage of IRA incentive(3$/kgH2) but back to normal business
  - JPN is implementing hydrogen promotion act and go long term planning to build infrastructure for hydrogen

- **Fuel Cell progress**
  - Fuel Cell technologies are steadily progressing for many applications
  - FCVs implementation is fur behind BEVs in passenger cars but gaining in large commercial vehicles

- For middle to long term Energy transition is inevitable
- **Advance Infrastructure investment is a key for future**
- **With high inflation, cheapest time is now, making a decision now is the cheapest solution!**
- We need more discussion necessary among people and politician, stakeholders

- PGM will play an important role for both catalyst for automotive(Fuel Cell and ICE) and energy sector

“End of stone age was not due to the lack of stone”

The technological innovations and new ideas (Wisdom) will change the society.

You can't change the past, but you can change the future
Now we have a chance to design the future.
Let's have fun and challenge ourselves


It is a time to discuss what we can do for the next generation
Thank you
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