Social Shaping of the Hydrogen Future: a Comparative Case Study on the Hydrogen Niche Formation in Iceland, Korea and the UK

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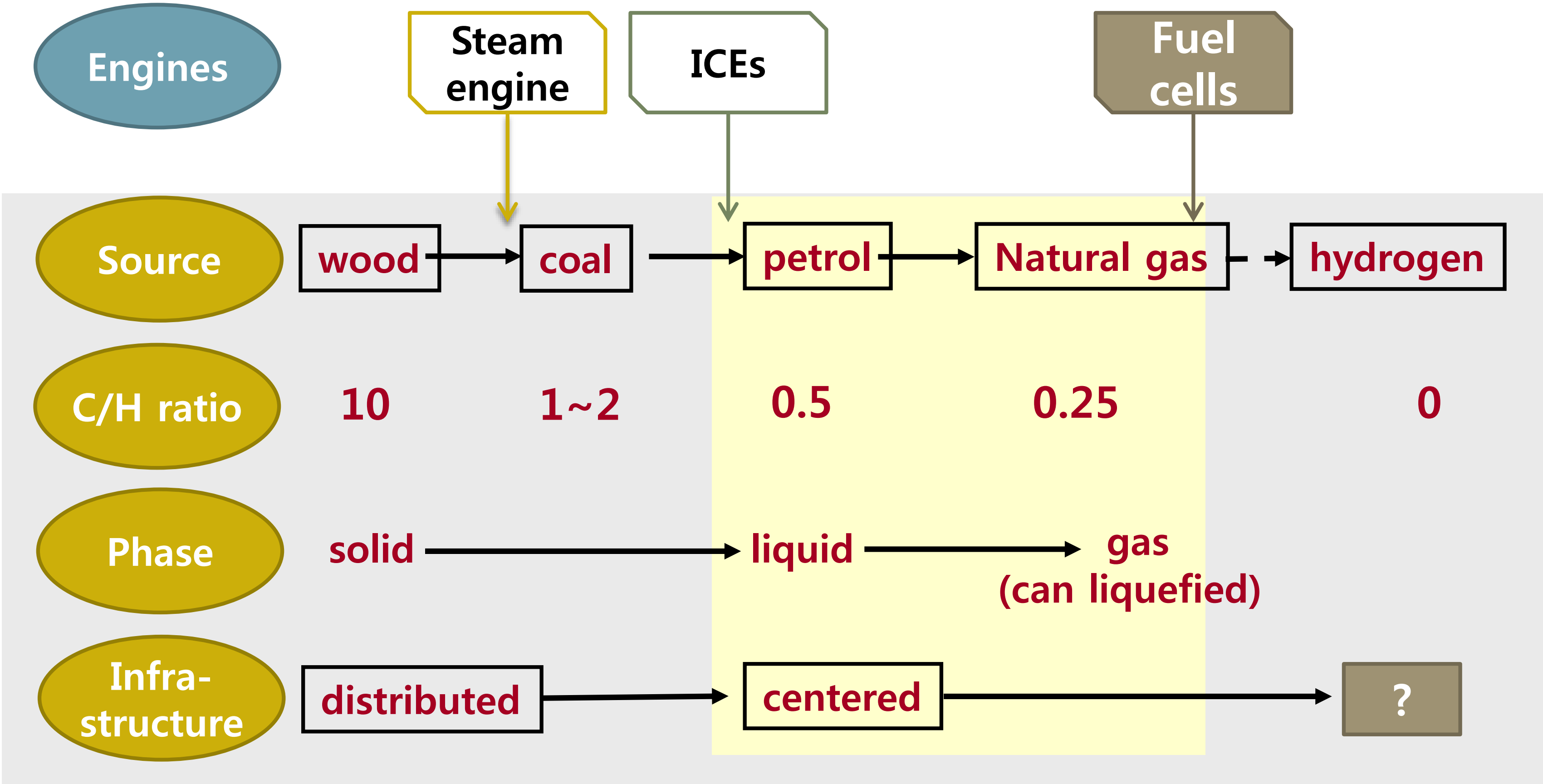
Context of this research

- Focus on ‘hydrogen niche’ formation in the early stage of the transition
  - **1990s~mid 2000s**; when the expectations on hydrogen peaked globally.
  - I applied the concept of *sociotechnical niche* from the multi-level sociotechnical transition perspective.
- Niche formation is very important, because of the path dependency
  - Varied starting points will diversify the future, due to self-reinforcement (snowball effect)
  - To contrast, three developed countries – Iceland, Korea, and the UK – were deliberately chosen for a comparative study.
- This presentation aims to emphasize social aspects of the hydrogen future, which is one of possible options for the post-petroleum era.
  - Different societies / countries vision the hydrogen future differently.
  - Government policies are articulated from the visions.

Contents

Why hydrogen – a megatrend?



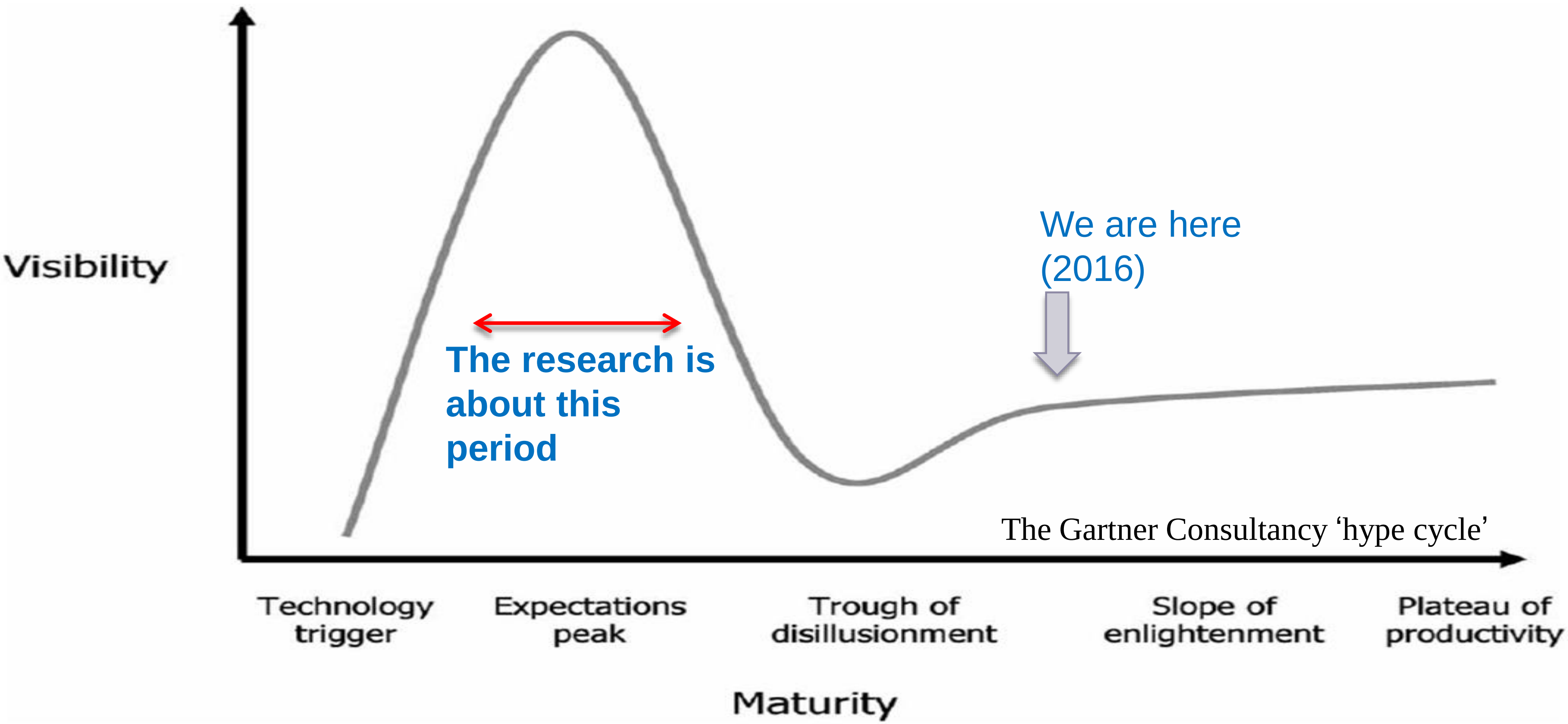
Hydrogen

- Hydrogen is NOT an energy resource, but a medium.
  - Hydrogen is abundant in elemental existence, but the H_2 molecule form of is rare and/or hard to capture on earth.
  - Hydrogen production costs energy (SMR, electrolysis, etc.), which means it may not be carbon-free.
- But, when produced, hydrogen has many advantages over other renewables, probably the only real alternative to petroleum.
  - Energy-containing **material** – able to store and transport, even pipeline distribute.
  - Generate high-efficient electricity, and can be burnt, too.
  - Electricity-hydrogen-electricity: good complement to electrical grid
  - **No great effort to change user behavior**, which is acquainted to petrol system.
- Hydrogen can be both economical and environment-friendly, when;
  - Coupled with carbon capture and use when SMR
  - Generated from unused electricity

Hydrogen – weaknesses and limitations

- Low energy density per volume
  - Need to be liquefied or high-pressure compressed
- Small molecules mean easy leakage
  - Higher standard needed than CNG.
- Untold truth – we are depending on fossil fuels for hydrogen generation, at least at the time being, and for somehow longer.
  - SMR or side-production in industries
- Technological advancement has been surprisingly slow
  - Despite all the R&D investment, especially since late 1990s.
- Uncertainty in social acceptance
  - Particularly safety issues and perceptions

The hydrogen ‘hype cycle’



Fuel cells

The Hydrogen Economy(2002)

US initiative (2003)

Low oil prices

Financial crisis

Slow FCEV development

Climate change

Widening uses

FCEV introduction

FCEV is the key application for ‘the slope of enlightenment’, i.e. reactivate the hydrogen future

ICEV	Hybrid	FCEV	EV
Refueling	Refueling	Refueling (hydrogen)	Charging
Short fueling time	Short fueling time	Short fueling time	Long charging time
Long range	Long range	Long range	Short range
Petrol stations	Petrol stations	Hydrogen stations	Charging stands
Engine sound	Engine sound	Electric motor	Electric motor
>100 years with us	20 years	?	100 years niche
Reliable, all-weather	Reasonably reliable	Unknown	Questioning

Demanding behavioral changes!

Reasons why FCEVs are important;

- Industrial and economic interests of MNEs and governments
- Demand side: everyday use for general public – multi-facet interface of society-technology interactions

FCEVs – now on!

- Waited longer than 10 years after prototype, FCEVs are finally being introduced to the market from 2015.

Toyota Mirai (2015)

Hyundai ix-35 FC (2015)

Honda Clarity (2017)

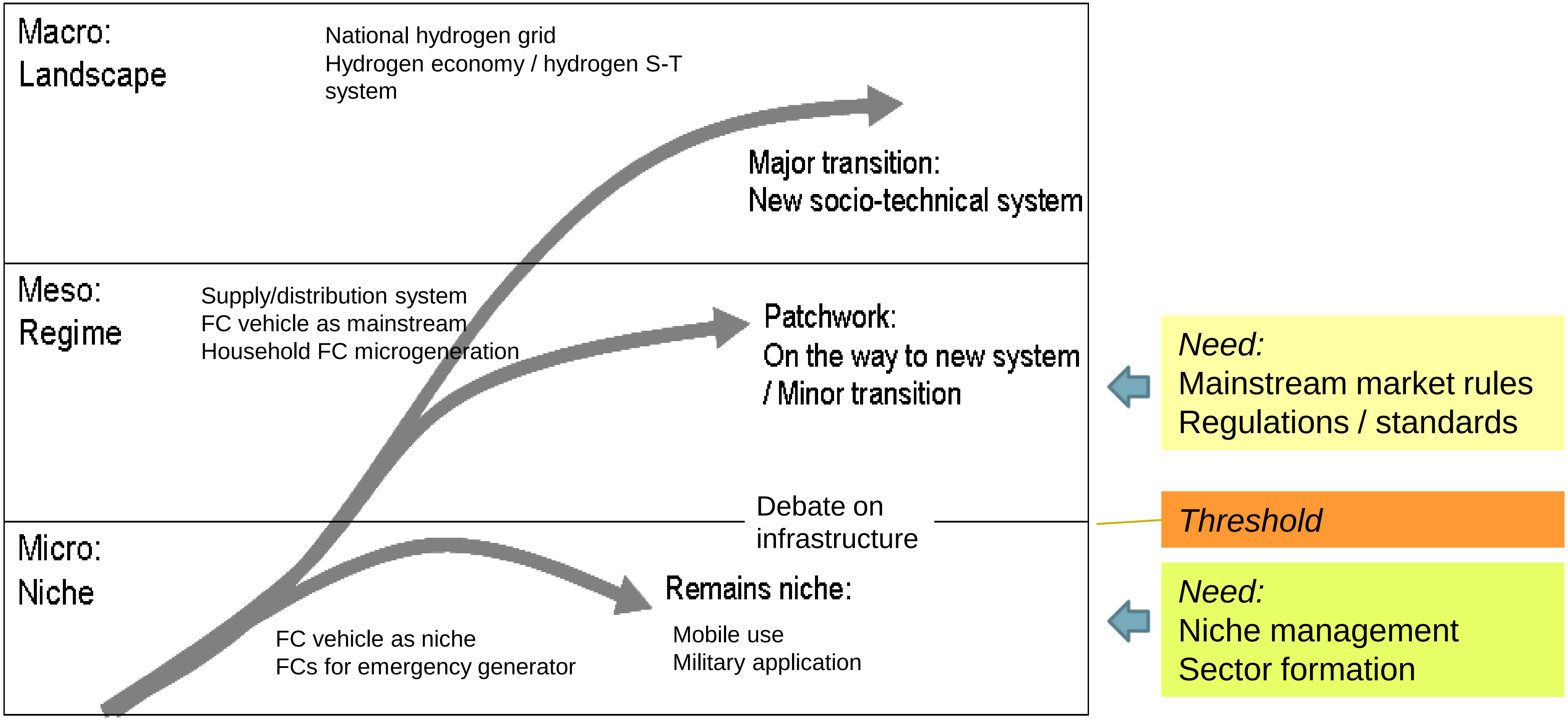
- They need hydrogen not only hydrogen infrastructure(i.e. fueling stations, hydrogen production) but also regulations, standards, legislations, and other institutional components

Theory

Sociotechnical transition

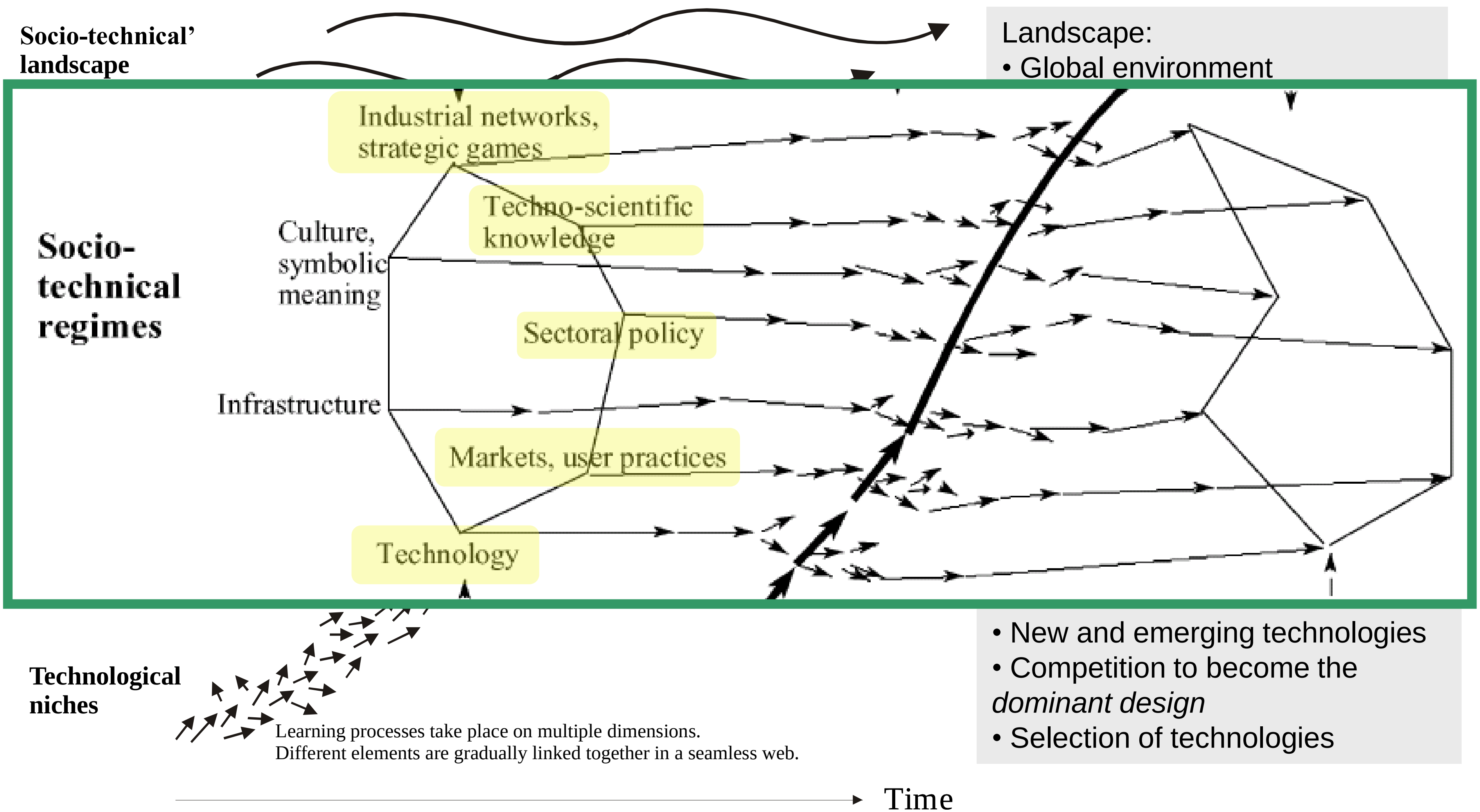
Sociotechnical transition - MLP

Transition pathway of the hydrogen energy transition based on scenarios



Rip and Kemp's diagram(1996) / modified

Sociotechnical transition - MLP



Landscape:
- Global environment

- New and emerging technologies
- Competition to become the *dominant design*
- Selection of technologies

Geels(2004)

Niche formation

- Characteristics of sociotechnical niche
  - Geographical niche
  - Specific, specialised usage (i.e. military, space, backup)
  - Under demonstration
  - Economically uncompetitive
  - Low public awareness
- Sociotechnical experiments and scaling-up
  - Demo projects, especially local activities
  - **Gathering information on public awareness and acceptance**
  - **Promotion of social awareness and acceptance**
  - Small systems operation to simulate for larger ones
  - Finding obstacles, not only technological but also institutional ones.
  - Reducing risks

Demo projects as sociotechnical experiment

dimension	Traditional approach	Sociotechnical exp.
Where	Special location	Broader, general location
Who	Experts, volunteers	General public
What	Technical improvement	Social awareness and acceptance
How long	Rel. short	Rel. long

- Living-scale, everyday use of general public
- Learning and social acceptance

vs.

Niche formation (ii) – network and policies

- Network development and alignment
  - Network of actors: industry stakeholders, government departments and agencies, policy researchers, and users.
  - **The network will steer and shape the transition**, and supposedly provide transition governance.
  - The network will work as a policy network, especially in the early stage.
- Developing gov. policies
  - Government policies are based on shared visions and expectations of the network and the general public: **articulated visions**
  - Policies can give signals and messages to various actors. In the early stage, which may convince and guide the participants.
  - Policies can influence the transition both directly and indirectly. (e.g. RD&D projects)

Research methods

Comparative case study framework

Research methods

- Selection of countries
  - Iceland: a test-bed for the first Hydrogen Society in the world.
  - United Kingdom: a European developed country, putting more weight on sustainability.
  - South Korea: lately developed country with a rapid catching-up experience.
- Semi-structured in-depth interviews (government, quasi-government agencies, firms, policy researchers, scientific researchers, NGO etc.)
  - Iceland: 7 interviews
  - United Kingdom: 13 interviews
  - South Korea: 18 interviews
- SCI publication data for comparison of Korea and the UK on technology selection
- Social network analysis(SNA) for Korea's gov-funded R&D programs

Comparative case study framework – Topics to address

- Social perception of hydrogen energy
  - Influence of societal experiences
  - Expectations and visions
  - The source of social acceptance
- Economic aspects and social selection of technologies
  - Industrial conditions
  - R&D activities and capabilities
  - Sociotechnical experiments
- Government policies, which articulate broader expectations, as transition management

Case studies

Cases of the three countries

Iceland at a glance: a living-scale experiment of socio-technical transition

Economy & energy environ.

Small economic size with
 high GDP per capita
Population: 270,000
Plenty of renewable energy
 (hydropower and geothermal)

Society & culture

Small, primary society
Environment-friendly
Challenging
Energy transition experiences
(coal → gas → renewable)
High social acceptability

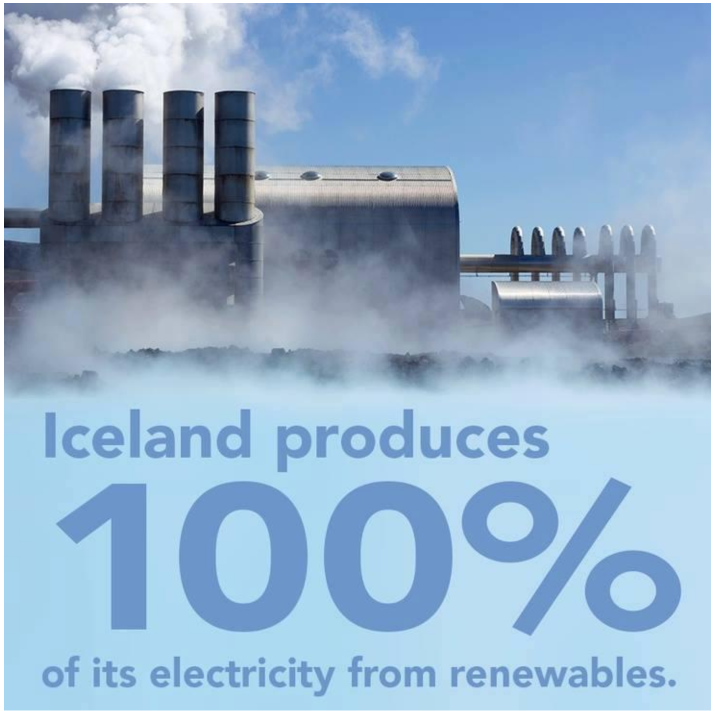
National innovation system

Low technological capability
Fishery → Aluminum processing
 → Finance
Energy firms
Almost no manufacturing industry
 except aluminum

Strategic aim	Transportation (FCV and marine use), demonstration, social acceptance Oil-free country
Focused hydrogen technology	Hydrogen storage, on-site hydrogen generation Knowledge from operational activities
Decision making	Small, simple, primary, flexible and effective
Key findings	Limitations (size, industrial structure etc.) / the dependence on foreign MNEs

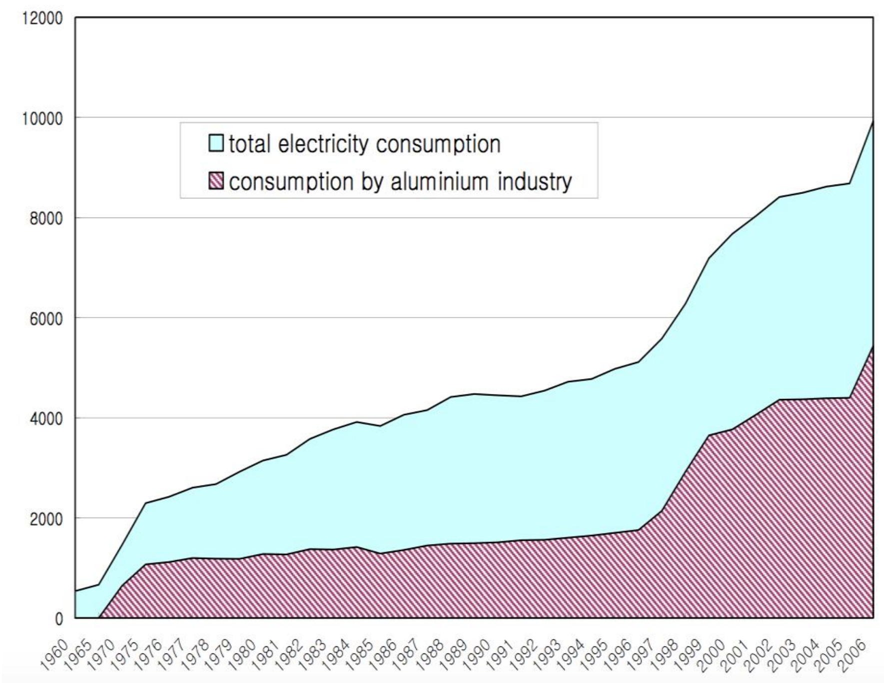
Iceland: social perception

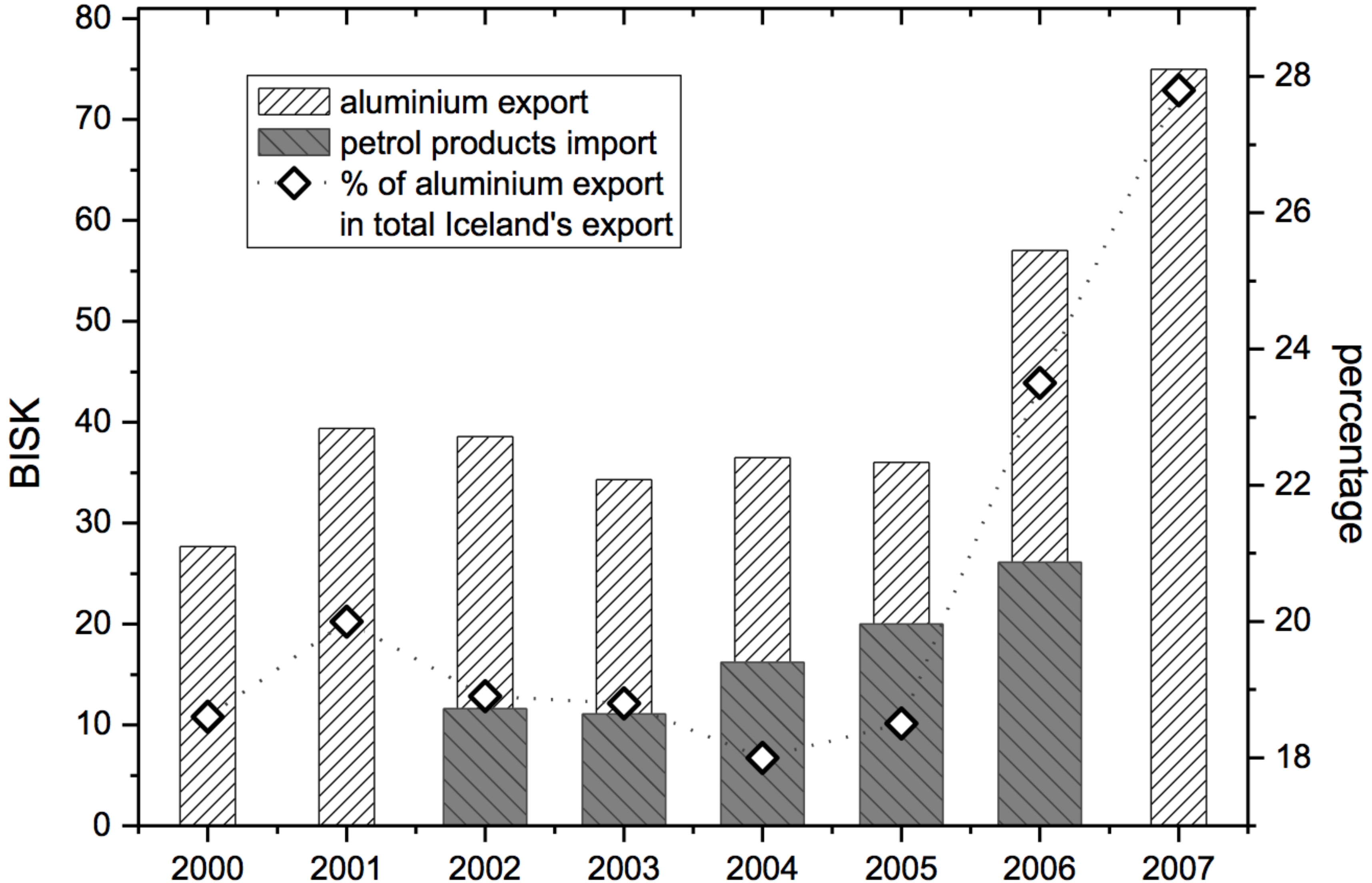
- Energy transition experience
  - Transition to hydropower and geothermal
  - Successful experiences are positive for a newly proposed hydrogen energy transition
- Expectation and vision
  - ‘clean Iceland’
  - ‘World-first carbon-free country’



Iceland: economic aspects

- Aluminum industry boomed Iceland's economy
  - MNEs like Alcoa, Alcan and Century Aluminum Company
  - Exporting Aluminum is exporting hydropower electricity – They think exporting hydrogen makes sense, too.
  - Iceland need to reduce carbon emission elsewhere, to increase aluminum production
- Energy security concern
- Focus on transportation
  - Renewable electricity: already 100%
  - Heating: 99% by geothermal
- Lacks manufacturing industry
  - Iceland do not produce cars, so it must depend on imported FCEVs
  - Lacks industrial R&D capabilities





aluminium export
petrol products import
% of aluminium export in total Iceland's export
BISK
percentage
0
10
20
30
40
50
60
70
80
18
20
22
24
26
28
2000
2001
2002
2003
2004
2005
2006
2007

Iceland: Hydrogen energy policy development (1998~2006)

(~1997)

- No specific policy or R&D programme on hydrogen energy

(1998)

- The **government statement** on the Hydrogen Economy (world 1st)

(1999~2005)

- The Icelandic New Energy Ltd. established, which has performed most of activi ties
- Demo projects like fuel cell bus, Hydrogen fuelling station
  - Social aspect studies and developing PR.
  - International partnership; IPHE
  - Supporting domestic R&D

(2006~)

- National Hydrogen Roadmap: strategic selection of target technologies, the plan for deployments

Iceland: sociotechnical experiment (mid 2000s)

- Iceland claimed itself as a global testbed for hydrogen
  - World's first commercial hydrogen station
  - Fuel cell bus: ECTOS/HyFLEET-CUTE
  - Fuel cell vessel: New-H-Ship
  - Passenger vehicles: SMART-H2
  - Hy-Society: social and economic aspect
- Pros
  - Living-scale demos thanks to small society
  - High awareness of general public
  - Good government support and delivery mechanism (Icelandic New Energy, ltd.)
- Limitations:
  - Extremely dependent on foreign suppliers
  - Small market – hard to magnet MNEs (they prefer California!)
  - Lacks R&D capacity – R&D is one of key components of sociotechnical exp.

United Kingdom at a glance
: Sustainability matters

Economy & energy environ.

Large economic size with
high GDP per capita
North Sea oil
Long history of industrialization
and economic changes

Society & culture

Large, complex society
High environmental concern
Sensitive to climate change
High social acceptability
for renewable energy

NSI

High technological capability
But weak manufacturing industry
Large energy firms
Knowledge-based service industry

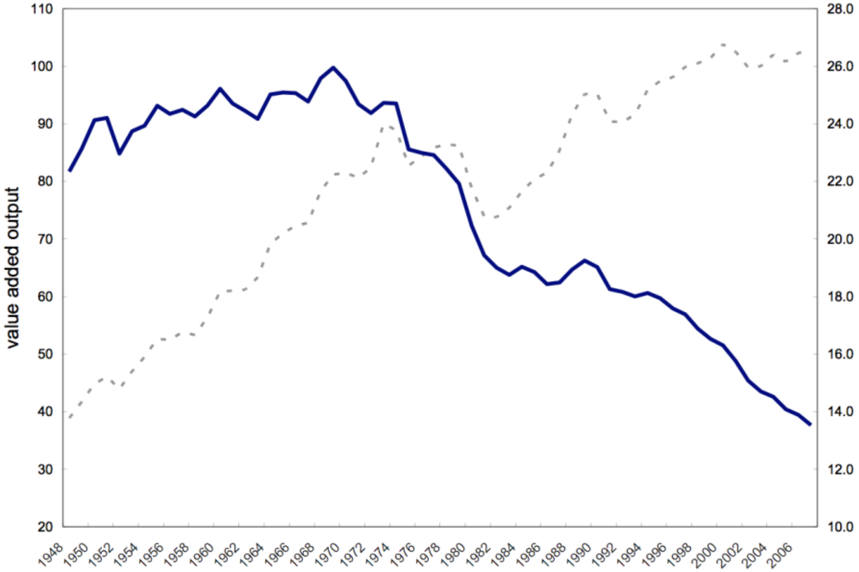
Strategic aim	Sustainability & against the climate change, energy security Industrialization of hydrogen energy, especially fuel cells
Focused hydrogen technology	Hydrogen generation and storage as an electricity storing method
Decision making	fragmented, complex governance
Key findings	Limitations (industrial structure, governance) The potential of knowledge-intensive SMEs

UK: social perception

- Strong concern on the climate change
  - The UK is one of the leading states that advocate the global agenda of climate change
    - Moderate weather and dated infrastructure – vulnerable to heavy rain, snow, colder winter, hotter summer, etc.
  - Environmentalism
  - Sustainable development
- The UK has lead energy transitions in history, since the Industrial Revolution
  - Wood → coal → petrol → gas → …
- Rise and fall of the North Sea oil
  - People aware the petrol era may end someday

UK: economic aspects

- Overall, manufacturing industry has declined
  - No automobile company headquartered in the UK does R&D on FCEV.
  - However, a few strong actor in hydrogen energy sector, as well as strong basic research in leading universities
    - Johnson-Matthey, Rolls-Royce Fuel Cell, RD Shell
- Oil industry
  - BP and Shell: preparing for the future?
- Gov hopes hydrogen energy to contribute to further economic growth.



UK: Hydrogen energy policy development (2000~2005)

(~2001) Research-councils based, less-organised R&D programmes
(2002) DTI started organised activities, such as formation of network of interest groups
The Carbon Trust established.
(2003) Fuel Cells UK: A fuel cell vision for the UK 2003
- It requested leadership and vision on fuel cells, contained messages to stakeholders, and requested for government actions.

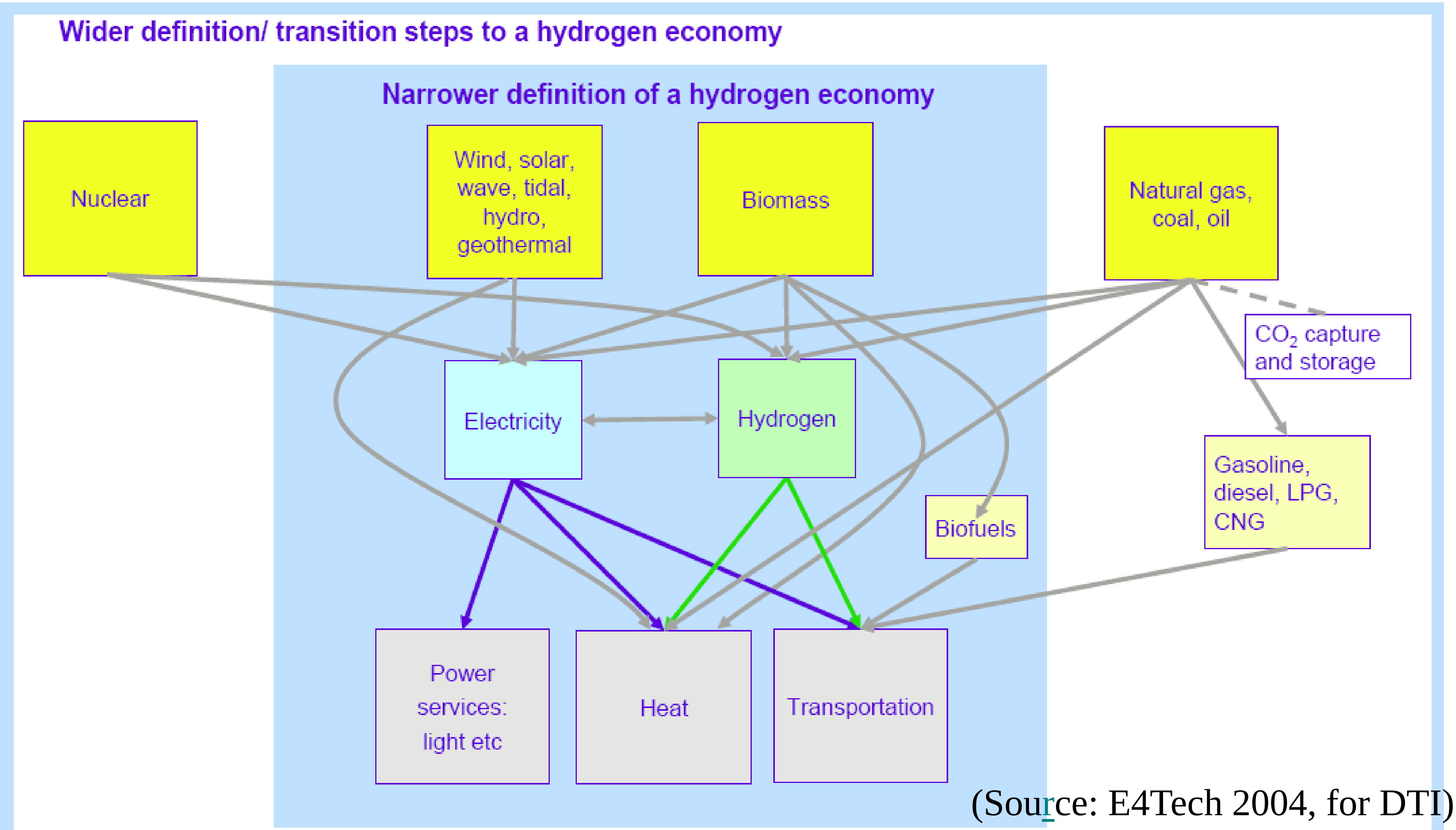
(2004) Tyndall Centre: Hydrogen Energy Scenarios to 2050
- To map out the stages required for a national energy infrastructure based on hydrogen produced from renewable sources.

(2004) **A strategic framework for hydrogen energy in the UK** (official policy paper)
- Hydrogen energy is a desirable addition, to CO2 reduction and improved upstream energy security as key goals for UK innovation and wealth creation.
- The UK's technical strength and industrial weakness

(2005) Fuel Cells UK: Roadmap for fuel cell sector development
- Assessment of the UK situation: strength and weaknesses in fuel cells
- Steps, actions and timescales to overcome challenges

(2005) UK sustainable hydrogen energy consortium: UK Hydrogen Futures to 2050
- Roadmap development and designing scenarios
- Hydrogen transition (adopted socio-technical system approach)
- Various social aspects, such as acceptability and risk

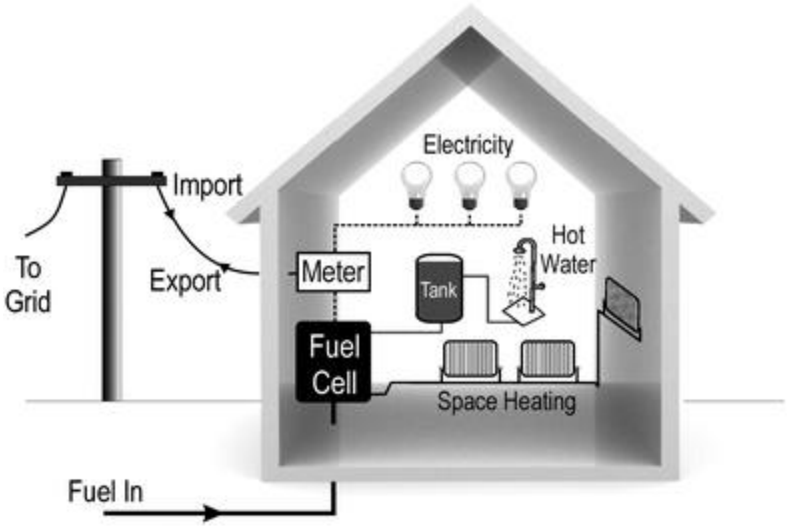
UK's vision on hydrogen economy



(Source: E4Tech 2004, for DTI)

UK: sociotechnical experiment (mid 2000s)

- Demo project: CUTE in London
  - Fuel cell bus: HyFLEET-CUTE
  - A real-living experiment
- CHP demo projects
  - Combined heat and power: appropriate to British housing conditions
  - Especially in Northern England region
    - Relatively low-income region
- Limitations:
  - Not much support from domestic industries
  - Unexpected social acceptance issue: *"Green Luxury"*



Korea at a glance:

Economic prospect dominates: industrial opportunity from hydrogen energy

Economy & energy environ.

Large economic size with mid-high GDP per capita
Imported fossil fuels
Underdeveloped renewable energy
Large firms are important

Society & culture

Large, complex society
Little environmental concern
Challenging culture
Rapid changes
High social acceptance for new technologies

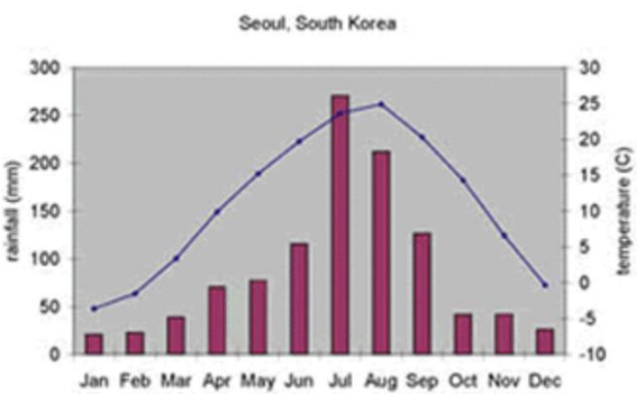
NSI

High technological capability, especially applications & production
Electronics and automobile industry
GRIs

Strategic aim	Industrialization of FCV, energy security
Focused hydrogen technology	Fuel cells
Decision making	Centralized, top-down (government lead), lack of policy research capability
Key findings	The role of government The importance of large firms

Korea: social perception

- Rapid catching-up experience in socioeconomic development
  - *Dynamic* culture
  - Tech-friendly: people easily accept and try new technologies
  - People view new techs as new a “growth engine”.
  - Relatively less concern on safety issues of new techs
- Industrial competitiveness is a huge concern, since Korea’s economy is highly depending on export.
- Relatively less concern on the climate change
  - Like the US and developing countries – “Climate change is made by European developed countries.”
  - Korea’s climate: monsoon, extreme weather
- Energy security matters much
  - Korea imports 99% of energy resource (including uranium for nuclear power) from abroad.



Korea: economic aspects

- Strong manufacturing industry
- Gov and Korean firms spend a lot of money on R&D
  - Gross R&D expenditure: ~2% of GDP (now it is 3%!)
  - Majority of R&D spending goes to applied technologies, not basic science.
- Automobile industry
  - One of Korea's largest industry, in terms of both export and employment
  - Hyundai Motor Company has long been focusing on FCEV
    - It thinks EV is not very promising: EVs can't fully substitute ICEVs.
    - It thought hybrid (Prius) is kind for a temporary transition.
    - HMC is not like TESLA. It is a mainstream car maker, which produce millions of cars.
  - Gov supports FCEV R&D for Korea's automobile industry
    - Automobile-relating technologies: PEMFC, high pressure storage tank
- Other than automobile industry, large firms lead hydrogen energy development.
  - Doosan(heavy industry and energy), POSCO(steel), GS-Caltex(petrol)

Korea: Hydrogen energy policy development (2000~2005)

(~2002)

- Several national-level R&D programmes on hydrogen energy as part of new & renewable energy research. (Hyundai Motor Company started in-house R&D on FCV in 1998)

(2003)

- Fuel cell technology was selected as the one of ten ‘Next Generation Technologies for Economic Growth’
- The first policy research report on Hydrogen technologies was reported to the Presidential Advisory Council of Science and Technology; This report was mainly technological, paid no attention on scenarios or socio-economic aspects.

(2004)

- National RD&D Organization for Hydrogen & Fuel Cell, was launched.
- South Korea joined IPHE

(2005)

- The Hydrogen Economy Master Plan published by MOCIE
    - The aim of this master plan is shown clearly that it is focused on FCEVs. (industrialisation > energy security > sustainability)

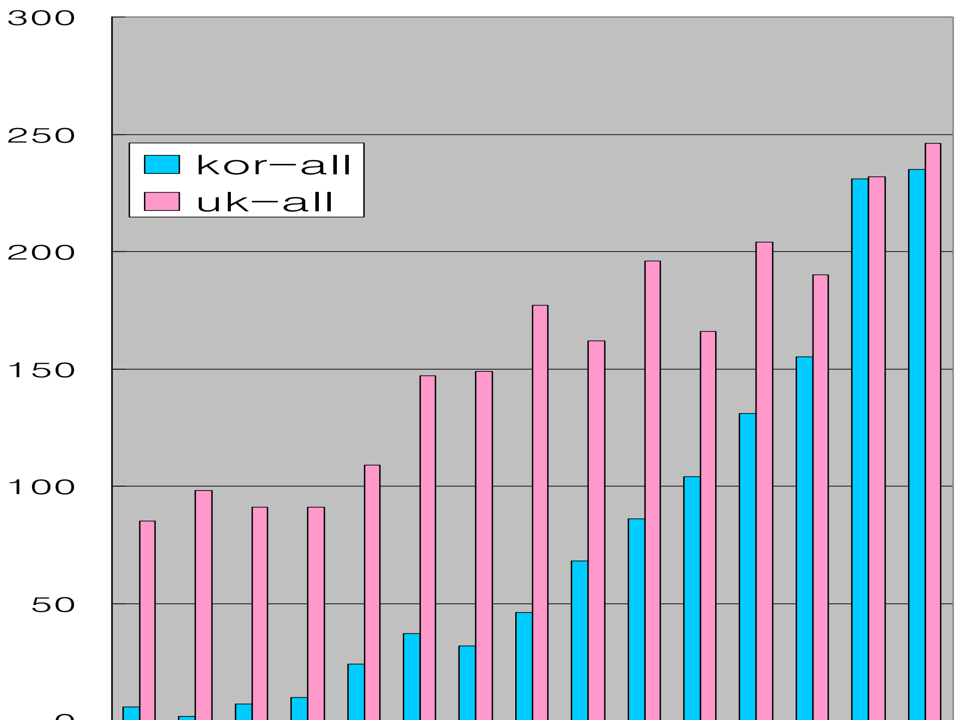
Korea: sociotechnical experiment

- (Unfortunately,) Korea paid less attention on proper sociotechnical experiments
  - Of course there have been demo projects, but they lacked social considerations
  - No EU project such as CUTE
  - Hyundai's FCEV development has been placed only at their in-house research labs
  - Korea's only hydrogen fuelling station is located in a government research institute (KIER)
- There has been CHP demos, but CHP is not suitable for Korean housing conditions
  - Regional central heating, apartments – highly efficient, centralized heating system
  - Korea's electricity price is lowest among developed countries → no market for distributed power

UK and Korea: technologies

- Industrial interests and hydrogen visions influences R&D activities
- Government policies strongly steer the direction of technological trajectory.

1. Hydrogen technology emerging, and Korea's catching-up in hydrogen technologies

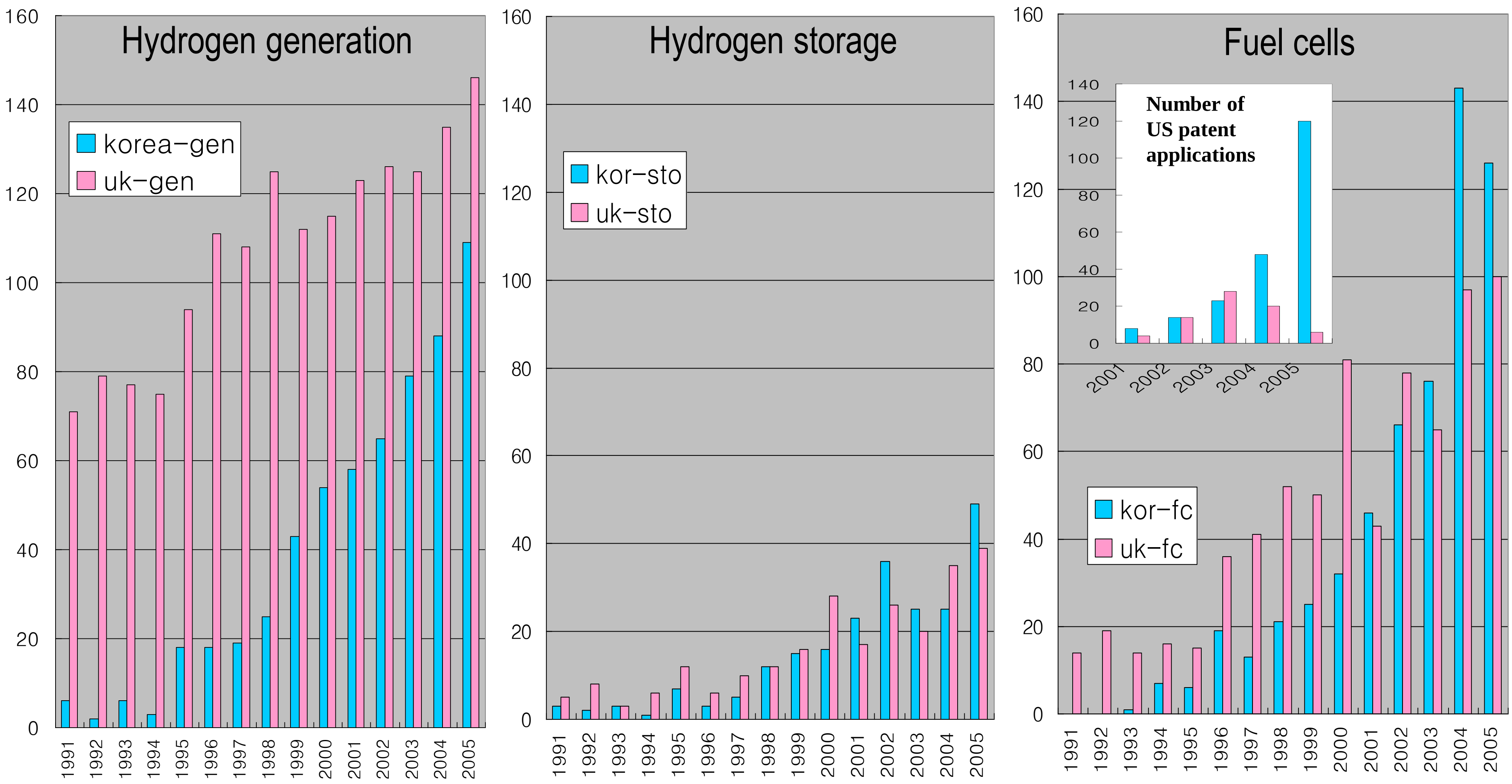


	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
kor–all	6	2	7	10	24	37	32	46	68	86	104	131	155	231	235
uk–all	85	98	91	91	109	147	149	177	162	196	166	204	190	232	246

SCI publications in the UK and South Korea. Subjects related to Hydrogen generation, storage, and fuel cells.

UK and Korea: technologies

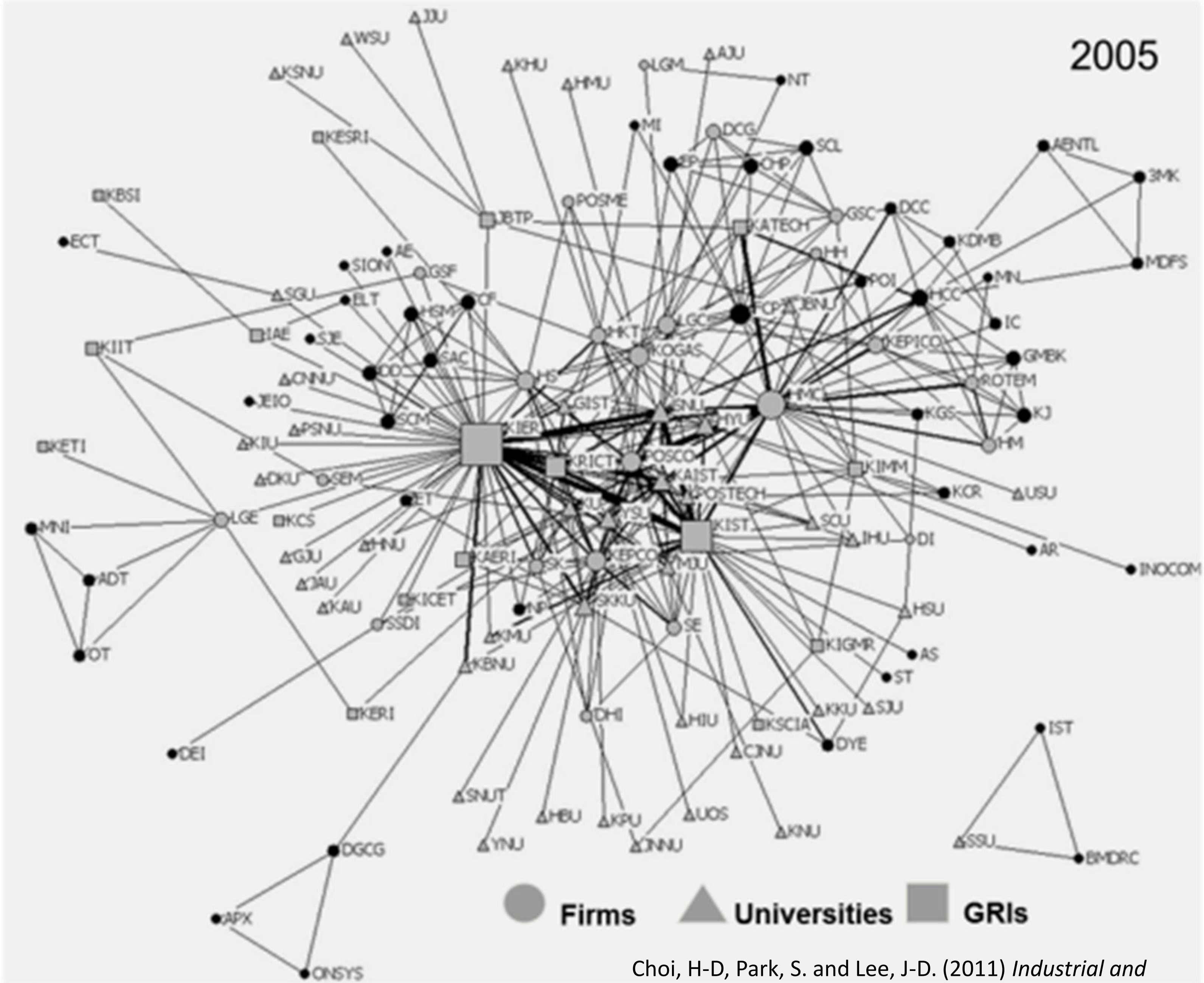
2. Technology selection: SCI publications break-down



Meanwhile, in Iceland…: technologies

- Iceland strategically select target technologies to develop:
  - Geothermal hydrogen production
  - Hydrogen from H_2S
  - Electrolysis (using hydropower electricity) – with Norsk hydro
- Although there are good research universities (two) and research institutes (on hydrogen, one), Iceland is not very able to carry out FCEV development

Korea's government-funded R&D on hydrogen energy (1989~2005)



Choi, H-D, Park, S. and Lee, J-D. (2011) *Industrial and Corporate Change*, vol. 20, pp.751-787.

Summary

Final remarks

Summary:
social shaping of the hydrogen future

- Findings from case studies
  - Surprising similarity in expectations in the 3 countries.
  - However, visions are different from each other, which involved their own contexts and conditions.
  - Contrasting niche formation phenomena, which will lead different hydrogen futures.
  - For the transition, R&D capability and market force are more important than controllability in a sociotechnical experiment.
- This presentation shows the path-dependence of sociotechnical transition in different societies.
  - Post-petrol ‘hydrogen future’ may vary.

Published works

- Park, S. (2013) “The country-dependent shaping of ‘hydrogen niche’ formation: a comparative case study of the UK and South Korea from the innovation system perspective” *International Journal of Hydrogen Energy*, vol. 38, pp.6557-6568.
- Choi, S., Park, S.* and Lee, J-D. (2011) “Government-driven knowledge networks as precursors to emerging sectors: a case of the hydrogen energy sector in Korea” *Industrial and Corporate Change*, vol. 20, pp.751-787.
- Park, S. (2011) “Iceland’s hydrogen energy policy development (1998-2007) from a sociotechnical experiment viewpoint” *International Journal of Hydrogen Energy*, vol. 36, pp.10443-10454.
- Park, S. (2011) “Co-evolution of policy and emerging technology: hydrogen energy policies in Iceland, the United Kingdom, and Korea” *The Korean Journal of Policy Studies*, vol. 26, pp.117-143.

Merci beaucoup!