# Global Hydrogen and Fuel Cell RD&D Environment

International Partnership for the Hydrogen Economy

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# Objective

Offer an overview of international hydrogen RD&D activities:

- **International Partnership for the Hydrogen Economy (IPHE)**
- **Germany and the EU: Klaus Bonhoff**
- **Japan: Haruhiko Ando**

**Additional:**

- ✓ **Australia**
- ✓ **Canada**
- ✓ **China**
- ✓ **Korea**
- ✓ **Russia**
- ✓ **UK**

# IPHE PURPOSE:

*To serve as a mechanism to organize and implement effective, efficient, and focused international research, development, demonstration and commercial utilization activities that advance the transition to a global hydrogen economy; and to provide a forum for advancing policies and common codes and standards*

# IPHE Members:

- Australia
- Brazil
- Canada
- China
- European Commission
- France
- Germany
- Iceland
- India
- Italy
- Japan
- Korea
- New Zealand
- Norway
- Russian Federation
- United Kingdom
- United States

# IPHE Work Groups

**Regulations, Codes and Standards**

- Performing meta-gap analysis to identify effective role for IPHE
- Development of an online Global Hydrogen Regulation Map

❖ **Demonstration and Infrastructure**

- Creating website summarizing IPHE demonstration projects worldwide
- Sharing information on demonstration plans and test protocols.

❖ **Education**

- Performing outreach
- Planning an international hydrogen youth competition

# IPHE

## Joint IPHE – IEA Infrastructure Workshops: "Building the Hydrogen Economy: An Infrastructure Strategy"

- In 2007, three workshops were held in the United States, France, and China
- 2 main goals: Summarize analysis and lessons learned; develop vision and pathways forward

# IPHE Projects

| Category | Projects |
|---|---|
| Demonstration | 7 |
| Fuel Cell | 7 |
| Production | 3 |
| Storage | 5 |
| Transmission and Distribution | 1 |
| Regulations, Codes and Standards | 5 |
| Socio-Economics | 2 |
| **Total** | 30 |

# IPHE Focus Areas

**Four Strategic Priorities**

- Accelerating market penetration & early adoption of $H_2$, FC & infrastructure
- Policy and regulatory actions to support widespread deployment
- Raising profile w/policy-makers and public
- Monitoring relevant technology development

**Current Initiatives**

- Global IPHE Projects
- Fuel Cell Cost Analysis Comparison
- "State of the Nation" Document
- Commercially Available Products List
- Brief for Policy Markers
- Overview of Demonstration Projects in IPHE Countries

# Industry Activity

## Correlation between public investment & industrial growth?

- **PricewaterhouseCoopers 2007 Review of public fuel cell companies:**
  - 26 public companies spanning the supply chain from fuels to components, stacks to integration, infrastructure development and across fuel cell markets, portable, mobile and stationary
  - Public firms concentrated in US, UK, Canada and Germany*


- **From 2006**
  - Revenues increased 59% to $416M
  - R&D consistent at $213M
  - Employment increased by 10% to 3,434
  - Market capitalization increased 20% to $3.8B
  - Increasingly developing strategic relationship with OEMs and energy providers; supply chains needed for volume production and focus on generating near term revenues
  - Companies are not yet profitable – firms share net losses of $644M

*OEMs and energy companies not included in the survey

# Industry Focus on Commercialization

## According to Fuel Cell Today ramp-up of activity in 2007*

- 12,000 new units shipped
  - 98% of units low temperature (PEM, DMFC)
  - 8000 units in transport sector (APU, materials handling)
  - UPS for ICT and CHP dominate stationary markets
  - Military driving portable markets
- Global Manufacturing: 100,000 units per annum
  - 25% from companies dedicated to $H_2$/fuel cells
- Cost reductions averaging 10% to 20% per annum


*Fuel Cell Today: Fuel Cells: Commercialization Industry Review 2008

# Global Public Investments/Activities

- Governments have played a key role in developing $H_2$ and fuel cell technologies through investing $1 B US in 2007*
  - Key contributors include: **US, Japan, Germany, EC, South Korea, China, Russia, Canada, UK**
  - Leveraging significant private sector investment
    - Many countries are home to industrial leaders across the value chain
- Drivers include energy security, environmental performance, health, and economic competitiveness

**Fuel Cell Today: Fuel Cells: Commercialization Industry Review 2008*

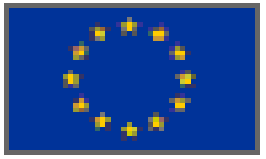
# Global Public Investments/Activities

- **Countries with Roadmap and/or Strategic Plans for $H_2$ and FC:**
  - US, Brazil, Canada, China, EU, France, Germany, Iceland, India, Japan, Korea, Norway, UK, Australia (in progress)

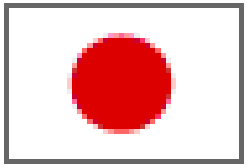
| | |
|---|---|
| Canada | ~$30 M annually |
| China | ~$30 M annually |
| EC | ~470 M Euro (’08 – ’17) matched by industry |
| Germany | ~700 M Euro (’08 – ’16) matched by industry |
| Japan | ~ $300 M annually over 5 years |
| Korea | ~$60 M annually, with ~$50 M added from industry |
| Russia | ~$30 annually |
| UK | ~$13 M annually and $10 M for demo |

# Germany and the EU

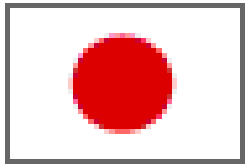
**Presented by**
**Klaus Bonhoff**



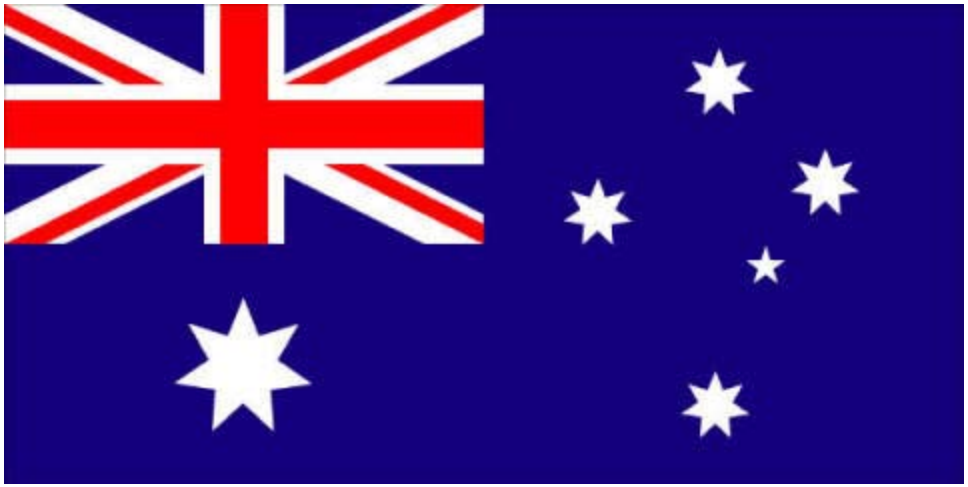
# Japan



**Presented by**
**Haruhiko Ando**



# Australia



# Australia

## Hydrogen Technology Roadmap


**To assess areas where Australia has research capabilities and strengths, compared to research overseas**

**To identify opportunities that Australia should take to prepare for the possible emergence of a hydrogen economy**

**To be completed early 2008**

# Australia

## Initial findings from Roadmap process:

- Recognition of potential role for $H_2$
  - Establishing a vision to actively maintain involvement in $H_2$ and FC development: “By 2020, effectively exploit the $H_2$ and FC market and supply chain opportunities.”
- Impending emissions trading scheme driving continued pursuit of hydrogen and fuel cell technologies.
- Currently have a “wide but not deep R&D effort”
  - Recommendation to form a High-Level Coordination Group to work with government, business and research sectors to implement final roadmap recommendations.

# Australia

## National Hydrogen Materials Alliance

**Launched November 2006**


**Goal:**

- **New materials that improve the efficiency and economics of hydrogen generation, storage and use**
- **Draw together Australian expertise in the above fields to work in an "alliance" mode**
- **Focus this expertise into the most promising R&D direction for Australian conditions**

***$9.6 million between 2006/07 and 2008/09***

# Australia

**Proposed Demonstration project**:

University of Melbourne Hydrogen Combustion Engines

- Long-term research project started in July 2007 to study efficient hydrogen fuelled vehicle technologies
- First stage of this project will be the development of a hydrogen-fuelled, turbo charged 6-cylinder engine.
- Assistance from Ford Motor Company of Australia and a $1.2 million grant from the Victorian Government.

# Canada

# Canada

- $7 M in 2008 for hydrogen R&D for transport
- Canada produces nearly 3 million tonnes of hydrogen per year, about one-third of the US hydrogen production rate, making Canada the largest per-capita hydrogen producer in the OECD
- Robust demonstrations such as BC Hydrogen Highway, Hydrogen Village, buses for 2010 Olympics
- Niche market development: fork-lift trucks, stationary and remote power, military applications, and micro applications (i.e. laptops)

# Canada

**“Moving Toward Greater Diversification”**

**Six alternative technologies**

- Diesels
- Hybrids
- Fuel Cells ($H_2$ from NG)
- Advanced Biofuels (Cars, Light Trucks)
- Fuel Cells (Zero C $H_2$)
- Advanced Biofuels (Heavy trucks also)

# Canada

## RD&D Priorities:

- **Hydrogen Production and Purification**
  - Electrolytic hydrogen production
  - Magnetic liquefaction of hydrogen
  - Controls to integrate hydrogen production from wind
- **Hydrogen Storage**
  - Compressed gaseous storage
  - Solid storage materials - Carbon, metal hydrides
  - Automated hydrogen dispensers – up to 10,000 psi
- **Hydrogen Safety**
  - Conducting experimental studies to validate hydrogen dispersion models
  - Quantitative Risk Analysis
  - Hydrogen Sensors
- **Utilization**
  - Technical challenges – cost, lifetime, stack performance
  - Technical outputs – high temperature membranes, ceramics for SOFCs, mobile/portable APU, modelling of fuel cell cogen, advanced batteries, control systems

# Canada

## Hydrogen Highway

- 8 nodes between Vancouver airport and Whistler for 2010 Vancouver Olympics – 3 already in operation
- Demonstration activities: fuel quality protocols, safety and emergency response, codes and standards, and communications

## Vancouver Fuel Cell Vehicle Program

- 5 Ford Focus fuel cell vehicles delivered to users in March 2005
- Objectives: communication, technology, regulation

## Hydrogen Village

- Collaborative effort of Focus on hydrogen production and delivery technology, as well as stationary, mobile, and portable fuel cell applications

# China

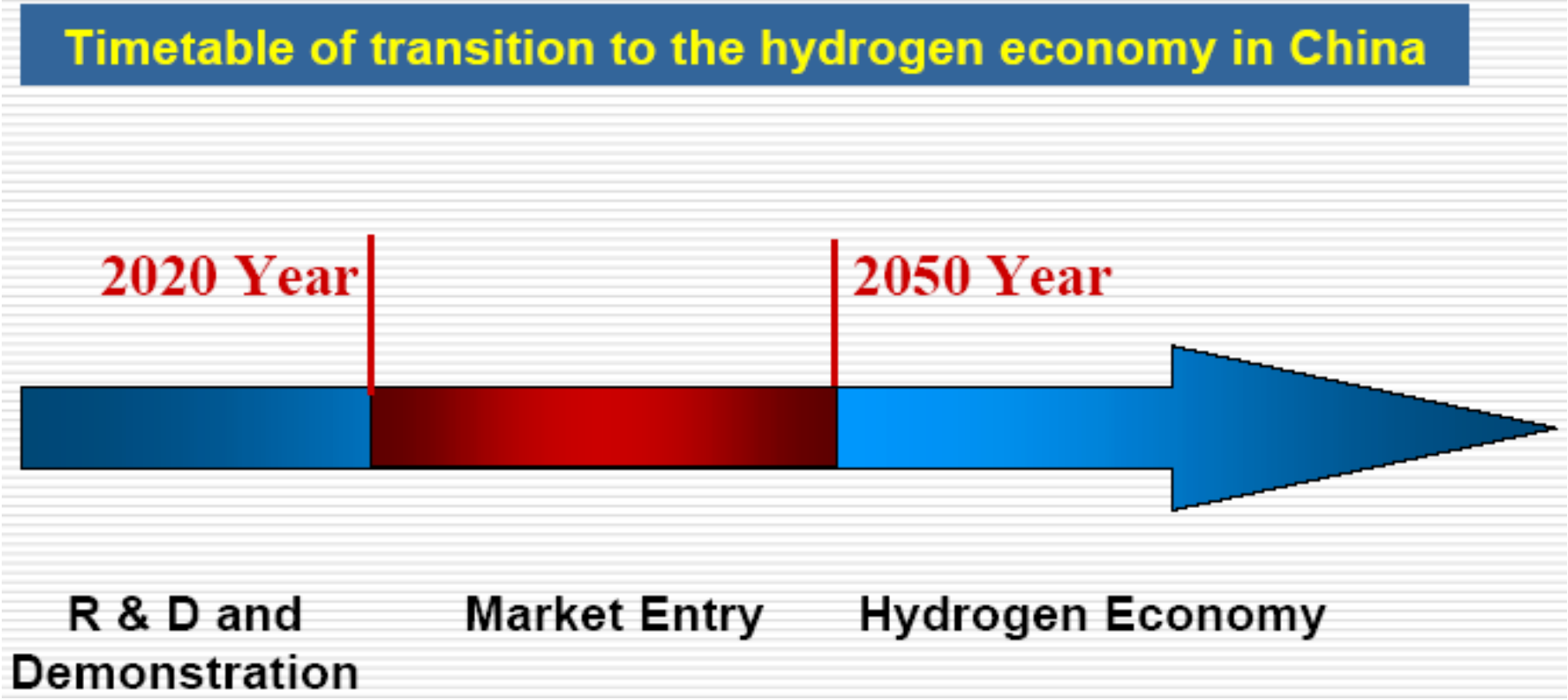
# China

## Strategic Plan:

- **In 2006, launched a National Mid-to-Long Term Plan (2006 – 2020) that includes hydrogen along with EE, nuclear, renewables and advanced transportation.**
- **$H_2$ Roadmap also published in 2006**
  - **Production (fossil, nuclear and renewable sources)**
  - **Hydrogen storage**
  - **Delivery**
  - **Conversion (PEMFC)**
  - **Safety Codes and Standards**

# China

## Roadmap:



# China

Budget:

- **2000 – 2007:**
  - ✓ $13 M for National Basic Research Programs
  - ✓ $130 M for National High-Technology Development Programs (focus on Electric Automobiles)
- **2008:**
  - ✓ ~$30 M for Hydrogen and FC RD&D

# China

Projects:

- Clean Coal Power Generation ($H_2$ and power cogeneration demonstration) – launched in 2005.
  - 8 company consortium
  - Three phases including IGCC plant construction, development and scale up, and engineering and demonstration.
- $H_2$ from Nuclear:
  - Phase I and II laboratory scale development to be completed in 2010
  - Phase III pilot demo plant by 2015
  - Thermo-chemical water-splitting

# China

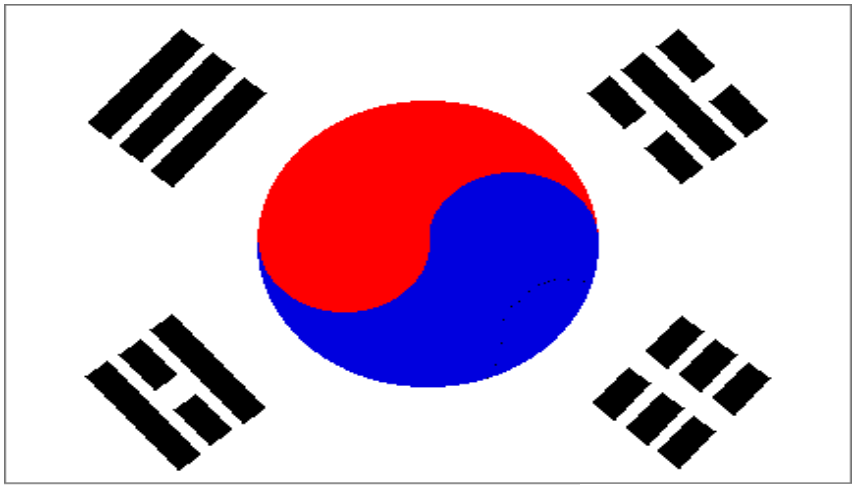
- Renewable Production
  - Biomass Fermentation
  - Direct algae production
- Storage
  - Liquefaction and compressed
  - Novel storage: physical and adsorption
- Utilization
  - PEM fuel cells for transport
  - DM FC for portables
  - Molten Carbonate and Solid Oxide FCs for stationary power

# China

## Demonstrations:

- **First developing country to conduct FC Bus demo**
  - 3 Buses for Phase I in Beijing completed in 2007
  - 3 – 6 Buses for Phase II in Shanghai through the 2010 World Expo (solicitation expected soon)
  - $32 M project funded by GEF-UNDP ($12 M) and China Government
  - Fueling station built in Beijing and Shanghai
- **Tshinghua and Tongi University Buses and Passenger Cars**
  - 5 buses developed in 2005
  - 10 passenger cars developed in 2005-6

# Korea



# Korea

## Two main funding agencies:

- Ministry of Knowledge Economy (MKE)
  - Applied and commercial technologies
  - Provides R&D funding to the Korean Energy Management Company (KEMCO)
- Ministry of Education, Science and Technology (MEST)
  - Long-term, fundamental R&D

# Korea

- MKE and private funding totaled $111 M in 2007
  - R&D, Demonstration and Technical Validation for fueling stations and fuel cells for stationary, transportation and portables.
- MEST created the $H_2$ Energy Research Center (HERC)
  - Focus on facilitating the development of $H_2$ production, storage, and utilization technologies.

Korea

# Demonstration Projects


**Vehicles:**

- MKE launched $H_2$ and FC automobile demonstration in 2006.
  - ✓ Hyundai Motors leads consortium of companies.
  - ✓ Target: 300 km range.
  - ✓ Operating 18 cars and 2 buses
  - ✓ $52 M budget
  - ✓ Ends in 2009.

# Korea

## Hydrogen Stations:

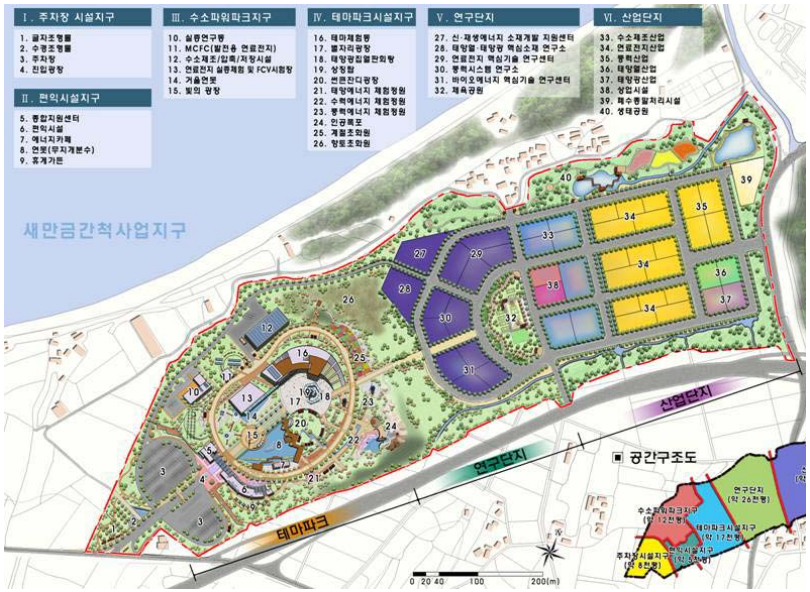
- 8 stations expected,
  4 currently operating.
- 350 bar


## Residential FC Power:

- From 2006 – 2009, expect
  210 units (1kW, grid connected)
- $54 M budget
- Natural Gas

# Korea

## $H_2$ and FC Power Complex




- 360,000 square meters
- $100 M budget
- Completed by 2010
- Demonstration and testing center, Research and evaluation center, educational kiosks and exhibition hall.
- Includes renewable energy technologies.

# Russia

# Russia

- **2007-2012: ~$30 M annually**
  - ✓ ~$ 20 M will be allocated by private companies (Norilsk Nickel, Gazprom, RAO “United Energy Systems” and others) for projects to be implemented through public private partnership

- The main objectives of the national program is to accelerate research and development in the priority areas of science and engineering, and to accelerate commercialization of the innovative technologies and new products.

# Russia

## RD&D

- Becoming increasingly organized and centralized
  - Two federal programs fund the $H_2$ and FC activities
    - National Science R&D
    - National Technology Development
- Growing number of organizations are also studying proton exchange membrane (PEM), solid oxide (SOFC) and molten carbonate fuel cell (MCFC) technologies.
  - Initially focused on alkaline fuel cells (AFC)
  - 2003 - 2006: Norilsk Nickel and Russian Academy of Science signed $120 M agreement to develop PEM stacks and SOFC (3 – 5 kW)

# United Kingdom

# United Kingdom

- UK FC Development and Deployment Roadmap
  - Identifies actions and strategies needed for the UK to overcome the challenges around the long-term development and deployment of FCs
- The King Review of Low Carbon Cars (Oct. 2007)
  - Recognized potential role of novel battery or hydrogen technology to decarbonize the road transport sector
- Active R&D community (Over 35 groups)
  - Focus on materials/components, storage, integration with renewables, socioeconomics
  - SOFC and PEMFC are main priorities
  - ***Supported with ~$20 M from government in 2007***

# United Kingdom

- Low Carbon Vehicles Innovation Platform
  - ✓ Partially supported by Department of Transportation
  - ✓ Support low carbon vehicle RD&D
  - ✓ First competition worth ~ $25 M (viable technologies leading to fleet procurement over next 5 – 7 years)
  - ✓ Second call will be for ~ $85 M (longer-term, more radical solutions)

# United Kingdom

## Industry Activities:

- Membrane Electrode Assembly
  - ~ $12 M consortium to address cost reduction
- PEMFC
  - ~ $10 M for advanced stack technology
- Storage
  - ~ $3 M for novel metal hydrides not yet reported in literature, followed by scale-up of the most promising
- Vehicles
  - ~$4 M effort to lower entry barriers for $H_2$ vehicles
  - Advanced FC, lightweight materials, and hybrid system to achieve 200 mile range

# United Kingdom

## Demonstrations:

- Five projects totaling ~ $10 M
  - 10 buses and 60 vehicles in London
- UK Hydrogen Filling Station
  - Air Products
  - 6 vehicles per day
  - Production via zero emission biomass process (Green Gases Ltd)

# Summary

- Key drivers are energy security, environment/climate and competitiveness.
- Continuing to see growth in public and private investment in hydrogen and fuel cell technologies
- Transportation is the primary focus
  - Storage, renewable production, PEMFCs
- IPHE will continue to work with the public and private sectors to facilitate technology and policy development

# Thank you.

## Questions?