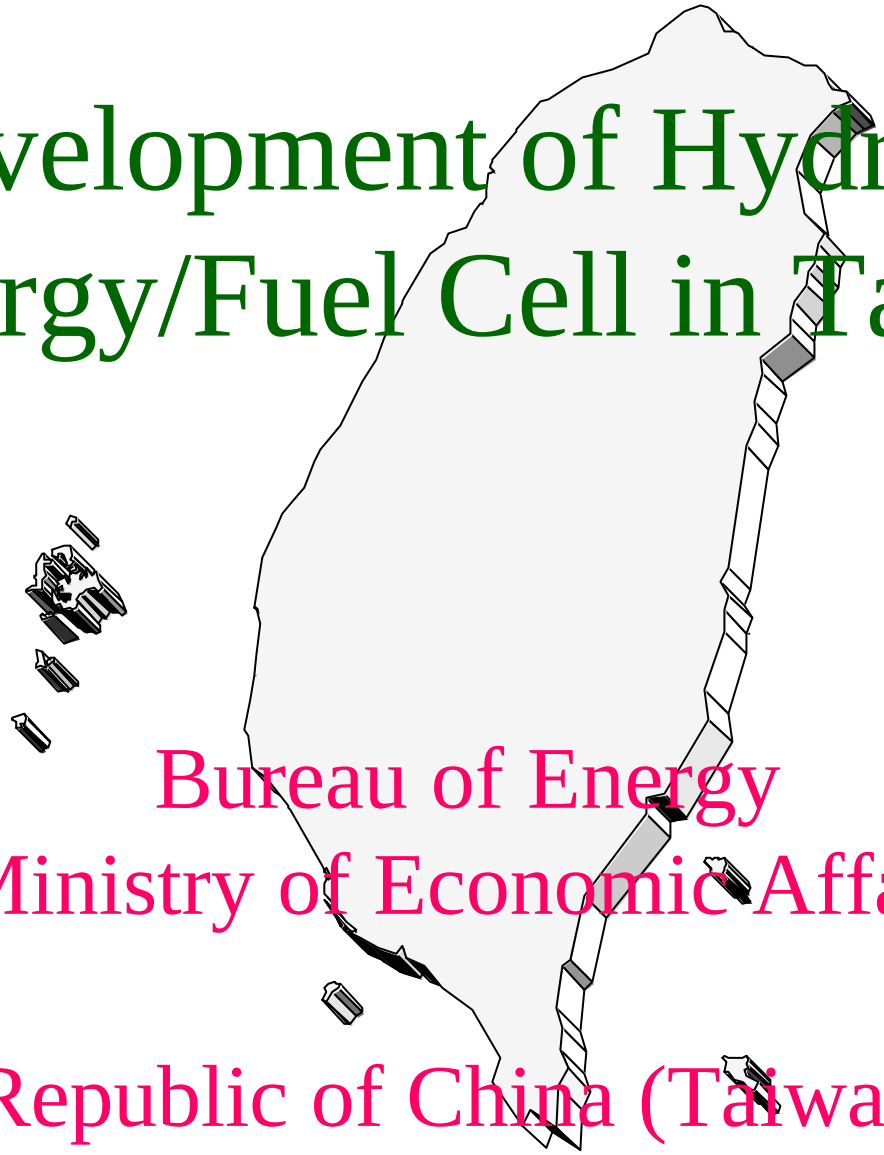
# Development of Hydrogen Energy/Fuel Cell in Taiwan

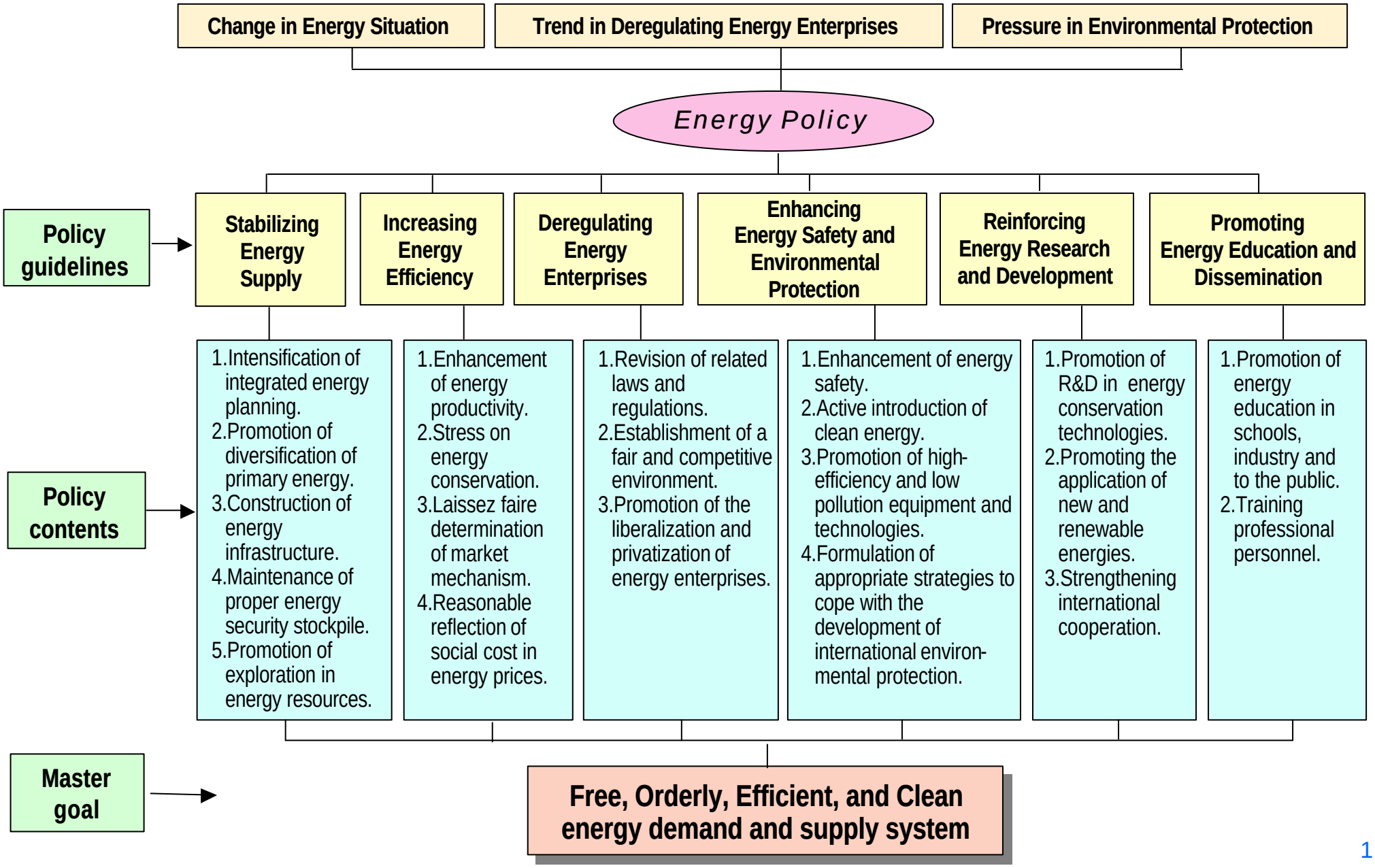


Bureau of Energy

Ministry of Economic Affairs

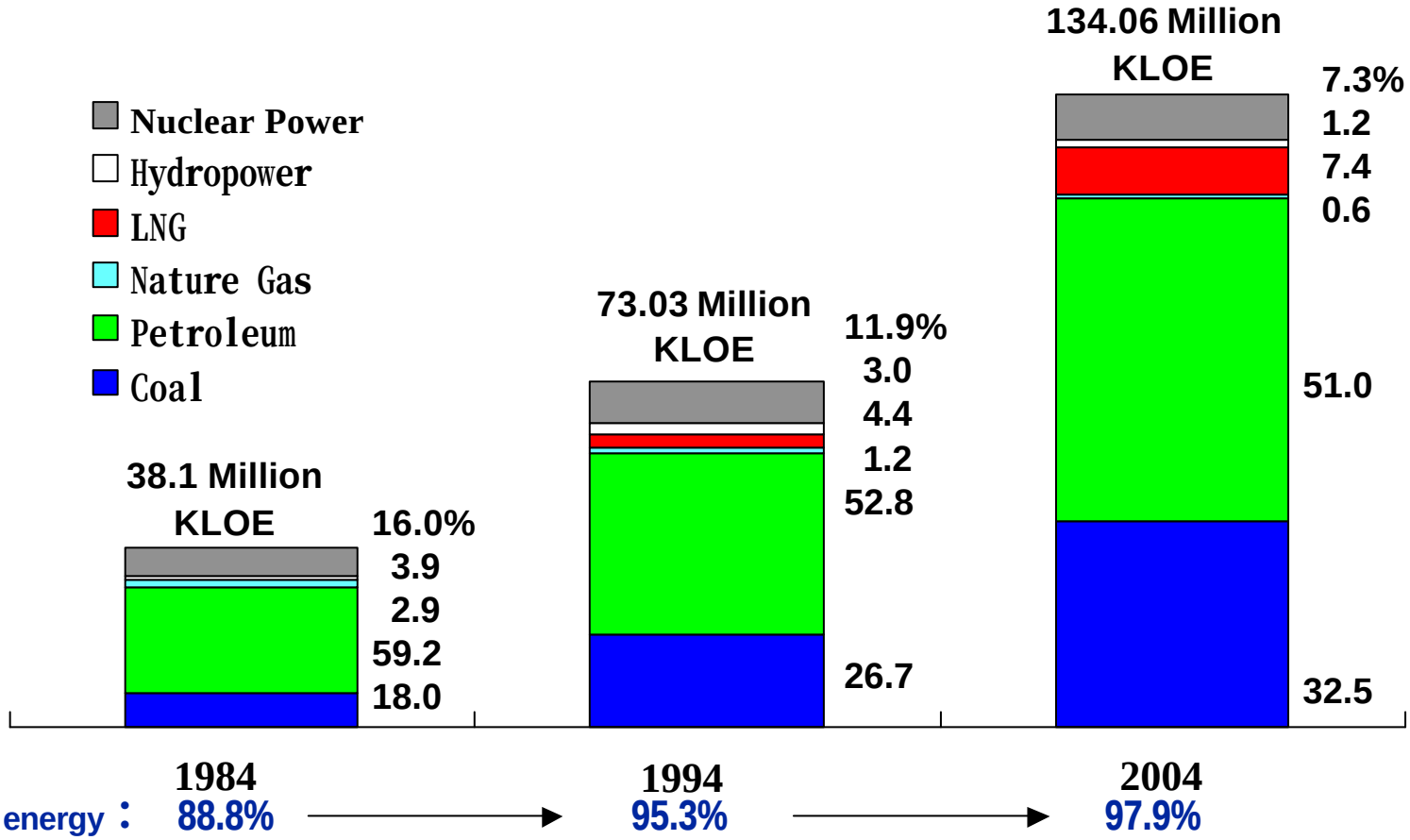
Republic of China (Taiwan)

# Taiwan's Energy Policy



# Structure of Energy Supply in Taiwan

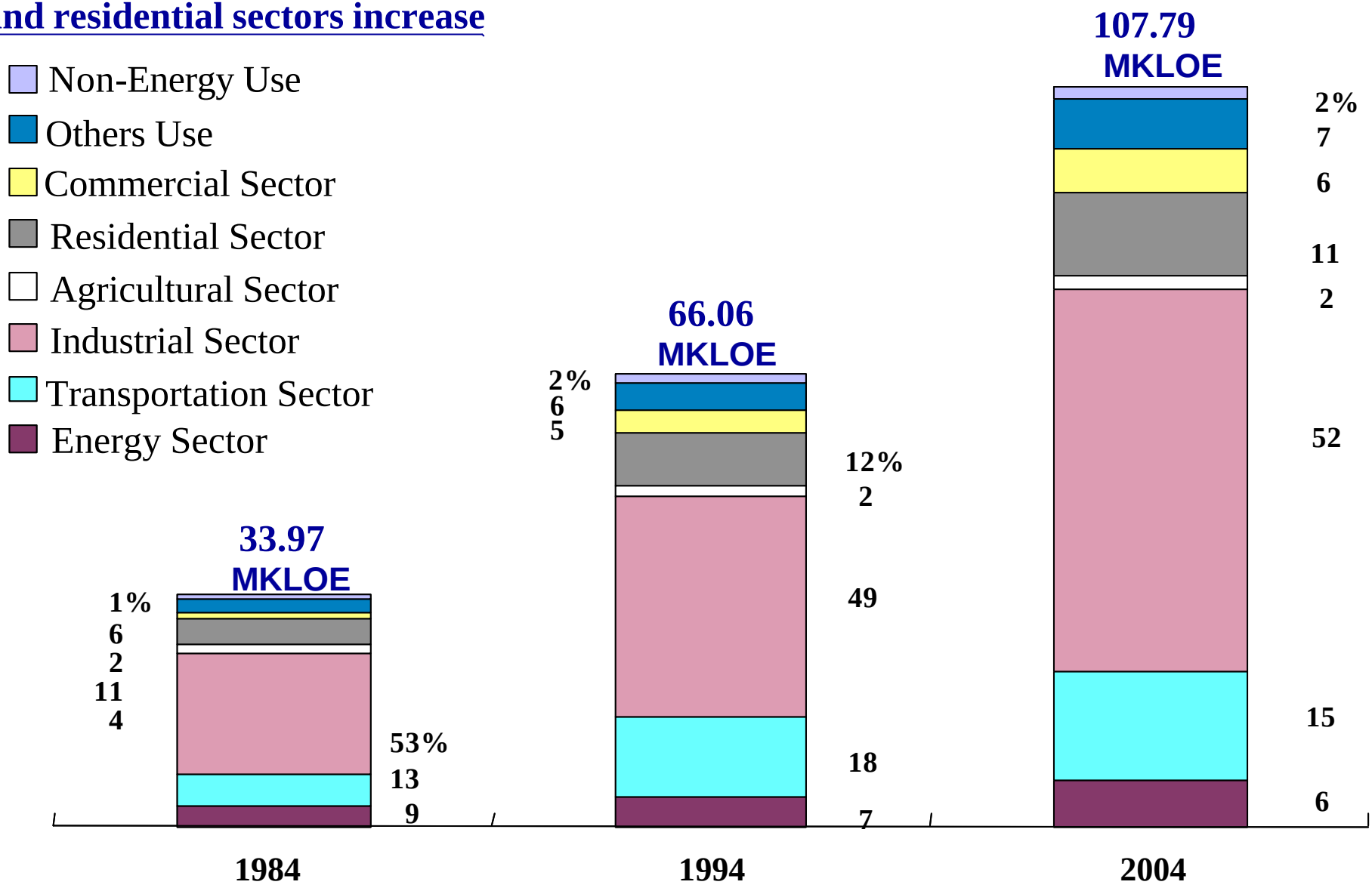
- Due to the shortage of indigenous energy, more than 97.9% of energy is imported.
- Imported crude oil is the major portion of energy supply and 76.7% of it is from the Middle East.
- During 1984~2004, average annual growth rate of energy supply is 6.4%




Dependence of imported energy：1984 88.8% → 1994 95.3% → 2004 97.9%

# Structure of Energy Consumption (by Sector)

↓**The shares of energy consumption in commercial and residential sectors increase**



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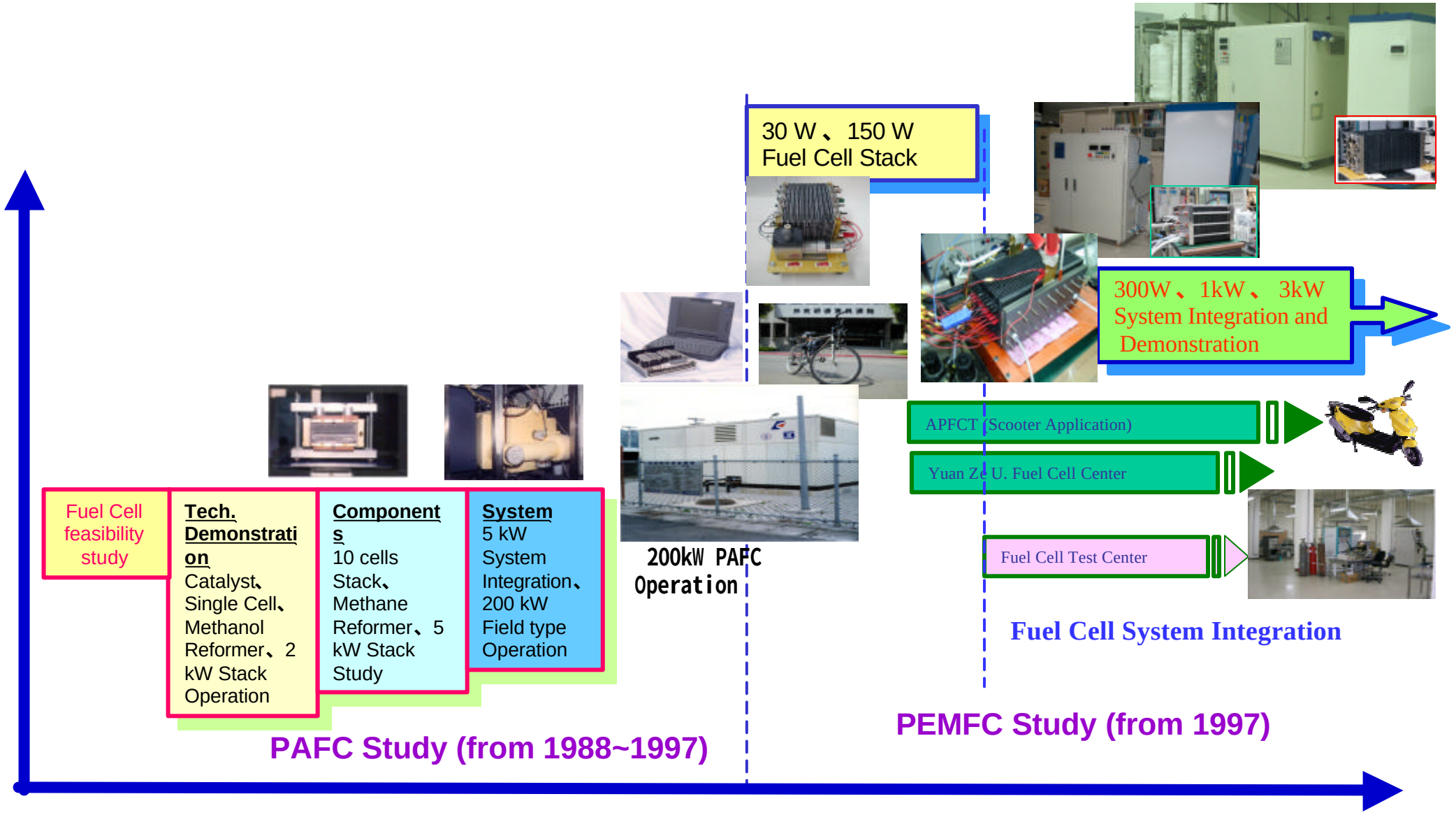
# Fuel Cells & $H_2$ Development Strategies

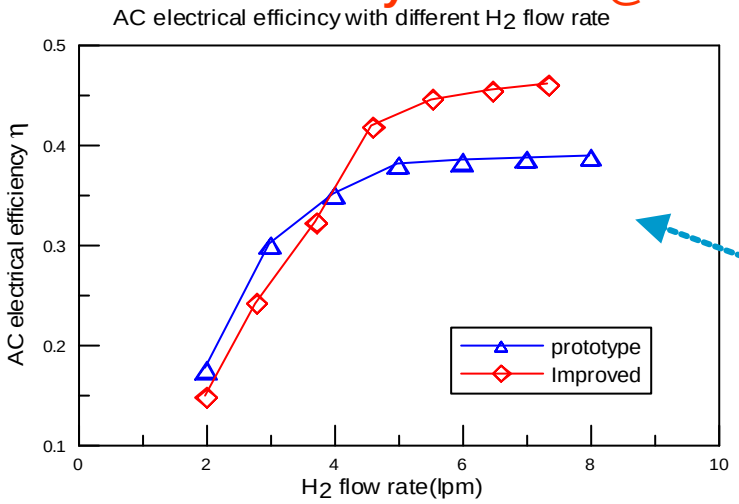
- Focus on system technology platforms that have the widest possible applications
- Look for the best synergies between the fuel cell technologies and the existing infrastructures (reducing entry barriers & accelerating commercialization)
- Conduct technology validations through lab. and field demonstrations
- Develop $H_2$ infrastructure technologies that would enhance the long-term energy security

# History of Taiwan FC/$H_2$ Development



# CHP System Technology Development

## •1 kW PEMFC System Eff. @ 46%




## 1 kW PEMFC ($H_2$) Combined Power and Heat System

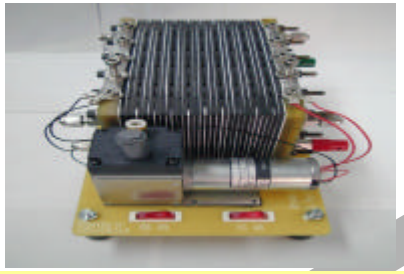
**Power Module Specifications:**

- Hydrogen Consumption: 12.0 slpm
- Electricity Output: 1 kW、Single Phase、110V/220V AC
- Overall Efficiency: 75%
- Electrical Efficiency: 46%

**Water Tank Specifications:**

- Storage Capacity: 250 Liters
- W/D/H: 50/50/130 cm

## 300W PEMFC Power System



**Power Module Specifications:**

- Hydrogen Consumption: 3.6 slpm
- Electricity Output: 300W、DC12V
- Electrical Efficiency: 40%
- Air Cooling

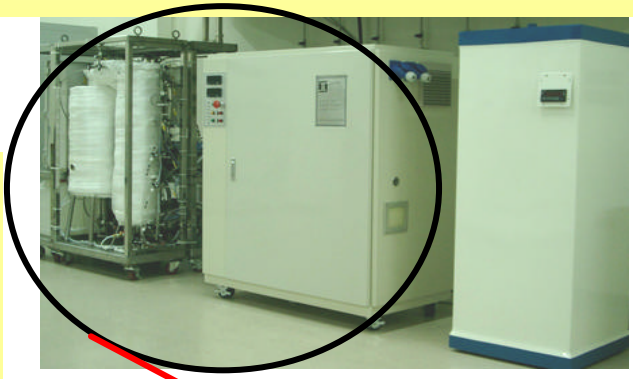
## 3 kW PEMFC (Reformate) Combined Power and Heat System

**Power Module Specifications:**

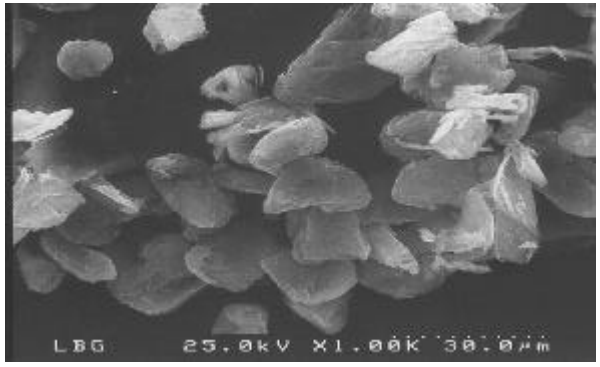
- Methane Consumption: 25.0 slpm
- Electricity Output: 3 kW、Single Phase、110V/220V AC
- Overall Efficiency: ~ 55%
- Electrical Efficiency: ~ 20%

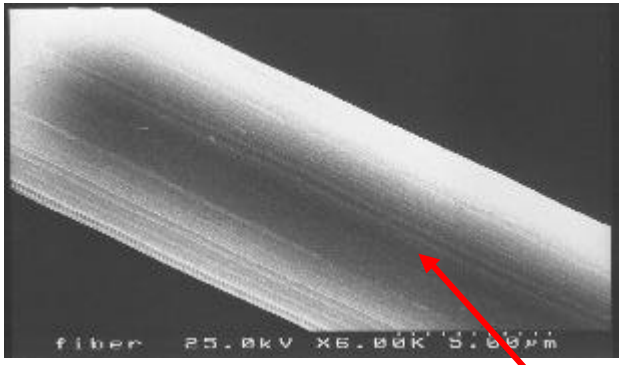
**Water Tank Specifications:**

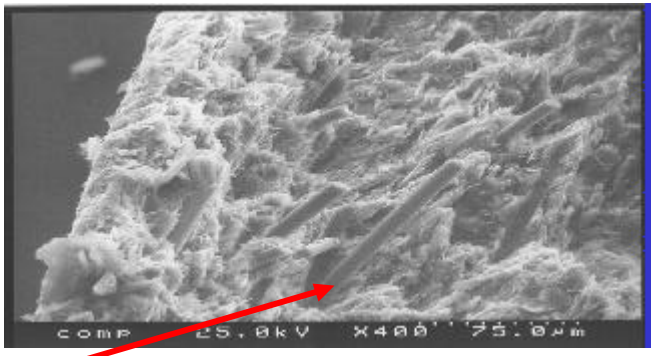
- Storage Capacity: 250 Liters
- W/D/H: 50/50/130 cm

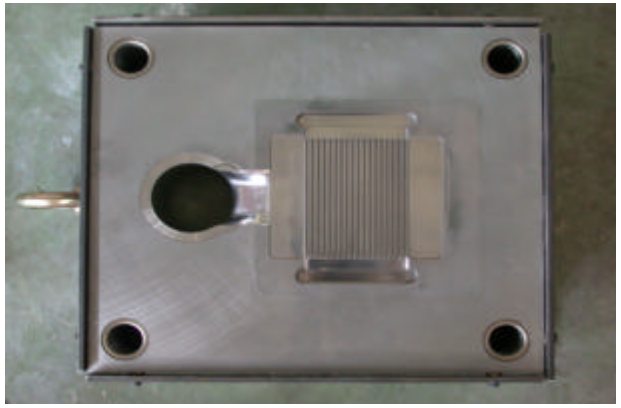


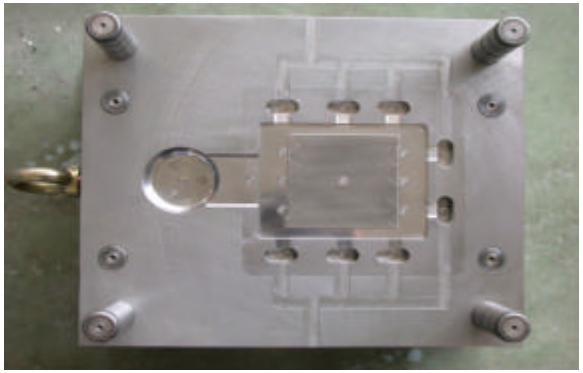
# Composite Bi-polar Plate Development

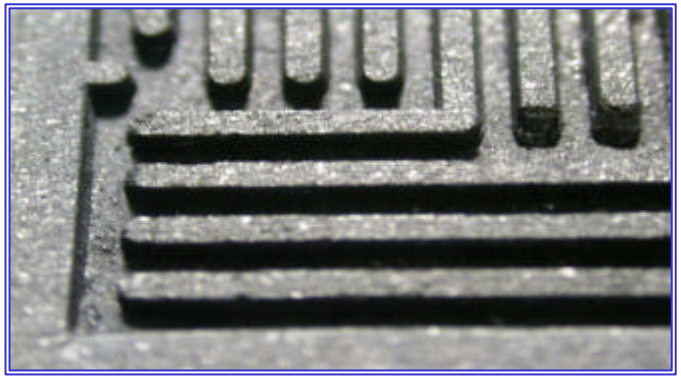


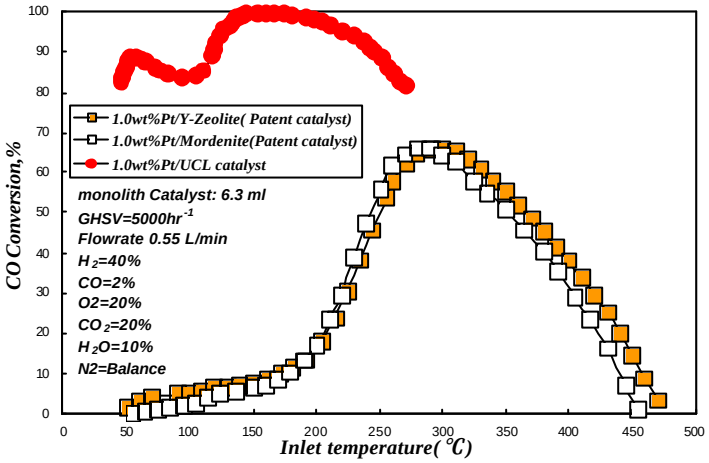


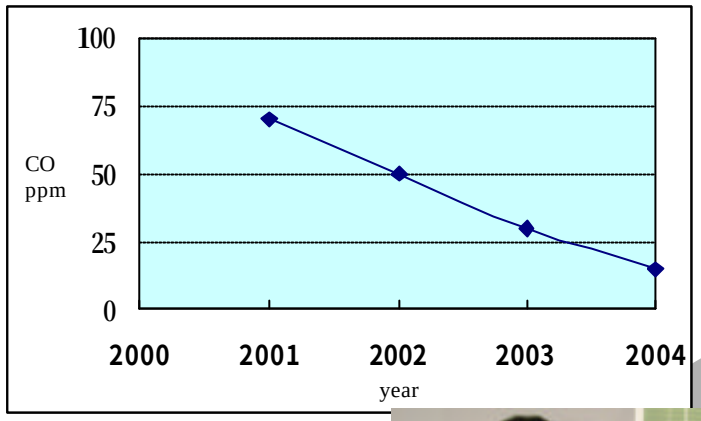


| Items / Properties | Targets | Achieved |
|---|---|---|
| Conductivity | > 100 s/cm | 170 s/cm |
| Corrosion Current | < 16 mA/cm$^2$ | 0.45 mA/cm$^2$ |
| Tensile Strength | >3000 psi | 4500 psi |
| Bending Strength | >4000 psi | 7800 psi |

# NG & MeOH Reformer Development

## •PrOx Catalyst Development




## 3 kW NG Reformer (III)

—$H_2$ ≧ 50 L/min
—$H_2$ Conc. ≥ 45%
—CO Conc. ≤ 20 ppm

## 3 kW NG Reformer (II)

## 1 kW NG Reformer

—$H_2$ ≧ 20 L/min
—$H_2$ Conc. ≥ 37%
—CO Conc.≤ 70 ppm

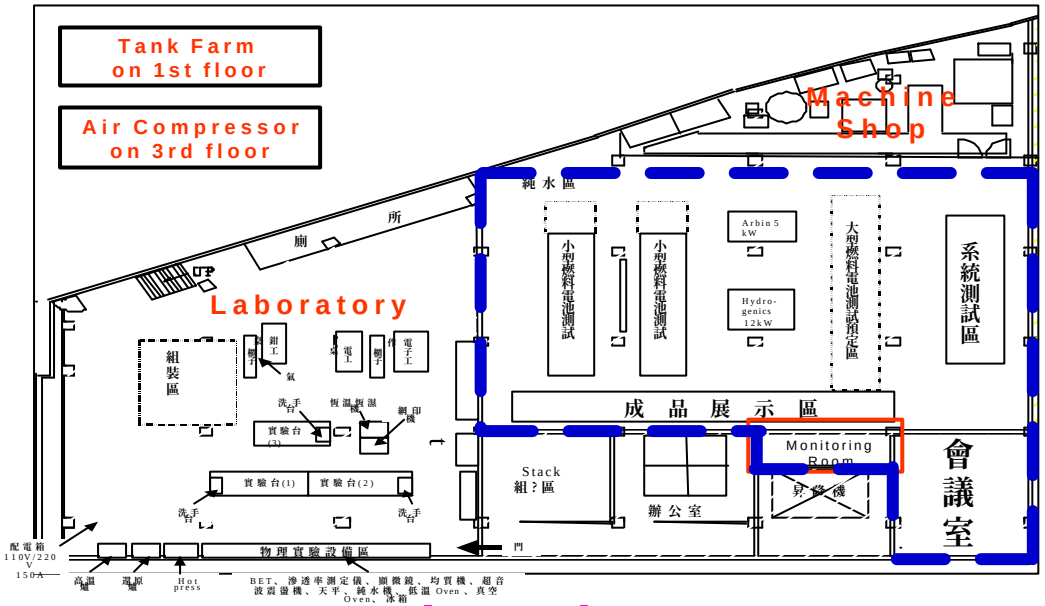
## 3 kW NG Reformer (I)

## 1 kW Methanol Reformer

**50* 30*20 cm (H*W*D)**

—$H_2$ ≧ 30 L/min
—$H_2$ Conc. ≥ 50%
—CO Conc. ≤ 20 ppm

# National Fuel Cell Test Center

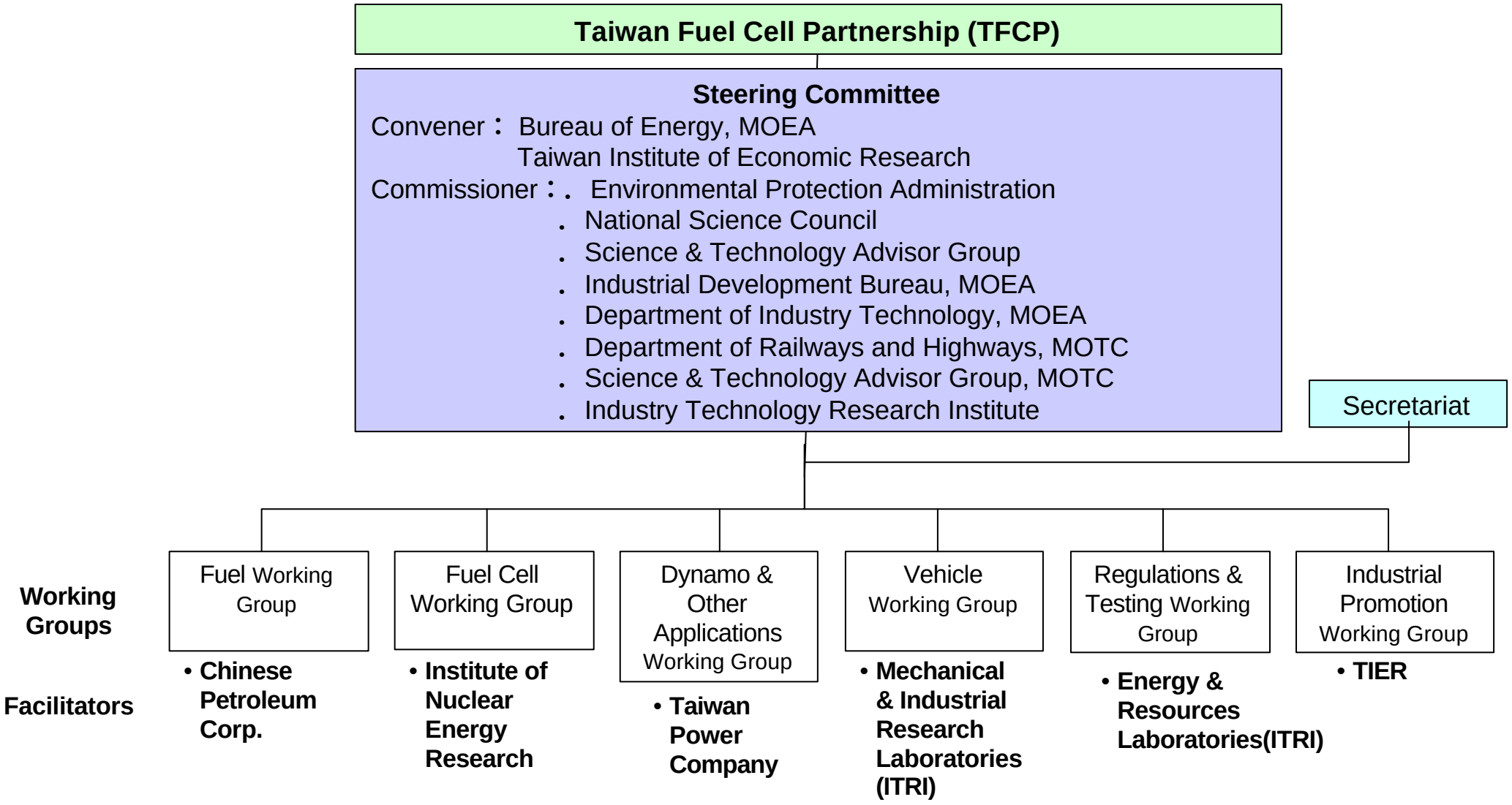



Floor Plan

300~600 W Test Stations (In House)


2, 5 & 12 kW Test Stations (Industrial Grade)

# Taiwan Fuel Cell Partnership



# Summary of Other Activities and Achievement

- 1 kW portable power unit suitable for increasing outdoor recreational power demands
- Taiwan Fuel Cell Partnership becomes a member of the US Fuel Cell Council and interactions at the Working Group level start
- The 1st round robin test, based on ***ASME PTC 50-2002***, was completed in 2004 and the 2nd round robin test is underway

# MOEA Milestones of Taiwan's Fuel Cell Development

| | |
|---|---|
| 1987 | TPC/ERL/ Feasibility Study |
| 1988 | EC/ERL/ PAFC Program |
| 1995 | EC/ERL/TPC/ 200kW PAFC Power Plant Demonstration |
| 1998 | EC/ERL/ Adjusted to Develop PEMFC Technology |
| 1999 | TIER/ Fuel Cell Scooter Promotion |
| 2000 | EC/ITRI/ Fuel Cell HPS Program |
| | EC/YZU/ Fuel Cell Research Program |
| | APFCT/ Fuel Cell Stack and Scooter |
| 2001 | DoIT/TBIRDC/ Fuel Cell Bike |
| | EC/MRL/ Hybrid Fuel Cell Vehicle |
| | EC/EPA/TIER Taiwan Fuel Cell Partnership |
| 2002 | DoIT/MRL/ DMFC Program |
| | DoIT/Jemmytex/ 1kW PEMFC Generator Using Hydrogen |
| | NSC/Universities/ 48 Fuel Cell Projects |
| | Dupont/APFCT Fuel Cell Scooter Program |
| | EC/ERL 1 kW Hydrogen Combined Power & Heat System Prototype |
| 2003 | AEC/INER/ SOFC & DMFC Program |
| | DoIT/YZU Fuel Cell Research Program |
| | IDB/APFCT/ PEM Stack Assemble Line Project |
| 2004 | BOE/TIER Strategic Fuel Cells and Hydrogen Development Planning Completed |
| | BOE/ERL 3 kW NG-based Combined Power & Heat System Prototype |

# MOEA $H_2$ Infrastructure Technology & PEMFC System Development

## Hydrogen Infrastructure Technology Development

**Distributed Hydrogen Production($H_2$>10 $Nm^3$/hr @ $\eta_{th}$ > 80%, FER) and Storage(> 4wt% material-based) Technology, and $H_2$-based Economic Modeling**

☆ Hydrogen Production/Storage

- Improvement of fossil-based reformation technologies & energy system
- Pre-study of long-term, advanced $H_2$ production/storage technologies
- Domestic hydrogen resources projection a priori

☆ $H_2$ Economy Evolution & System Demonstrations

- Establishment of $H_2$-economy modeling capability
- Laws & regulations adaptation and adoption
- Hydrogen energy system demonstrations

2005 2006 2007 2008

## PEMFC Applications Development

**3 kW Stationary PEMFC CHP System Applications and Development ($\eta_{th}$ > 70%, Durability > 2500 hrs)**

☆ System Durability Improvement & Cost Reduction

- High performance stationary/portable system development
- Key components commercialization
- High performance NG/MeOH/LPG reformer development

☆ PEMFC Applications & Demonstrations

- Alliance/partnership, education and training
- Laws & regulations adaptation and adoption
- Hydrogen energy system integration and demonstrations

**Hydrogen Energy Technology Demonstration and Commercialization**

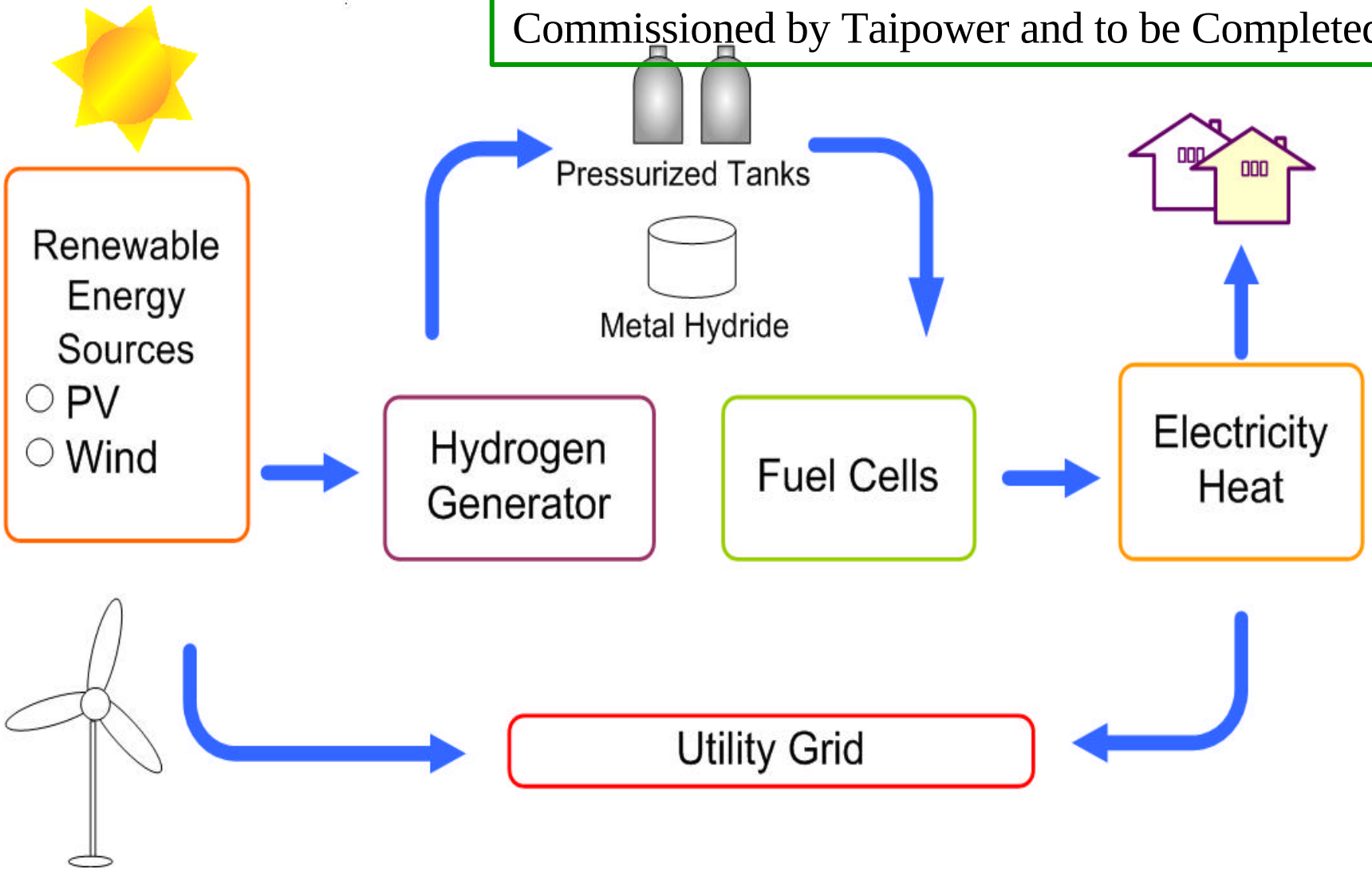
**Establishment of an Innovative Energy Resource Station by 2008**

**Renewable Energy Integrated Demonstration and Commercialization**

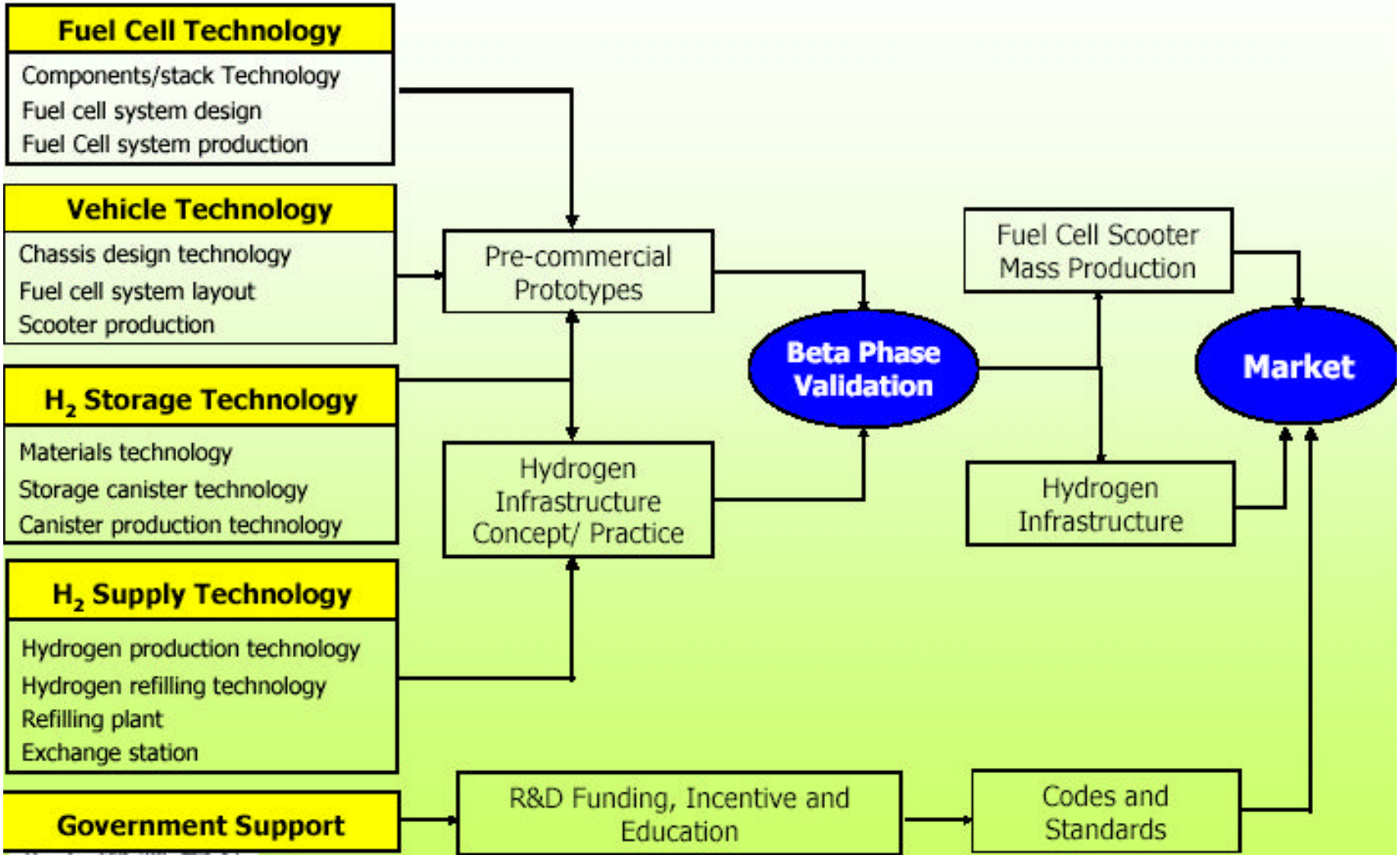
**PEMFC CHP System Demonstration and Commercialization**

# Integrated Renewable Energy and Fuel Cell Power Generation Demonstration

Commissioned by Taipower and to be Completed in 2006

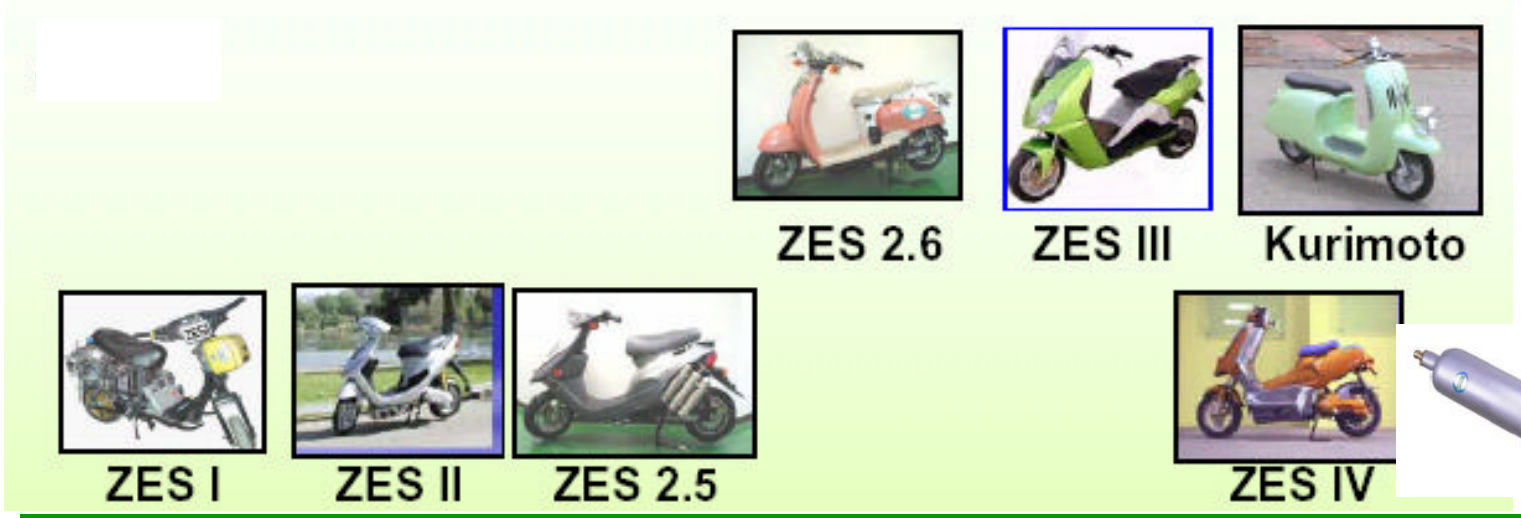


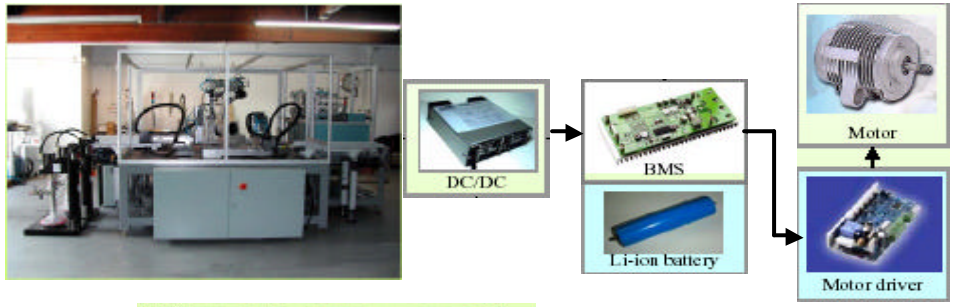
# PEMFC Scooter System Development

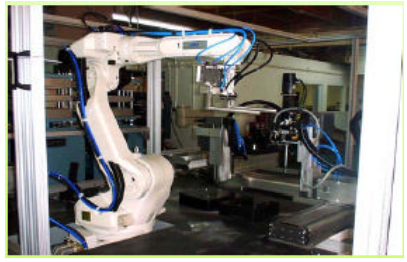



Courtesy of Asia-Pacific Fuel Cell Technology Co.

# PEMFC Scooter System Development



Courtesy of Asia-Pacific Fuel Cell Technology Co.

# A Mini-hydrogen Corridor Concept (2007-2010)

Refining & Manufacturing Research Institute

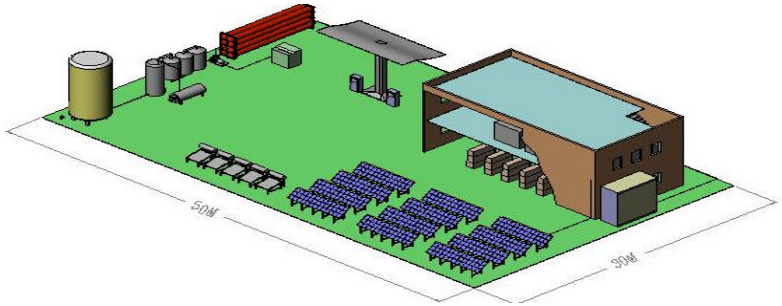
Southern Taiwan Science Park


ITRI Southern Campus



Fuel Cell Bus & Car

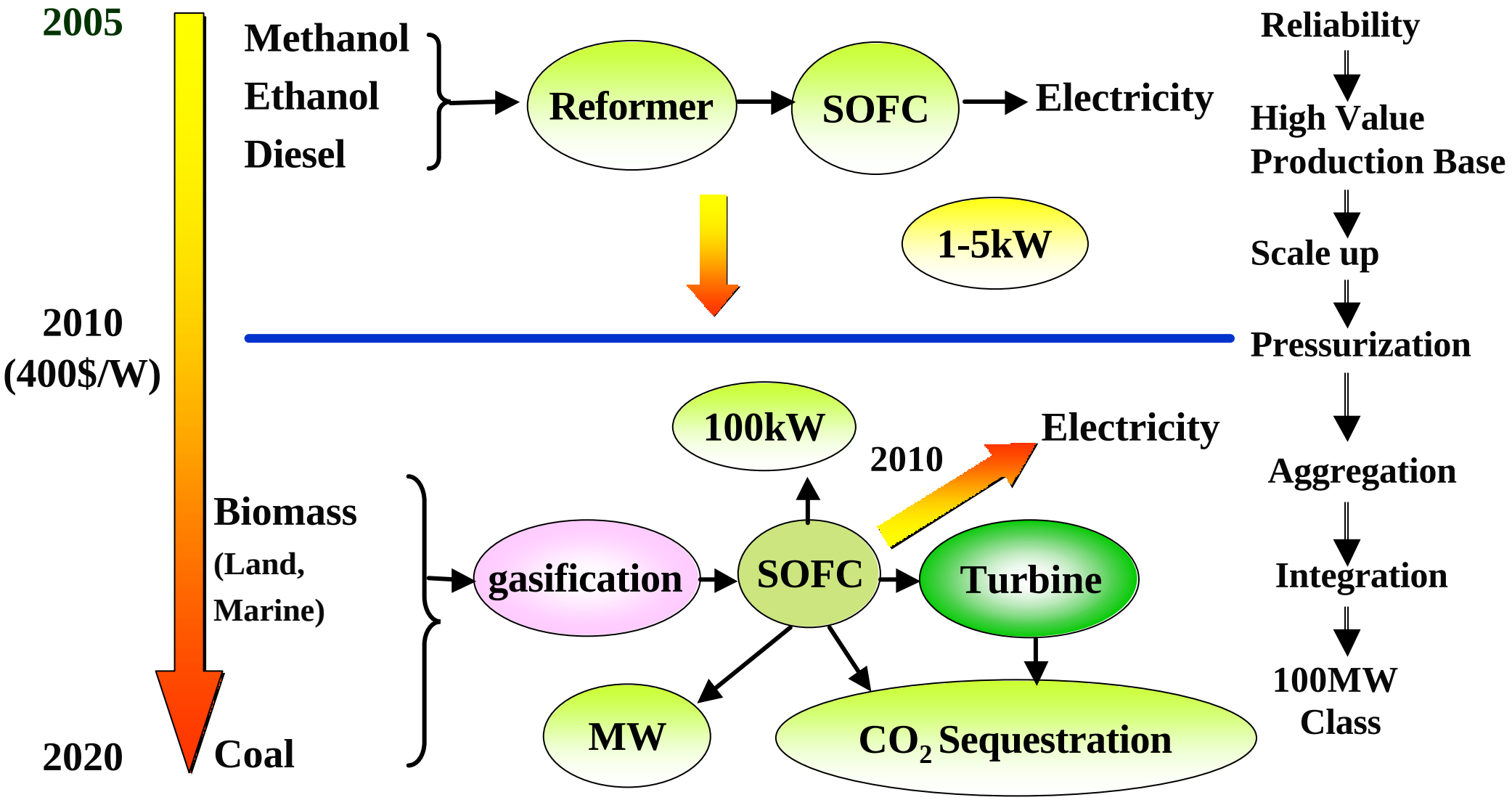

Hydrogen Station



Innovative Energy Tech. Station

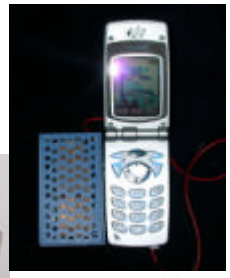
# SOFC Technology Development

Carried out by INER



# DMFC Technology Development

Sponsored by DoIT




Cellular phone(2010)

Notebook PC(2007)

Power Pack(2005)

Energy Conversion Efficiency

System Energy Efficiency

| | 2002 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|
| System | 200Wh/Kg<br>60~70 ℃ | 400Wh/Kg<br>50~60 ℃ | 600Wh/Kg<br>50~60 ℃ | | 1200Wh/Kg<br>50~60 ℃ |
| Conducting Membrane | $10^{-4}$ S/cm<br>$10^{-6}$ cm/s | $10^{-3}$ S/cm<br>$10^{-7}$ cm/s | $10^{-2}$ S/cm<br>$10^{-8}$ cm/s | | $10^{-2}$ S/cm<br>$10^{-9}$ cm/s |
| MEA | 100 mA/cm$^2$ | 200 mA/cm$^2$ | 300 mA/cm$^2$ | | 400 mA/cm$^2$ |
| Catalyst | 200 mA/mg | 250 mA/mg | 300 mA/mg | | 450 mA/mg |
| *Year* | | | | | |

# Public and Private R&D Investment in $H_2$ Infrastructure & Fuel Cells Technologies

| | 2003 | 2004 | 2005 |
|---|---|---|---|
| **Public Budget** | NT$ 250 M (US$ 7.6 M) | NT$ 260 M (US$ 8.1 M) | NT$ 350 M* (US$ 11.1 M) |
| **Private Investment** | NT$ 100 M (US$ 3 M) | NT$ 100 M (US$ 3 M) | NT$ 100 M* (US$ 3.1 M) |
| **Total** | NT$ 350 M (US$ 10.6 M) | NT$ 360 M (US$ 11.1 M) | NT$ 450 M* (US$ 14.2 M) |

***: Figures are estimates up to May, 2005**

Source: TIER/ITRI

# Public and Private R&D Investment in $H_2$ Infrastructure & Fuel Cells Technologies

| | |
|---|---|
| **Academia** | Basic Research in DMFC, SOFC, PEMFC and $H_2$ |
| **Research Institutes** | R&D in PEMFC, SOFC, DMFC and $H_2$ Key Components and System Technology |
| **Private Sector** | Development of Key Components, and Integration/Demonstration of PEMFC, DMFC and Metal Hydrides |

Source: TIER/ITRI

# Concluding Remarks

- Significant progress made for PEMFC CHP system development in Taiwan and future focus on performance/durability improvement, cost reduction and field demonstrations
- DMFC & SOFC also making headway into system integration with potential industrial and energy impacts
- Hydrogen infrastructure technology a new R&D element, focusing on high-efficiency, cost-effective and distributed production methods and composite /chemical storage technologies

# Concluding Remarks

- Substantial, long-term resource commitments from the public and private sectors to hydrogen and fuel cell technology R&D activities with a coordinated objective to advance technology deployment and early commercilization
- International cooperation, e.g. IPHE, on technology development, demonstrations, standards and codes will cut cost and accelerate early markets development and the hydrogen transition