Roadmap to Deploying Technologies for Sustainable Development
An Analysis of End-use Technologies in a Post-Fossil Scenario

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Motivation

Describe the potential of renewable energy sources to achieve sustainable-development (SD)

- Focusing on end-use and fuel cell applications

Assist target setting in long-term technology policy making to achieve SD

- Significant cost and performance improvements could be brought about by successful combination of RD&D and supporting policies
Key Technologies in the R/C Sector
For lighting, refrigerating, heating space/water, cooking etc.

Fuel cell-based cogeneration system (stationary)
• Produces on-site heat and electricity with high efficiency (75% maximum) from hydrogen in a wide range of system size.

Solar PV and solar thermal energy
• Utilize sun light to produce electricity and heat on-site and without emissions.

Electricity production from fuel cell vehicles
• Utilize fuel-cell vehicle while parked (96% average) and produces on-site electricity. 130 km equivalent hydrogen can produce 44KWh.
Key Technologies in the R/C Sector
Key Technologies in the Industry Sector
For driving motors, process heating, steam generation etc.

- Improved heat recovery from boilers
- Improved steam turbine system for the steam-electricity cogeneration
- Improved combustion (gas) turbine system for the steam-electricity cogeneration
- Electric furnaces
Key Technologies in the Industry Sector
Key Technologies: Transportation Sector
For passenger and freight transport

The Internal-Combustion Engine (ICE)
• Used practically by all road vehicles of today. Has the potential of improving fuel consumption of a car from 8-30 to 4.5-9 liter per 100km by 2100.

Electric motors
• No emissions. Technical spillover between FC cars and electric cars. Economic and technical performance of batteries is the main technical obstacle when external source is used for electricity supply.

Hydrogen-based fuel cells
• No emissions. 50-100% higher fuel economy. Flexible feedstock for hydrogen production. Hydrogen storage tanks still to be improved.

Methanol/ethanol-based fuel cells with reformer
• Lower emissions. 50-100% higher fuel economy. The need for reformers is the main technical obstacle.
Key Technologies: Transportation Sector

Honda: FCX (4.8 liter per 100km, 260-355 km)

Ford: Think (Equ to 2.5 liter per 100 km, 68km)

Other EVs: Range up to 220km
MESSAGE and the PF Scenario

MESSAGE

- describes a possible transformation of the global energy system in 100 years while assuring technical/geographical consistencies in the energy systems

The PF scenario

- is one of many scenarios calculated by MESSAGE and describes future energy systems with maximum use of renewable sources
Residential and Commercial Sector in the PF scenario

Non-thermal purposes (electricity)  
Thermal purposes
Residential and Commercial Sector in the PF Scenario – CO₂ Emission Mitigation

Saving of 4.8 GtC in 2100
Industry Sector in the PF scenario

Non-thermal purposes (electricity)

Thermal purposes

- FC cogeneration
- solar PV
- methanol
- hydrogen
- diesel engine
- grid and CHP turbines

- cogen.
- solar
- biomass
- coal
- d_heat
- methanol
- hydrogen
- oil products
- electricity
- gas_hp
- gas

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Industry Sector in the PF Scenario

CO₂ Emission Mitigation

Saving of 0.8 GtC in 2100
Transportation Sector in the PF Scenario

- Coal based
- Gas based
- Oil based
- Electricity based
- Ethanol (ICE)
- Fuel cell (ethanol)
- Fuel cell (methane)
- Fuel cell (hydrogen)
Transportation Sector in the PF Scenario
CO₂ Emission Mitigation

Saving of 5.9 GtC in 2100
Introduction of Low-emission Vehicles

From left to right: 2010, 2020, 2030, 2040, 2050

- Fuel cell vehicles (hydrogen)
- Fuel cell vehicles (ethanol)
- Fuel cell vehicles (methanol)
- Electric vehicles
Fuel Consumption Rates of Automobiles

1990 average: 11.8 liters
2050 average: 7.3 liters
Methanol and Ethanol Consumption

![Bar chart showing consumption of methanol and ethanol across different regions, with colors and categories indicated.](chart.png)
Policy Relevance

Technological development schedule that leads to the sustainable development

Technological policy must in place to follow the schedule

Technology developments are accompanied with the technological cost reduction
ECS Research on Technology Policies

Analysis of technology policies such as procurement, subsidies, and public R&D support:


Quantifying the effectiveness of the R&D using an extended learning curve concept, which relates technology cost and cumulative capacity and R&D:

- Klaassen *et al.* (2003); McDonald and Schrattenholzer (2002)

Development of the tool for optimal R&D allocation using the learning curve:

- Miketa and Schrattenholzer (2004); Barreto and Kypreos (2003), Kouvaritakis (2001)
Conclusions

With successful technology policies, it appears possible for future energy systems to be based on renewables and synthetic fuels.

By 2100, our sustainable-development scenario features …

- A shift from centrally produced energy supply to on-site production of electricity as well as from furnace-based technologies to solar and fuel cell-based technologies in the residential and commercial sector;
- Energy efficiency improvement of the industrial energy system including CHP further proceeds;
- Fuel cell technologies as the preferred transportation technologies, with synthetic fuels supplying 85% of total transportation demand;
- A global average on-the-road vehicle fuel consumption of 7.3 liter (from 11.8 liter) per 100 km and a car ownership of 50 (from 10) per 100 persons.