Energy Technology Perspectives 2006
Results, Technologies and R&D Needs

Dolf Gielen
RD&D Workshop, 15-16 February 2007
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Structure of this Presentation

- Technology development
- ETP2006 scenarios
- Technologies
- R&D needs
Technology Development
Technological change is a slow process

Limited by:
- Time for RD&D
- Rate of product stock turnover
- Competing existing technologies

Typical time from invention to 50% of market 10-30 years

Technology RD&D should be finished by 2025 in order to have a significant impact by 2050
Technology Life Cycle

R&D
- Technologies in need for R&D to overcome technical barriers and to reduce costs. The outcome is still uncertain, especially in the early stages of development.

Demonstration
- Demonstration of the technology. Often government funding is needed to finance part or all of the costs of the demonstration.

Deployment
- Successful technical operation, but in need of support to overcome cost barriers. With increasing deployment learning-by-doing effects will result in gradually decreasing costs.

Competitive
- Technology is cost competitive in some or all markets, but some technologies may require sustained incentives to value CO₂ emission reduction or other benefits.
Technology Development Criteria

- A technology should function adequately
- It should be cost-effective
- It should have no significant external effects
- It should have scope for widespread application
- It should be acceptable from a supply security and CO2 reduction viewpoint
ETP2006 scenarios
The Scenario Background

- The six IEA Energy Technology Perspectives 2006 scenarios complement the two IEA World Energy Outlook (WEO) scenarios.
- The WEO scenarios for 2030 show that current trends are not sustainable.
- The ETP Baseline Scenario corresponds with the WEO Reference Scenario.
- The ETP scenarios show how CO₂ emissions can be stabilized and how supply security can be enhanced between now and 2050.
- The emphasis is on the role that energy technologies can play.
- A radical technology change needed.
Scenario Scope

- 2050 time horizon
- Analysis based on a technology-rich partial equilibrium model (MARKAL based)
- Renewables analysis GIS-based
- Fed by spreadsheet analysis for end-use sectors
ETP2006 Scenarios

- Scenarios analysed:
  - Baseline Scenario
  - Accelerated Technology Scenarios (ACT)
  - TECH Plus scenario

- ACT and TECH Plus scenarios:
  - Analyse the impact from R&D, Demonstration and Deployment measures
  - Incentives equivalent to 25 $/tonne CO₂ for low-carbon technologies implemented world-wide from 2030 and on
  - Individual scenarios differ in terms of assumptions for key technology areas
## Technology Assumptions

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Renewables</th>
<th>Nuclear</th>
<th>CCS</th>
<th>$H_2$ fuel cells</th>
<th>Advanced biofuels</th>
<th>End-use efficiency</th>
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<tbody>
<tr>
<td>ACT Map</td>
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<td></td>
<td></td>
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<td>2.0 % p.a. global improvement</td>
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<tr>
<td>ACT</td>
<td>Relatively optimistic across all technology areas</td>
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<tr>
<td>ACT</td>
<td></td>
<td>Slower cost reductions</td>
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<tr>
<td>ACT</td>
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<td></td>
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<td></td>
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<td>1.7 % p.a. global improvement</td>
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<tr>
<td>ACT</td>
<td></td>
<td>Lower public acceptance</td>
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<tr>
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<tr>
<td>TECH Plus</td>
<td>Stronger cost reductions</td>
<td>Stronger cost reductions &amp; technology improvements</td>
<td>Break-through for FC</td>
<td>Stronger cost reductions &amp; improved feedstock availability</td>
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</table>
Global CO₂ Emissions 2003-2050
Baseline, ACT and TECH plus Scenarios

TECH Plus: More optimistic on progress for certain key technologies
Emission Reduction by Technology Area
ACT Map Scenario

MAP Scenario – 2050
32 Gt CO₂ Reduction

- Power Gen 34%
- End-use efficiency 45%
- Coal to gas 5%
- Nuclear 6%
- Fossil fuel gen eff 1%
- CCS 12%
- Hydro 2%
- Biomass 2%
- Other renewables 6%

Industry 10%
- Energy & feedstock efficiency 6%
- Materials & products efficiency 1%
- Process innovation 1%
- Cogeneration & steam 2%

Buildings 18%
- Space heating 3%
- Air conditioning 3%
- Lighting, misc. 3.5%
- Water heat. cooking 1%
- Appliances 7.5%

Transport 17%
- Fuel economy in transport 17%
- Biofuels in transport 6%

Improved energy efficiency most important contributor to reduced emissions
Power Generation

ACT Scenarios 2050

- Coal
- Coal-CCS
- Oil
- Gas
- Nuclear
- Hydro
- Biomass
- Other renewables

TWh

2003 Baseline 2030 (WEO 2005) Baseline 2050 Map Low Nuclear Low Renewables No CCS Low Efficiency TECH Plus 2050
Renewables analysis

- Detailed GIS systems for wind, solar, and geothermal
- Constraints considered (resource quality, distance to population centres, population density)
- 30 categories for wind, 20 for solar
- 15 world regions
Renewables analysis (contd.)

- Cost reductions are a function of investments (global technology learning)
- Low learning rates
- Intermittency, intra-regional grid connections and maximum rate of expansion constrain maximum renewable power generation
- If these constraints are removed, more renewable power generation would be possible
- This is a key technology issue
Electricity Generation
CO₂ Capture and Storage a Key Option

- CCS is crucial for the role coal can play in a CO₂ constrained world – without CCS coal-fired generation in 2050 drops below today’s level.
- By 2050 more than 5 TWh electricity globally can be produced by coal-plants equipped with CCS.
- There is an urgent need for more R&D and for full-scale CCS demonstration plants.
- Generation from renewables can quadruple by 2050.
- Nuclear can gain a much more important role in countries where it is acceptable.
CCS also in Industry and for Other Parts of the Energy Supply

- Coal Power plants: 53%
- Biomass Power plants/CHP: 5%
- Gas Ammonia production: 5%
- Gas DRI production: 3%
- Gas GTL: 5%
- Gas Refineries: 9%
- Gas Industrial Furnaces: 8%
- Gas/oil Refineries: 9%
- Coal Blast furnaces: 4%
- Process Cement: 5%
- Gas/oil DRI production: 3%
- Gas Gas processing: 3%
- Gas Gas/oil: 5%
- Gas Gas/oil Ammonia production: 5%
- Gas Gas/steam: 3%
- Gas Gas/oil DRI production: 3%
Map Scenario: Two-thirds of CO\textsubscript{2} emissions reduction is from improved fuel efficiency and one-third from biofuels.
Key New Technologies

- This workshop
  - CCS
  - Wind
  - Biomass for electricity and CHP
  - Solar PV & CSP
  - IVth generation Nuclear

- Another workshop
  - Large-scale electricity storage (scale hours/weeks)
  - 2nd generation biofuels (lignocellulosic ethanol, new biodiesel options)
  - Better car batteries/H2-FCVs
## Key Targets

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<tr>
<td>CCS USCSC</td>
<td>2000</td>
<td>1600</td>
<td>0</td>
<td>10</td>
<td>250</td>
<td>10%</td>
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<tr>
<td>CCS IGCC</td>
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<td>1600</td>
<td>0</td>
<td>10</td>
<td>250</td>
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<td>Wind onshore</td>
<td>900-1100</td>
<td>750-900</td>
<td>47</td>
<td>200</td>
<td>1000</td>
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<td>Wind offshore</td>
<td>1500-2500</td>
<td>1400-1800</td>
<td>1</td>
<td>30</td>
<td>250</td>
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<td>Biomass IGCC</td>
<td>2500</td>
<td>1800</td>
<td>&lt;1</td>
<td>10</td>
<td>150</td>
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<td>Solar PV</td>
<td>3750-3850</td>
<td>1000-1100</td>
<td>4</td>
<td>10</td>
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<td>Solar CSP</td>
<td>2000-2300</td>
<td>1700-1900</td>
<td>0.4</td>
<td>5</td>
<td>200</td>
<td>12%</td>
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<tr>
<td>Nuclear</td>
<td>2000</td>
<td>1700</td>
<td>370</td>
<td>420</td>
<td>750</td>
<td>2%</td>
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</table>
RD&D Needs

- 2050 stabilisation does not require more basic R&D
- Longer term emission reductions will require breakthroughs in the transportation sector
- More funding needed for applied R&D (technology deployment)
- Unclear if increased funding alone will be sufficient
- Unclear if reallocation of funding is needed
- Unclear if more international collaboration is needed
- Unclear what should be the role of governments and industry
A DRAFT summary of RD&D needs
Is such a table really feasible?

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<td>Ultra supercritical steam cycle 4 demo plants 700 C</td>
<td>0.1</td>
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<td>IGCC 5 demo plants</td>
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<td>5.0</td>
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<td>15 CCS coal fired power plants (add-on cost)</td>
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<td>5.0</td>
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<td>Small scale hydropower &amp; reservoir management</td>
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<td>Hot dry rock geothermal 25 demo projects</td>
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<td>Biomass IGCC 10 demo projects</td>
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<td>Black liquor gasifier 5 demo plants</td>
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<td>Solar Thin Film PV</td>
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<td>Nuclear generation IV 5 demo reactors</td>
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<td>Grid integration &amp; load management</td>
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<td>Improved Li-ion batteries for plug-in hybrids</td>
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<td>Hydrogen economy</td>
<td>5</td>
<td>10</td>
<td>7.5</td>
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<td>Lignocellulosic ethanol 5 demo plants</td>
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<td>0.5</td>
<td>0.4</td>
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<tr>
<td>FT-biodiesel/jet fuel 5 demo plants</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
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<td>Zero-emission buildings 10,000 demo</td>
<td>1</td>
<td>0.5</td>
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<tr>
<td>Seasonal heat &amp; cold storage 10,000 demo</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
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<td>3 CCS blast furnaces</td>
<td>0.5</td>
<td>0.4</td>
<td>0.1</td>
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<tr>
<td>3 CCS cement kilns</td>
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<td>0.2</td>
<td>0.1</td>
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<td>3 CCS black liquor IGCC</td>
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<td>New waste separation technologies</td>
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<td><strong>Total</strong></td>
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<td>32.4</td>
<td>19.3</td>
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<tr>
<td><strong>Annual</strong></td>
<td></td>
<td>2.5</td>
<td>1.9</td>
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</table>
Thank You

dolf.gielen@iea.org
Map: OECD Emissions 32% below 2003 level, while emissions in Developing Countries are 65% higher
## Primary Energy Supply

<table>
<thead>
<tr>
<th>[mtoe/yr]</th>
<th>Baseline</th>
<th>ACT Map</th>
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<tbody>
<tr>
<td></td>
<td>2004</td>
<td>2050</td>
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<tr>
<td>Coal</td>
<td>2,451</td>
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<tr>
<td>Oil</td>
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<td>Gas</td>
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<td>5,349</td>
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<td>Nuclear</td>
<td>710</td>
<td>810</td>
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<td>Hydro</td>
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<td>Other Renewables</td>
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<td>TPES</td>
<td>10,624</td>
<td>22,112</td>
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