Potentials for Bioenergy to Mitigate Climate Change

A summary of recent findings from the IPCC and IEA

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1. How much energy does biomass currently supply and what are future projections?

In 2004 biomass and waste provided 10.5% of global primary energy, almost 2/3 of this used “traditionally,” for household heating and cooking in developing countries.

Over the next several decades, although less biomass will be used due to improvements in fuel efficiency and reductions in traditional usage, overall use of bioenergy will increase from use for transport fuel and for combined heat and power.

Estimates for the contribution of biomass to global primary energy demand in 2030 range from 9.6-11.1%, based on two different policy scenarios from the IEA.

Greater variations in long-term demand projections for bioenergy reflect significant uncertainties, particularly regarding the development and commercialization of second generation technologies: in 2050 the demand for biomass for energy could be 70-130EJ, not including use in households, for heat, or industry.

In some scenarios biomass is expected to provide 10-25% of world primary energy over the next century.

Key Facts: Demand for Biomass

**Current Demand**

- Globally, in 2004 biomass and waste provided 10.5% (46 EJ, 1176 Mtoe) of global primary energy (WEO-IEA 2006a) (Figures 1,2)

- Traditional household usage of biomass accounts for almost two thirds of global biomass, or almost 7% of world energy demand (WEO-IEA 2006a: 420)

**Demand in 2030**

- In 2030 the share of biomass contributing to global primary energy demand is expected to decrease to 9.6%, despite expected increases in biomass energy output to 69 EJ (1645 Mtoe) in Reference Scenario Projections (WEO-IEA 2006a)

- In 2030 in a more supportive policy scenario, biomass and waste could supply 11.1%, or 70 EJ (1703 Mtoe), of the world’s primary energy¹ (WEO-IEA 2006a) (Alternative Scenario) (Figures 3, 4)

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¹ This 58 Mtoe (about 1 EJ) variation represents the net of two opposing trends expected in the next several decades. While fuel efficiency and reduced traditional usage of biomass for heating and cooling in developing countries is expected to decrease, biomass use for transport and combined heat and power ultimately account for the positive variation (WEO-IEA 2006a: 175-6).
Demand in 2050

• In 2050 energy demand for primary biomass for power and fuels is expected to be between 70-130 EJ, depending in large part on development and commercialization of second-generation technologies
• This demand does not include estimates of domestic biomass use, increased biomass for the production of heat, and biomass in industry
• Demand for bioenergy in 2030 will depend upon the contribution of 2nd generation technologies, which are believed to offer competitive production compared to oil prices between 40-50 US$/barrel, assuming biomass prices of 2 US$/GJ (Hamelick/ Faaij, 2006) (IPCC 2007.III.11.3.1.4; 19)
• In some scenarios biomass is expected to provide 10-25% of world primary energy over the next century (IPCC 2007. III Technical Summary; 25)

Overall Energy Demand in 2050

For comparison, overall energy demand in 2050 could be 702-926 EJ in a range of IEA technology scenarios

• In the ETP Baseline Scenario, world primary energy demand more than doubles from 2003 to 2050, reaching 926 EJ (22,112 Mtoe) (WEO-IEA 2006b; 63)
• In the ETP Map Scenario, world primary energy demand is 702 EJ (16,762 Mtoe) (WEO-IEA 2006b; 64)
• In the technologically optimistic ETP TECH Plus Scenario, baseline energy demand of 735 EJ (17,556 Mtoe) (WEO-IEA 2006b; 65)
2. How much biomass will potentially be available for bioenergy in the future?

There are significant variations in projections of the future availability of biomass due to great uncertainty regarding a number of important factors, including productivity and future patterns in food consumption.

Estimates in the potential energy supply of primary biomass range from 125-760 EJ.

It is important to note that the extent to which the above physical potentials can and will be exploited is unknown.

The potential for agriculture to supply biomass for bioenergy is of particular interest due to its implications for food and agricultural markets. Although no certain estimates exist, it is estimated that biomass from agriculture could supply around 22 EJ/yr in 2025 and over 400 EJ/yr by 2050.

Key Facts: Biomass Supply Potentials, 2050

(IPCC 2007.III.11.3.1.4; 17-8)

The following data regarding biomass potentials were reached by accounting for food and timber demands. Factors such as diet (meat consumption) and agricultural productivity were considered. These projections do not assume constraints on water.

- Energy Potentials from agriculture
  - Supply from crop cultivation on arable land could range from 20-400 EJ
  - Crops on degraded lands could contribute another 60-150 EJ
  - Energy potential from the use of agricultural residues is 15-70 EJ
  - Energy potential from the use of dung is another 5-55 EJ

- Energy potentials from forestry based biomass supply range from 12-74 EJ

- Energy potentials from waste material are 13 EJ, an increase from 8 EJ currently

- Total supply potentials of primary biomass thus range between 125-760 EJ
- Potentials from waste, landfill gas, digester gas are much smaller

Agricultural Supplies of Biomass

(IPCC 2007. III. Technical Summary; 61)

- There are no accurate estimates of future agricultural biomass supply; estimates range from around 22 EJ/yr in 2025 to more than 400 EJ/yr in 2050.
3. What is the potential for bioenergy use to reduce carbon emissions?

- Due to significant economic and technological uncertainties, the exact potentials for bioenergy to reduce carbon emissions in the long term remain unknown.
- The IPCC estimates that over the next century bioenergy, in supplying 10-25% of world global energy, could provide 5-30% of cumulative carbon emission abatement.
- In 2050 the use of bioenergy could account for between 6-9% of total CO₂ emission reductions, assuming incentives equivalent to prices of 25 US$/tCO₂.
- Bioenergy supplied by agricultural sources has the potential to mitigate 0.56-2.32 Gt CO₂, bioenergy from agricultural sources could reduce 0.56-2.32 Gt CO₂.

### Key Facts: Bioenergy and CO₂ Emission Reductions

**Uncertainty of Data** *(IPCC 2007. III. 11.3.1.4; 19)*

- Do to the scarcity of relevant scenarios treating the long-term (2030), the potential for biomass to mitigate climate change, although potentially significant, is still very uncertain
- Important factors that will determine end mitigation include
  - baseline economic growth
  - energy supply alternatives
  - rates of technological change (2nd generation fuels)
  - land use competition
  - mitigation alternatives

**Baseline Emissions; Without Bioenergy Usage**

- Baseline Scenarios show projections of CO₂ emissions in the absence of bioenergy usage and other mitigating factors.
  - One scenario set estimates CO₂ emissions of 27.4 Gt in 2030 and 58 Gt in 2050, up from 24.5 Gt emitted in 2003 *(2050 ETP Baseline) (WEO-IEA 2006b; 44)*

**Biomass Energy Potential Relative to Cumulative Abatement**

- Bioenergy could account for 5-30% of cumulative CO₂ abatement in its provision of 10-25% of total primary energy over the century *(IPCC 2007. III. TS; 25)*

**IEA 2006b Scenario Projections, 2050**

- A closer look at one set of scenarios from the Energy Technology Perspectives IEA 2006 report shows the potential role for bioenergy to reduce emissions relative to other contributing factors.
  - Throughout this report economic incentives equivalent to 25 US$/tCO₂ were assumed *(IPCC 2007. III. 5.4.2.3; 60)*

- Over the range of scenarios the use of bioenergy could result in 6-9% of total emission reductions below baseline projections by 2050.
• This corresponds to actual reductions of 1.9-2.5 Gt, out of total reductions of 26.8-32.1 Gt CO2 (ACT Scenarios) (WEO-IEA 2006b) (Table 3)

• A related scenario with very optimistic technological predictions estimates that bioenergy usage in 2050 could account for 7.7% of total reductions.
  • This corresponds to 2.9 out of 37.4 Gt total reductions (TECH Plus) (WEO-IEA 2006b) (Table 3)

Agriculturally Supplied Biomass and Mitigation (IPCC 2007. III. Technical Summary; 61)

• The contribution of agriculture to bioenergy and mitigation potentials depends on the relative prices of fuels. Estimates of the economic mitigation potential of biomass energy supplied from agriculture are
  • 70–1260 MtCO2-eq/yr at up to 20 US$/tCO2-eq
    • This represents 5-80% of all other agricultural mitigation measures combined
  • 560–2320 MtCO2-eq/yr at up to 50 US$/tCO2-eq
    • This represents 20-90% of all other agricultural mitigation measures combined
4) How much energy might liquid biofuels\textsuperscript{2} supply to the transport\textsuperscript{3} sector?

- Liquid biofuels are projected to provide 3\% of total transport energy in 2030 baseline projections.
- Depending on pricing and technological progress, in 2030 bioenergy could supply between 3-10\% of total transport energy.
- In 2050 liquid biofuels could meet 13-25\% of transport energy demand over several policy scenarios, compared to baseline projections of 3\% for 2050.

**Key Facts: Transport Energy Demand and Liquid Biofuels**

*Energy Supply to Transport Sector, EJ* (IPCC 2007. III. 11.3.1.4; 16)

- Assuming around 60\% conversion efficiency, biofuels could potentially supply between 8-25 EJ transport fuel (from 14-40 EJ primary biomass).
- Higher estimates exist—biofuels could supply 30-50 EJ transport fuel in 2030 (from 45-85 primary biomass).

**2030**

- In 2030 the share of biofuels used as gasoline and diesel fuel additives/substitutes reaches 3\% of transport energy demand in baseline projections, and between 5-10\% in more supportive policy environments and depending on technological advancements (IEA-2006a) (IPCC 2007. III. Summary for Policy Makers; 19)

**2050**

- Biofuels are expected in baseline projections to contribute roughly 3\% of total global transport energy demand in 2050, corresponding to about 2.6 Mb/d of oil (Baseline).
- The share of transport demand met by biofuels rises to 13\% in one scenario and to almost 25\% in the most technologically optimistic scenario (Map; TECH Plus Scenarios) (WEO-IEA 2006b; 87)

**Interesting Side Note: Regional Growth in Biofuels Consumption**

- The European Union and the United States account for more than half of the additional growth in biofuels consumption in 2030 (WEO-IEA 2006a) (Table 4)

\textsuperscript{2} In WEO-IEA 2006a studies only first generation biofuels are considered viable before 2030 (WEO-IEA 2006a; 395)

\textsuperscript{3} “The transport sector includes road, rail, air and water transport as well as energy used for pipelines. Only technologies in road transport have been considered in the ACT and TECH Plus scenarios. In 2003 road transport constituted about 80\% of total transport demand. The only scenarios discussed in this section are the Map and TECH Plus scenarios. There are only minor differences for the transport sector in the other scenarios. The only exception is the Low Efficiency scenario, however, the implications for technology and fuel choices in the transport sector of the lower efficiency progress in this scenario were not assessed.” (WEO-IEA 2006b; 87)
5) What is the potential for liquid biofuel to reduce transport sector emissions?

- In 2030 liquid biofuels could provide transport emission reductions of 0.6-1.5 Gt CO₂ at carbon prices less than 25 US$/tCO₂
- In 2050 liquid biofuels may meet 13-25% of transport demand and reduce emissions by 1.8-2.3 Gt CO₂, corresponding to between 5.6-6.4% of total emission reductions across all sectors, at carbon prices greater than 25 US$/tCO₂
- CO₂ transport emission reductions of 2.3 Gt by 2050, in the most technologically optimistic scenario above, account for about 6% of total reductions across all sectors

Key Facts: Emission Reductions from Transport Sector

2030

- By 2030, biofuels could supply 5% energy to the transport sector and reduce transport emission reductions by 36 Mt CO₂, assuming an average reduction in CO₂ emissions of 25% from gasoline (Alternative Policy Scenario) (IEA-2006a) (IPCC 2007. III. 5.4.2.3; 59-60)
- For carbon prices less than 25 US$/tCO₂, liquid biofuels could reduce emissions by 0.6-1.5 GtCO₂-eq (IPCC 2007. III. TS; 39-40) (5.4.2.3; 60)
- Transport biofuels, assuming only small contributions from cellulosic biomass, could supply 10% of energy at costs of 25 US$/tCO₂-eq (IPCC 2007. III. TS; 39)
- The above two statistics should be comparable but it has been difficult to trace the source scenario to be absolutely certain of coherency

2050

Background Information Regarding 2050 Projections and Scenarios

- Total transport CO₂ emissions are expected to reach 11.7 Gt in 2050 baseline projections, levels 2.3 times higher than in 2003 (Baseline) (WEO-IEA 2006b; 89) (Figure 10)
- The following scenarios from the Energy Technology Perspectives 2006 IEA report assume economic incentives for bioenergy equivalent to 25 US$/tCO₂ (IPCC 2007. III. 5.4.2.3; 60)
- The following scenarios assume substantial contributions to biofuel production will come from Fischer-Tropsch conversion processes and cellulosic feedstocks; fuels from vegetable oil and grains represent somewhat lower shares
- The following ACT and TECH Plus scenarios only consider road transport technologies; in 2003 road transport accounted for 80% of total transport demand (WEO-IEA 2006b; 87)

Reduction Potentials Across ACT Scenarios (WEO-IEA 2006b; 29-30) (Figure 6)

- Biofuels in transport account for 5.6-6.4% reductions in ACT scenarios
- Use of renewables in power generation: 5-16%
- Improved energy efficiency: 31-53%
- Carbon capture and storage: 20-28% when present
- Fuel switching: 11-16%
- Nuclear: 2-10%
- Other options: 1-3%
Reduction Potentials for the ACT Map Scenario

- In 2050 transport biofuels could account for 6%, or 1.8 Gt CO$_2$, of total emission reductions below baseline projections, by supplying 13% of total transport demand (20.1 EJ; 480 Mtoe) (IPCC 2007. III. 5.4.2.3; 60). WEO-IEA 2006b; 87) (WEO-IEA 2006b: 51) (Table 3)

Reduction Potentials for TECH Plus Scenario

- In the most technologically optimistic scenario, by 2050 biofuels could account for 6%, or 2.3 Gt CO$_2$ of total emission reductions, by supplying 25% of transport energy (36 EJ; 870 Mtoe) (TECH Plus) (WEO-IEA 2006b) (Table 3)
Table 3: CO2 Reductions by Scenario; WEO-IEA 2006b

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Map</th>
<th>Low Nuclear</th>
<th>Low renewables</th>
<th>No CCS</th>
<th>Low Efficiency</th>
<th>TECH Plus</th>
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<td>1445</td>
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<td>2133</td>
<td>2936</td>
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<td>23</td>
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<td>464</td>
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<td>2060</td>
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<td>CCS in power generation</td>
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<td>1043</td>
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<td>1123</td>
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<td>CCS in industry</td>
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<td><strong>Use of biofuels in transport</strong></td>
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<td>1794</td>
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<td>End-use efficiency</td>
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<td>15036</td>
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<td>14653</td>
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<td><strong>Combined Biofuel Reductions</strong></td>
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<td>1891</td>
<td>2530</td>
<td>2178</td>
<td>2003</td>
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<td><strong>Total reduction</strong></td>
<td>32053</td>
<td>31125</td>
<td>31283</td>
<td>28324</td>
<td>26807</td>
<td>37420</td>
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<td><strong>Total CO2 Emissions in 2050</strong></td>
<td>25969</td>
<td>26897</td>
<td>26738</td>
<td>29656</td>
<td>31214</td>
<td>20602</td>
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<td><strong>CO2 Emissions Relative to 2003</strong></td>
<td>6%</td>
<td>10%</td>
<td>9%</td>
<td>21%</td>
<td>27%</td>
<td>-16%</td>
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Shares of CO2 Emission Reductions in 2050 by Contributing Factor (%)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Map</th>
<th>Low nuclear</th>
<th>Low renewables</th>
<th>No CCS</th>
<th>Low Efficiency</th>
<th>TECH Plus</th>
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<tbody>
<tr>
<td>Total bioenergy</td>
<td>7.3</td>
<td>7.6</td>
<td>6.0</td>
<td>9.0</td>
<td>8.1</td>
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<td>Biomass power generation</td>
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<td>1.8</td>
<td>0.3</td>
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<td>1.5</td>
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<td>Increased use of biofuels in transport</td>
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<td>5.8</td>
<td>5.7</td>
<td>6.4</td>
<td>6.0</td>
<td>6.2</td>
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<td>Hydropower</td>
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<td>2.1</td>
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<td>1.2</td>
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<td>6.6</td>
<td>4.5</td>
<td>11.3</td>
<td>7.2</td>
<td>7.2</td>
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<tr>
<td>End-use efficiency</td>
<td>46.2</td>
<td>46.9</td>
<td>46.6</td>
<td>53.1</td>
<td>30.7</td>
<td>39.2</td>
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<td>Other methods</td>
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<td>14.2</td>
<td>45.3</td>
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<td>Totals</td>
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<td>100.0</td>
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</tbody>
</table>
Focus: Road Transport Energy from Biomass

2004

• Liquid biofuels accounted for 1%, or 6 Mtoe, of road transport energy in 2004

2030

• In 2030 biofuels supply 4% (92 Mtoe; 4 EJ) of road transport in reference projections, and possibly 7% (147 Mtoe; 6 EJ) in a more supportive policy environment (Reference Scenario) (Alternative Policy Scenario) (WEO-IEA 2006a; 44)

• In the above scenarios second generation biofuels are not assumed to be economically viable before 2030 (WEO-IEA 2006a; 225)

2050

(WEO-IEA 2006b) (Table 3) (Figure 8)

• Since the ACT and TECH Plus scenarios only consider road transport technologies (WEO-IEA 2006b; 87), the mitigation potentials below are identical to those found in the total transport emissions section.

• Road transport biofuel usage could account for 5.6%, or 1.8 Gt, of total CO2 reductions, corresponding to over a quarter of total transport sector reductions (Map Scenario)

• In the most optimistic of technology scenarios, biofuel usage for road transport could account for 6.2% (2.3 Gt) of total CO2 reductions, corresponding to just under a quarter of total transport sector reductions (TECH Plus)

Figure 8

Figure 3.9  Share of road transport in global CO2 emission reductions relative to Baseline in the Map and TECH Plus scenarios, 2050

Total CO2 emissions reduction: 32.1 Gt

Map

- Rest of economy 77%
- Transport 23%

Total CO2 emissions reduction: 37.4 Gt

TECH Plus

- Rest of economy 74%
- Transport 26%

WEO-IEA 2006b; 136
6. What is the potential for bioenergy to reduce carbon emissions in the power sector?

**Key Points: Bioenergy for Power Generation**

- In 2030 biomass will contribute between around 3%, or 28-43 EJ, toward electricity generation.
- In 2050 bioenergy could contribute 2% of energy generation in baseline projections and up to 6% in more supportive policy scenarios.

- CO2 reduction potential estimates from bioenergy use in power generation range from 0.1-0.3 Gt CO2-eq per year by 2030, assuming incentives equivalent to 25 US$/t CO2.
- By 2030 bioenergy usage in electricity generation could reduce world emissions by 1.22 Gt CO2-eq compared to baseline projections, assuming “maximum economic potentials,” at costs up to 100 US$/t CO2 eq.
- Heat and CHP estimates are not included in IPCC analysis, although some very rough estimates, seen below, can be made regarding the displacement of fossil fuel by biomass in heat and power plants:
- New bioenergy plants could contribute 5% of heat generation at costs of 30 –100 US$/MWh with the replacement of fossil fuels in CHP plants.
- Therefore, in 2030 the worldwide demand for biomass for electricity generation could range between 28-43 EJ.

- *It is important to realize that heat data, according to Ralph Sims, “is largely guesswork!” Furthermore for WEO studies, “… estimates focus on electricity generation. Heat is not explicitly modelled or estimated in the WEO, therefore underestimating total demand for biomass.”* (IEA 2006a; 11.3.1.4; 16)

**Shares of Bioenergy for Electricity Generation**

- Bioenergy (landfill gas, combined heat and power, biogas, and direct combustion for heat) presently contributes 2.6% to the OECD power mix, 0.4% to Economies in Transition (EIT) and 1.5% to non-OECD countries (IPCC 2007; III; 4.3.3.3; 68).
- In 2004 biomass and waste contributed 1% (227 TWh) to world electricity generation, a share which is expected to rise to 2% (805 TWh) by 2030 in Reference Scenario Projections, and to 3.3% (983 TWh) in a more supportive policy environment (IEA 2006a; Annex A; 493) (IEA 2006a; Annex A; 529).

**Bioenergy and Electricity Generation in 2050**

- By 2050, biomass contributes 2% of electricity generation in the baseline and between 3.0-6.5% in a range of technology scenarios and at effective costs of 25 US$/t CO2 (ACT, TECH Plus Scenarios) (WEO-IEA 2006b; 83) (Table 14).
Mitigation Potentials from Electricity Generation, 2030

- CO₂ reduction potentials from bioenergy use in power generation could range from 0.1 to 0.3 GtCO₂ eq/yr by 2030, at effective costs of 25 US$/t CO₂ (ETP) (IPCC 2007; III; 4.4.3.3)
- The maximum economic reduction potentials by 2030 from the use of bioenergy for electricity generation, at costs up to 100 US$/tCO₂ eq., are 1.22 Gt CO₂ emissions, with almost 1 Gt of this from use in non-OECD countries (Table 5)

Heat and Power

- Heat generation data is very uncertain, and the following variations in data reflects this:
  - The IPCC reports that around 8.6 EJ, or about 200 Mtoe, of “modern” biomass is used per year for heat and power generation globally (IPCC 2007; III; 4.3.3.3; 36-37)
  - A 2006 IEA-WEO report estimated that in 2004 biomass and waste contributed 3.1 EJ (74 Mtoe), 1.8%, of heat and power generation demand (WEO-IEA 2006a) (Reference Tables; 493) (mentioned in IPCC 2007. III. 4.3.3.3;68)
  - By 2030 baseline models show usage of projections of biomass and waste usage for heat and power generation rising to 10.8 EJ (265 Mtoe), or 3.8% (WEO-IEA, 2004a) (IPCC.III.4.4.3.3; 68) (IEA 2006a; Annex A; 49)

Biomass Supplied Combined Heat and Power (IPCC 2007; III. 4.4.3.3; 68)

- Biomass for heat and CHP estimates vary greatly and are not included in the most recent IPCC analysis, although potentials could be significant.
- However, several rough and uncertain estimates have been made in recent IPCC literature based on the following assumptions:
  - Biomass could feasibly supply 5% of heat energy from displaced coal and gas CHP plants at costs of 30 –100 US$/ MWh
  - As fossil fuels for heat generation are displaced, 7-8% of the replacement capacity built in OECD regions could be bioenergy plants
- Resulting Estimates (IPCC 2007; III; 4.4.3.3; 68)
  - The biomass feedstock required to meet these potentials, assuming thermal conversion efficiencies of 20-30%, would be around 9-13 EJ in OECD, 1-3 EJ in EIT, and 18-27 EJ in non OECD regions
  - Therefore, in 2030 the worldwide demand for biomass for electricity generation could range between 28-43 EJ (IPCC 2007; III; 11.3.1.4;16) (4.4.3.3;68)

Mitigation % for Specific Carbon Price Ranges (US$/tCO\textsubscript{2} eq avoided)

<table>
<thead>
<tr>
<th>Region</th>
<th>Gt CO\textsubscript{2}-eq saved in 2030</th>
<th>&lt;0</th>
<th>0-20</th>
<th>20-50</th>
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</table>

Note: 20% of worldwide reductions by 2030 are possible at negative costs.

Figure 14

Figure 2.26: CO\textsubscript{2} emissions from electricity generation and source of reduction, 2003-2050

Key point:
CO\textsubscript{2} emissions from electricity generation are below the 2003 level in all ACT scenarios.

(WEO-IEA 2006b; 85)
Annex I: Liquid Biofuel Reduction Potentials

All comparisons are to gasoline except where noted

- Corn-based ethanol emission reduction potentials range from 13-30%
- Sugar-based ethanol emission reduction potentials can reach 90%
- European sugar beet-based ethanol emission reduction potentials range from 40-60%
- European rapeseed biodiesel emission reduction potentials range from 40% to 60% compared to conventional automotive diesel
- Jatropha-based fuel blends could result in yearly reductions between 2.5-9.4 Mt CO₂
- Ligno-cellulosic emission reduction potentials range from 70-90%
- With the use of ligno-cellulosic technologies, current agricultural land could contribute up to 700EJ per year in biomass energy by 2050, without endangering food supply, forests, or biodiversity

Annex II: Key Definitions

**Biomass and waste**: Includes solids such as wood, animal products, gas and liquids derived from biomass, industrial waste, and municipal waste. Total primary and final demand include traditional biomass (fuel wood, charcoal, dung and crop residue), even if not traded commercially.

**Biofuels**: Liquid biofuels for transport. *(Note: this WEO definition is not standard)*

**Total primary energy**: Total primary energy demand and supply are equivalent, and refer to inland use of energy in its initial form after production or importation.

**Electricity generation**: Total electricity generated by power plants, including own usage, transmission, distribution, and losses.

**Other renewables**
Other renewables include geothermal, solar, wind, tide, and wave energy for electricity generation. The direct use of geothermal and solar heat is also included in this category.

**Note: Transport and Road Transport Distinctions** *(WEO-IEA 2006b: 87)*
“The transport sector includes road, rail, air and water transport as well as energy used for pipelines. Only technologies in road transport have been considered in the ACT and TECH Plus scenarios. In 2003 road transport constituted about 80% of total transport demand. The only scenarios discussed in this section are the Map and TECH Plus scenarios. There are only minor differences for the transport sector in the other scenarios. The only exception is the Low Efficiency scenario, however, the implications for technology and fuel choices in the transport sector of the lower efficiency progress in this scenario were not assessed.”
Annex III: Scenarios


Reference Scenario

The WEO Reference Scenario projects based on government policies adopted, but not necessarily enacted, by mid 2006. As such, it does not account for measures potentially or even likely to be enacted.

Alternative Policy Scenario

This scenario models how the energy market would evolve if countries were to adopt all policies currently under consideration.

Note: “In neither scenario [Reference or Alternative Policy] are second-generation biofuels technologies, such as ligno-cellulosic ethanol or biomass gasification, assumed to penetrate the market.” (WEO-IEA 2006a; 395)

Energy Technology Perspectives; WEO-IEA 2006b

ETP Baseline

The Energy Technology Perspectives (ETP) Baseline Scenario was developed by extending the World Energy Outlook (WEO) 2005 Reference Scenario from 2030 to 2050. As in the WEO Reference Scenario, the ETP Baseline includes the effects of technology developments and improvements in energy efficiency that can be expected on the basis of government policies already enacted.

The ACT Map Scenario

The ACT Map Scenario is relatively optimistic in four technology areas: progress in cost reductions for renewable power generation technologies; constraints on the development of nuclear power plants; the risk that CO₂ capture and storage (CCS) technologies will not be commercialised by 2050; and the effectiveness of policies to increase the adoption of energy efficient end-use technologies.

ACT Scenarios (Accelerated Technology Scenarios)

Each of the four ACT scenarios assumes the same policies and efforts as the Map yet account for different rates in technological progress, namely cost reduction and public acceptance. “Low nuclear” factors in constraints on nuclear power generation; “Low renewables” assumes slower rates of cost reduction for renewable power generation technologies; “No CSS” models an energy market without commercialized carbon capture and storage (CCS) technologies; and “Low efficiency” describes a market with less efficient end-use technologies.

TECH Plus

TECH Plus Scenario assumes accelerated progress compared to the MAP scenarios for advanced renewable technologies, including biofuels.

ACT Map and TECH Plus Scenarios assume economic incentives equivalent to 25 US$/tCO₂ (IPCC 2007. III. 5.4.2.3; 60)