Outline of DNE21+ Model
-Primary Energy-

April 25, 2008

1. Introduction

○ Eight types of primary energy are considered (coal, oil(conventional and unconventional), natural gas(conventional and unconventional), hydro power and geothermal, nuclear, wind power, photovoltaics and biomass (plantation type, residue type)).

○ Additional examples of primary energy include solar heat, wave energy, salinity difference, etc. Only the eight energy types above are considered in this study in view of the overall problems associated with potentials and costs at the evaluation time points up to 2050.

2. Coal

○ Coal resources have been estimated based on a report, Survey of Energy Resources 1998 of the World Energy Commission (WEC).

○ It is estimated that reserves of coal resources worldwide are 885 Gtoe.

○ Production costs are estimated based on H-H. Rogner (”An Assessment of World Hydrocarbon Resources,” Annu. Rev. Energy Environ.1997). Concession costs and the like are estimated to generally correspond with FOB costs at 2000. Future concession costs are estimated based on the difference between production costs estimated in this study and forecasts from the price forecasts from the IEA World Energy Outlook 2007.

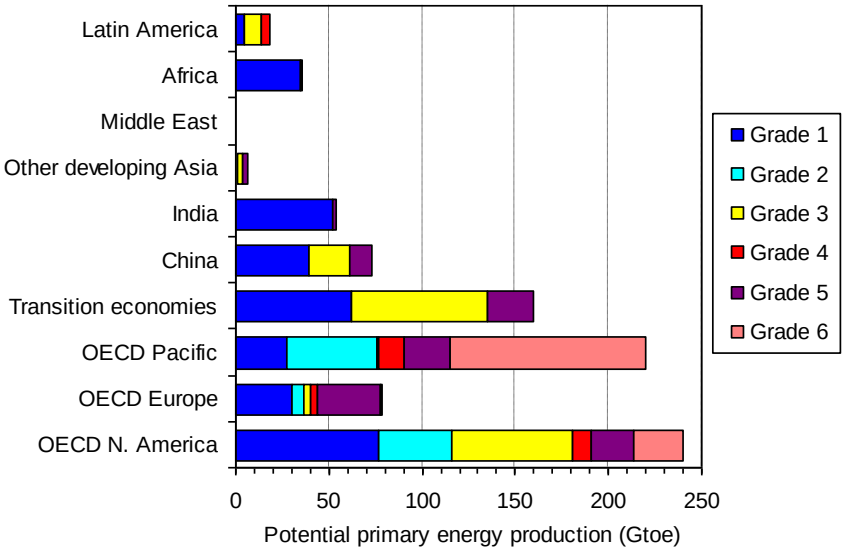

Fig.1 Estimated coal reserves

Table 1 Estimate of coal production cost and concession costs etc.

Production Cost ($/toe)	Concession Cost etc.($/toe)
34 – 136	33 – 90

3. Conventional Oil and Natural Gas

○ Estimates of the US Geological Survey (USGS) have been used (USGS, World Petroleum Assessment 2000–Description and Results; USGS, 1995 National Assessment of United States Oil and Gas Resources.).

○ Worldwide reserves of oil (including NGL) are estimated at 241 Gtoe, and reserves of natural gas are estimated at 243 Gtoe.

○ Production costs for conventional oil and natural gas are estimated based on H-H. Rogner (”An Assessment of World Hydrocarbon Resources,” Annu. Rev. Energy Environ.1997). Concession costs and the like are estimated to generally correspond with FOB costs at 2000. Future concession costs are estimated based on the difference between production costs estimated in this study and the price forecasts from the IEA World Energy Outlook 2007.

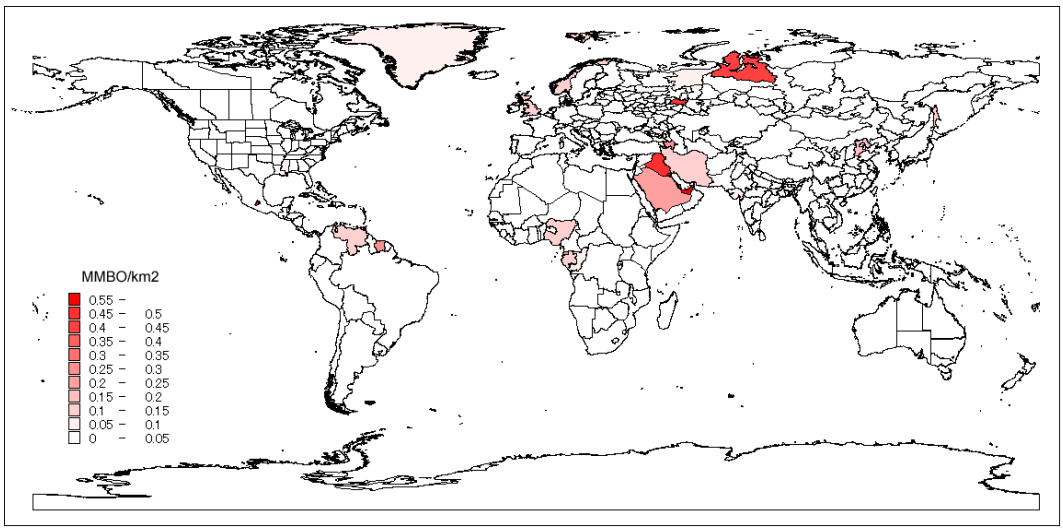

Fig.2 Oil reserves (unit: million barrels/km^2)

Source) application of RITE based on US Geological Survey http://pubs.usgs.gov/dds/dds-060/

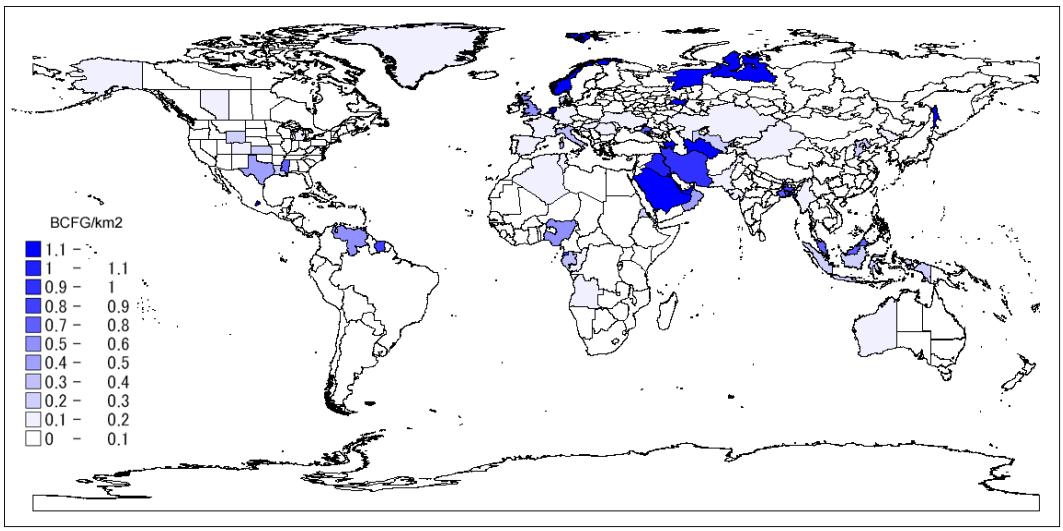

Fig.3 Natural gas reserves (unit: billion cubic feet/km^2)

Source) application of RITE based on US Geological Survey http://pubs.usgs.gov/dds/dds-060/

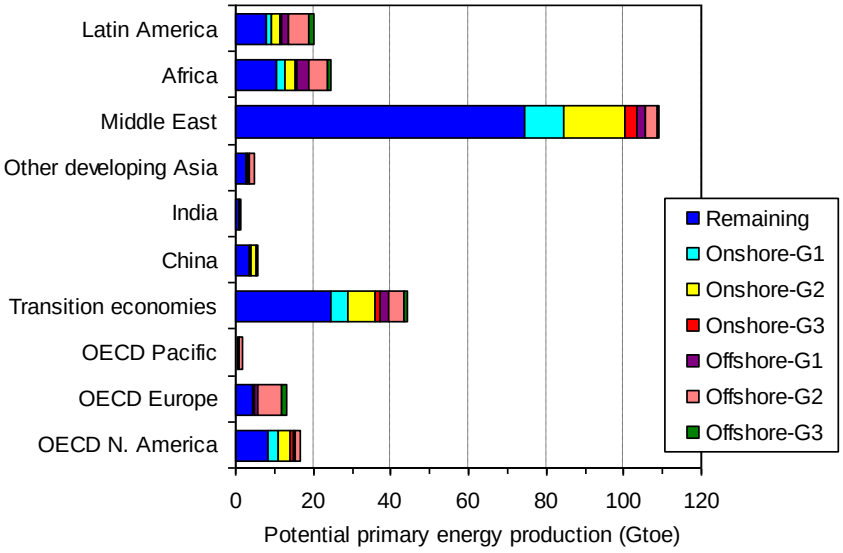

Fig.4 Estimated conventional oil reserves (including NGL)

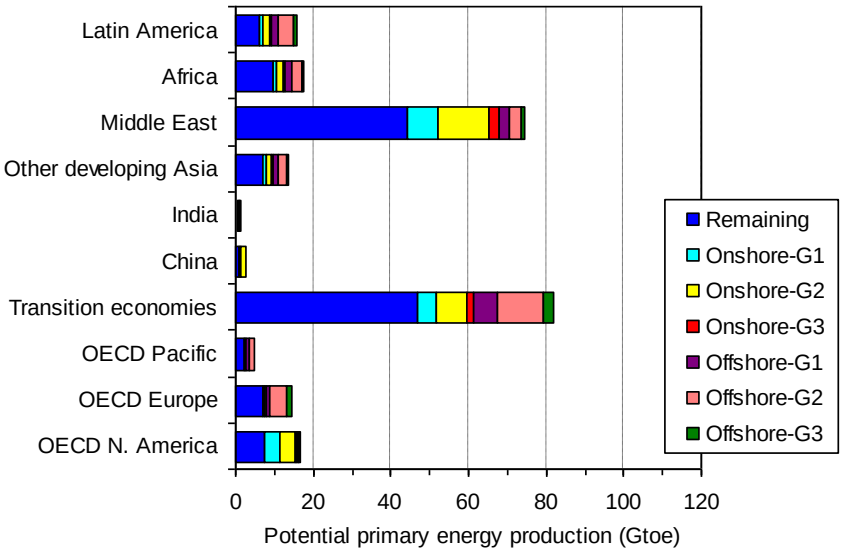

Fig.4 Estimated conventional natural gas reserves

Table 2 Estimated conventional oil and natural gas production costs and concession cost etc.

	Production cost ($/toe)	Concession Cost etc.($/toe)
Conventional Oil	29 – 81 (4.5 – 12.7 [$/bbl])	202 – 551 (31.7 – 86.4 [$/bbl])
Conventional Natural Gas	20 – 149	108 – 386

4. Unconventional Oil and Natural Gas

○ Unconventional fossil fuels resources including unconventional oil resources such as heavy crude, oil sands, oil shale and unconventional natural gas resources such as coal bed methane and methane hydrate are estimated using H-H. Rogner (”An Assessment of World Hydrocarbon Resources,” Annu. Rev. Energy Environ.1997).

○ Worldwide unconventional oil resources are estimated at approximately 2,300 Gtoe and unconventional natural gas resources are estimated at approximately 19,600 Gtoe (comprising approximately 18,800 Gtoe of methane hydrate). However since the timeframe used for evaluation in this model extends to 2050, results of large scale use of these natural resources are not available.

○ Production costs for unconventional oil and natural gas have been estimated based on H-H. Rogner (”An Assessment of World Hydrocarbon Resources,” Annu. Rev. Energy Environ.1997). Concessions costs etc. were estimated based on estimates for conventional oil and natural gas.

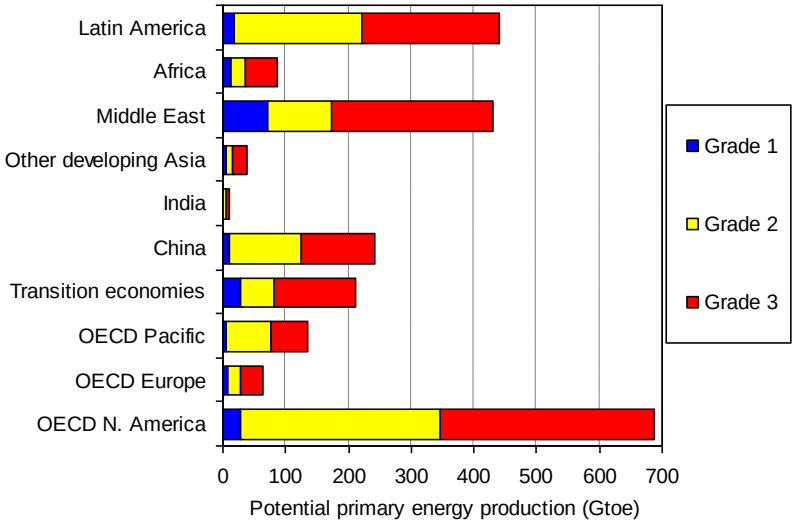

Fig.6 Estimate of unconventional oil reserves

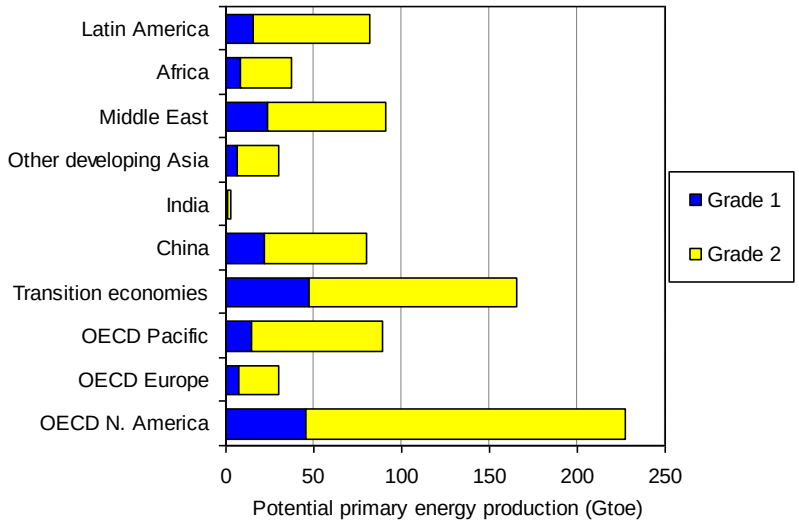

Fig.7 Estimate of unconventional natural gas reserves (excluding methane hydrate)

Table 3 Estimate of concession cost etc. and production cost for unconventional oil and natural gas

	Production Costs ($/toe)	Concession Cost etc. ($/toe)
Unconventional Oil	131 – 381 (20.5 – 59.8 [$/bbl])	218 – 599 (34.2 – 94.0 [$/bbl])
Unconventional Natural Gas	189 – 429	135 – 431

5. Hydro power

○ Hydro power resources are estimated based on a report (Survey of Energy Resources 1998) of the World Energy Commission (WEC).

○ It is estimated that reserves of hydro power resources worldwide are approximately 14,000 TWh/yr.

○ Power generation costs for hydro power are found in the power generation section.

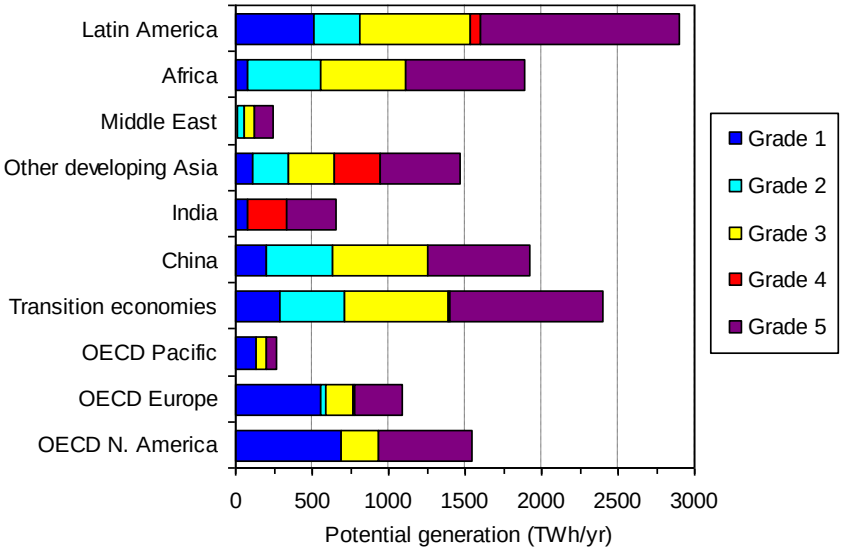

Fig.8 Potential generation of hydro power (including geothermal)

6. Nuclear

○ Evaluation extends to 2050. Since development drilling costs of uranium resources occupy a small proportion of nuclear power electrical generation costs, restrictions on uranium have not explicitly been considered.

○ Nuclear power generation costs are found in the power generation section.

7. Wind power

○ Wind power generation potential is estimated using land usage mesh data from Chiba University and average daily wind speed data (1994 - 2000) from approximately 9000 land-based observatories collected by NOAA and NCDC.

○ Worldwide reserves of wind power are estimated to be approximately 12,000 TWh/yr.

○ Power generation costs for wind power are found in the power generation section.

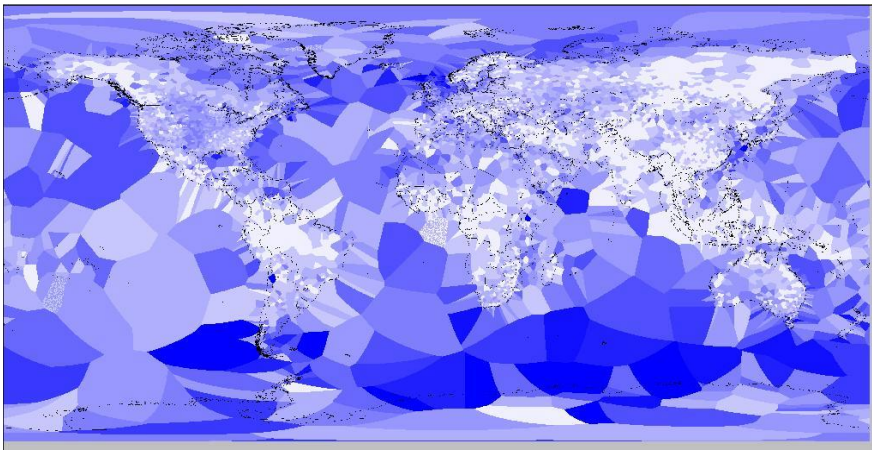

Fig.9 Distribution of average wind speed

Source) NCDC Measurement Data ftp://ftp.ncdc.noaa.gov/pub/data/globalsod/

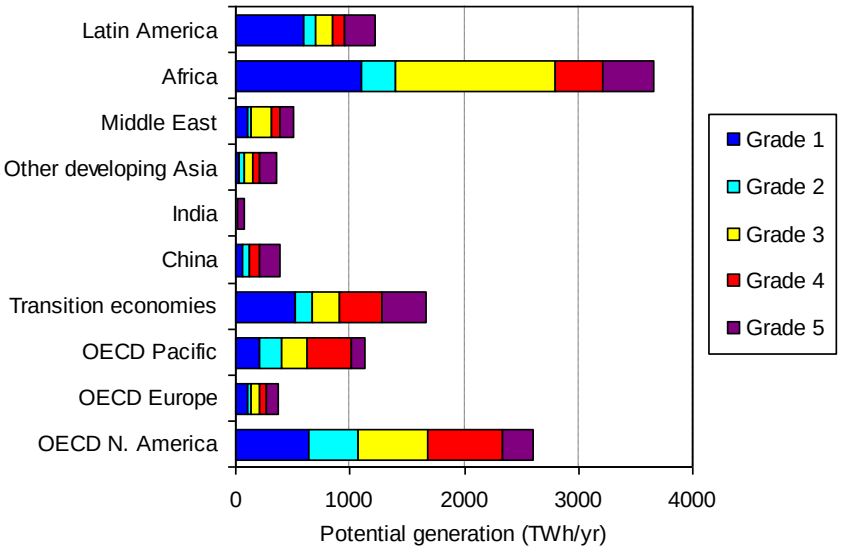

Fig.10 Generation potential for wind power

8. Photovoltaics

○ Generation potential of photovoltaics is estimated using land usage mesh data from Chiba University and average monthly solar irradiance by mesh provided by the NASA SeaWIFS Solar Irradiance Satellite.

○ Worldwide reserves of photovoltaics are estimated to be approximately 1,270,000 TWh/y.

○ Power generation costs for photovoltaics are found in the power generation section.

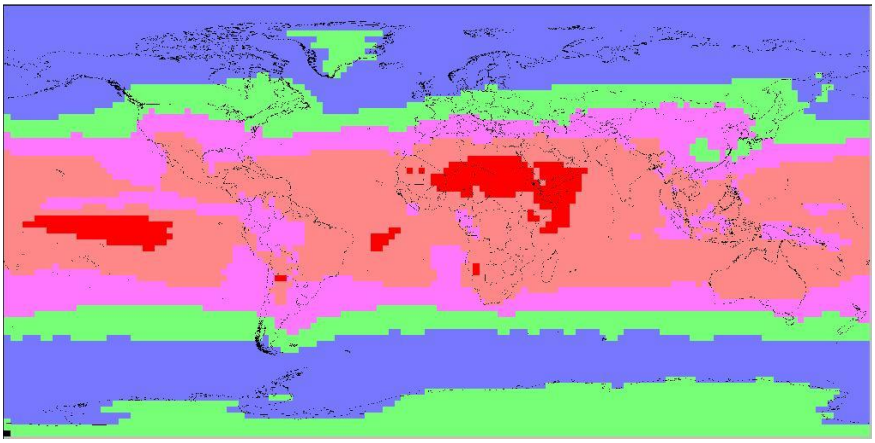

Fig.11 Distribution of annual average for solar irradiance satellite data

Source) SeaWIFs Solar Irradiance Data http://www.giss.nasa.gov/data/seawifs/data/

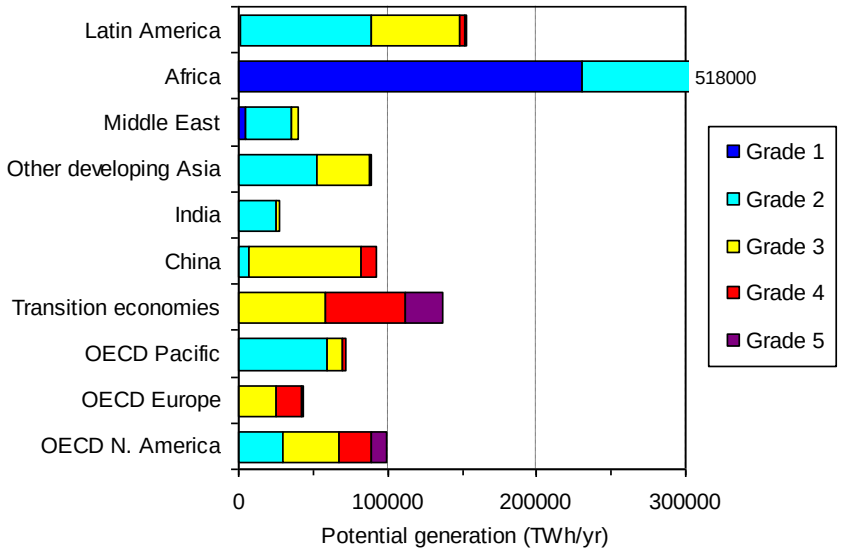

Fig.12 Generation potential for photovoltaics

9. Biomass

- ○ Estimation of the supply cost and reserves of biomass is difficult to the large surrounding uncertainty.
- ○ Estimates for plantation type biomass and residue type biomass are discussed below.
- ○ Worldwide, annual supply potential for plantation biomass is estimated to be approximately 2,700 Mtoe/yr, and for residue biomass approximately 160 Mtoe/yr (estimated value as at 2000, differs with respect to time)

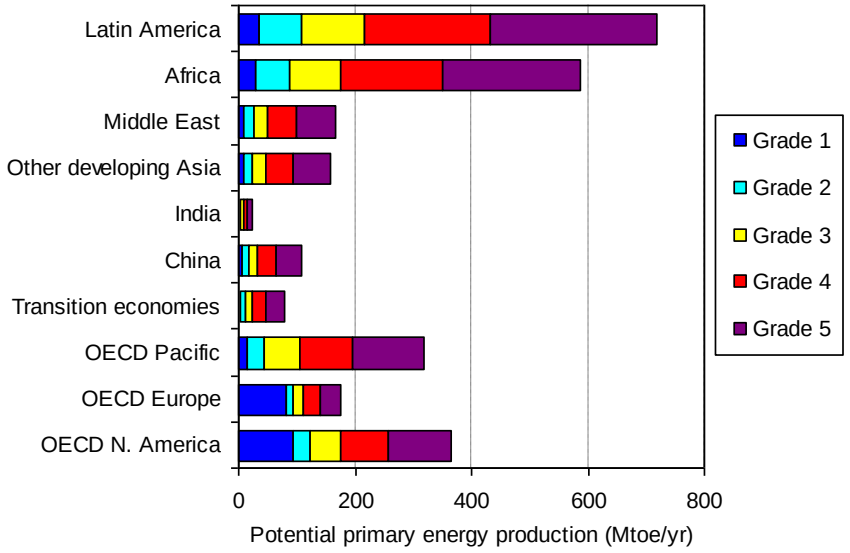

Fig.13 Potential supply amount of plantation type biomass (only commercial biomass)

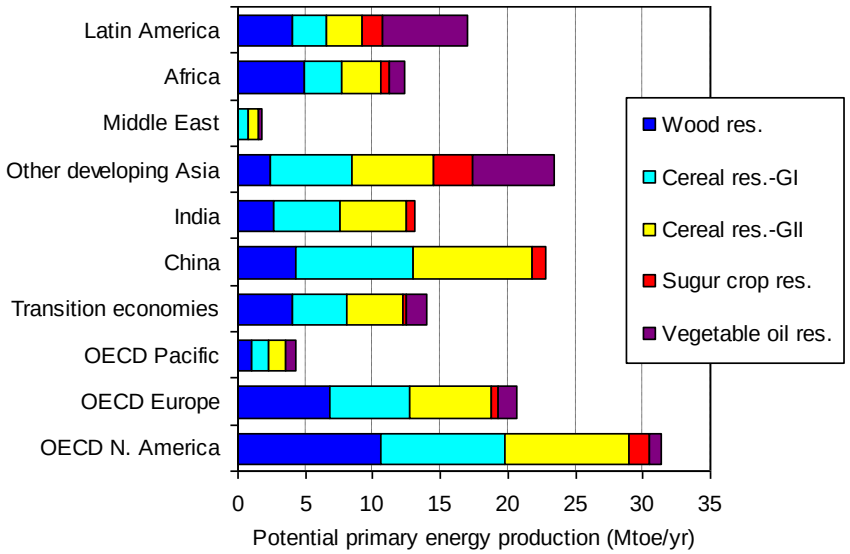

Fig.14 Potential supply amount of residue biomass (only commercial biomass)

Table 4 Estimate of production cost for plantation type and residue type biomass

Plantation Type($/toe)	Residue Type($/toe)
55 –*	60 – 160

* Significant differences occur with respect to time and region.

○ Since the DNE21+ model is a cost minimization model, it is difficult to evaluate non-commercial biomass since it does not appear in the cost base. As a result, non-commercial biomass is handled as an exogenous scenario.

○ There is no distinction made in the IEA statistics between commercial and non-commercial biomass. In contrast, the IPCC SRES B2 marker scenario takes OECD non-commercial biomass to have a value of zero.

○ In the DNE21+ model at 2000, it is assumed that all OECD biomass use is commercial. All non OECD biomass use is assumed to be non-commercial with the exception of biofuel for the transportation sector. (It is assumed that only non OECD biofuel for the transportation sector is commercial).

○ In addition, the future scenario for non-commercial biomass is constructed by assuming that non OECD non-commercial biomass use conforms to the rate of change (decrease rate) for non-commercial biomass in the IPCC SRES B2 marker scenario so that the estimates do not vary across various scenarios (the presence or absence of CO_2 emission controls etc.).