STATUS AND ECONOMICS OF WIND ENERGY

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ABSTRACT

Submitted paper is aimed on questions of stand, safety and economics of wind energy.

1. WORLD ENERGY RESOURCES AND CONSUMPTION

In 2005, total worldwide energy consumption was 500 EJ = 5.10^{20} J (or 138,900 TWh) with 86,5% derived from the combustion of fossil fuels. This is equivalent to an average power of 15 TW = $1,5.10^{13}$ W).

Not all of the world's economies track their energy consumption with the same rigor, and the exact energy content of a barrel of oil or a ton of coal will vary with quality.

Most of the world energy resources are from the sun's rays hitting earth - some of that energy has been preserved as fossil energy, some is directly or indirectly usable e.g. via wind, hydro or wave power. This 174 PW = $1,74.10^{17}$ W is the total amount of solar energy received by the planet, only 89 PW are absorbed by land and the oceans.

The estimates of remaining worldwide energy resources vary, with the remaining fossil fuels totaling an estimated 0,4 YJ = $0,4.10^{24}$J and the available nuclear fuel such as uranium exceeding 2,5 YJ. Fossil fuels range from 0,6-3 YJ if estimates of reserves of methane clathrates are accurate and become technically extractable. Mostly thanks to the Sun, the world also has a renewable usable energy flux that exceeds 120 PW (8 000 times 2004 total usage), or 3,8 YJ/yr, dwarfing all non-renewable resources.

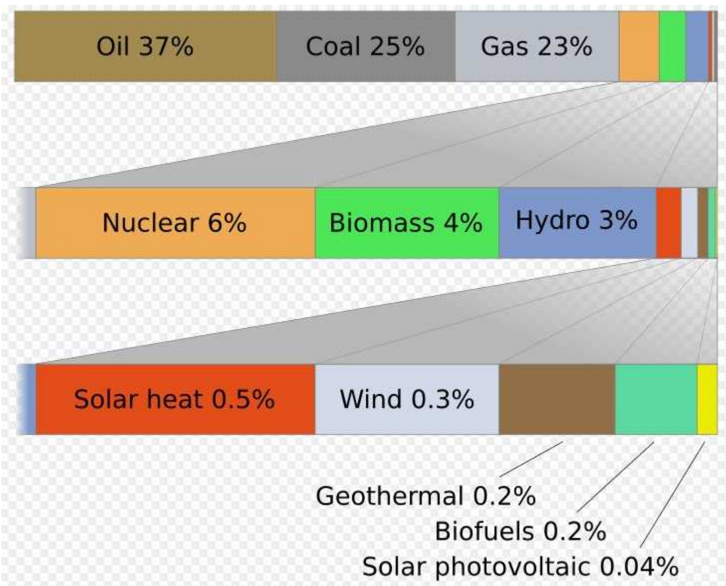

Fig. 1. Global Power Usage [1]

Since the advent of the industrial revolution, the worldwide energy consumption has been growing steadily. In 1890 the consumption of fossil fuels roughly equaled the amount of biomass fuel burned by households and industry. In 1900, global energy consumption equaled 0,7 TW ($0{,}7.10^{12}$ watts).

Coal fueled the industrial revolution in the 18th and 19th century. With the advent of the automobile, airplanes and the spreading use of electricity, oil became the dominant fuel during the twentieth century. The growth of oil as the largest fossil fuel was further enabled by steadily dropping prices from 1920 until 1973. After the oil shocks of 1973 and 1979, during which the price of oil increased from 5 to 45 US dollars per barrel, there was a shift away from oil. Coal and nuclear became the fuels of choice for electricity generation and conservation measures increased energy efficiency. Over the last forty years, the use of fossil fuels has continued to grow and their share of the energy supply has increased. In the last three years, coal, which is one of the dirtiest sources of energy, has become the fastest growing fossil fuel.

The twentieth century saw a rapid twentyfold increase in the use of fossil fuels. Between 1980 and 2004, the worldwide annual growth rate was 2%.

Table 1. Total energy consumption of world [2]

Fuel type	Power in TW	Energy/year in EJ
Oil	5,6	180
Gas	3,5	110
Coal	3,8	120
Hydroelectric	0,9	30
Nuclear	0,9	30
Geothermal, wind, solar, wood	0,13	4
Total	15	471

In 2005 nuclear energy accounted 6,3% of world's total primary energy supply. The nuclear power production in 2006 accounted 2,658 TWh (23,3 EJ), which was 16% of world's total electricity production. In November 2007, there were 439 operational nuclear reactors worldwide, with total capacity of 372,002 MWe. A further 33 reactors were under construction, 94 reactors were planned and 222 reactors were proposed.

2. RENEWABLE RESOURCES – WIND POWER

In 2004, renewable energy supplied around 7% of the world's energy consumption [3]. The renewables sector has been growing significantly since the last years of the 20th century, and in 2005 the total new investment was estimated to have been 38 billion US dollars. Germany and China lead with investments of about 7 billion US dollars each, followed by the United States, Spain, Japan, and India. This resulted in an additional 35 GW of capacity during the year [1].

The available wind energy estimates range from 300 TW to 870 TW [4]. Using the lower estimate, just 5% of the available wind energy would supply the current worldwide energy needs. Most of this wind energy is available over the open ocean. The oceans cover 71% of the planet and wind tends to blow stronger over open water because there are fewer obstructions.

According to the Global Wind Energy Council, the installed capacity of wind power increased by 27% from the end of 2006 to the end of 2007 to total 94,1 GW, with over half the increase in the United States, Spain and China [5]. Doubling of capacity took about three years. The total installed capacity is approximately three times that of the actual average power produced as the nominal capacity represents peak output; actual capacity is generally from 25-40% of the nominal capacity [6].

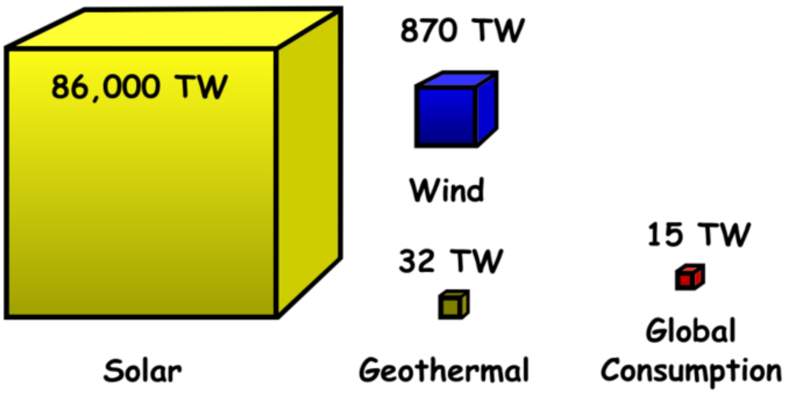

Fig. 2. Available renewable energy [7]

Although wind currently produces about 1% of world-wide electricity use [8], it accounts for approximately 19% of electricity production in Denmark, 9% in Spain and Portugal, and 6% in Germany and the Republic of Ireland. Globally, wind power generation increased more than fivefold between 2000 and 2007 [9].

Wind energy is plentiful, renewable, widely distributed, clean, and reduces greenhouse gas emissions when it displaces fossil-fuel-derived electricity. Therefore, it is considered by experts to be more environmentally friendly than many other energy sources. The intermittency of wind seldom creates problems when using wind power to supply a low proportion of total demand. Where wind is to be used for a moderate fraction of demand, additional costs for compensation of intermittency are considered to be modest [10].

The modern wind power industry began in 1979 with the serial production of wind turbines by Danish manufacturers Kuriant, Vestas, Nordtank, and Bonus. These early turbines were small by today's standards, with capacities of 20 to 30 kW each. Since then, they have increased greatly in size, while wind turbine production has expanded to many countries all over the world.

There are now many thousands of wind turbines operating, with a total capacity of 73,904 MW of which wind power in Europe accounts for 65% (2006). 81% of wind power installations are in the US and Europe, but the share of the top five countries in terms of new installations fell from 71% in 2004 to 62% in 2006. By 2010, the World Wind Energy Association expects 160GW of capacity to be installed worldwide [11].

Table 2. Installed windpower capacity [8]

Ranking total 2007	Country/region	Total Capacity installed end 2007	Additional Capacity 2007 (Difference 2007-2006)	Rate of Growth 2007	Ranking total 2006	Total Capacity installed end 2006	Total Capacity installed end 2005
		MW	MW	%		MW	MW
1	Germany	22247,4	1625,4	7,9	1	20622,0	18427,5
2	USA	16818,8	5215,8	45,0	3	11603,0	9149,0
3	Spain	15145,1	3515,1	30,2	2	11630,0	10027,9
4	India	7850,0	1580,0	25,2	4	6270,0	4430,0
5	China	5912,0	3313,0	127,5	6	2599,0	1266,0
6	Denmark	3125,0	-11,0	-0,4	5	3136,0	3128,0
7	Italy	2726,1	602,7	28,4	7	2123,4	1718,3
8	France	2455,0	888,0	56,7	10	1567,0	757,2
9	United Kingdom	2389,0	426,2	21,7	8	1962,9	1353,0
10	Portugal	2130,0	414,0	24,1	9	1716,0	1022,0
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12	The Netherlands	1747,0	188,0	12,1	11	1559,0	1224,0
14	Austria	981,5	17,0	1,8	14	964,5	819,0
24	Poland	276,0	123,0	80,4	26	153,0	73,0
28	Czech Republic	116,0	59,5	105,3	34	56,5	29,5
33	Bulgaria	70,0	34,0	94,4	37	36,0	14,0
35	Hungary	65,0	4,1	6,8	33	60,9	17,5
37	Estonia	58,1	25,1	76,1	39	33,0	33,0
38	Lithuania	52,3	-2,7	-4,8	35	55,0	7,0
41	Latvia	27,4	0,0	0,0	41	27,4	27,4
48	Croatia	17,8	0,6	3,5	47	17,2	6,0
50	Russia	16,5	1,0	6,5	49	15,5	14,0
53	Switzerland	11,6	0,0	0,0	52	11,6	11,6
54	Romania	9,0	6,2	226,1	57	2,8	0,9
56	Slovakia	5,0	0,0	0,0	54	5,0	5,0
...							
	Total	**93849,1**	**19695,8**	**26,6**		**74153,3**	**59033,0**

3. ECONOMICS AND FEASIBILITY

Despite constraints facing supply chains for wind turbines, the annual market for wind continued to increase in 2007 at an estimated rate of 31% following 32% growth in 2006. In terms of economic value, the wind energy sector has become one of the important players in the energy markets, with the total value of new generating equipment installed in 2007 reaching 25 billion €, or 36 billion US$ [12].

In 2004, wind energy cost one-fifth of what it did in the 1980s, and some expected that downward trend to continue as larger multi-megawatt turbines are mass-produced. However, installed cost averaged 1300 €/kW in 2007 [12], compared to 1100 €/kW in 2005. Not as many facilities can produce large modern turbines and their towers and foundations, so constraints develop in the supply of turbines resulting in higher costs.

Wind and hydro power have negligible fuel costs and relatively low maintenance costs; in economic terms, wind power has a low marginal cost and a high proportion of capital cost. The estimated average cost per unit incorporates the cost of construction of the turbine and transmission facilities, borrowed funds, return to investors (including cost of risk), estimated annual production, and other components, averaged over the projected useful life of the equipment, which may be in excess of twenty years. Energy cost estimates are highly dependent on these assumptions so published cost figures can differ substantially. A British Wind Energy Association report gives an average generation cost of onshore wind power of around 3,2 pence/kWh (2005) [15]. Cost per unit of energy produced was estimated in 2006 to be comparable to the cost of new generating capacity in the United States for coal and natural gas: wind cost was estimated at 55,80 $/MWh, coal at 53,10 $/MWh and natural gas at 52,50 $/MWh.

Existing generation capacity represents sunk costs, and the decision to continue production will depend on marginal costs going forward, not estimated average costs at project inception. For example, the estimated cost of new wind power capacity may be lower than that for "new coal" (estimated average costs for new generation capacity) but higher than for "old coal" (marginal cost of production for existing capacity). Therefore, the choice to increase wind capacity will depend on factors including the profile of existing generation capacity.

Many potential sites for wind farms are far from demand centres, requiring substantially more money to construct new transmission lines and substations.

Since the primary cost of producing wind energy is construction and there are no fuel costs, the average cost of wind energy per unit of production is dependent on a few key assumptions, such as the cost of capital and years of assumed service. The marginal cost of wind energy once a plant is constructed is usually less than 1 cent/kWh. Since the cost of capital plays a large part in projected cost, risk (as perceived by investors) will affect projected costs per unit of electricity.

4. INVESTMENT APPRAISAL

Investment appraisal is the planning process used to determine whether a firm's long term investments such as new machinery, replacement machinery, new plants, new products, and research and development projects are worth pursuing. Many formal methods are used in capital budgeting, including the techniques such as Net present value, Profitability index, Internal rate of return, etc. [14].

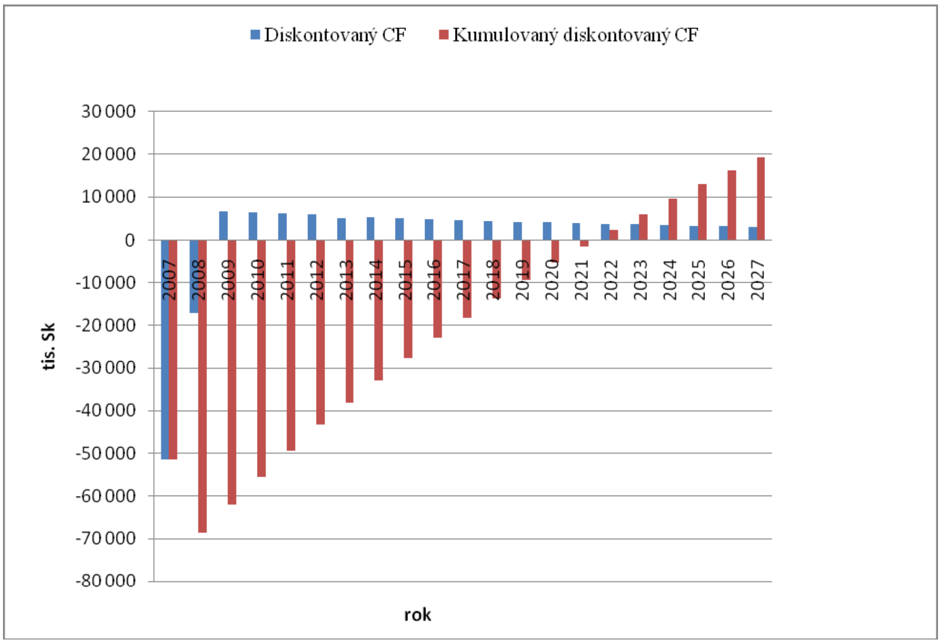

Fig. 3. DCF and NPV of wind-power plant for discount rate 5%

These methods use the incremental cash flows from each potential investment, or project. Each potential project's value should be estimated using a discounted cash flow (DCF) valuation, to find its net present value (NPV). This valuation requires estimating the size and timing of all of the incremental cash flows from the project. These future cash flows are then discounted to determine their present value. These present values are then summed, to get the NPV. The NPV decision rule is to accept all positive NPV projects in an unconstrained environment, or if projects are mutually exclusive, accept the one with the highest NPV. This work was supported by Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences under the project S.G.A. No. 1/3141/06 Impact of Distributed Electricity Sources Connecting on Electric Power System Operation.

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