Strategies for Sustainable Energy

Lecture 5. Production Part I

ENG2110-01
College of Engineering
Yonsei University
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Strategies for Sustainable Energy

Lecture 5. Production Part I

Outline

Section 1: Estimating Sustainable Energy Production from Wind
Section 2: Estimating Sustainable Energy Production from Solar
Section 3: Obstacles to Sustainable Energy Production from Wind
Section 4: Obstacles to Sustainable Energy Production from Solar

4. Production: Wind

Estimating Energy Production from Wind

How much wind power could we plausibly generate?

Three types of wind power

- **on-shore (land-based)**
- **shallow off-shore (shore-based)**
- **deep off-shore (sea-based)**

Power per person = wind power per unit area x area per person

If typical wind speed is 6 m/s = 13 miles/h = 22 km/h

The power per unit area of wind farm is 2 W/m^2.

Area per person = 4000 m^2/person

Power per person = 200 kWh/d/person if 100% of England was windfarms.

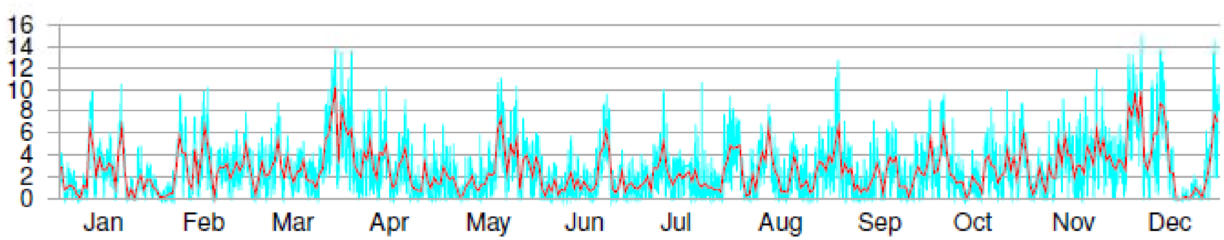


Figure 4.1. Cambridge mean wind speed in metres per second, daily (red line), and half-hourly (blue line) during 2006. See also figure 4.6.

Estimating Energy Production from Wind

PRODUCTION

Power per person = 200 kWh/d/person if 100% of England was wind farms.

If 10% of England was wind farms, then 20 kWh/d/person.

This would require double the current global fleet of wind turbines.

Also remember the power per unit area. We will compare this with other technologies.

Conclusion: The maximum contribution of onshore wind is much less than our consumption.

Wind:
20 kWh/d

POWER PER UNIT AREA	
wind farm (speed 6 m/s)	$2\,W/m^2$

Table 4.4. Facts worth remembering: wind farms.

Population density:
ROK: 2050 m^2/person
UK: 4000 m^2/person
China: 7200 m^2/person
USA: 31,250 m^2/person

4. Production: Wind

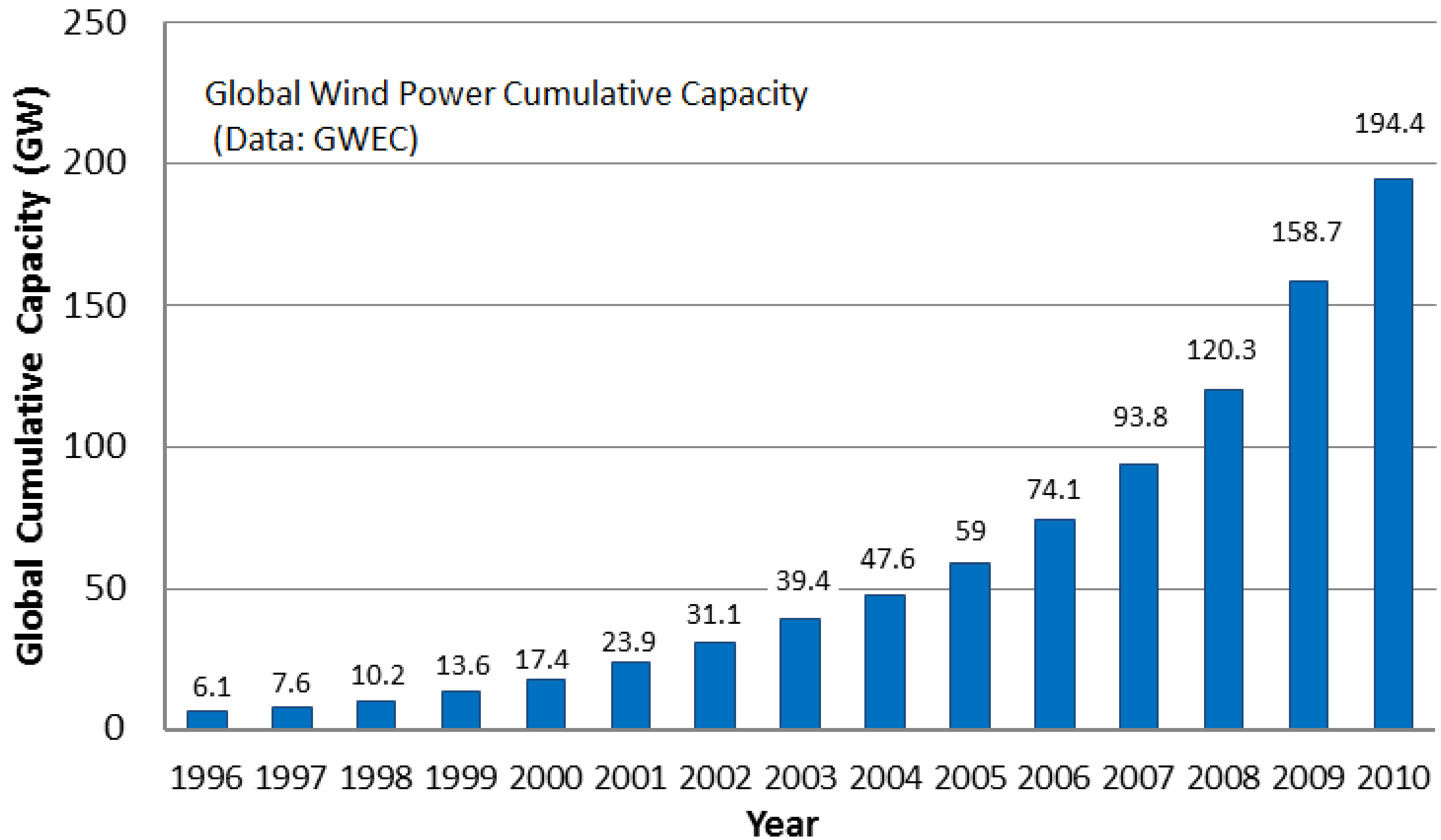
Estimating Energy Production from Wind

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electricity, windmills for mechanical power, windpumps for water pumping or drainage, or sails to propel ships.
At the end of 2010, worldwide nameplate capacity of wind-powered generators was 197 gigawatts (GW).

Energy production was 430 TWh, which is about 2.5% of worldwide electricity usage; and has doubled in the past three years. Several countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, 14% in Ireland and 9% in Germany in 2010. As of May 2009, 80 countries around the world are using wind power on a commercial basis.

http://en.wikipedia.org/wiki/Wind_power

Estimating Energy Production from Wind



http://en.wikipedia.org/wiki/Wind_power

4. Production: Wind

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Estimating Energy Production from Wind

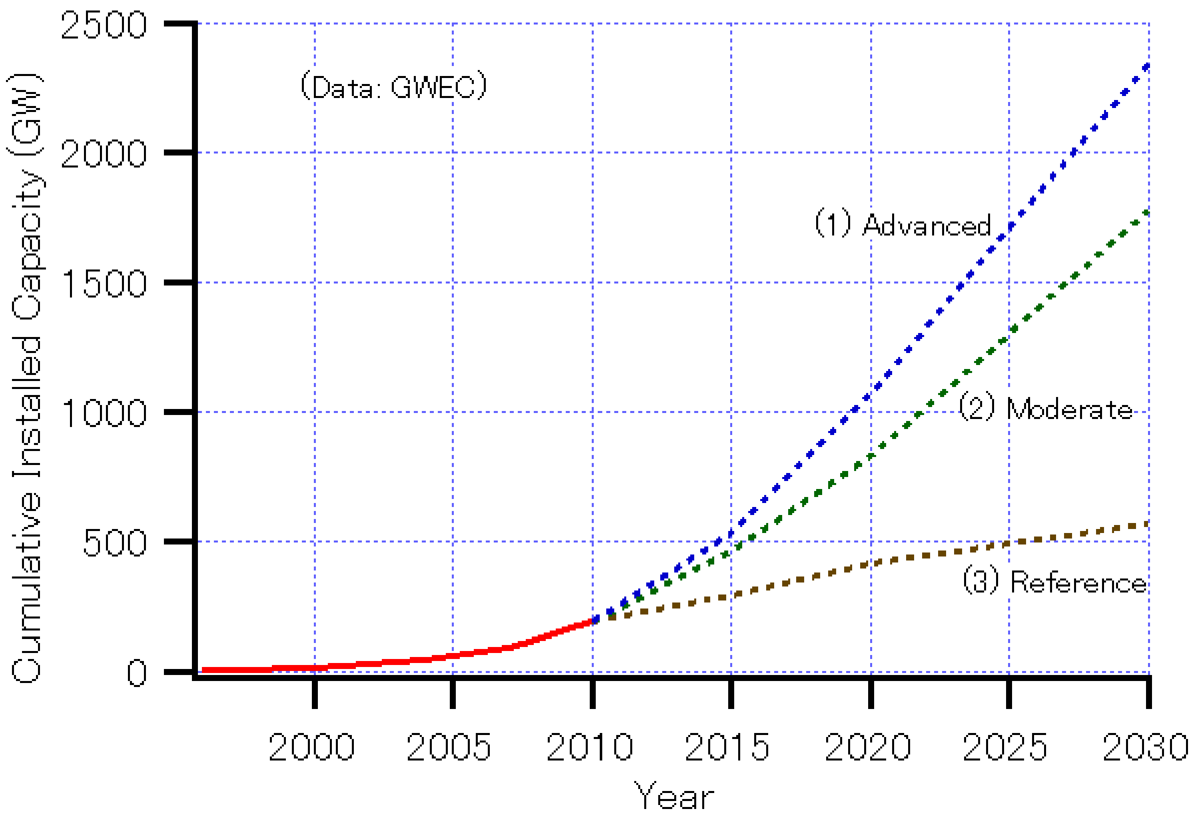
Top 10 wind power countries (February 2011)[3]

Country	Windpower capacity (MW)
China	44,733
United States	40,180
Germany	27,215
Spain	20,676
India	13,066
Italy	5,797
France	5,660
United Kingdom	5,204
Canada	4,008
Denmark	3,734

http://en.wikipedia.org/wiki/Wind_power

4. Production: Wind

Estimating Energy Production from Wind



http://en.wikipedia.org/wiki/Wind_power

Estimating Energy Production from Wind

Capacity factor

Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 20–40%, with values at the upper end of the range in particularly favourable sites. For example, a 1 MW turbine with a capacity factor of 35% will not produce 8,760 MW·h in a year (1 × 24 × 365), but only 1 × 0.35 × 24 × 365 = 3,066 MW·h, averaging to 0.35 MW.

Unlike fueled generating plants, the capacity factor is limited by the inherent properties of wind. Capacity factors of other types of power plant are based mostly on fuel cost, with a small amount of downtime for maintenance. Nuclear plants have low incremental fuel cost, and so are run at full output and achieve a 90% capacity factor. Plants with higher fuel cost are throttled back to follow load. Gas turbine plants using natural gas as fuel may be very expensive to operate and may be run only to meet peak power demand. A gas turbine plant may have an annual capacity factor of 5–25% due to relatively high energy production cost.

In a 2008 study released by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, the capacity factor achieved by the wind turbine fleet is shown to be increasing as the technology improves. The capacity factor achieved by new wind turbines in 2004 and 2005 reached 36%.[22]

http://en.wikipedia.org/wiki/Wind_power

4. Production: Wind

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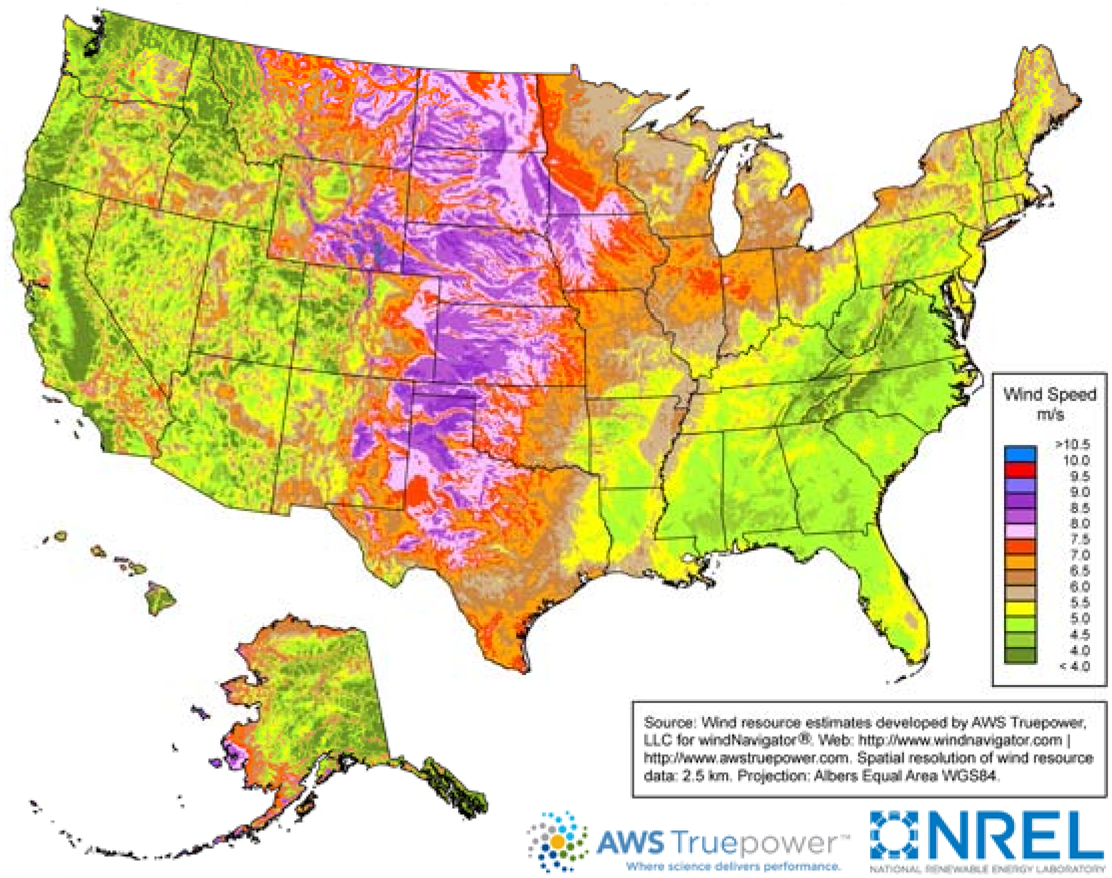
Estimating Energy Production from Wind: United States

80-Meter Wind Resource Maps



Click on a state to view the wind map for that state. Puerto Rico and the U.S. Virgin Islands do not have 80-meter wind maps available but have 50-meter wind maps.

The U.S. map shows the predicted mean annual wind speeds at 80-m height (at a spatial resolution of 2.5 km that is interpolated to a finer scale). Areas with annual average wind speeds around 6.5 m/s and greater at 80-m height are generally considered to have suitable wind resource for wind development.

http://www.windpoweringamerica.gov/wind_maps.asp

4. Production: Wind

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Estimating Energy Production from Wind: United States

Potential capacity

The U.S. Department of Energy's 2008 report 20% Wind Energy by 2030 envisioned that wind power could supply 20% of all U.S. electricity, which included a contribution of 4% to the nation's total electricity from offshore wind power.

On February 11, 2010, the National Renewable Energy Laboratory released the first comprehensive update of the wind energy potential by state since 1993, showing that the contiguous United States had potential to install 10,459 GW of onshore wind power. The capacity could generate 37 petawatt-hours (PW·h) annually, an amount nine times larger than current total U.S. electricity consumption. The U.S. also has large wind resources in Alaska and Hawaii.

In addition to the large onshore wind resources, the U.S. has large offshore wind power potential, with another NREL report released in September 2010 showing that the U.S. has 4,150 GW of potential offshore wind power nameplate capacity, an amount 4 times greater than the country's 2008 installed capacity from all sources of 1,010 GW.

http://en.wikipedia.org/wiki/Wind_power_in_the_United_States

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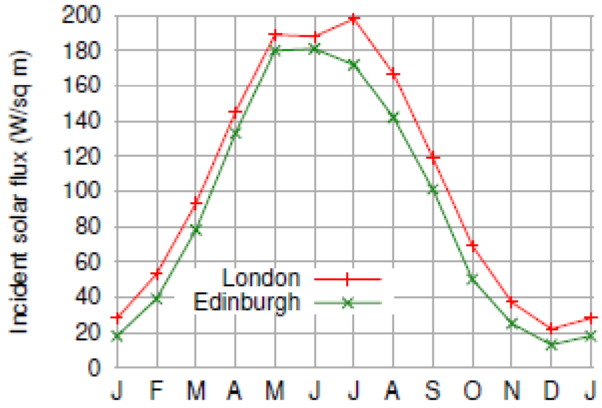
Estimating Energy Production from Solar Energy



Different types of Solar Power

- Solar Heating (or Solar Thermal)
- Solar Photovoltaic (generates electricity)
- Biomass (solar power generates "energy crops" via photosynthesis
- Food (energy for humans and other animals)

At noon on a cloudless day, the power of sunshine is 1 kW/m^2.
This applies to land oriented toward the sun.

You don't get all this power.
Due to the tilt of the Earth's rotational axis, the UK gets about 60% of this energy.
The average intensity over the course of the day is 32% of the maximum value at noon.
Some days are cloudy. In the UK, you only have good sun 34% of daylight hours.

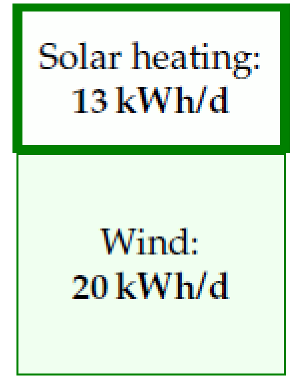
So we have 110 W/m^2 that we could attempt to gather in the UK.

6. Production: Solar

Estimating Energy Production from Solar Energy

Solar Thermal (Solar Heating)

The simplest solar power technology is a panel making hot water.
If we cover all south-facing roof with solar thermal panels.
That's 10 m^2 per person.
50% efficiency turning sunlight into hot water.
This yields 13 kWh per day per person.



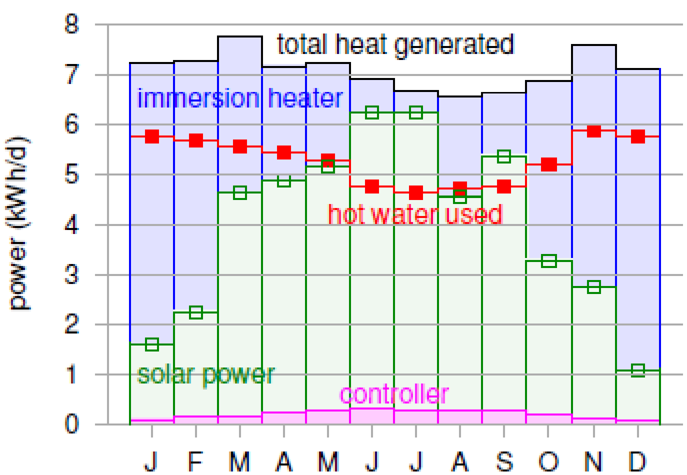


Figure 6.3. Solar power generated by a 3 m^2 hot-water panel (green), and supplementary heat required (blue) to make hot water in the test house of Viridian Solar. (The photograph shows a house with the same model of panel on its roof.) The average solar power from 3 m^2 was 3.8 kWh/d. The experiment simulated the hot-water consumption of an average European household – 100 litres of hot (60 °C) water per day. The 1.5–2 kWh/d gap between the total heat generated (black line, top) and the hot water used (red line) is caused by heat-loss. The magenta line shows the electrical power required to run the solar system. The average power per unit area of these solar panels is 53 W/m^2.

This is low-grade energy (heat).
Solar thermal is not generating electricity.

6. Production: Solar

Estimating Energy Production from Solar Energy

Solar Photovoltaic (electricity from solar energy)

Typical solar panels have a 10% efficiency.
Expensive panels have a 20% efficiency.
An average south-facing panel with an expensive panel could generate

$$20\% \times 110\ W/m^2 = 22\ W/m^2$$

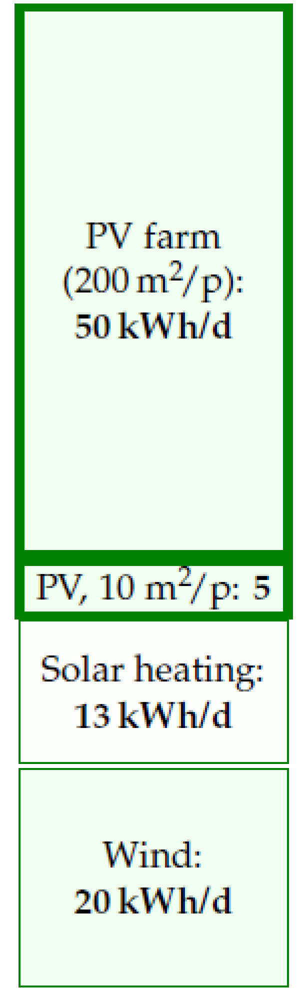
If every person had 10 m2 of expensive panels we would have

5 kWh/d/person

They cost four times as much as solar thermal and deliver half the power, but the power is in the form of high-grade energy--electricity.

If we had solar farms with cheaper panels (10% efficiency)
(Fantasy land)

$$10\% \times 110\ W/m^2 = 11\ W/m^2$$
$$11\ W/m^2 \times 200\ m^2/person = 50\ kWh/day/person$$



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Estimating Energy Production from Solar Energy

Manufacturing a solar panel consumes more energy than it will ever deliver.

False. The energy yield ratio (the ratio of energy delivered by a system over its lifetime, to the energy required to make it) of a roof-mounted, grid-connected solar system in Central Northern Europe is 4, for a system with a lifetime of 20 years (Richards and Watt, 2007); and more than 7 in a sunnier spot such as Australia. (An energy yield ratio bigger than one means that a system is A Good Thing, energy-wise.) Wind turbines with a lifetime of 20 years have an energy yield ratio of 80.

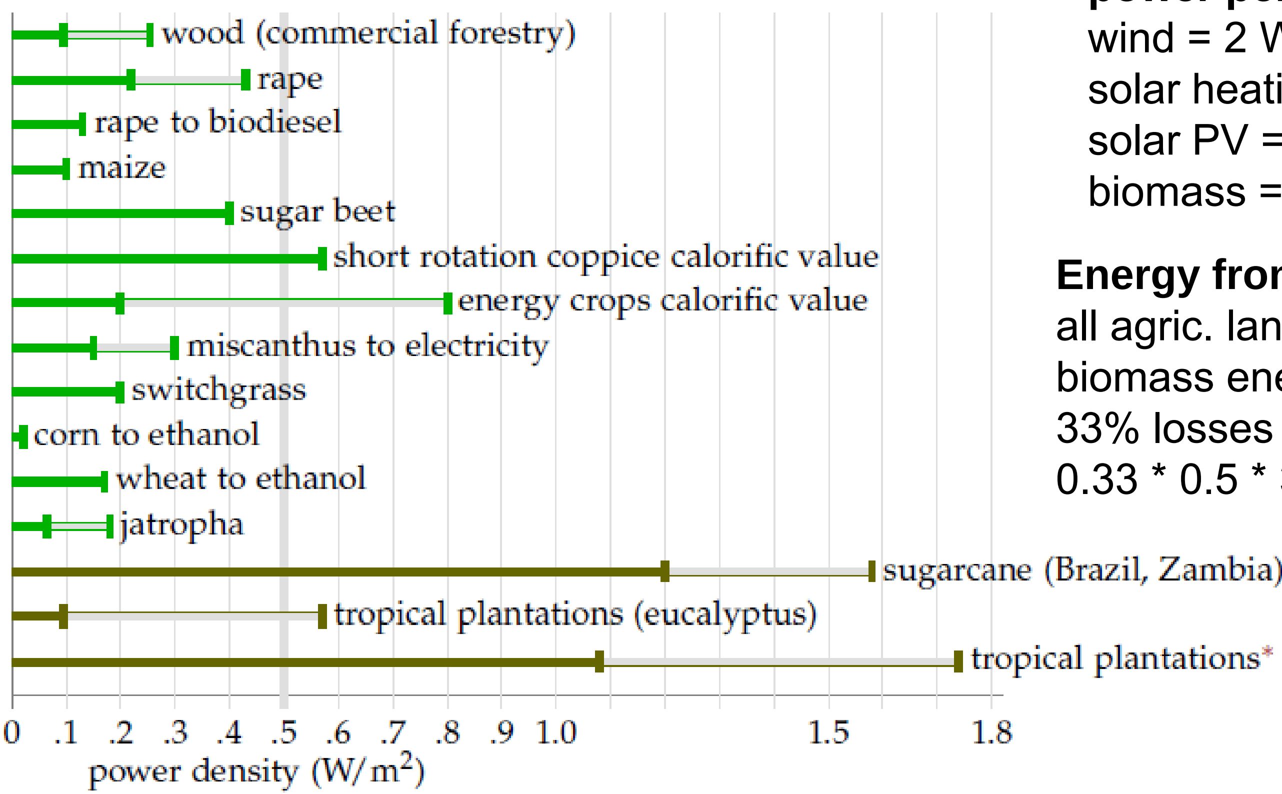
6. Production: Solar

Estimating Energy Production from Solar Energy

Solar Biomass

Options

1. Grow energy crops, which are burned for energy (coal substitution)
2. Grow energy crops, convert to biodiesel (petroleum substitution)
3. Grow food crops, burn waste products for energy (coal subs.)
4. Grow food, feed to humans and animals. (food)



power per area

wind = 2 W/m^2

solar heating = 50 W/m^2

solar PV = 20 W/m^2

biomass = < 2 W/m^2

Energy from biomass

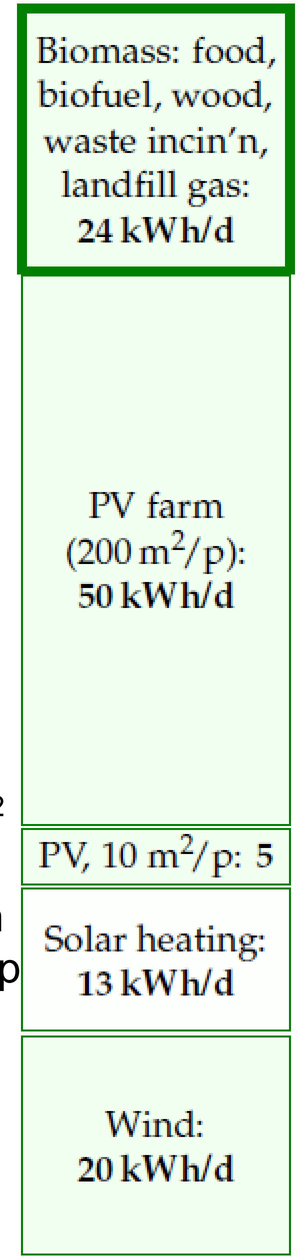
all agric. land for energy

biomass energy = 0.5 W/m^2

33% losses

0.33 * 0.5 * 3000 m^2/person

= 24 kWh/d/p



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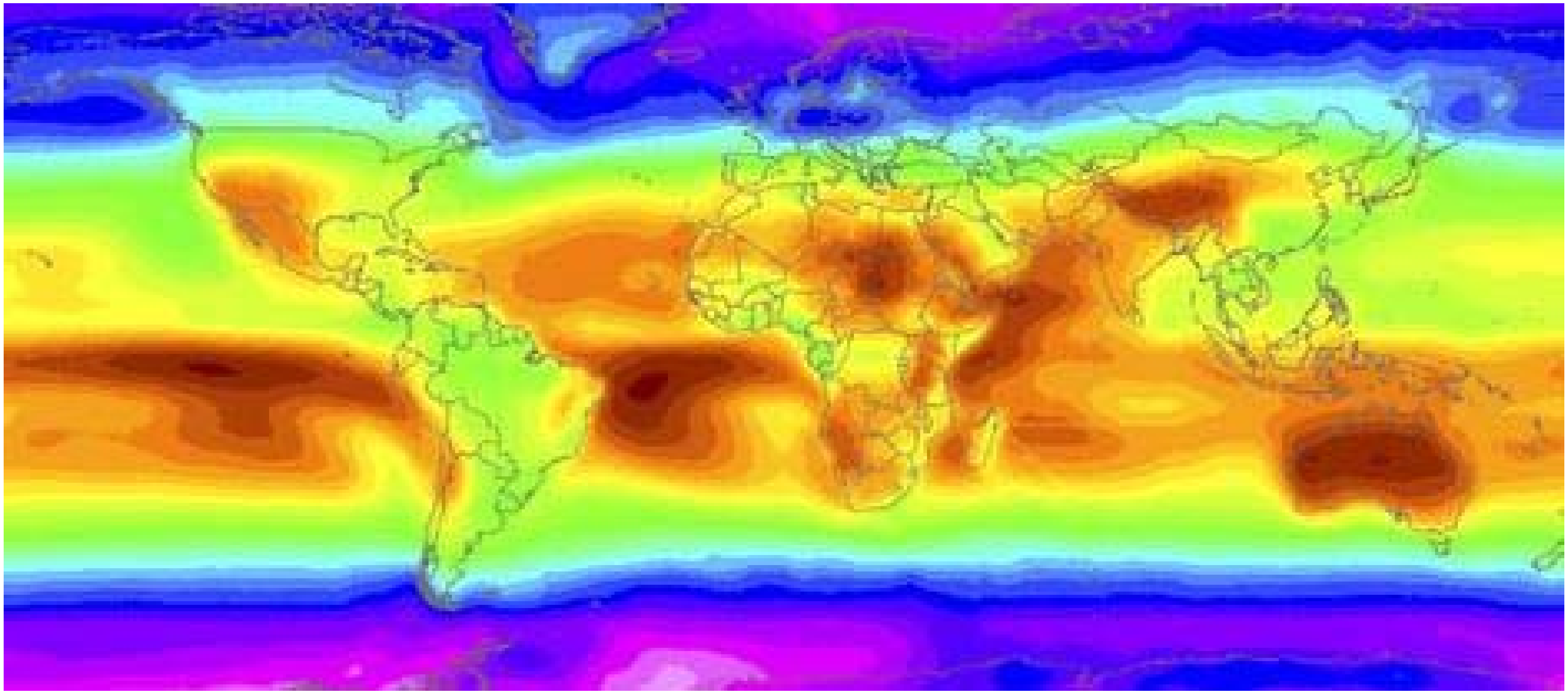
Estimating Energy Production from Solar Energy

Sunlight is unevenly distributed across the world's surface.



6. Production: Solar

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Estimating Energy Production from Solar Energy

Composition of Electricity by Resource (TWh per year 2008)

Country	Fossil Fuel					Nuclear	rank	Renewable								Biomass, others					total	rank
	Coal	Oil	Gas	sub total	rank			Hydro	Geo Thermal	Solar PV*	Solar Thermal	Wind	Tide	sub total	rank	Bio mass	waste	other	sub total	rank		
World total	8,263	1,111	4,301	13,675	-	2,731	-	3,288	65	12	0.9	219	0.5	3,584	-	198	69	4	271	-	20,261	-
Proportion	41%	5.5%	21%	67%	-	13%	-	16%	0.3%	0.06%	0.004%	1.1%	0.003%	18%	-	1.0%	0.3%	0.02%	1.3%	-	100%	-
China	**2,733**	23	31	**2,788**	2	68	8	**585**	-	0.2	-	13	-	**598**	1	2.4	-	-	2.4	14	**3,457**	2
India	569	34	82	685	6	15	12	114	-	0.02	-	14	-	128	6	2.0	-	-	2.0	16	8306	5
USA	**2,133**	58	**911**	**3,101**	1	**838**	1	282	**17**	1.6	**0.88**	**56**	-	**357**	4	**50**	22	0.8	**73**	1	**4,369**	1
Indonesia	61	43	25	130	19	-	-	12	8.3	-	-	-	-	20	17	-	-	-	-	-	149	20
Brazil	13	18	29	59	23	14	13	**370**	-	-	-	0.6	-	**370**	3	**20**	-	0.2	**20**	4	463	9
Pakistan	0.1	32	30	62	22	1.6	16	28	-	-	-	-	-	28	14	-	-	-	-	-	92	24
Bangladesh	0.6	1.7	31	33	27	-	-	1.5	-	-	-	-	-	1.5	29	-	-	-	-	-	35	27
Nigeria	-	3.1	12	15	28	-	-	5.7	-	-	-	-	-	5.7	25	-	-	-	-	-	21	28
Russia	197	16	**495**	708	4	163	4	167	0.5	-	-	0.01	-	167	5	0.02	2.5	-	2.5	13	**1,040**	4
Japan	288	**139**	**283**	711	3	258	3	83	2.8	**2.3**	-	2.6	-	91	7	**15**	7.3	-	**22**	3	**1,082**	3
Mexico	21	49	131	202	13	9.8	14	39	7.1	0.01	-	0.3	-	47	12	0.8	-	-	0.8	17	259	14
Philippines	16	4.9	20	40	26	-	-	9.8	**11**	0.001	-	0.1	-	21	16	-	-	-	-	-	61	26
Vietnam	15	1.6	30	47	25	-	-	26	-	-	-	-	-	26	15	-	-	-	-	-	73	25
Ethiopia	-	0.5	-	0.5	29	-	-	3.3	0.01	-	-	-	-	3.3	28	-	-	-	-	-	3.8	30
Egypt	-	26	90	115	20	-	-	15	-	-	-	0.9	-	16	20	-	-	-	-	-	131	22
Germany	291	9.2	88	388	6	148	6	27	0.02	**4.4**	-	**41**	-	72	9	**20**	9.4	-	**29**	2	637	7
Turkey	58	7.5	99	164	16	-	-	33	0.16	-	-	0.85	-	34	13	0.14	0.1	-	0.22	19	198	19

http://en.wikipedia.org/wiki/Electricity_generation

6. Production: Solar

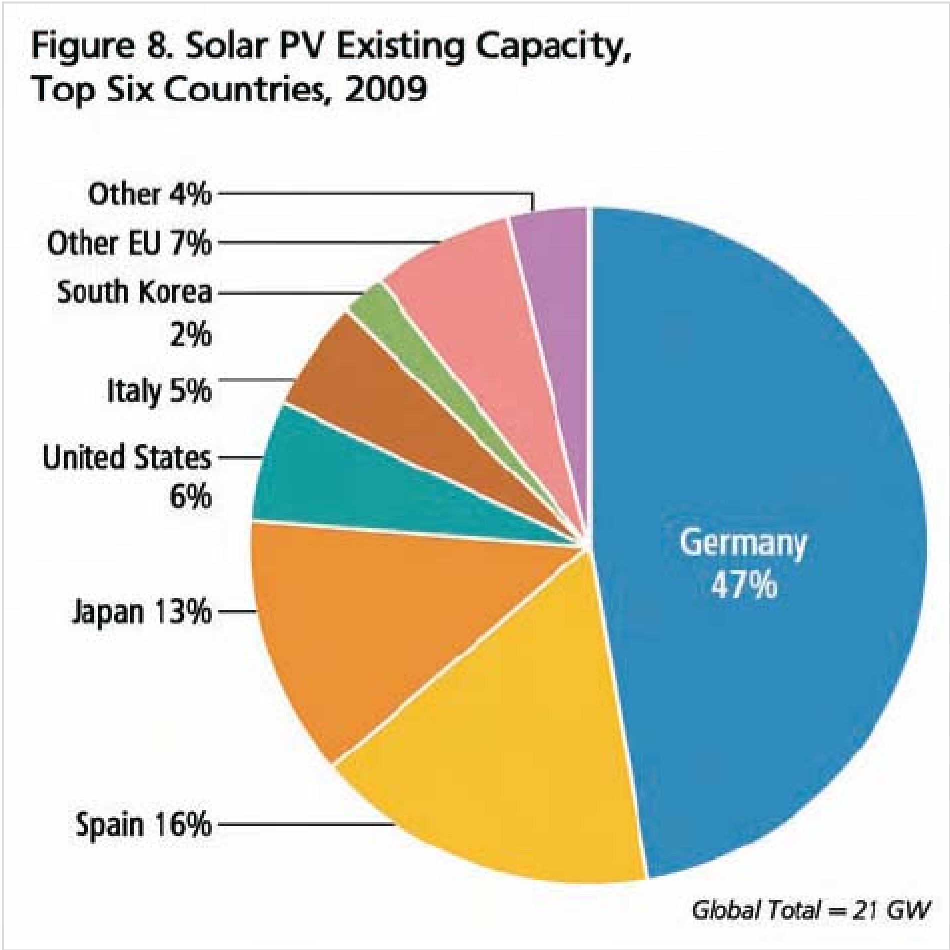
Estimating Energy Production from Solar Energy

Germany	291	9.2	88	388	6	148	6	27	0.02	**4.4**	-	**41**	-	72	9	**20**	9.4	-	**29**	2	637	7
Turkey	58	7.5	99	164	16	-	-	33	0.16	-	-	0.85	-	34	13	0.14	0.1	-	0.22	19	198	19
DR Congo	-	0.02	0.03	0.05	30	-	-	7.5	-	-	-	-	-	7.5	22	-	-	-	-	-	7.5	29
Iran	0.4	36	173	209	11	-	-	5.0	-	-	-	0.20	-	5.2	26	-	-	-	-	-	215	17
Thailand	32	1.7	102	135	18	-	-	7.1	0.002	0.003	-	-	-	7.1	23	4.8	-	-	4.8	10	147	21
France	27	5.8	22	55	24	**439**	2	68	-	0.04	-	5.7	**0.51**	75	8	2.1	3.8	-	5.9	9	575	8
UK	127	6.1	177	310	7	52	10	9.3	-	0.02	-	7.1	-	16	18	8.1	2.9	-	11	5	389	11
Italy	49	31	173	253	9	-	-	47	5.5	0.2	-	4.9	-	58	11	4.4	3.3	0.9	8.6	6	319	12
South Korea	192	15	81	288	8	151	5	5.6	-	0.3	-	0.4	-	6.3	24	0.5	0.2	0.1	0.7	18	446	10
Spain	50	18	122	190	14	59	9	26	-	**2.6**	0.02	**32**	-	61	10	2.5	1.6	0.3	4.3	11	314	13
Canada	112	9.8	41	162	17	94	7	**383**	-	0.03	-	3.8	0.03	**386**	2	8.3	0.2	-	8.5	7	651	6
Saudi Arabia	-	**116**	88	204	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	204	18
Taiwan	125	14	46	186	15	41	11	7.8	-	0.004	-	0.6	-	8.4	21	0.5	3.0	-	3.5	12	238	16
Austria	198	2.8	39	239	10	-	-	12	-	0.2	0.004	3.9	-	16	19	2.2	-	-	2.2	15	257	15
Netherlands	27	2.1	63	92	21	4.2	15	0.1	-	0.04	-	4.3	-	4.4	27	3.7	2.9	0.1	6.8	8	108	23
Country	**Coal**	**Oil**	**Gas**	**sub total**	**rank**	**Nuclear**	**rank**	**Hydro**	**Geo Thermal**	**Solar PV**	**Solar Thermal**	**Wind**	**Tide**	**sub total**	**rank**	**Bio mass**	**Waste**	**other**	**sub total**	**rank**	**Total**	**rank**

http://en.wikipedia.org/wiki/Electricity_generation

6. Production: Solar

Estimating Energy Production from Solar Energy

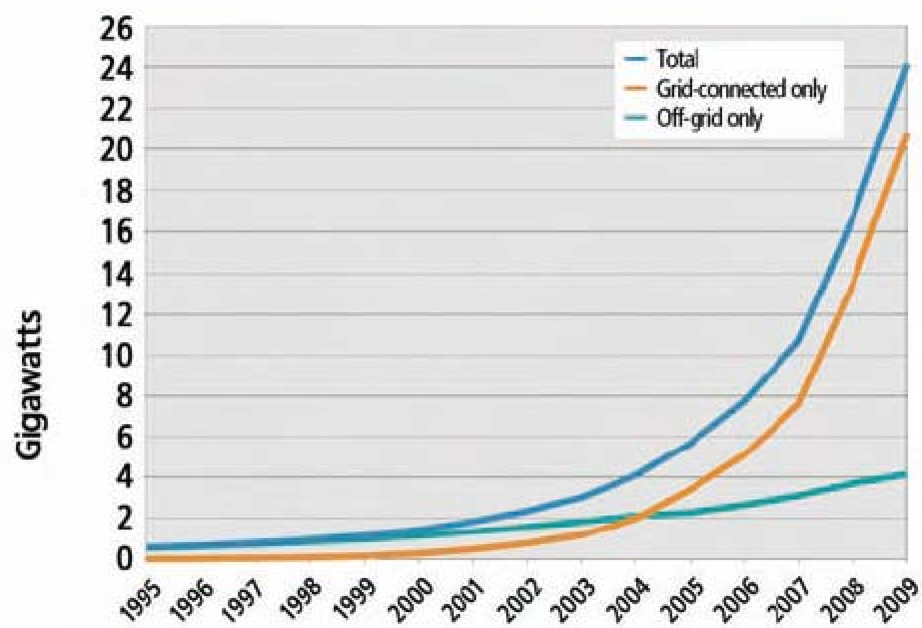


http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf

6. Production: Solar

Estimating Energy Production from Solar Energy

Figure 7. Solar PV, Existing World Capacity, 1995–2009



Cumulative global PV installations are now nearly six times what they were at the end of 2004. Analysts expect even higher growth in the next four to five years.[68] Thin film's share of the global market increased from 14 percent in 2008 to 19 percent in 2009 for cells, and from 16 to 22 percent for modules.[69]

http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf

6. Production: Solar

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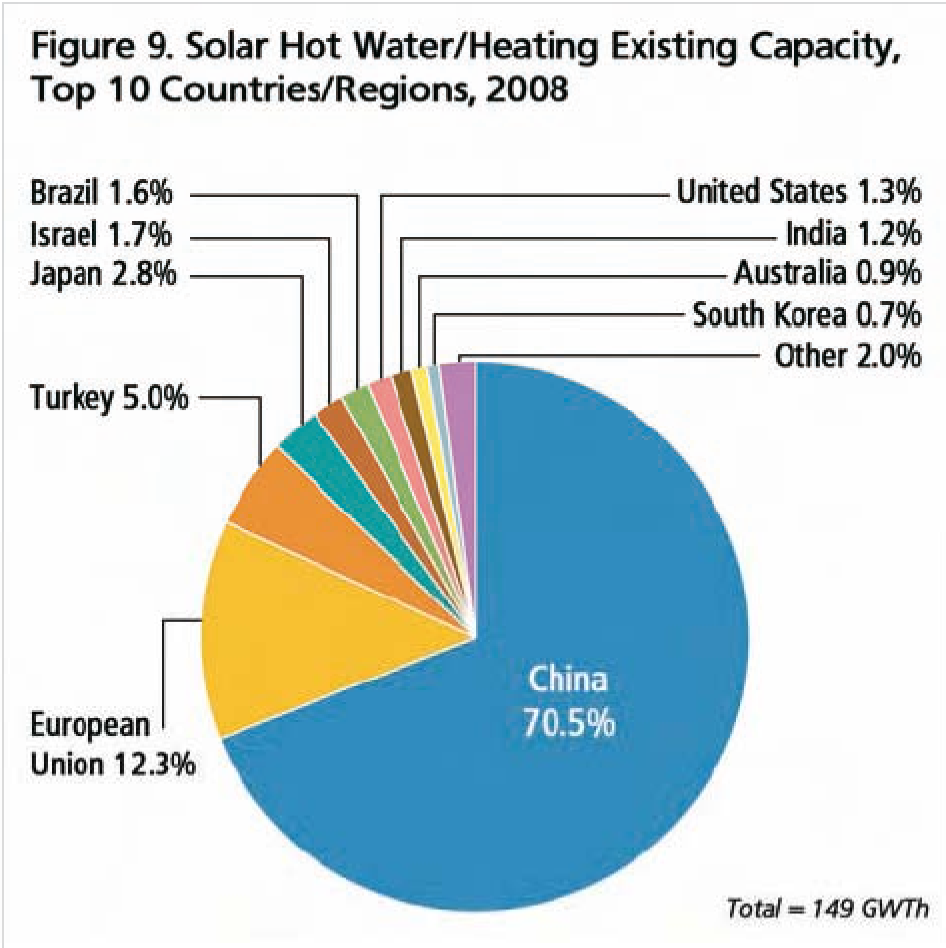
Estimating Energy Production from Solar Energy



http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf

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Obstacles to Energy Production from Wind

Windmills kill birds!

Costs to birds

Do windmills kill "huge numbers" of birds? Wind farms recently got adverse publicity from Norway, where the wind turbines on Smola, a set of islands off the north-west coast, killed 9 white-tailed eagles in 10 months. I share the concern of BirdLife International for the welfare of rare birds. But I think, as always, it's important to do the numbers. It's been estimated that 30 000 birds per year are killed by wind turbines in Denmark, where windmills generate 9% of the electricity. Horror! Ban windmills! We also learn, moreover, that *traffic* kills *one million* birds per year in Denmark. Thirty-times-greater horror! Thirty-times-greater incentive to ban cars! And in Britain, 55 million birds per year are killed by *cats* (figure 10.6).

Obstacles to Energy Production from Wind

Windmills are noisy!

Source/Activity	Indicative noise level dB (A)
Threshold of hearing	0
Rural night-time background	20-40
Quiet bedroom	35
Wind farm at 350m	35-45
Car at 40mph at 100m	55
Busy general office	60
Truck at 30mph at 100m	65
Pneumatic drill at 7m	95
Jet aircraft at 250m	105
Threshold of pain	140

http://www.bwea.com/ref/noise.html

6. Production: Wind

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Obstacles to Energy Production from Wind

Windmills are a momentum sink! They will change the world's climate by draining momentum from the world's air currents.

Weather response to a large wind turbine array

D. B. Barrie and D. B. Kirk-Davidoff

University of Maryland Department of Atmospheric and Oceanic Science, College Park, MD, USA

Received: 8 December 2008 – Published in Atmos. Chem. Phys. Discuss.: 29 January 2009
Revised: 8 January 2010 – Accepted: 15 January 2010 – Published: 26 January 2010

Abstract. Electrical generation by wind turbines is increasing rapidly, and has been projected to satisfy 15% of world electric demand by 2030. The extensive installation of wind farms would alter surface roughness and significantly impact the atmospheric circulation due to the additional surface roughness forcing. This forcing could be changed deliberately by adjusting the attitude of the turbine blades with respect to the wind, which would enable the "management" of a large array of wind turbines. Using a General Circulation Model (GCM), we represent a continent-scale wind farm as a distributed array of surface roughness elements. Here we show that initial disturbances caused by a step change in roughness grow within four and a half days such that the flow is altered at synoptic scales. The growth rate of the induced perturbations is largest in regions of high atmospheric instability. For a roughness change imposed over North America, the induced perturbations involve substantial changes in the track and development of cyclones over the North Atlantic, and the magnitude of the perturbations rises above the level of forecast uncertainty.

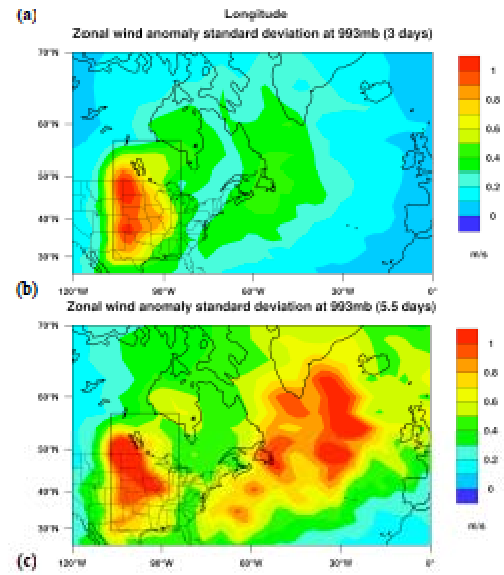

Fig. 3. Growth and propagation of anomalies. **(a)** A Hovmoller plot shows the standard deviation of anomalies versus forecast lead time and longitude, highlighting the growth rate and group velocity of perturbations. **(b)** The standard deviation over all cases of the anomalous lower tropospheric zonal wind field one half day after the roughness change is depicted. This plot is equivalent to a time slice of panel (a) at time day=3. The largest effects are confined to the wind farm. **(c)** Same as panel (b) except at time day=5.5. The largest effects are now located over the North Atlantic.

http://www.atmos-chem-phys.org/10/769/2010/acp-10-769-2010.pdf

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6. Production: Solar

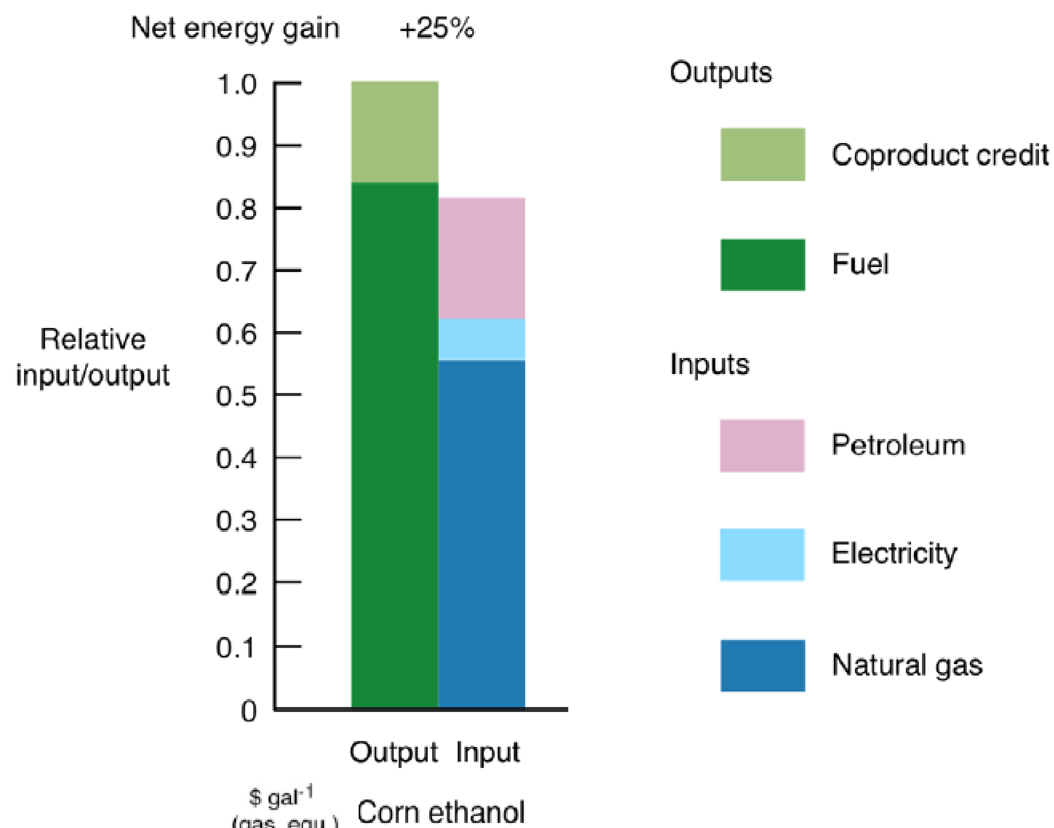
Obstacles to Energy Production from Solar Energy

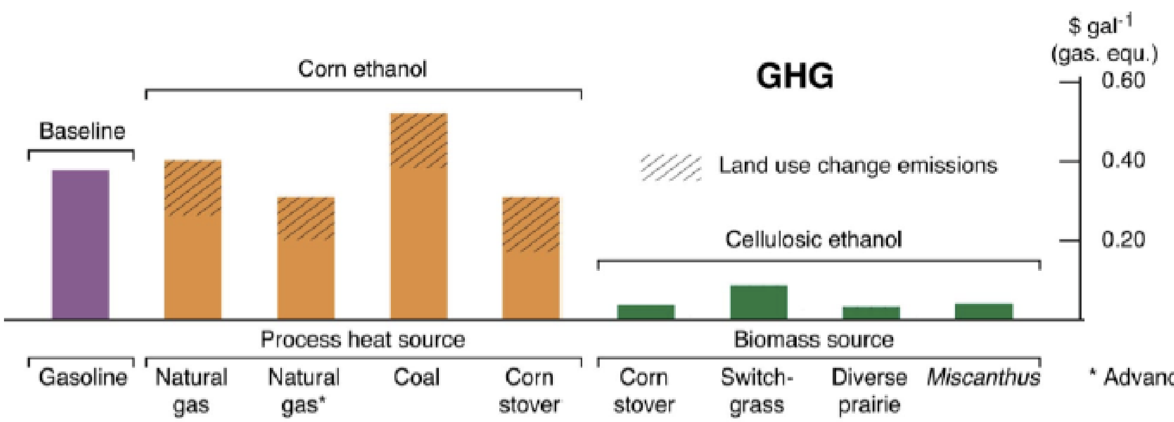
Does biomass generate net energy?

A little bit.

Does biomass lower CO_2 emissions?

Depends on what plant you use.





Slides from Dr. Jason Hill, University of MN, (2009).

6. Production: Solar

YONSEI UNIVERSITY

Obstacles to Energy Production from Solar Energy

Some people say:

When you use land that could be used to grow food to instead grow energy for those rich enough to pay for it, you are committing a crime against humanity!

BIOFUEL GENOCIDE

In summary, the world is facing a global food price crisis that threatens billions of people in the developing world with famine. Prices for major food commodities such as wheat, rice, corn and soybean have doubled in the last year or so. Global non-observance of basic human "entitlement" means that millions who cannot buy food will starve to death.


THE TIMES
THE SUNDAY TIMES

Archive Article Please enjoy this article from The Times & The Sunday Times

From The Sunday Times

June 10, 2007

Top scientist says biofuels are scam

Jonathan Leake and Steven Swinford

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http://sites.google.com/site/biofuelgenocide/

6. Production: Solar

Obstacles to Energy Production from Solar Energy

Photovoltaics are expensive!

Typical kWh usage by homes in three selected US average homes is shown below. For example, in a Sacramento, California home, it would cost around $16-$20,000 (depending on 8-10,000 above that you may change) to satisfy around 25% of that homes energy needs.

Detroit, Michigan (Edison)	7000 kWh/year	19 kWh/day
Sacramento, California (SMUD)	8485 kWh/year	23 kWh/day
Gainsville, Alabama	11,127 kWh/year	30 kWh/day

Guideline electricity generation costs today (cents/kWh)

Combined cycle gas turbine	3-5
Wind	4-7
Biomass gasification	7-9
Remote diesel generation	20-40
Solar PV central station	20-30
Solar PV distributed	20-50

http://www.solarbuzz.com/StatsCosts.htm

Commercial electricity ~ 9 cents/kWh (Knoxville, TN, November, 2010)