Advancing the Climate Agenda
SOME NUMBERS

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I think it is important, when discussing negotiations towards the goal of radical reductions in carbon emissions, to bear in mind the *scale* of what's required to achieve this goal. The climate problem is largely an energy problem. So we must imagine the energy systems of 2050. The only ultra-low-carbon energy *supplies* will be renewables, nuclear power, and coal with carbon capture and storage (as yet an unproven technology). On the *demand* side we will hopefully switch to more efficient technologies for energy consumption in transport, heating, electrical stuff, and so forth. And we mustn't forget the assumption that economic growth will continue; and growth tends to increase energy consumption. In this note I'd like to supply some numbers comparing **renewables** with current consumption, to convey the required scale for renewables to make a substantial contribution.

Figure 1.1. A 25 kW (peak) concentrator photovoltaic collector produced by Californian company Amonix. Its 225 m^2 aperture contains 5760 Fresnel lenses with optical concentration ×260, each of which illuminates a 25%-efficient silicon cell. One such collector, in an appropriate desert location, generates 138 kWh per day – enough to cover the energy consumption of half an American. Note the human providing a scale. Photo by David Faiman.

I like to talk about energy production and consumption *per person*, as I think this helps make the numbers more comprehensible. Today, the average European has a total energy consumption of 125 kWh per day. The average American consumes 250 kWh per day. Let's look at one of the most promising renewable power sources: concentrating solar power in deserts. Figure 1.1 shows a concentrator photovoltaic collector, roughly six storeys high. The average output of one such collector is 138 kWh per day – enough to cover the energy consumption of *half an American* today. Even if efficiency measures led to Americans' energy consumption being halved, we'd need roughly one of these collectors per person if solar power in deserts supplied all future energy.

Figure 1.2 shows another concentrating solar technology. Each of these dish concentrators has a similar size to the device in figure 1.1, and has a similar power output. Let's now discuss the land area requirements for renewables.

Figure 1.2. Stirling dish engine. These beautiful concentrators deliver a power per unit land area of 14 W/m^2. Photo courtesy of Stirling Energy Systems. `www.stirlingenergy.com`

People often say "a small square in the desert could supply all today's energy consumption." This is true, as long as we are clear about how "small" the square is. The beautiful concentrators in figure 1.2 deliver an average power per unit land area of 14 W/m^2. The prototype solar power stations in Spain deliver 5 W/m^2 (PS10, Solúcar) or 10 W/m^2 (Andasol). The compact linear fresnel reflector is claimed by Ausra to deliver 18 W/m^2.

Figure 1.3 shows two yellow squares, each 600 km by 600 km. The one overlapping Texas shows the area within North America that, completely filled with concentrating solar power, would provide everyone there (500 million people) with an average power of 250 kWh/d (today's average consumption). The one in Africa, completely filled with concentrating solar

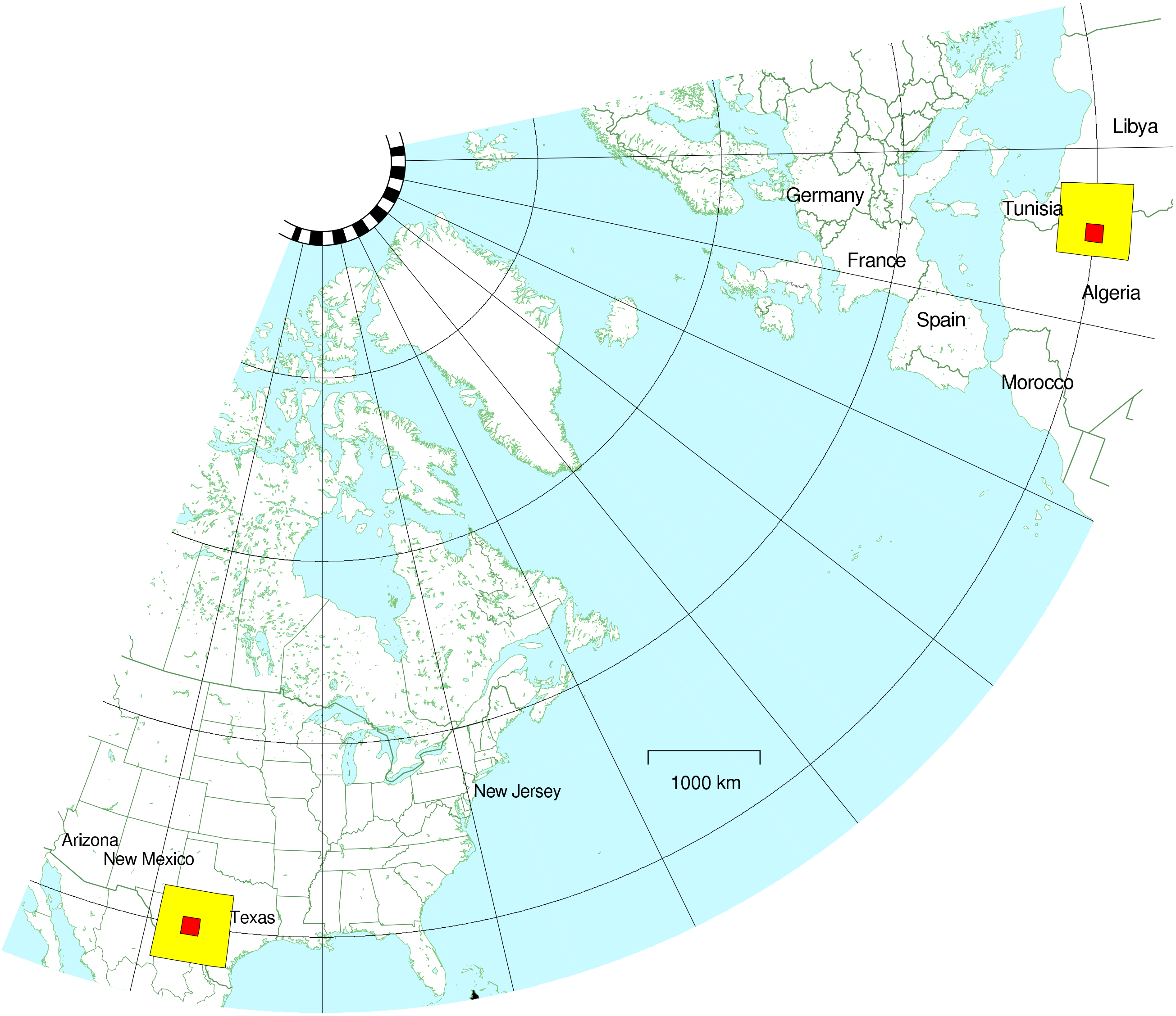

Figure 1.3. The little square in the desert. The 600 km by 600 km square in North America, completely filled with concentrating solar power, would provide enough power to give 500 million people the average American's consumption of 250 kWh/d.

This map also shows the square of size 600 km by 600 km in Africa, which would supply 125 kWh/d to everyone in Europe and North Africa.

I've assumed a power density of 15 W/m^2.

The area of one yellow square is a little bigger than the area of Arizona, and 16 times the area of New Jersey. Within each big square is a smaller 145 km by 145 km square showing the area required in the desert – one New Jersey – to supply 30 million people with 250 kWh per day per person.

power, would provide enough power to give 1 billion people the average European's consumption of 125 kWh/d.

Notice that while each yellow square may look "little" compared with Africa, it does have the same area as Germany.

"Ah, but we would use a *diversity* of renewables, not just solar!", you might say. Well, diversity doesn't reduce the scale of renewable facilities required. (In fact, using diverse sources probably *increases* the land area required, since the other renewables have lower power per unit area than solar power.)

Table 1.4 shows the power per unit area offered by other renewable sources in northwest Europe.

The message of this table is that *all renewables are diffuse*.

I am not anti-renewables. I'm not saying "renewables are pathetic." Far from it. (The numbers for nuclear and "clean coal" are also quite disturbing!) Nor am I denying the importance of efficiency measures (though I think achieving, say, a halving in energy consumption is going to be very difficult.) What I'm saying is that the developed lifestyle requires a lot of energy per person. It is not going to be easy to get off fossil fuels. But it is possible.

These numbers, and many more, are available, along with sources, in my free book *Sustainable Energy – without the hot air*, available online from `www.withouthotair.com`. The book comes out on paper on December 1st 2008.

POWER PER UNIT LAND OR WATER AREA	
Wind	2 W/m^2
Offshore wind	3 W/m^2
Tidal pools	3 W/m^2
Tidal stream	6 W/m^2
Solar PV panels	5–20 W/m^2
Plants	0.5 W/m^2
Rain-water (highlands)	0.24 W/m^2
Hydroelectric facility	11 W/m^2
Solar chimney	0.1 W/m^2
Concentrating solar power (desert)	**15** W/m^2

Table 1.4. Renewables are diffuse. The top part of the table shows the power per unit area for renewables in the UK, and the bottom two lines show the power per unit area for renewables in deserts.

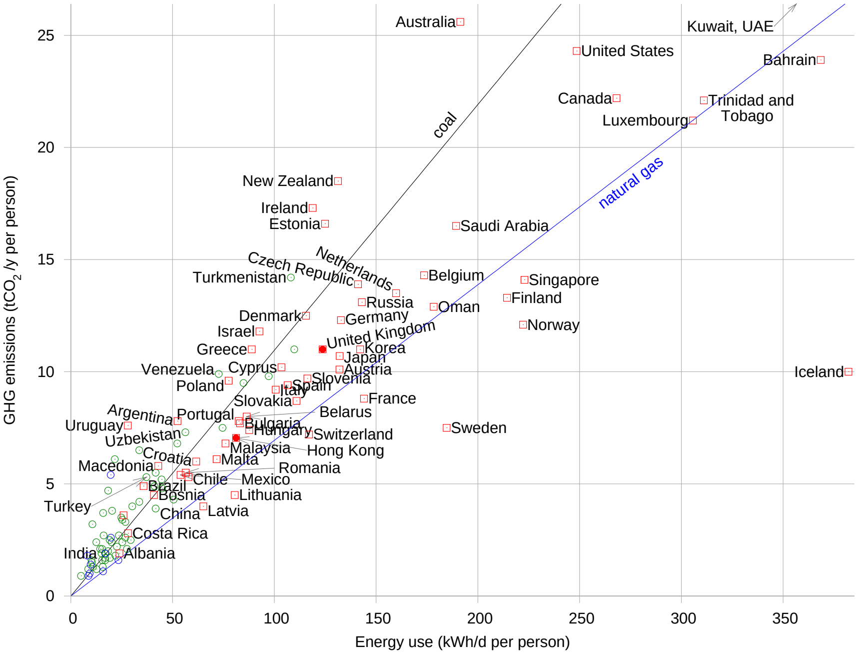

Figure 1.5. Greenhouse-gas emissions per capita, versus power consumption per capita. The lines show the emission-intensities of coal and natural gas. Squares show countries having "high human development;" circles, "medium" or "low." See also figures **??** (p**??**) and **??** (p**??**). Source: UNDP Human Development Report, 2007.