Renewable Electricity Production in USA within the Broader Scope of U.S. Potential Reduction of Greenhouse Gases Emissions in the XXIst Century

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Analysis of the U.S. renewable electricity production up to 2013 shows that if there is a recent and fast increase from onshore wind and Solar PV power, the overall contribution from all renewables technologies (including conventional hydropower) in the short term and up to 2020 would be insufficient to ensure a sensible decrease of CO2 emissions and an increase in performance indicators of the US electricity production sector. As shown from a comparison with the performance indicators of the electricity production sector in the European Union (EU) from 1990 to 2011, there are obviously many opportunities to increase the relevant U.S. indicators near the level of the EU ones. And combining a fast increase of all renewables electricity production with an increase of "negaWatts" production from demand side management, electricity conservation and more efficient uses of electricity is a simple, efficient and affordable solution that should be at the core of new policies and measures to fight climate change that are to be defined by all countries in spring 2015 in order to be officially presented, discussed and adopted within the process of the UNFCCC COP21 conference in Paris in December 2015.

Table 1 summarizes the evolution of electricity production in USA from provisional data from U.S. EIA released in February 2014 [1]. There was a slight increase of 0.3 % from 2012 to 2013, but with 4,058 TWh, the total 2013 production was lower than in 2011 (4,101 TWh). At 1,586 TWh (39.1 % of the 2013 total), the major 2013 contribution was from coal (+ 72 TWh and + 4.8 % from 2012 to 2013). At 253.3 TWh (6.2 % of the total), non-hydro renewables contribution increased by 35 TWh: +16 % year to year, resulting from + 19.1 % from wind (167.66 TWh, 4.1 % of total) and +113.8 % from solar (PV + Solar Thermal power, 9.25 TWh, 0.23 % of total). Including conventional hydropower (269.1 TWh in 2013, 6.6 % of total, a decrease by 2.6 % compared to 2012 and less than the 319.4 TWh in 2011), all renewables contribution was 522.5 TWh (12.9 % of the total electricity production, + 5.6 % compared to 2012).

Electricity in USA. Data: EIA	2013		*Change 2013/2012*		2012		*Change 2012/2011*		2011	
BCCONSULT 3/2014	TWh	%	*TWh*	*%*	TWh	%	*TWh*	*%*	TWh	%
Coal	1 586,0	39,1%	*71,957*	*4,8%*	1 514,0	37,4%	*-219,387*	*-12,7%*	1 733,4	42,3%
Gas	1 125,9	27,7%	*-111,856*	*-9,0%*	1 237,8	30,6%	*212,537*	*20,7%*	1 025,3	25,0%
Oil	26,9	0,7%	*3,673*	*15,8%*	23,2	0,6%	*-6,992*	*-23,2%*	30,2	0,7%
Nuclear	789,0	19,4%	*19,686*	*2,6%*	769,3	19,0%	*-20,873*	*-2,6%*	790,2	19,3%
Hydropower	269,1	6,6%	*-7,104*	*-2,6%*	276,2	6,8%	*-43,115*	*-13,5%*	319,4	7,8%
Wind	167,665	4,1%	*26,843*	*19,1%*	140,822	3,5%	*20,645*	*17,2%*	120,177	2,9%
Biomass	59,894	1,5%	*2,272*	*3,9%*	57,622	1,4%	*0,951*	*1,7%*	56,671	1,4%
Geothermal	16,517	0,41%	*0,955*	*6,1%*	15,562	0,38%	*0,246*	*1,6%*	15,316	0,37%
Solar	9,252	0,23%	*4,925*	*113,8%*	4,327	0,11%	*2,509*	*138,0%*	1,818	0,04%
Other/ Storage	7,931	0,2%	*-0,905*	*-10,2%*	8,836	0,2%	*0,588*	*7,1%*	8,248	0,2%
Total	**4 058**	100%	***10,45***	***0,3%***	**4 048**	100%	***-52,89***	***-1,3%***	**4 101**	100%
Total RE with hydro	522,5	12,9%	*27,891*	*5,6%*	494,6	12,2%	*-18,764*	*-3,7%*	513,3	12,5%
Total Non-Hydro RE	253,3	6,2%	*34,995*	*16,0%*	218,3	5,4%	*24,351*	*12,6%*	194,0	4,7%

Table 1

Figure 1 shows the share of each production technologies in 2013. Fossil fuel based production was 67.1 % (39.1 % from coal, compared to 27.7 % from natural gas and 0.7 % from oil). With 789 TWh, nuclear energy contributed to 19.4 %, a small increase of 2.6 % compared to 2012, but around the same level than in 2011 (790.2 TWh)

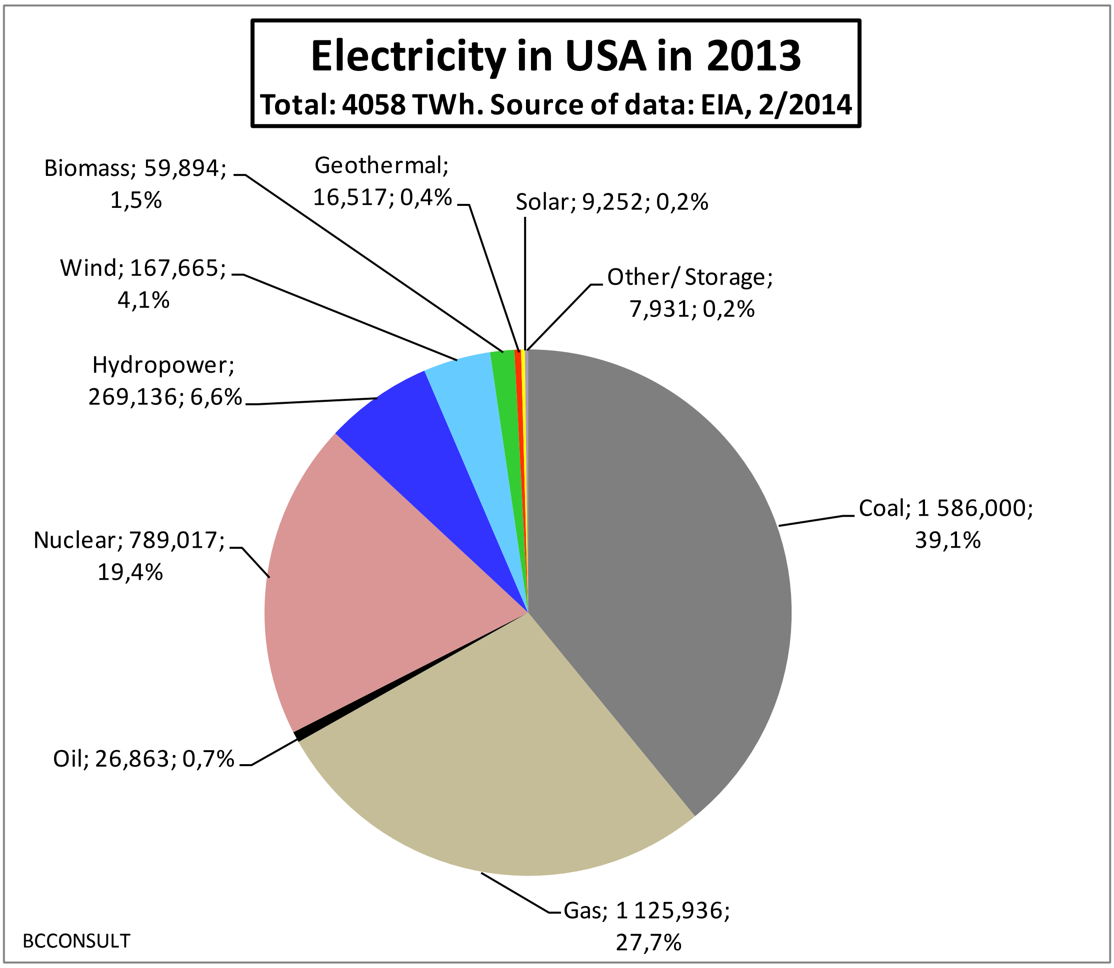

Figure 1: Share of U.S. 2013 electricity production

Table 2 and figure 2 details US electricity production on the 2002-2013 period, also from the EIA data [1]. Production from fossil fuels remained quite the same in 2002 and 2013 at a high level of around 2,740 TWh/year, resulting from annual average growth rates (AGR) of + 4.4 %/year for natural gas, -1.8 % for coal and -10.8 % for oil.

Nuclear production growth rate was only 0.1 % per year, and 0.2 % per year for conventional hydropower.

The higher growth rate was for non-hydro renewables at 11.2 % per year (**from 79.1 TWh in 2002 to 253,3 TWh in 2013**, a multiplication by a factor of 3.2 in 12 years. Within renewables, the higher AGRs were for solar (29.1 % per year, from 0.56 TWh in 2002 to 9.25 TWh in 2013 and for wind power (28.8 % per year, from 10.35 TWh in 2002 to 167.67 TWh in 2013).

TWh - Data from EIA	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**AGR (%/y)**
Coal	1933,3	1973,7	1978,3	2012,9	1990,5	2016,5	1985,8	1755,9	1847,3	1733,4	1514,0	1586,0	-1,8%
Gas	702,5	665,5	725,4	774,4	830,6	910,0	894,7	931,6	999,0	1025,3	1237,8	1125,9	4,4%
Oil	94,6	119,4	121,1	122,2	64,2	65,7	46,2	38,9	37,1	30,2	23,2	26,9	-10,8%
Total Fossils fuels	***2730***	***2759***	***2825***	***2910***	***2885***	***2992***	***2927***	***2726***	***2883***	***2789***	***2775***	***2739***	***0,028%***
Nuclear	780,06	763,73	788,53	781,99	787,22	806,43	806,21	798,86	806,97	790,20	769,33	789,02	0,1%
Hydropower	264,33	275,81	268,42	270,32	289,25	247,51	254,83	273,45	260,20	319,36	276,24	269,14	0,2%
Wind	10,35	11,19	14,14	17,81	26,59	34,45	55,36	73,90	94,65	120,18	140,82	167,67	**28,8%**
Biomass	53,71	53,34	53,54	54,28	54,86	55,54	55,03	54,49	56,09	56,67	57,62	59,89	**1,0%**
Geothermal	14,49	14,42	14,81	14,69	14,57	14,64	14,84	15,00	15,20	15,30	15,56	16,52	**1,2%**
Solar	0,56	0,53	0,58	0,55	0,51	0,61	0,86	0,89	1,21	1,82	4,33	9,25	**29,1%**
Other/ Storage	4,78	5,51	5,74	6,26	6,42	5,33	5,52	7,30	7,38	8,26	8,84	7,93	**4,7%**
Total	**3858**	**3883**	**3971**	**4055**	**4065**	**4157**	**4119**	**3950**	**4125**	**4101**	**4048**	**4058**	0,5%
Total RE with hydro	343,4	355,3	351,5	357,7	385,8	352,7	380,9	417,7	427,4	513,3	494,6	522,5	**3,9%**
Total Non-Hydro RE	79,1	79,5	83,1	87,3	96,5	105,2	126,1	144,3	167,2	194,0	218,3	253,3	**11,2%**

Table 2: 2002-2013 U.S. electricity production (TWh/year).

Table 2 and figure 2 show also that since 2002 the total US electricity production increased slightly up to 2007, recovered its pre-crisis level in 2010, but is now almost stable. As the US GDP is increasing, this is a signal that a decoupling of GDP and electricity production and consumption is also possible at the federal level, as it was already demonstrated in the past in California. The total contribution from fossil fuels in 2013 is quite the same than in 2002.

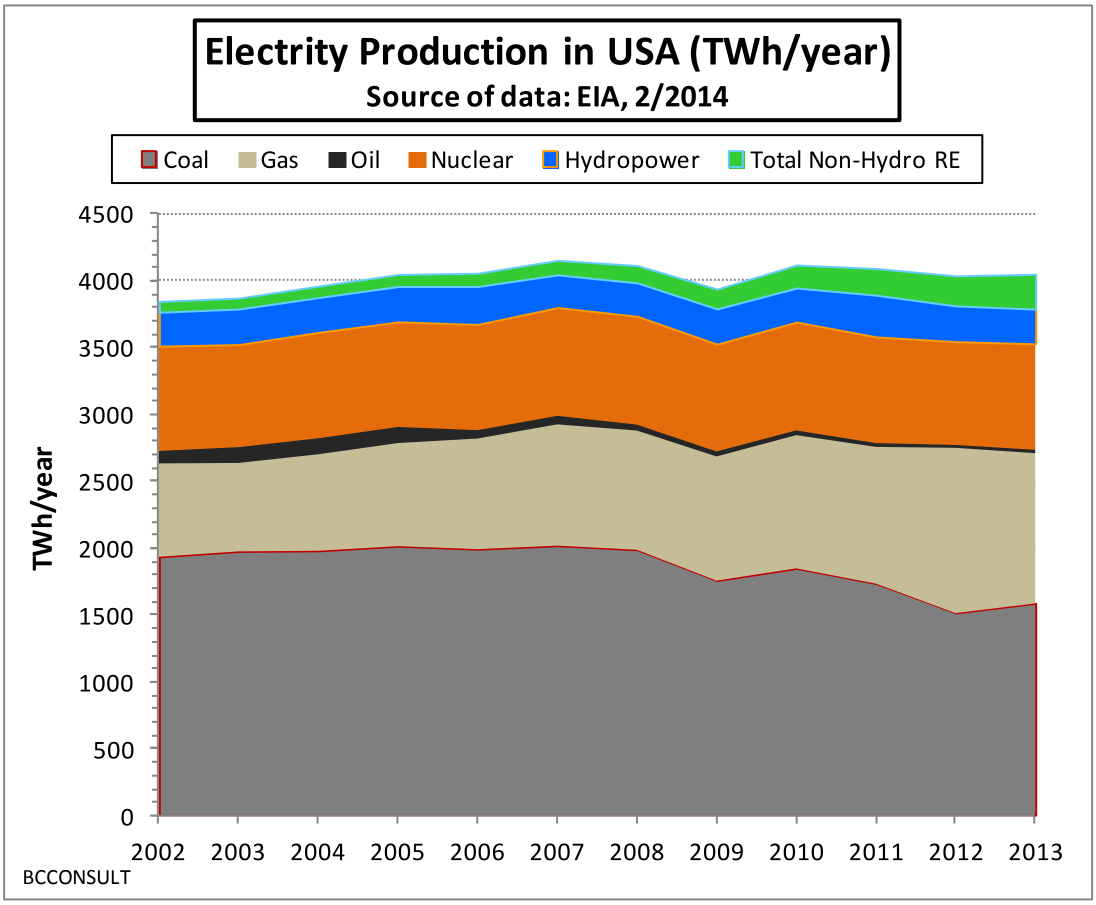

Figure 2: 2002-2013 electricity production in USA.

Table 3 and figure 3 show the stability of the relative contribution of fossil fuels-based electricity production, the slight decrease of relative shares of nuclear and conventional hydropower, and here again the fast relative development of non-hydro renewables.

USA - Data from EIA	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Coal	50,1%	50,8%	49,8%	49,6%	49,0%	48,5%	48,2%	44,4%	44,8%	42,3%	37,4%	39,1%
Gas	18,2%	17,1%	18,3%	19,1%	20,4%	21,9%	21,7%	23,6%	24,2%	25,0%	30,6%	27,7%
Oil	2,5%	3,1%	3,1%	3,0%	1,6%	1,6%	1,1%	1,0%	0,9%	0,7%	0,6%	0,7%
Total Fossils fuels	***70,8%***	***71,0%***	***71,1%***	***71,7%***	***71,0%***	***72,0%***	***71,0%***	***69,0%***	***69,9%***	***68,0%***	***68,6%***	***67,5%***
Nuclear	20,2%	19,7%	19,9%	19,3%	19,4%	19,4%	19,6%	20,2%	19,6%	19,3%	19,0%	19,4%
Hydropower	6,9%	7,1%	6,8%	6,7%	7,1%	6,0%	6,2%	6,9%	6,3%	7,8%	6,8%	6,6%
Wind	0,3%	0,3%	0,4%	0,4%	0,7%	0,8%	1,3%	1,9%	2,3%	2,9%	3,5%	4,1%
Biomass	1,4%	1,4%	1,3%	1,3%	1,3%	1,3%	1,3%	1,4%	1,4%	1,4%	1,4%	1,5%
Geothermal	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%	0,4%
Solar	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,1%	0,2%
Other/ Storage	0,1%	0,1%	0,1%	0,2%	0,2%	0,1%	0,1%	0,2%	0,2%	0,2%	0,2%	0,2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Total RE with hydro	8,9%	9,1%	8,9%	8,8%	9,5%	8,5%	9,2%	10,6%	10,4%	12,5%	12,2%	12,9%
Total Non-Hydro RE	2,1%	2,0%	2,1%	2,2%	2,4%	2,5%	3,1%	3,7%	4,1%	4,7%	5,4%	6,2%

Table 3: 2002-2013 shares of U.S. electricity production.

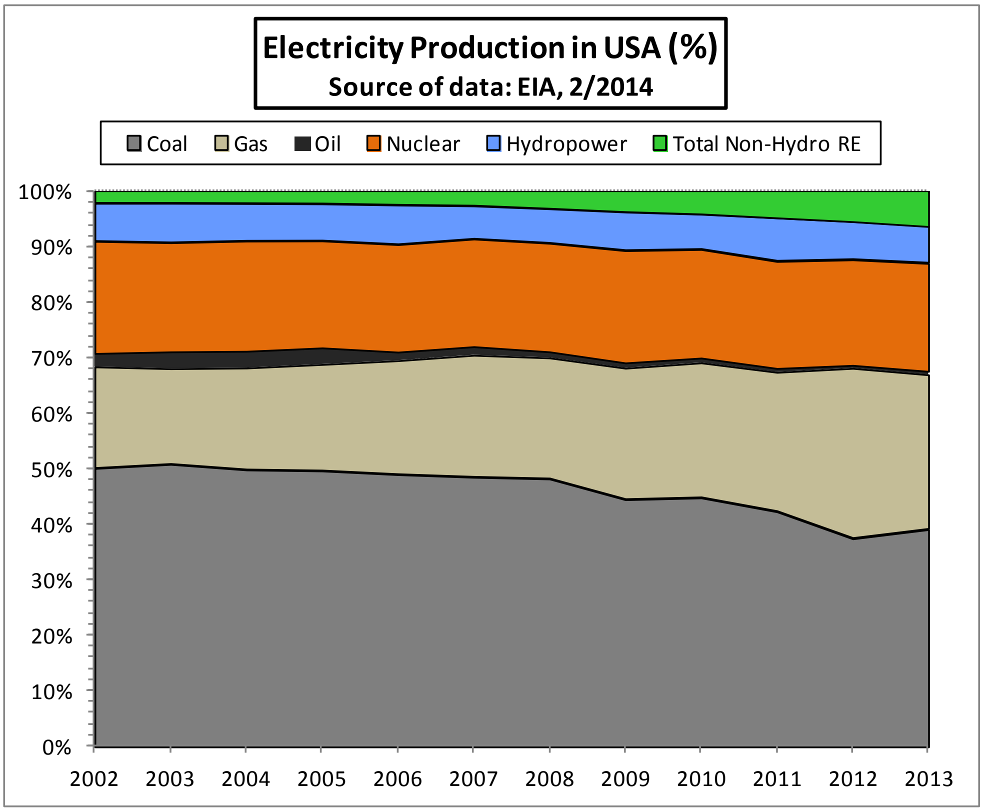

Figure 3: 2002-2013 U.S. shares of electricity production.

Figure 4 details the 2002-2013 development of conventional hydropower and other renewables. Only the wind power absolute contribution was sufficiently growing during this period, as solar production started to be noticeable only in the second decade of the century and as the growth of electricity from biomass and geothermal was small during the period.

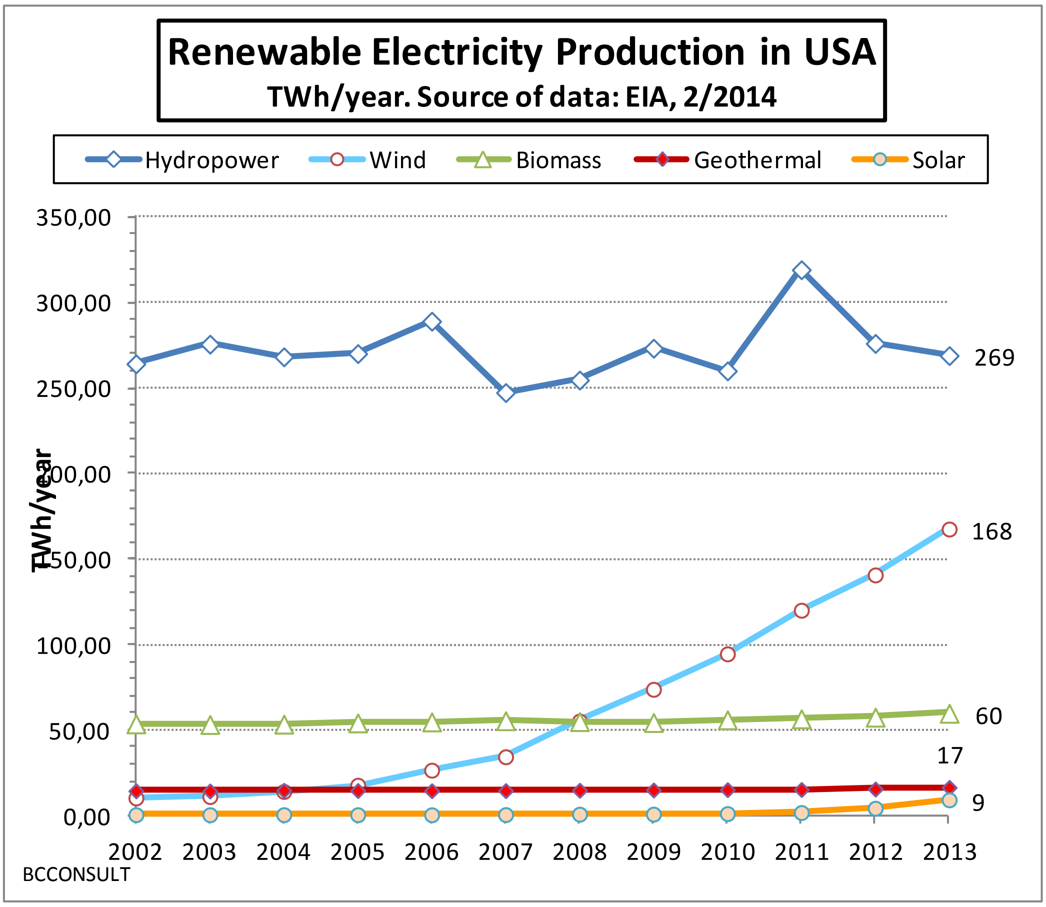

Figure 4: 2002-2013 U.S. renewable electricity production.

Figure 5 and figure 6 show the absolute and relative annual cumulated production from conventional hydropower and other renewables. It is obviously mainly the growth of wind power production that ensured the total growth on 2002-2013.

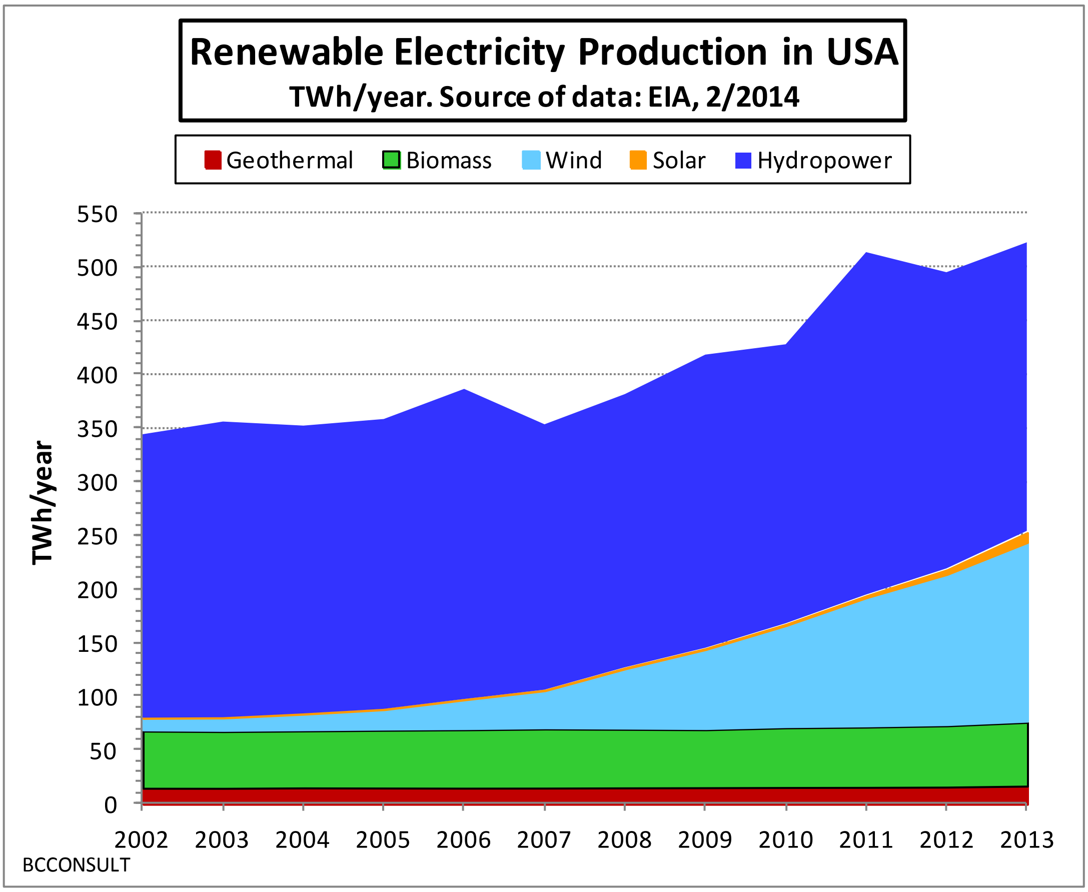

Figure 5: Annual cumulative production from hydropower and other renewables on 2002-2013.

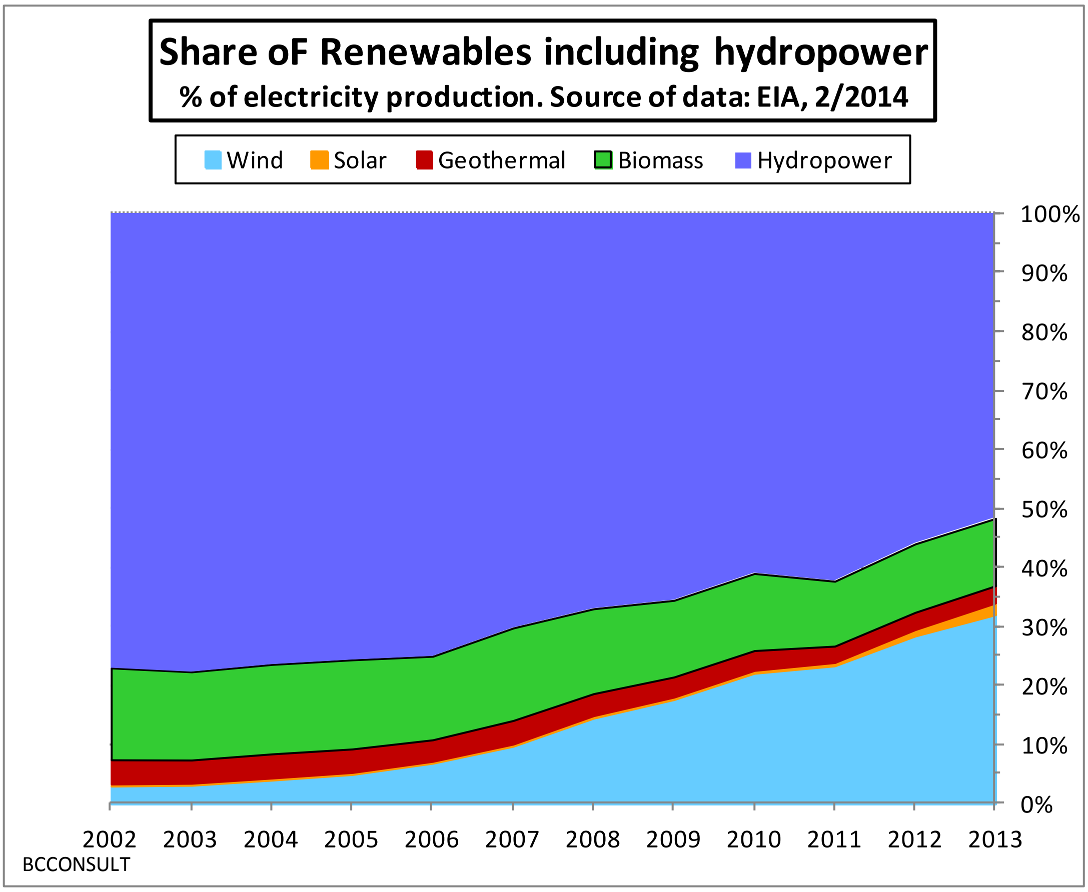

Fig 6: shares of hydropower and other renewables on 2002-2013.

Figure 7 shows that if at the turn of the century non hydropower renewables production was 68 % from biomass (compared to 18 % from geothermal energy, 13 % from wind power and less than 1 % from solar), in 2013 the biomass share decreased to 24 % compared to an increase at the end of 2013 to 66 % share for wind and to 3.7 % for solar.

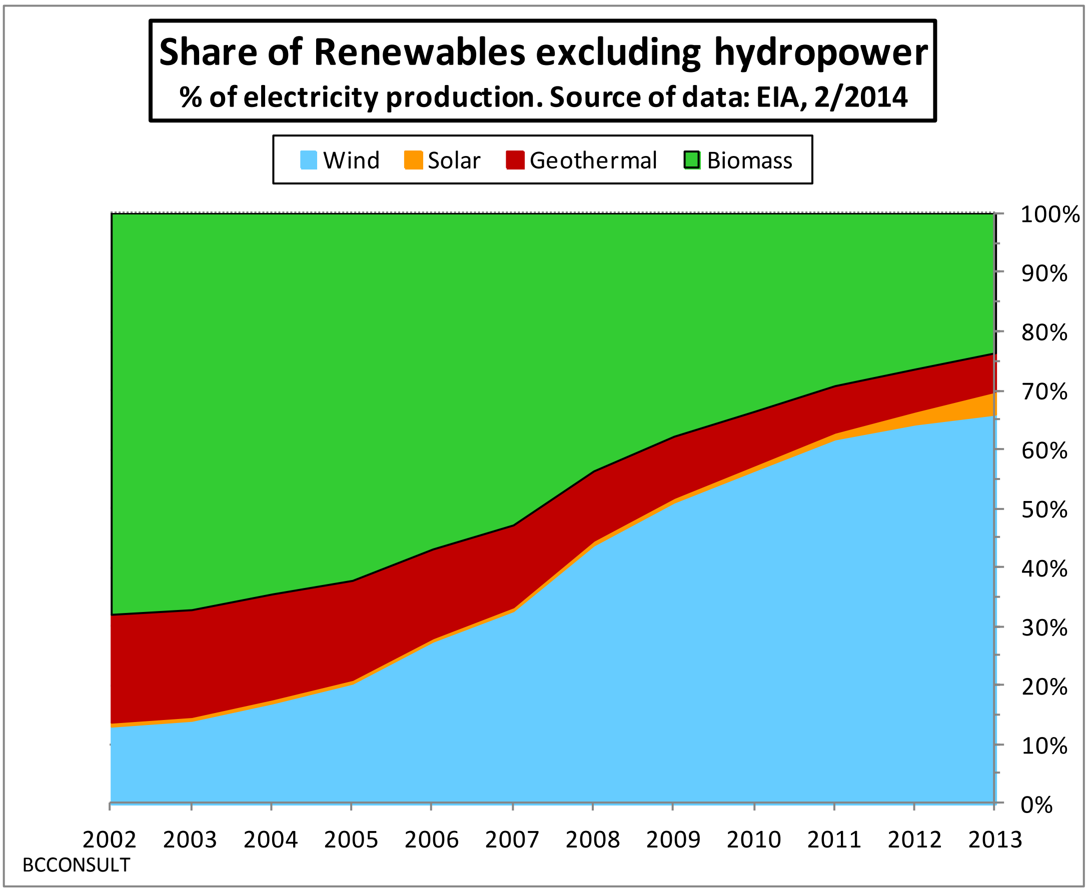

Fig 7: shares of annual 2002-2013 U.S. non-hydropower renewables.

Some conclusions can be drawn at this stage from this analysis:

- U.S. electricity production remains based by more than 2/3[rd] on the use of fossil fuels, and from around 40 % from coal.
- One century of conventional hydropower production development resulted in only 6.6 % of present electricity production and its future growth will be limited by availability of potential available sites to develop.
- Half a century development of nuclear energy resulted in a recent share of electricity production of only around 20 %, and this share will be difficult to maintain as ageing reactors are more and more difficult to operate with sufficient profitability, and refurbishing them or building new nuclear reactors is more costly than anticipated and compared to other options, including non hydro renewables such as onshore wind power and now also solar PV.
- The development of established renewables such as electricity from biomass and geothermal energy will continue, but at an insufficient pace to sufficiently decrease the share of fossil fuels-based production.
- So, obviously, the main “degree of freedom” to increase the electricity production from renewables and zero carbon emissions technologies is to increase the share of onshore wind and solar power (mainly from PV) due to the large availability of good quality sites and due to the continuing decreasing cost of energy delivered by those two renewable technologies.
- But this fast increase of wind and solar PV shares of electricity production will require new policies and measures (such as fair and efficient feed-in tariffs at States and/or at federal level) and will take time to be effective.
- And so, within new policies and measures to be included in the national plan against global warming to be presented at the COP 21 conference in Paris in December 2015 for the post-2020 period, it is necessary to add to this absolute increase of renewables electricity specific potential contribution and impacts of the “negaWatts” production, by more decoupling electricity demand from GDP growth from demand side management, electricity

conservation and more efficient uses of electricity. Related principles and solutions for that were already known and detailed at the beginning of the period under analysis; see for example reference [5] for the electricity sector.

The following comparison on the 1990-2011 period between the U.S. and the European Union (EU, 27 countries in 2011) will show that there are obviously numerous and large opportunities to ensure this decoupling without hurting neither the U.S. economy nor the quality of services provided to electricity users and at the end the quality of life of electricity consumers. This analysis is based on the "Kaya identity" approach applied to the electricity sector, which is described in reference [2] and [3], and on data from reference [4], covering the period up to 2011.

Figure 8 shows the U.S. and the EU population (left, 312 million in USA and 503 million in the EU in 2011) and their GDP at power purchase parity and expressed in constant 2005 US$ (meaning that in this analysis, GDP at power purchase parity for USA is the same that U.S. GDP expressed in constant 2005 US $). The difference in GDP is lower than the difference in population, so the difference in GDP per capita should be very different in the two areas.

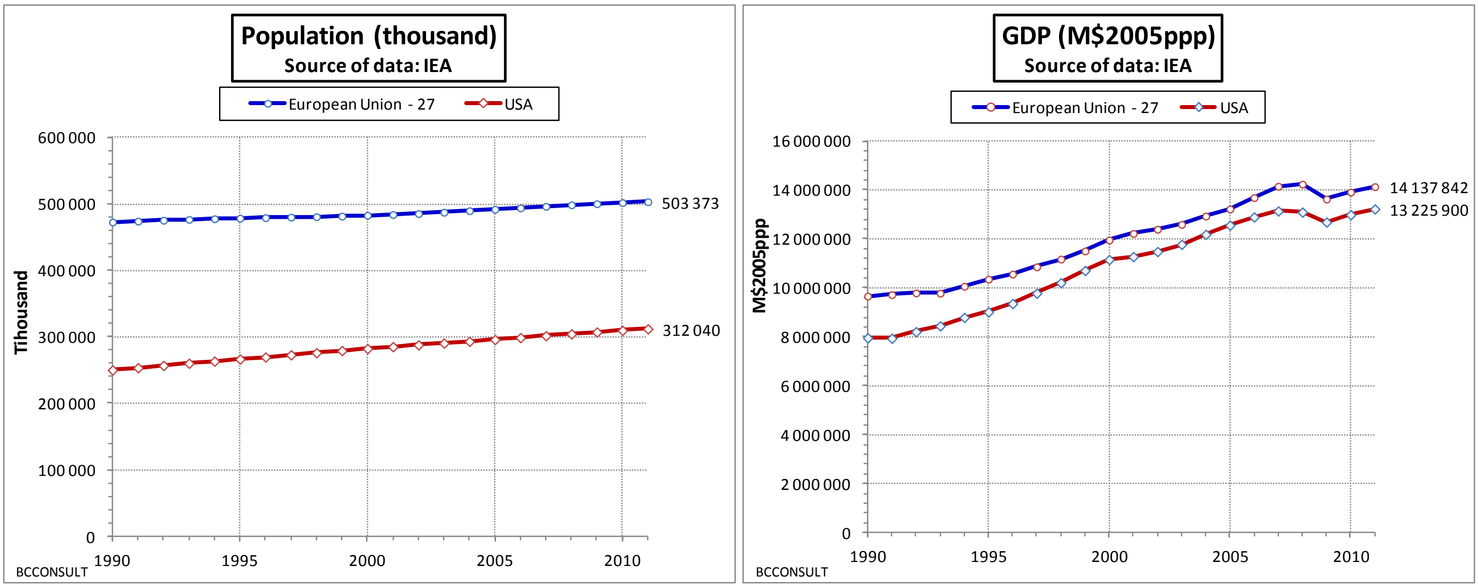

Figure 8: Population and GDPppp in U.S. and the EU

This difference in GDPppp per capita is shown in figure 9 (left: 53 % higher in USA in 2011 than in the EU), and on the right of the figure is the difference in electricity production per capita: 2.16 times more in U.S. than in the EU!

It is interesting to note than in the two areas, electricity production per capita is around the same in 2011 than in 2000.

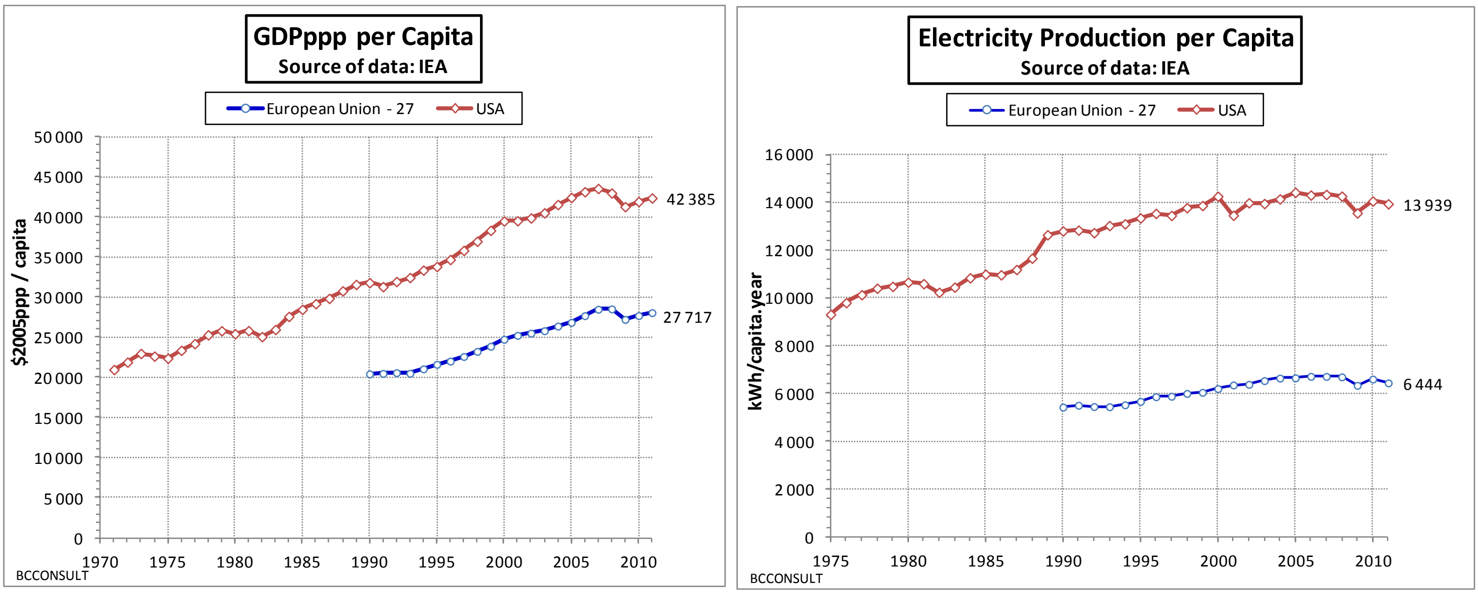

Figure 9: GDPppp and electricity production per capita in U.S and UE.

Figure 10 shows on the left the differences in electricity production in GWh/year (34 % more in USA in 2011 than in EU) and on the right the electricity intensity of GDP indicator in kWh/\$2005ppp of GDP (44 % higher in U.S. in 2011 than in the EU). Both in U.S. and in the EU, long term and recent decrease rates of this indicator are too low.

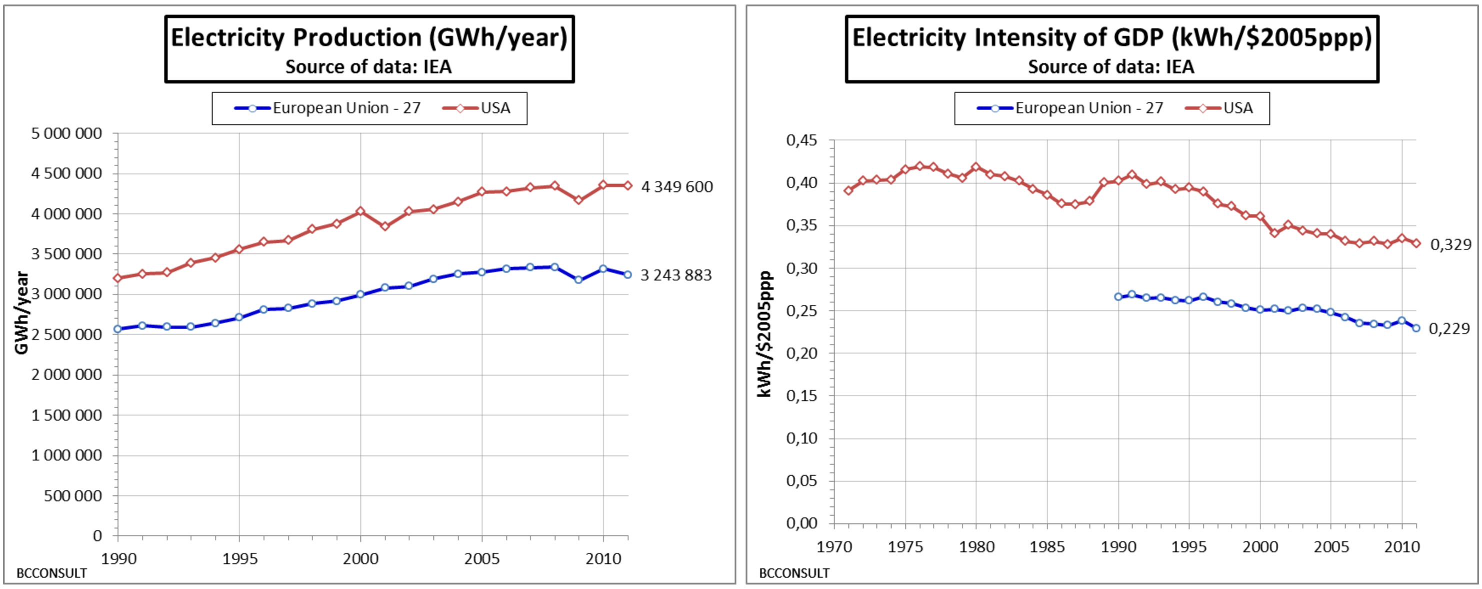

Figure 10: Electricity production (left) and the ratio of electricity intensity of GDP in U.S. and the EU.

The indicator of the carbon content of the electricity production is shown in the left of figure 11: it was 35 % higher in U.S. than in the EU in 2011. But in the two cases its decrease from 1990 to 2011 was not fast enough.

At the end, resulting from the product between this last indicator and the electricity intensity of GDP in figure 10 (right), the ratio of carbon intensity of GDP resulting from only electricity production is on the right of figure 11: in 2011 it was 92 % higher in U.S. than in the EU: creating a \$ of GDPppp requires 0.167 kWh of electricity in U.S. compared to only 0.087 kWh in the EU.

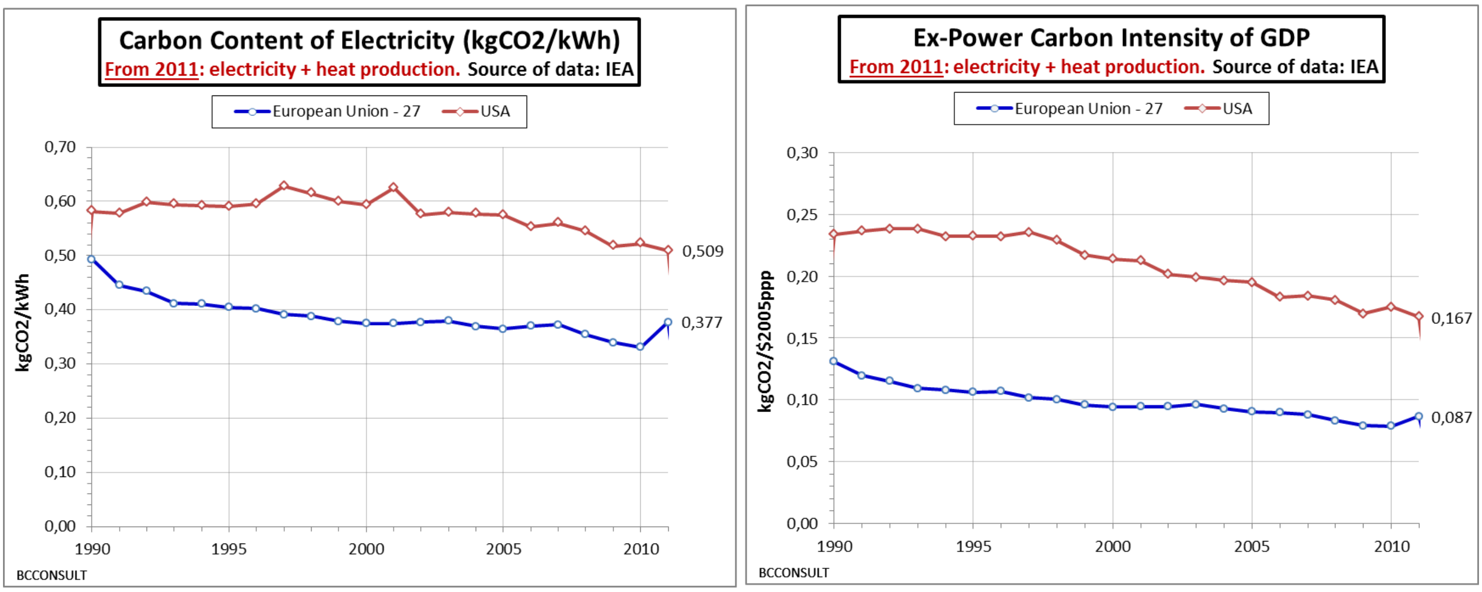

Figure 11: Carbon content of electricity (left) and intensity of GDP in Carbon from electricity production only (right).

Figure 12 shows on the left the total CO2 emissions from electricity production (81 % more in U.S. than in the EU in 2011) and on the right the CO2 emissions per capita from electricity production only: 2,431 kg/capita and per year in the EU compared to 7,089 kg per capita in 2011 in USA (2.92 times more!).

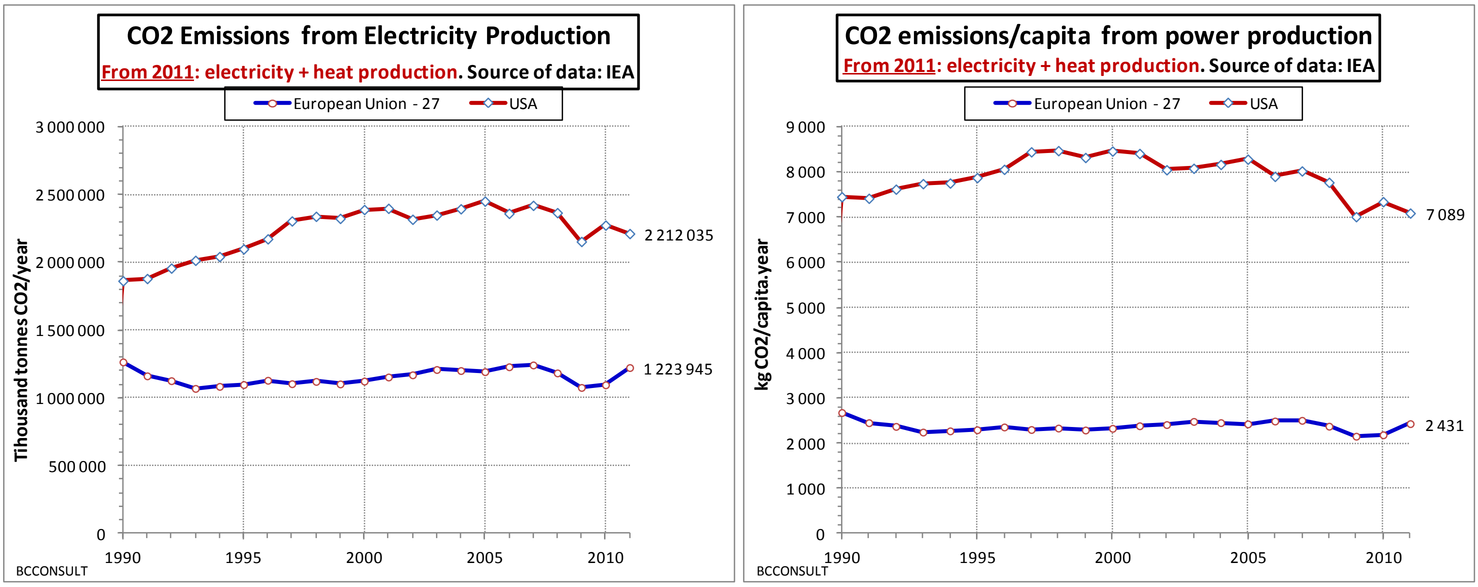

Figure 12: CO2 emissions from electricity, in absolute values (left) and per capita (right).

This analysis shows clearly that there are many opportunities to increase the performance of the U.S. electricity sector. Large and profitable opportunities are available from increasing the efficiency of the use of its production from demand side management, electricity conservation and from more efficient uses of electricity in all economic sectors. And then, major and affordable opportunities are available to the first world economy to decrease the carbon content of its electricity production: beginning in the very short term from an increasing share from all renewables and particularly from onshore wind and solar PV, and from replacing as soon as possible electricity production from coal by production in high efficiency combined cycle power plants using on short term natural gas, then more and more biogas and ultimately (but at a lower annual yield due to the large increase of direct RE electricity production), a larger share of methane produced from renewable energy sources.

This synergy between "negaWatts" and renewables for power production would create a more electricity efficient US economy and would be a strong, efficient and easy to implement solution for the fast and effective absolute decrease of the related greenhouse gases emissions in the electricity sector that is required for a U.S. and a world sustainable future.

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