GERMAN NUCLEAR DECOMMISSIONING AND RENEWABLES BUILD-OUT, by Willem Post, November 3, 2011

On 30 May 2011, the German government decided to close all nuclear reactors by 2022. The Bundestag passed the measures by 513 to 79 votes at the end of June, and the Bundesrat vote on 8 July confirmed this. Both houses of parliament approved construction of new coal and gas-fired plants and expand wind energy. CO2 emission reduction targets remained unchanged.
http://world-nuclear.org/info/inf43.html

Germany will be redirecting its economy towards renewable energy, because of the political decision to decommission its nuclear plants, triggered by the Fukushima event in Japan and subsequent public opposition to nuclear energy.

Germany has 23 nuclear reactors (21.4 GW), 8 are permanently shut down (8.2 GW) and 15 (13.2 GW) will be shut down by 2022.

Germany's 2010 generation mix was: 23% nuclear, 23% lignite, 18% hard coal, 14% natural gas, 16.8% renewables, 5.2% heating oil, pumped hydro, others. The renewables were: 6.2% wind, 4.7% biomass, 3.2% hydro, 2% solar, 0.8% waste.
http://www.germanenergyblog.de/?p=5436

Renewable energy would need to scale up from 16.8% (101.7 TWh) in 2010, to 57% (344 TWh) of total energy generation of 603 TWh in 2020 to achieve the CO2 emissions reduction targets (see next section) AND replace nuclear energy, according to a study by The Breakthrough Institute.
http://thebreakthrough.org/blog//2011/06/analysis_germanys_plan_to_phas-print.html

Increased energy efficiency measures would be required to ensure the 2020 energy production would be 603 TWh, the same as in 2010.

Germany's 2020 generation mix would be: 43% lignite, hard coal and gas, 57% renewables. The renewables would be: 34% wind (27% offshore, 7% onshore), 11% solar, 7% biomass, 3.9% hydro, 1.1 % other.

A high percentage of offshore wind energy is proposed in this study. It would have greater owning+O&M costs than onshore wind, but it would minimize visual and environmental impacts and costly delays due to public opposition; people dislike looking at, and be disturbed by the noise of, a multitude of 450-ft tall wind turbines and thousands of 80 to 135 ft high steel structures and wires of the transmission systems.
http://theenergycollective.com/willem-post/51642/dutch-renewables-about-face-towards-nuclear

GERMAN RENEWABLE ENERGY AND ENERGY EFFICIENCY TARGETS

In September 2010 the German government announced the following targets:

Renewable electricity: 35% by 2020, 50% by 2030, 65% by 2040 and 80% by 2050
Renewable energy: 18% by 2020, 30% by 2030, and 60% by 2050
Energy efficiency: Reducing the national electricity consumption 50% below 2008 levels by 2050
http://en.wikipedia.org/wiki/Renewable_energy_in_Germany

Germany has a target to reduce its nationwide CO2 emissions from all sources by 40% below 1990 levels by 2020, 55% by 2030, and 80% by 2050. That goal could be achieved, if 100% of electricity is generated by renewables, according to Mr. Flasbarth. Germany is aiming to convince the rest of Europe to follow its lead.

Germany's CO2 emissions were (in mmt): 1,230 in 1990 (Kyoto base year), 979 in 2006, 957 in 2007, 848 in 2008 and 788.8 in 2009, 826.5 in 2010.

The large CO2 emissions decreases in 2008 and 2009 are mainly due to decreased goods production in heavy industry and the increase in 2010 was due to renewed economic growth. It appears economic conditions had a significantly greater impact on CO2 emissions than any growth in wind, solar and biomass energy in 2008, 2009 and 2010.

http://www.reuters.com/article/2010/01/07/us-germany-emissions-interview-idUSTRE60625620100107
http://www.reuters.com/article/2011/03/22/us-germany-carbon-emissions-idUSTRE72L4XH20110322

A 2009 study by EUtech, engineering consultants, concluded Germany will not achieve its nationwide CO2 emissions target; the actual reduction will be less than 30%. The head of Germany's Federal Environment Agency (UBA), Jochen Flasbarth, is calling for the government to improve CO2 reduction programs to achieve targets.

http://www.spiegel.de/international/germany/0,1518,644677,00.html
http://e360.yale.edu/feature/germanys_unlikely_champion_of_a_radical_green_energy_path/2401/

SUMMARY OF ESTIMATED CAPITAL AND OTHER COSTS

The estimated capital costs and other costs for decommissioning the nuclear plants, restoring the sites, adding plants to replace nuclear plants, building out renewables to replace nuclear energy, adding wind and solar energy balancing plants, and reorganizing electric grids over 9 years **AND** satisfy above CO2 emission targets, are summarized below.

Increased energy efficiency: $20 b/yr($3,286 b in 2010) x 100% = 0.6% of GDP, or $250 pp/yr
Decommission 23 nuclear reactors and restore sites: 23 @ $1 billion/reactor = $23 billion
Plants to replace nuclear plants: 25,000 MW of CCGTs @ $1,250,000/MW = $31.3 billion
Wind turbines, offshore: (53,300 - 150, existing) MW @ $4,000,000/MW = $212.6 billion
Wind turbines, onshore: (27,900 - 27,204, existing) MW @ $2,000,000/MW = $1.4 billion
Solar systems: (82,000 - 17,320, existing) MW @ $4,500,000/MW = $291 billion
EEG feed-in tariff costs added to electric rates over 9 years $450.3 billion, less $142 billion revenue from sale of EEG energy (0.79% of total renewable energy): $308.3 billion
Balancing plants: 25,000 MW of OCGTs and CCGTs @ $1,250,000/MW = $31.3 billion
Reorganizing the German grid and neighbor grids: $100 billion
Biomass (incl. biogenic waste): 1,400 MW @ $3,000,000/MW = $4.2 billion

The below URL shows a capital cost estimate of 335 milliard euros, or $469 billion, which is similar to the above estimate.
http://www.welt.de/dieweltbewegen/article13506987/Energiewende-kostet-335-Milliarden-Euro.html

IMPACT OF NUCLEAR DECOMMISSIONING ON THE GERMAN ECONOMY

The existing power generation system is based on 60% fossil, 23% nuclear and 16.8% renewables. Exchanging the existing system with one based on 43% fossil and 57% renewables implies an owning+O&M cost of about 2 -3 times the current system because:

- the renewables energy production units are more capital intensive PER UNIT OF PRODUCTION than existing energy production units.
- the useful service lives of wind turbines is about 20 years and of solar panels about 25 years versus 40 to 60 years for existing energy production units.
- the reorganized grid serving the widely-distributed energy sources, fitted with demand and supply management, will have greater owning+O&M costs than the existing grid.
- almost ALL of the existing generators, plus about 25,000 of NEW CCGTs to replace the nuclear plants, will need to be staffed 24/7/365 and kept in proper operating condition to provide energy during periods of low renewables energy production. See next section.
- As renewables energy increases to about 57% of all energy production by 2020, the increased cost of energy will bear heavily on industry and commerce, thereby reducing their competitiveness in world markets, and job creation capacity in Germany.

The economic impact of the transition will increase the costs of German goods and services which will

- adversely affect its competitive position in world markets.
- lower the living standards of households, accelerating the current trend.
- affect, on a relative basis, Germany faring better than its neighbors, if these neighbors cannot be persuaded to follow Germany's lead.
- divert capital from economic development, such as energy efficiency, that provides returns on investments without subsidies.

Diverting scarce resources from unsubsidized, profitable ventures to subsidized build-outs of wind and solar energy that have high owning+O&M costs and rolling those costs into rate schedules and the prices of goods and services is a sure way to make Germany less competitive relative to the rest of Europe and East Asia, lower living standards and increase unemployment.

Wind and Solar Energy Variability and Intermittency: German wind energy output peaked at about 12,000 MW on July 24 2011, four days later the peak was 315 MW. Because utilities must take renewable energy BEFORE all other energy, temporary oversupply occurs, spot prices become negative, and production of existing coal and gas plants is lowered causing them to be less profitable. However, no conventional plants can be decommissioned, because:

- about 10 -15% of the time, there is insufficient wind speed (less than 7.5 mph) over large areas of Europe to turn the rotors of the wind turbines, meaning no or little wind energy is produced.
- during cloudy days and when snow covers the panels as little as 2% of rated capacity, or 340 MW, of solar energy is produced, and at night no solar energy is produced.

That means, absent economically-viable energy storage, almost ALL of the existing generators, plus about 25,000 of NEW CCGTs to replace the nuclear plants, will need to be staffed 24/7/365 and kept in proper operating condition to provide energy during periods of low renewables energy production; the plants will have low capacity factors and may need to be subsidized because they may not have enough revenues from energy sales to cover costs.

As these periods are mostly unpredictable, a significant percentage of the existing generators will be need to be in spinning mode 24/7/365 to immediately supply energy in case of steep-ramping wind energy ebbs. The NEW conventional generators will likely be gas-fired CCGTs, thus CONTINUING Germany's dependence on Russian gas. Russia will likely insist on a minimum gas purchase per year under a long term contract to recover its investment in the pipeline. Increased imports of nuclear energy from France and the Czech Republic may be required.

Utilities will be loathe to build these new CCGT plants without significant subsidies, as these plants would have low capacity factors. This new CCGT capacity might be lessened somewhat by more efficiently operating the existing plants nearer their rated outputs.

THE EEG PROGRAM

Germany's Renewable Energy Act (EEG) of 2000 guarantees investors above-market fees for renewable power for 20 years from the point of installation. An EEG surcharge is used to finance the difference between the feed-in tariffs paid to plant operators for renewable energy and the revenue generated from sales of the energy fed into the grid at the energy exchange.

In 2010, German investment in renewables was about 29.4 billion euros, of which about 25.8 billion euros in 7,400 MW of solar systems (3,485 euro/kW).

In 2010, about 79%, or about 80.7 TWh of renewable energy was covered by the EEG program at an average cost of 15.85 eurocent/kWh. The cost has been steadily rising from 10.87 eurocent/kWh in 2006 due to the rapid solar build-out.

EEG payments were: solar 5.1 billion euros for 11.7 TWh, biomass 4.2 billion for 25.1 TWh, wind 3.3 billion for 37.5 TWh, hydro 0.3 billion for 5 TWh, and other 0.1 billion for 1.2 TWh, for a total of 12.8 billion euros. The totals were 5.6, 7.6, 8.8 and 10.5 billion euros from 2006 to 2010.

In 2011, the EEG apportionment was 3.53 eurocents/kWh, or 14% of the consumer price, excl. VAT, 4.2 eurocents/kWh, incl. VAT, or 16% of the consumer price of 26.3 eurocent/kWh. The EEG apportionments were 0.8, 1.0, 1.1, 1.3, and 2.05 eurocent/kWh, excl. VAT, from 2006 to 2010. The 2011 apportionment reflects the energy production of the systems installed prior to 2011.

EEG Apportionments and Renewables Build-out: As the decommissioning of the nuclear plants proceeds, about 53,300 MW of NEW offshore and 696 MW of new onshore wind capacity (about 2 times existing, build rate about 6,000 MW/yr), 64,680 MW of NEW solar capacity (almost 4 times existing, build rate about 7,000 MW/yr) and 1,400 MW of NEW biomass capacity (about 0.3 times existing, build rate about 150 MW/yr) will need to installed during the next 9 years.

Renewables investments, subsidies, and EEG apportionments will increase, even though the feed-in tariffs for later solar installations are less/kWh than for earlier installations.

Total EEG Subsidy: The subsidy was calculated using the following assumptions and conditions;

- The annual production remains at 603 TWh in 2010 through 2020 due to increased energy efficiency.
- The renewables energy is 16.8% of production in 2010, or 101.8 TWh, and 57% , or 344 TWh.
- The build-out starts the beginning of 2012 and ends the end of 2020 for calculation purposes.
- The EEG percentage remains at 79% of renewables production.
- The EEG subsidy remains constant at 15.85 eurocent/kWh from 2012 to 2020; a conservative value because it should be rising due to the more expensive offshore build-out being added to the renewables mix. Future feed-in tariffs will likely not be reduced, because it would reduce capital inflows and slow down the renewables build-outs, which is undesirable if nuclear plants are to be decommissioned.
- The EEG apportionment increases at a constant 1.25 eurocent/kWh each year from 2013 to 2021; a conservative value.

Based on the above assumptions and conditions, the EEG subsidy will rise from 12.8 bn euros in 2010 to 43.1 bn euros in 2021, for a total of 321.67 bn euros for the 2012 - 2021 period. The revenue from selling the EEG energy is 101.45 bn euros. The net cost is 220.23 bn euros, or $308.3 billion. The 2021 apportionment reflects the energy production of the systems installed prior to 2021.

Impact on Household Electric Bills: The EEG apportionments will increase monthly electricity bills of households from 26.3 eurocents/kWh, incl. VAT in 2011, to 39.7 in 2021, a total increase of (39.7 - 26.3)/26.3 = 51% by 2021 compared with 2011. This increase is largely due to the solar and offshore wind build-outs. *This is a real increase based on 2011 euros.*

The EEG apportionments will be borne by all households, including those without solar systems. They act as a steadily-increasing regressive tax that will affect lower income more than higher income households, many of which receive feed-in tariff benefits from having solar systems.

http://thebreakthrough.org/blog//2011/06/analysis_germanys_plan_to_phas-print.html
http://mobile.bloomberg.com/news/2011-05-31/merkel-faces-achilles-heel-in-grids-to-unplug-german-nuclear.html
http://www.theecologist.org/News/news_analysis/829664/revealed_how_your_country_compares_on_renewable_investment.html
http://en.wikipedia.org/wiki/Solar_power_in_Germany
http://www.diw.de/sixcms/media.php/73/diw_wr_2011-06.pdf
http://www.econstor.eu/bitstream/10419/19388/1/358.pdf
http://www.bmu.de/files/english/pdf/application/pdf/ee_in_zahlen_2010_en_bf.pdf
http://www.polderpv.nl/EEG_impact_BRD.htm
http://www.polderpv.nl/PV_weltmeister_2010_II.htm
http://www.welt.de/dieweltbewegen/article13506987/Energiewende-kostet-335-Milliarden-Euro.html

GERMANY WILL NOT BE MAKING A GLOBAL WARMING DIFFERENCE

The Energy Information Administration, EIA, is projecting the world's energy consumption to increase by 53 percent, from 505 quadrillion Btu in 2008 to 770 quadrillion Btu in 2035. See the figure 12 spreadsheet of the report. Worldwide, the renewables fraction of total consumption will increase from 10.6% in 2010 to 15.2% in 2035, the fossil fraction from 84.1% to 79.1%
http://www.eia.gov/forecasts/ieo/world.cfm

World CO2 emissions were 29, 30.6 and 33 billion metric tonnes in 2008, 2009 and 2010, respectively, projected at 33 x 1.5 = 49.5

bmt in 2035.
China, the US, Europe and Germany emitted 7.7, 5.4, 4.3 and 0.79 bmt in 2009, respectively.
China, the US, Europe and Germany projected emissions are 11.7, 6.4, 4.4 and 0.55* bmt in 2030, respectively.

*Germany's CO2 emissions target for 2030 is 55% below 1990, or (1 - 0.45) x 1.230 = 0.55 bmt.

Conclusion: Germany's (irrational?) exuberance towards renewables will make no global warming and/or climate change difference.

http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions
http://theenergycollective.com/robertrapier/66900/why-debate-over-global-warming-academic
http://rainforests.mongabay.com/09-carbon_emissions.htm
http://www.guardian.co.uk/news/datablog/2011/jan/31/world-carbon-dioxide-emissions-country-data-co2
http://www.thinkglobalgreen.org/CARBONDIOXIDE.html

GERMAN ENERGY SYSTEM PLANS

Germany has made the following near-term plans to augment and upgrade its energy system:

Coal: 11 GW of new coal plants, 6 GW of old coal plants to be decommissioned, for a net gain of 5 GW of coal plants.

Wind and Solar Energy Balancing Plants: 5 GW of new, gas-fired OCGT and CCGT plants. The plants will reduce the shortage of quick-ramping generation capacity for accommodating variable wind and solar energy to the grid.

Biomass: 1.4 GW of new biomass (incl. biogenic waste) plants.

Transmission: Augment and upgrade transmission systems for:

- onshore and offshore wind energy in northern Germany.
- importing hydro and nuclear energy from France to avoid any shortages.
- exporting excess solar energy from southern Germany to France.

The total estimated capital cost of $53.75 billion for implementing the above measures is detailed below.

Coal plants: 11,000 MW @ $2,500,000/MW = $27.5 Billion
Retire 6,000 MW of old coal plants @ $300,000/MW = $1.8 billion
OCGT and CCGT plants: 5,000 MW @ $1,250,000/MW = $6.25 billion
Biomass plants: 1,400 MW @ $ $3,000,000/MW = $4.2 billion
Transmission systems: $14 Billion

Germany has fallen behind on transmission system construction in northern Germany because of public opposition and is using the nuclear decommissioning as leverage against public opposition; people dislike looking at, and be disturbed by the noise of, a multitude of 450-ft tall wind turbines and thousands of 80 to 135 ft high steel structures and wires of the transmission systems.

The $14 billion for transmission systems is just a minor down payment on the major grid reorganization required due to nuclear decommissioning and the widely-dispersed build-outs of renewables. The existing grid is mostly large-central-plant based.

GERMAN RENEWABLE ENERGY TO-DATE

Germany announced it had 16.8% of its electrical energy from renewables in 2010; it was 6.3% in 2000. The installed renewables capacity was 55.7 GW, producing 101.7 TWh of electricity, for an all-tech average capacity factor of 20.8%. The contribution to total production was 6.2% wind, 5.5% biomass (incl. biogenic waste), 3.2% hydro and 2.0% solar. Electricity production was 603 TWh in 2010.

http://www.volker-quaschning.de/datserv/ren-Strom-D/index_e.php
http://www.bmu.de/files/english/pdf/application/pdf/ee_in_zahlen_2010_en_bf.pdf

Wind: At the end of 2010, 27,204 MW of onshore and offshore wind turbines was installed in Germany at a capital cost of about $50 billion. Wind energy produced was 36.5 TWh, or 6.2% of total production.

Most wind turbines are in northern Germany. When wind speeds are higher wind curtailment of 15 to 20 percent takes place because of insufficient transmission capacity and quick-ramping gas turbine plants. The onshore wind costs the Germany economy about 9.1 eurocent/kWh and the offshore wind about 15 eurocent/kWh. The owners of the wind turbines are compensated for lost production.

The alternative to curtailment is to "sell" the energy at European spot prices averaging about 5 eurocent/kWh to Norway and Sweden which have significant hydro capacity for balancing the variable wind energy; Denmark has been doing it for about 20 years.

As Germany is very marginal for onshore wind energy (nationwide onshore wind CF 0.167) and nearly all of the best onshore wind sites have been used up, or are off-limits due to noise/visual/environmental impacts, most of the additional wind energy will have to come from OFFSHORE facilities which produce wind energy at about 2 to 3 times the cost of onshore wind energy.

http://theenergycollective.com/willem-post/61774/wind-energy-expensive

Biomass (incl. biogenic waste): At the end of 2010, about 4,910 MW of biomass was installed at a capital cost of about $18 billion. Biomass (incl. biogenic waste) energy produced was 33.5 TWh, or 5.5% of production. Plans are to add 1,400 MW of Biomass (incl. biogenic waste) plants in future years which would produce about 9 TWh/yr.

Hydro: At the end of 2010, about 4,780 MW of hydro was installed. Hydro energy produced was 19.5 TWh, or 3.2% of production. Hydro growth has been stagnant during the past 20 years. See below website.

As it took about $150 billion of direct investment, plus about $130 billion excess energy cost during the past 11 years to achieve 8.2% of total production from solar and wind energy, and assuming hydro will continue to have little growth, as was the case during the past 20 years (almost all hydro sites have been used up), then nearly all of the renewables growth by 2020 will be mostly from wind, with the remainder from solar and biomass (incl. biogenic waste).
http://www.renewableenergyworld.com/rea/news/article/2011/03/new-record-for-german-renewable-energy-in-2010??cmpid=WNL-Wednesday-March30-2011

Solar: At the end of 2010, about 17,320 MW of PV solar was installed in Germany at a capital cost of about $100 billion. PV solar energy produced was 12 TWh, or 2% of total production.

Most solar panels are in southern Germany (nationwide solar CF 0.095). When skies are clear, the solar production peaks at about 7 to 10 GW. Because of insufficient capacity of transmission and quick-ramping gas turbine plants, and because curtailment is not possible, part of the solar energy, produced at a cost to the German economy of about 30 to 50 eurocent/kWh is "sold" at European spot prices averaging about 5 eurocent/kWh to France which has significant hydro capacity for balancing the variable solar energy.
http://theenergycollective.com/willem-post/46142/impact-pv-solar-feed-tariffs-germany

Wind and Solar Energy Depend on Gas: Wind and solar energy is variable and intermittent. This requires quick-ramping gas turbine plants to operate at part-load and quickly ramp up with wind energy ebbs and quickly ramp down with wind energy surges; this happens about 100 to 200 times a day resulting in increased wear and tear. Such operation is very inefficient for gas turbines causing them to use extra fuel/kWh and emit extra CO2/kWh that mostly offset the claimed fuel and CO2 reductions due to wind energy.
http://theenergycollective.com/willem-post/64492/wind-energy-reduces-co2-emissions-few-percent

Wind energy is often sold to the public as making a nation energy independent, but Germany will be buying gas mostly from Russia supplied via Nord Stream, the newly constructed pipeline under the Baltic Sea that connects Vyborg, a Russian port, with Lubin, a coastal northeast German village.

GERMANY WITHOUT NUCLEAR ENERGY

A study performed by The Breakthrough Institute concluded to achieve the 40% CO2 emissions reduction target and the decommissioning of 21,400 MW of nuclear power plants by 2022, Germany's electrical energy mix would have to change from 60% fossil, 23% nuclear and 16.8% renewables in 2010 to 43% fossil and 57% renewables by 2020. This will require a build-out of renewables, reorganization of Europe's electric grids (Europe's concurrence will be needed) and acceleration of energy efficiency measures.

According to The Breakthrough Institute, Germany would have to reduce its total electricity consumption by about 22% of current 2020 projections AND achieve its target for 35% electricity generated from renewables by 2020. This would require increased energy efficiency measures to effect an average annual decrease of the electricity consumption/GDP ratio of 3.92% per year, significantly greater than the 1.47% per year decrease assumed by the IEA's BAU forecasts which is based on projected German GDP growth and current German efficiency policies.

The Breakthrough Institute projections are based on electricity consumption of 544 and 532 TWh in 2008 and 2020, respectively; the corresponding production is 604 TWh in 2008 and 592 TWh in 2020.

The capacities and capital costs of the 2020 renewables build-outs will be based on the following conditions and assumptions:

- Hydro energy and biomass energy are 11% of renewables.
- The current wind energy to solar energy ratio is maintained at 3 to 1
- Wind energy and solar energy are 57 - 11 = 46% of renewables, of which solar energy 11.5% (2% in 2010), wind energy 34.5% (6.2% in 2010)
- Wind energy is 80% offshore and 20%. These percentages minimize the onshore build-out of wind energy to avoid delays due to public opposition.
- Total energy production is 592 TWh.
- The current levels of feed-in tariff subsidies are maintained. Higher levels may be required to attract sufficient capital.

http://thebreakthrough.org/blog//2011/06/analysis_germanys_plan_to_phas-print.html
http://www.iea.org/textbase/nppdf/free/2007/germany2007.pdf

Build-out of Wind Energy: The estimated capacity of the offshore wind turbines will be [{0.57 (all renewables) - 0.11 (assumed biomass + hydro)} x 3/4 x 592 TWh] x 0.80 offshore/(8,760 hr/yr x average CF 0.35) = 0.0533 TW.

The estimated capacity and the capital cost of the onshore wind turbines will be [{0.57 (all renewables) - 0.11 (assumed biomass + hydro)} x 3/4 x 592 TWh] x 0.20 onshore/(8,760 hr/yr x average CF 0.167) = 0.279 TW.

Capital cost offshore = (53,300 MW - 150 MW, existing) @ $4 trillion/TW = $212.6 billion.
Capital cost onshore = (27,900 MW - 27,204 MW, existing) @ $2 trillion/TW = $1.4 billion.

Caveat: Recent studies of the grids of Colorado, Texas, Ireland and the Netherlands, based on measured, real-time, 1/4-hour grid operations data sets of the Irish, Colorado and Texas grids, show wind energy does little to reduce CO2 emissions. Such data sets became available during the past 2 to 3 years. Prior studies, based on assumptions, estimates, modeling scenarios, and statistics, etc., significantly overstate CO2 reductions.
http://theenergycollective.com/willem-post/64492/wind-energy-reduces-co2-emissions-few-percent

Build-out of PV Solar Energy: The estimated capacity and capital cost of the PV solar capacity will be [{0.57 (all renewables) - 0.11 (assumed biomass + hydro)} x 1/4 x 592 TWh]/(8,760 hr/yr x average CF 0.095) = 0.082 TW.

Capital cost = (82,000 - 17,320, existing) MW @ $4.5 trillion/TW = $291 billion. Solar capital costs/kW have declined due to mass production by China (has 65-70% of the world's panel market) in recent years, but this trend has ended which means current costs will be the ones going forward.

Reorganizing Electric Grids: For GW reasons, a self-balancing grid system is needed to minimize CO2 emissions from gas-fired CCGT balancing plants. One way to implement it is to enhance the interconnections within Germany and with its neighbors (owning+O&M costs, including transmission losses), and with European-wide selective curtailment of wind energy, and with European-wide demand management, and with additional impounded and pumped hydro storage capacity.

These measures will reduce, but not eliminate, the need for CCGT balancing energy at greater wind energy penetrations during high-windspeed weather conditions.
http://www.dena.de/fileadmin/user_upload/Download/Dokumente/Publikationen/ESD/Flyer_dena_Grid_Study_II_Englisch.pdf

European-wide agreement is needed, the capital cost will be in excess of $100 billion and the adverse impacts on quality of life (noise, visuals, psychological), property values and the environment will be significant over large areas.

Other Capital Costs: The capacity of the quick-ramping CCGT balancing plants was estimated at 25,000 MW; their capital cost is about 25,000 MW x $1,250,000/MW = $31.3 billion. The capital costs of decommissioning the 23 nuclear reactors and restoring the sites will be about $23 billion.

INCREASED ENERGY EFFICIENCY

Increased energy efficiency would be more attractive than major build-outs of renewables, because it provides the quickest and biggest "bang for the buck", AND it is invisible, AND it does not make noise, AND it has minimal environmental impact, AND it usually reduces at least 3 times the CO2 per invested dollar, AND it usually creates at least 3 times the jobs per invested dollar, AND it usually creates at least 3 times the energy reduction per invested dollar, AND it does all this without public resistance and controversy.

Sometimes people mention the rebound effect as a negative of energy efficiency, i.e., people going back to old habits of wasting energy. It is a concept fostered by proponents of renewables who see EE as a competitor and by proponents of conspicuous consumption who make money on such consumption.

People with little money love their cars getting 35-40 mpg, love getting small electric and heating bills. The rebound is mostly among people who do not care about such bills.

A MORE RATIONAL APPROACH

Global warming is a given for many decades, because the fast-growing large economies of the non-OECD nations will have energy consumption growth far outpacing the energy consumption growth of the slow-growing economies of the OECD nations, no matter what these OECD nations do regarding reducing CO2 emissions of their economies.

It is best to PREPARE for the inevitable additional GW by requiring people to move away from flood-prone areas (unless these areas are effectively protected, as in the Netherlands), requiring new houses and other buildings to be constructed to a standard such as the Passivhaus standard* (such buildings stay cool in summer and warm in winter and use 80 to 90 percent less energy than standard buildings), and requiring the use of new cars that get at least 50 mpg, and rearranging the world's societies for minimal energy consumption; making them walking/bicycling-friendly would be a good start.

If a nation, such as the US, does not do this, the owning+O&M costs of its economy will become so excessive (rising resource prices, increased damage and disruptions from weather events) that its goods and services will become less competitive and an increasing percentage of its population will not be able to afford a decent living standard in such a society.

For example: In the US, the median annual household income (inflation-adjusted) was $49,445, a decline of 7% since 2000. As the world's population increases to about 10 billion by 2050, a triage-style rationing of resources will become more prevalent.

http://www.usatoday.com/news/nation/story/2011-09-13/census-household-income/50383882/1

* A 2-year-old addition to my house is built to near-Passivhaus standards; its heating system consists of a thermostatically-controlled 1 kW electric heater, set at 500 W, that cycles on/off on cold days less than 300 hours/yr. The addition looks inside and out entirely like standard construction.
http://theenergycollective.com/willem-post/46652/reducing-energy-use-houses