If all countries would focus on renewables in the same way as the most successful countries in terms of renewable energy technologies growth rates, the results would be impressive.

Renewable energy technologies do have an impact on the environment, as do all energy technologies. However, the relative impacts of renewables are far less than those of fossil fuels and nuclear power. A major EU study concluded that when climate change and the possible impact of catastrophic accidents of nuclear plants are taken account of, renewables have a significantly lower environmental impact.

Thus, in conclusion it should be mentioned that renewable energy should no longer have the alternative tag – it is a mainstream set of energy options able to provide cost-effective and reliable low-carbon energy. After extensive R&D and commercialization over the past 20 years, wind power, biomass heating and power, solar heating and power and the other renewable energy options are important elements of the modern energy mix. Renewable energy has some different characteristics to fossil fuels and nuclear power. Some of the technologies offer more intermittent power, and are less concentrated than oil or uranium. Taken as a group however, and utilizing modern energy grids and networks, renewable can be integrated to provide predictable and reliable energy solutions.

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Environmental impact of the smart grid

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The Green Smart Grid Initiative.

Few issues are getting more attention within the energy industry and among policymakers these days than the smart grid and climate change. Yet most do not see these two areas as being connected. More precisely, the smart grid – and smart grid practices like demand response – is not being viewed as having a role in the attainment of climate change goals [4].

The Green Smart Grid Initiative (GSGI) is an effort to demonstrate that the smart grid indeed can be a major positive force in addressing climate change. Among the issues it seeks to help parties gain an understanding of are the following:

1. **Smart Grid and Renewable Energy;**
2. **Smart Grid and Energy Efficiency**

1. Energy Efficiency.

Major building block in plans to address climate change is energy efficiency. Most energy efficiency efforts are focused on replacement of devices and equipment with more efficient items, or focused on energy efficient design and labeling of products and buildings. The smart grid introduces and fosters new types of energy efficiency by allowing the operation of the electricity system to be dynamically optimized at all times. Also, and importantly, the smart grid does not stop at the customer's meter. It provides customers with new pricing and billing options and stimulated be more efficiency. The latter has been shown to spur customers to take actions to be more energy efficient overall in their electricity usage [4].

New figures from Bloomberg New Energy Finance show 7% growth in global smart grid investment in 2012. The company expects just over 10% compound annual growth for the next five years, nearly doubling the market to $25.2bn per annum by 2018.

London and New York, 24 January 2013 – Utilities worldwide spent $13.9 bn in 2012, up 7% on the previous year, on smart grid technologies such as advanced metering and fault management, according to figures released today by research company Bloomberg New Energy Finance.

Roughly half of the total – $7.1bn – was spent on smart metering and related infrastructure and services. The next biggest category was distribution automation, followed by integrated demonstration projects in areas such as demand response, home energy management and smart electric vehicle charging [3].

2. Renewable Energy.

Some engineers think that the increasing use of renewable energy is a key component of any strategy and plan for addressing climate change. What is less known is that many renewable energy options provide power on an intermittent and variable basis or do not deliver power at times of peak demand – when the demand for power is greatest and emissions can be higher than average. By using smart grid technologies, and smart grid practices like demand response, the electricity system can accept and manage the amount of renewable energy that policymakers and the renewable energy industry desire and expect to be developed [4].

The National Renewable Energy Laboratory's (NREL) Renewable Electricity Futures Study (RE Futures) is an initial investigation of the extent to which renewable energy supply can meet the electricity demands of the continental United States over the next several decades. This study explores the implications and challenges of very high renewable electricity generation levels –from 30% up to 90%, focusing on 80%, of all U.S. electricity generation –in 2050. At such high levels of renewable electricity generation, the unique characteristics of some renewable resources, specifically geographical distribution and variability and uncertainty in output, pose challenges to the operability of the nation's electric system.

Key Findings.

Renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the country.

Increased electric system flexibility, needed to enable electricity supply and demand balance with high levels of renewable generation, can come from a portfolio of supply- and demand-side options, including flexible conventional generation, grid storage, new transmission, more responsive loads, and changes in power system operations.

The abundance and diversity of U.S. renewable energy resources can support multiple combinations of renewable technologies that result in deep reductions in electric sector greenhouse gas emissions and water use.

The direct incremental cost associated with high renewable generation is comparable to published cost estimates of other clean energy scenarios. Improvement in the cost and performance of renewable technologies is the most impactful lever for reducing this incremental cost [2].

Emissions.

By increasing the use of renewable energy and energy efficiency, the smart grid will lead to a major decrease in the carbon emissions that are leading to global climate change. It will also increase other types of efficiency that lead to additional CO2 reductions. Below you will find some facts relating to the contribution that the smart grid can make to reducing carbon emissions. The Smart Grid can reduce emissions by 60 to 211 million metric tons of CO2 a year by 2030. Basis data you can see in the **Table 1**. The Smart Grid helps reduce emissions by managing electricity peak load. CO2 emissions on peak can be 230% higher than off peak [4].

Table 1. Basis for Direct Energy/Carbon Reduction Estimates

Direct Reduction Mechanism	Reduced Energy Consumption (2030)			
	Est	Low	High	Baseline Energy Consumption End Use Sectors
Conservation Effect of Demand Response Consumer Information	6	1	10	Residential
	6	1	10	Sm./Med. Commercial
Measurement and Verification for Efficiency Programs: Marginal Efficiency Measures Enabled by Acurate M&V	7	5	20	Residential (Heat Pump & AC)
	7	5	20	Sm./Med. Commercial (HVAC+ Lighting)
Smart Grid-Enabled Diagnostics in. Residential and Small/Medium Commercial. Buildings	15	10	20	Residential (Heat Pump & AC)
	20	10	30	Sm./Med. Commercial (HVAC+ Lighting)
Conservation Voltage Reduction and Advanced Volt/VAr Control	2	1	4	Total Electric Supply
Load Shifting from Demand Response	0.04	0.02	0.06	Total Electric Supply
Support Additional Electric Vehicles (EVs) /Plug-In Hybrid Electric Vehicles (PHEVs)	3	2	5	Light Vehicle Transportation (cars, vans, SUVs, light trucks)
Solar Photovoltaic Integration (20% RPS):Reduced Energy for Regulation	(Note: Estimates for extra regulation required for meeting a 25% RPS with solar PV integration are not available, but may be similar to that for wind. If so, and PV is used instead of wind, or to supplement it, in meeting a 25% RPS requirement, the savings are already included in the estimates for wind integtration.)			
Wind Energy Integration (20% RPS):Reduced Energy for Regulation	20	10	30	Additional Regulation

Climate Impact.

Climate change will have a major impact on the electric grid. Rising temperatures will lead to increased air conditioning use, stressing the grid during times of peak demand. Severe weather may destroy air grid. Smart grid technologies such as synchrophasors, advanced control and monitoring equipment, and smart meters will make the electric system better able to respond to the impacts of climate change, whether it is through preventing power outages, speeding up outage restoration times, or limiting peak demand through demand response.

Between 2003 and 2012, weather-related outages are estimated to have cost the U.S. economy an inflation-adjusted annual average of $18 billion to $33 billion. Continued investment in grid modernization and resilience will mitigate the costs of weather-related outages over time. These investments may include installing smart grid technology such as smart meters, outage management systems, synchrophasors, and advanced control capabilities [1].

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Arrangement and functional concept of a gas-fired power plant

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Gas is a major source of electricity generation. Approximately 21% of the world’s electricity production is based on natural gas. The global gas-fired generation capacity amounts to 1168 GW_e (2007). The combustion (gas) turbines being installed in many of today's natural-gas-fueled power plants are complex machines, but they basically involve three main sections:

- **The compressor**, which draws air into the engine, pressurizes it, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.
- **The combustion system**, typically made up of a ring of fuel injectors that inject a steady stream of fuel into combustion chambers where it mixes with the air. The mixture is burned at temperatures of more than 2000 degrees F. The combustion produces a high temperature, high pressure gas stream that enters and expands through the turbine section.
- **The turbine** is an intricate array of alternate stationary and rotating aerofoil-section blades. As hot combustion gas expands through the turbine, it spins the rotating blades. The rotating blades perform a dual function: they drive the compressor to draw more pressurized air into the combustion section, and they spin a generator to produce electricity.

There are two types of gas-fired power plants, viz. open-cycle gas turbine (OCGT) plants and combined-cycle gas turbine (CCGT) plants. Open-cycle gas turbines (OCGT) for electricity generation were introduced decades ago for peak-load service. Simple OCGT plants consist basically of an air compressor and a gas turbine aligned on a single shaft connected to an electricity generator. Filtered air is compressed by the compressor and used to fire natural gas in the combustion chamber of the gas turbine that drives both the compressor and the electricity generator. Almost two-thirds of the gross power output of gas turbine is needed to compress air, and remaining one-third drives the electricity generator. OCGT generators have relatively low electrical efficiency ranging between 35% and 42% (lower heating value, LHV). Aero-derivative gas-turbines provide efficiency of 41-42% but their size is limited to 40-50 MW_e.