SHAPING OUR FUTURE WITH SUSTAINABLE ENERGY:
A DIRECTION FROM YOUNG ENGINEERS

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ABSTRACT

It is broadly accepted that current energy systems should become more sustainable in both a global and local context. However, setting common goals and shared objectives and determining the appropriate means by which to get there is the subject of heavy debate. Therefore, the American Society of Mechanical Engineers (ASME) and the German Association of Engineers (VDI) initiated a joint project aimed at providing a young engineers’ perspective to the global energy conversation. The young engineer project teams set a common goal of assembling a completely sustainable energy system for the U.S. and Germany by 2050. This includes not only the electricity market, but the overall energy system. Based on the current global energy paradigm, a completely sustainable energy system seems very ambitious. However, multiple analyses show that this path is possible and would in the medium to long run not only be desirable, but also competitive in the market. This future ‘energy puzzle’ consists of many important pieces, and the overall picture must be shaped by an overarching strategy of sustainability. Besides the many detailed pieces, four main critical issues must be addressed by engineers, politicians and everybody else alike. These challenges are:

i) Rational use of energy: This uncomfortable topic is rather unappealing to communicate, but is a key issue to reduce energy demand and to meet the potentials of renewable energy carriers.
ii) Balancing of electricity demand and generation: This is a challenge to the electricity markets and infrastructures that are currently designed for base-load, mainly fossil power plants. The overall mix of renewable energy generation, storage technologies, grid infrastructure, and power electronics will decide how efficient and reliable a future energy system will be.
iii) Cost efficiency and competitiveness:
It is a prerequisite for industrialized countries to stay competitive and to establish RE in the market. Developing economic technologies while at the same time establishing a strong RE market is the secret of success.

iv) Acceptance of the system and its consequences: The best energy strategy cannot be realized without broad public acceptance for it. Therefore, the understanding of the energy technologies and an objective discussion must be promoted – without old fashioned emotionalizing of certain risks.

The paper will present details on the four mentioned aspects, compare the situations between the U.S. and Germany, and propose solutions for appropriate political frame conditions to achieve a sustainable energy system.

**Keywords:** energy policy, sustainability, renewable energies.

**NOMENCLATURE**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>CCPP</td>
<td>Combined Cycle Power Plants</td>
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<td>CSP</td>
<td>Concentrated solar power plants</td>
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<tr>
<td>CHP</td>
<td>Combined heat and power</td>
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<tr>
<td>DOE</td>
<td>US Department of Energy</td>
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<tr>
<td>EEG</td>
<td>German Renewable Energy Law (Erneuerbare Energien Gesetz)</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>FACTS</td>
<td>Flexible AC transmission systems; type of power electronics for the electricity grid</td>
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<td>LEC</td>
<td>Levelized electricity cost</td>
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<tr>
<td>MENA</td>
<td>Middle East and North Africa</td>
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<tr>
<td>PV</td>
<td>Photovoltaics</td>
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<td>RE</td>
<td>Renewable energies</td>
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<td>US</td>
<td>United States of America</td>
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**INTRODUCTION**

In early 2011, the American Society of Mechanical Engineers (ASME) and the German Association of Engineers (VDI) initiated a joint project aimed at providing a young engineer’s perspective to the global energy conversation.

The main project goals at first were the exchange of knowledge & experience of the U.S. and German energy systems, and discussing current and emerging energy policies. Furthermore, the project group aimed at pushing for the acceptance of the best new ideas & technologies. The background of the team members ranged from wind and solar energy, nuclear and fossil power plants, battery systems, manufacturing processes, and law; as well as from universities, renowned research institutes, and large companies.

Meeting twice in 2011, the binational young engineer project team set a common goal of assembling a completely sustainable energy system for the U.S. and Germany by 2050. The collective focus of the project team was to think about how to establish optimal conditions within a complex energy production, transmission, and distribution system and creating a completely sustainable energy system at the same time.

Being aware of different views upon sustainability, a uniform definition was the first milestone on the way to a successful project. Especially when looking at nuclear energy, the German and the US society seem to have different perspectives. The German society widely agreeing on nuclear energy not being sustainable and the US society not having a clear position on this topic, the joint project group agreed upon a consistent definition of sustainability, not considering nuclear energy as a sustainable energy source due to final depository problems and the possible risk of an ultimate MCA.

After having agreed upon a consistent definition for sustainability, the project group identified four fields of action, where the United States and Germany could actually work together in order to push the idea of a 100% sustainable energy system by 2050. Naturally, the energy systems of the United States and Germany are hard to compare, but the rational use of energy, the balancing of electricity demand and generation, cost efficiency and competitiveness, and public acceptance are clearly four key areas of action for both countries on their way to a completely sustainable energy system.

Consisting of nine young engineers from different disciplines, four small teams worked on each key area in order to point out action guidelines for these areas that both countries should follow.

The results of the joint project group work were presented at the World Engineering Convention in Geneva in September 2011 and shall be further discussed at the ASME Sustainability Conference 2012 in San Diego, based on this paper.

**SUSTAINABILITY**

According to the so-called Brundtland Commission (UN, 1987), “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Looking at the energy systems of today, this aim is by far not reached, although everybody seems to wish to become more sustainable. Furthermore, there are many interpretations of what sustainability means in concrete. Looking at BP on the one hand, sustainability means amongst others working on a better contract management for deepwater oil drilling and increasing the production of natural gas (BP, 2011). For others, sustainability means to rigorously promote an immediate shift to an autonomous and decentralized energy system based on renewable energies (Scheer, 2007).

Sustainability seems to be rather an idea comparable to “liberty” or “justice” (Blewitt, 2008). In consequence, when discussing about energy sustainability, we must at first define what we really mean. Our American and German team came up with a joint definition as summarized in Figure 1, which is based on a definition developed in (Trieb, 2006). The energy system is described by the confluence of security of supply,
economic development, ecological conservation and social responsibility.

Figure 1: Characteristics of a sustainable energy system

Security of supply is the basis for industrial and developed countries. Especially for Germany the availability of base-load electricity was its industrial backbone, starting in the 1950ies until now. However, for long-term security, energy carriers should origin from diversified and redundant sources. The current US and German system is mainly based on oil, coal, gas, and nuclear; only four energy carriers. Additionally, a large part of them is imported from countries that might politically abuse their energy exporting power. Expanding the energy system to natural, regenerating resources like water, wind, solar irradiation or geothermal energy is not only politically wise. It is an obligation to use them, since they are the only recourse that will be available for generations to come. Hoping for new technologies to appear will not help in the long run, but only postpone necessary steps towards a secure system.

The sustainable energy system must of course be economical advantageous. It should be available for low cost and without long-term subsidies. In many discussions this is mentioned as reason why fossil fuels are still important and will be needed for decades to come. But it is mainly a question of how “cost” is defined and who will pay for it. Nevertheless, scenarios show that even with the classical definition of cost – the price the consumer must pay– renewable or sustainable energy, respectively, will become competitive. If they are enabled to benefit from early subsidies or “investments”, they have the potential to come down by economies of scale to costs that are below fossil fuels in the future. Another economical aspect, especially important for the energy sector, is security of investment. Energy systems should not be built based on plans that change every one or two years. Investments are high and should be founded on long-term concepts only. This, as well, is true for incentives or regulatory framework conditions.

Ecological aspects are omnipresent, first and foremost the discussion about greenhouse gas emissions and climate change. But not only carbon dioxide or methane emissions should be avoided. Emissions also include noise, e.g. from planes or factories, chemical substances, e.g. air pollutants or effluents, or nuclear waste. Conserving an enjoyable environment and the diversity of eco-systems for all is the overarching premise for ecological sustainability. Destroying these environments for the short-term usage of energy carriers is not reconcilable with sustainability.

Social aspects gain more and more importance for the organization of the energy system. The equality of access seems to be taken for granted in industrial countries, but unfortunately it is not that self-evident in other countries. Inequalities are seldom compatible with sustainability and must be avoided. Derived from that argument, there should be a low risk associated with the energy system. Risk by itself is never quantifiable, and although measures might indicate a low risk, the “feeling” of risk in a society should be taken seriously. This feeling usually occurs when few people decide on issues from which a high risk for individuals might arise –without giving the individual the possibility to influence it. This will lead to dissatisfaction and to non-sustainable system. Satisfaction of society or “public acceptance” is a pre-requisite for a stable energy system. It implies a variety of aspects, from switching the light on (which directly gets bright) to not seeing moving wind turbines on the horizon.

All these aspects demand a societal consensus across all parties. They also rely on and further foster political cooperation in both a local and international context. The current energy system is far away from being sustainable. The transition to a sustainable one will therefore take time and reduce privileges. In consequence, energy technologies should not only be measured by cost per unit of energy, but rather by its cost for society and by its ability to help achieving a sustainable energy system.

In that sense, the exhaustive use of fossil fuels and nuclear energy might help for some time to provide energy, but are far away from being compatible with sustainability. However, it must be accepted that there is no technology without drawbacks. The use of biomass must assure that there is no conflict between energetic use and nutrition. Geothermal power might carry radioactive water to the surface. Shadows of rotating wind rotors might influence the living-comfort of residents. All these problems must be addressed to find more sustainable ways of their application. In the end, a diversified energy mix depending on society and resources will be the best compromise.

THE ENERGY PUZZLE

Considering the discussion about a sustainable energy supply system, it is often forgotten that there is no unique solution. Neither there is just one aspect that has to be focused on, nor one technology that is the unique solution, nor one
system that guarantees a sustainable energy supply. On the contrary, the energy system resembles a big puzzle consisting of many different parts. In order to achieve a 100% sustainable energy system, all of these parts have to be considered and made compatible.

Important aspects of the energy discussion are the technological potential and improvement. The existing potential of renewable energy sources has to correspond to the total demand of energy. Additionally, the compatibility of different systems – e.g. centralized and decentralized supply system – and technologies has to be assured. The stability of supply guarantees an energy supply at all times during a day and a year. Furthermore, the consideration of energy storage systems is essential.

However, this report emphasizes the four most crucial parts of the energy puzzle, which have been determined by the young engineer project team (Figure 2). First, a smart energy generation and an intelligent load management system are required, in order to dispatch the volatile generation (wind and solar power) with the volatile demand of energy. An efficient and rational use of energy leads to a lower overall energy demand. On the one hand the potential of renewable energies can be quite low in some areas and only an efficient use will guarantee an overall supply. On the other hand a lower energy demand leads to less required power plants, grid and storage capacities and finally fewer resources. Hence, the system will be much more cost-efficient and competitive compared to the current system.

The cost-efficiency and competitiveness are crucial to afford the installation of a sustainable energy system and to ensure the acceptance by the public and the economy. Finally, the installation of e.g. wind parks, further power lines etc. always affects the surrounding population. The public will not oppose energy projects, when local people and their environment are involved and respected in making decisions. A broad acceptance of the energy turnaround and a compatible design with nature and mankind is essential.

**RATIONAL USE OF ENERGY**

A sustainable energy system will most likely depend on volatile energy sources such as wind and sunlight. In order to cope with the volatility of these sources, large surplus power capacities, numerous energy storage systems and a smart and powerful energy distribution grid are necessary. However, independent from the sources, the less energy is consumed the less of those installations are required. Thus, the sustainable energy system will be much more cost-efficient and cost-competitive than the current supply system.

**The potentials**

Besides efficiency potentials on the generation side, i.e. increasing the conversion efficiency of power units and plants, large energy saving potentials are on the demand side.

In Germany the biggest saving potential can be found in private households, transportation, and the industry sector due to very high end energy consumption (Figure 3).

![Figure 3: Final energy consumption by sectors (AGEB, 2011).](image)

In private households in Germany most of the final energy (> 70%) is used for space heating (Prognos, 2007). This energy consumption is caused by an inadequate insulation, and poorly designed air circulation systems in combination with the orientation of the building and its heat absorption. Including the trade & services and industry sector, about 40% of the overall German final energy use is dedicated to heat buildings. If all buildings were constructed as passive houses, about 80% of space heating energy could be saved (FVEE, 2010; Allendorf, 2011), that is about one third of the total German end energy demand. Besides the above mentioned points, current fuel-fired heating can be replaced by efficiently working heat pumps in combination with solar- or geothermal systems. Natural gas or oil can be used more efficiently to generate dispatchable electricity than for space heating. The electricity in turn can be
used to operate the heat pumps or solar and geothermal systems which consume very little energy.

Furthermore, large potentials are connected to the transportation sector. Due to an increasing mobility of the people and increasing freight traffic, the traffic sector will even become more important. Most effective saving methods are the introduction of shared driving systems, i.e. 2 to 4 people per car instead of one, the utilization of public transportation, bicycles or even walking especially for short distances. This relies amongst others on a habitual change of people which is already observable in Germany and is promoted by the application of mobile technologies like ‘smart phones’. Also freight traffic should be shifted from the roads to more efficient systems such as trains or ships.

In industry processes, heat recovery and mechanical energy recovery systems should be installed. Exhaust heat at all temperature levels can be stored in thermal storage systems, reconverted into electricity or re-fed into the system to preheat the material. In alternating processes, i.e. accelerate/brake; up/down (elevator, cranes) etc. mechanical energy can be perfectly recuperated. As well, the installation of motor-speed controlled engines and the maintenance and optimization of pressurized air systems are intelligent easily implementable solutions to save energy (Prognos, 2007).

The implementation

Today most parts of the population are not aware of how to use energy more efficiently and it is a politically disagreeable and not acquainted topic. Due to being the crucial point of a sustainable energy system, public awareness has to be raised dramatically. Every single person and household must engage in the rational use of energy and contribute to it.

In order to raise the public awareness for energy efficiency and conservation, several actions are proposed.

- Installation of a nationwide action plan including consultancy as well as technical and financial support;
- Labeling of consumer goods regarding the energy consumption for production and transportation of the product;
- Implementation of efficiency benchmarking in all areas and constant adaptation to most efficient processes;
- Introduction of a mandatory “integrated energy-, material- and process management” for industry.

In a nationwide action plan all people are to be sensitized by advertisments, informative seminars and reports etc. Information about existing incentive programmes and arrangements to increase the energy efficiency easily have to be spread to all people. Low cost appropriation (smart meters, current consumption measures) has to be offered. Also low cost consultation for municipalities and individual persons is to be provided to reveal hidden efficiency potentials and to develop integrated energy concepts for houses, buildings, villages and municipalities. These consultancy programmes and seminars can be organized on the municipality level cooperating with local public utility companies.

All relevant information concerning the topic should be collected and easily shared for example via a webpage and at the town hall. Finally, the rational use of energy is to become a part of school education in form of project days and competitions with other schools.

People’s awareness can be raised further by a mandatory labeling of food and consumer goods considering the energy consumption for production and transportation to the (super-)market as well as possible fuel/energy consumption during its life-time. This labeling can be done by indicating the consumption of energy and water and the emission of greenhouse gases in the form of traffic lights. The classification will help the customer to compare similar products quickly. Additionally, the labeling can entail benefits for local companies, since their transportation ways are quite short. Two examples of labeling are shown in Figure 4.

![Figure 4: Examples for energy labeling: Decathlon SA (Decathlon, 2012) and German energy pass for buildings (Dena, 2012).](image)

In complex industrial processes the determination of energy saving potentials can be quite difficult. The mandatory introduction of an ‘integrated energy-, material- and process management’ will help to survey one’s production line and to identify saving potentials. Furthermore, the exact knowledge about these data helps to benchmark each process and to make them comparable with other processes. This benchmarking has to be done continuously and the allowed range of energy consumption has to be lowered little by little.

BALANCING ELECTRICITY

Electricity is one of the most important goods of a developed society. Without it, normal live comes to a stand-still. In Germany, about 25% of end energy is used as electricity, only exceeded by district and process heat, and individual transport. In the U.S., about 18% of end energy is electricity, surpassed only by natural gas and petroleum (LLNL, 2011). In a sustainable energy system:

- Natural gas and oil for heat will be substituted by electricity to a large degree.
- Transportation fuels will shift from fossil based fuels to biofuels or electric drives.

In consequence, the major share of end energy in a future energy system will be provided by electricity.
The importance of balancing electricity

Permanently available energy has been the key success factor for our industrial societies. Since the industrial revolution, fossil fuels, including coal, natural gas, and petroleum, have been used exclusively to satisfy the increased energy requirement of the modern society. One of the main reasons for such high demand for the fossil fuels comes from the fact that the fossil fuels are an ideal form of chemical energy for storage, which can easily be transported and converted into other forms of energy. Although the production of electricity can match the instantaneous energy demand satisfied by fossil fuels, there is inherent problem when dealing with electricity; electricity is difficult to store comparing to fossil fuels. More specifically, if there is no immediate demand for the surplus electricity, it is immediately lost. One potential approach to this problem is to come up with an electrical grid, which consists of electricity generation, power transmission, and distribution. For the electricity generation in the grid, it is not a major problem if the complete portfolio of power plants based on non-intermittent resources such as fossil and nuclear are adapted, because such power resources can promote the steady flow of electricity output. However, with new power plants based on renewable energy (RE) using intermittent resources like wind for electricity generation, the creation of steady electricity output will become a challenge. That is, a thorough study on the intermittency of various power sources is a must for the smart generation of electricity, and its load management will gain an important role in a future energy system. Consequently, electricity management will become a major part of a country’s security of supply and energy sustainability.

The current status in the US and Germany

In the U.S. about 3900 TWh, of electricity are generated (LLNL, 2011), which is more than six times the German generation of about 600 TWh (AGEB, 2011). The portfolio of power plants in Germany is divided into three main classes of plants: base load, mid load and peak load. The categories are derived from the plants’ overall cost structure. Plants with high investment and low fuel cost (lignite and nuclear) are used as base load plants. Almost 50% of electricity production is in this category (cf. Table 1). If the demand is higher than the base load capacity, mid load plants (hard coal) are switched on. At peak demand during noon or in the evening hours, peak load plants (e.g. gas turbines) are used, which are characterized by a rather low investment and high fuel cost. This situation is shown in Figure 5.

The sources for the electricity production in the U.S. are also shown in Table 1. Comparing the U.S. numbers to German number, they are in the same order of magnitude. There is slightly more dependency on coal, natural gas, and water (hydro) in the U.S. On the other hand, there is less dependency on nuclear, wind, and biomass in the U.S. electricity production. Overall, the numbers seems somewhat close to each other.

### Table 1: Shares of gross electricity production in the US and Germany

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<tr>
<td>Lignite</td>
<td>48%</td>
<td>25%</td>
</tr>
<tr>
<td>Hard coal</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Natural gas</td>
<td>21%</td>
<td>13%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>6%</td>
<td>23%</td>
</tr>
<tr>
<td>Oil and diesel</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Water</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>Wind</td>
<td>2%</td>
<td>6%</td>
</tr>
<tr>
<td>Biomass</td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>&lt; 1%</td>
<td>1%</td>
</tr>
<tr>
<td>Others</td>
<td>&lt; 1%</td>
<td>4%</td>
</tr>
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Most of the potential RE technologies to be used in Germany depend on the fluctuating availability of resources, e.g. wind power or the application of photovoltaics (PV). When the resources are available, electricity from RE can be produced. This production, however, is independent from the real demand, which is illustrated in Figure 6. There will be times of overproduction, in which the exceeding electricity could be used to charge electric storage systems (pumped hydro, adiabatic compressed air storage, and batteries) or produce synthetic fuels like hydrogen or methane (power to gas). For an efficient energy system, the overproduction should be used as efficient as possible during later times of underproduction.

Dispatchable electricity can be produced by discharging storage systems or by the use of flexible plants like combined cycle power plants (CCPP), which have besides their flexibility the highest efficiency in the field of fossil fired power plants (up to 61%). In a future power plant portfolio with high shares of fluctuating RE, conventional power plants will only be used during times of underproduction.

German utilities currently operate predominantly inflexible base load and mid load power plants. If the total amount of installed RE capacity is low, this does not cause major problems. Expensive peak load plants are not needed any more during times of high demand, because RE can bridge the gap to mid and base load plants. In the U.S. the summer peak hours for example correspond well to the highest PV production.

If the share of RE further increases, its production replaces more and more mid and base load from the grid. At first, these plants must reduce its production to a minimum. If further RE electricity is fed to the grid, the base load plants must sometimes shut down.

However, this is only possible to a certain degree up to which the stability of the grid is not endangered. For instance, thermal power plants are designed to stabilize very short-term disturbances in the grid, while PV currently is not. If the RE share is too high, RE must be curtailed from the grid. Situations like these already occur very often in Germany, such that the
grid operator must take action and curtail wind turbines – predominantly in the north of Germany. This does not only affect the German grid, but also the neighboring countries like the Netherlands and Belgium.

Figure 5: Ideal scheme of electricity demand and base, mid and peak load production.

Possible solutions for sustainable electricity supply

To allow higher shares of RE, the thermal power plants must become more flexible. Also, RE technologies must be designed for stabilizing the grid through the careful observation and prediction of their intermittency and dispatchability. Furthermore, storage capacity should be built in order to limit the times where base load plants must be shut down.

The energy sources for grid-stabilizing thermal plants do not necessarily have to be fossil or nuclear. That is, geothermal, biomass or solar-thermal / concentrated solar power (CSP) plants can also provide the same grid services and dispatchability as every other fossil or nuclear plant.

However, the potential for these plants are very limited for Germany. Drillings for geothermal plants should be quite deep; biomass plants are built, but will reach its potential due to the alternatives of biomass usage for gas, fuels or pellet heating; direct solar irradiation is too low for CSP. One solution for Germany is the large-scale import of dispatchable electricity from countries with more potential. Ideally, electricity from CSP plants is transferred from North Africa to Germany via high voltage direct current (HVDC) lines. These point to point connections would serve in Germany as substitution for other conventional power plants and could be connected at locations where currently nuclear plants are connected to the German grid. This idea was analyzed by (Trieb, 2006) and led to the foundation of the Desertec Foundation. Electricity losses during transport from North Africa to Germany would be relatively low (< 15 %) and the potential is far beyond the future demand (Trieb, 2006).

For Germany, a certain share of imported CSP capacity is important for grid stabilization and the idea should be implemented as soon as possible. Furthermore, the sole usage of domestic RE resources is not desirable for a cost-effective and diversified energy system. However, most of the remaining electricity will be produced from intermittent domestic sources and further solutions must be implemented complementarily as follows:

- In the case of Europe, wind potential from the north can only be used if enough grid capacity from north to south is built. These lines must be implemented as soon as possible to avoid further curtailing of RE production.
- Power electronics (FACTS, flexible AC transmission systems) must be further developed and implemented to stabilize the grid without thermal power plants.
- The fossil power plant system must be changed to a flexible and mainly natural gas-fired generation in order to be compatible with the fluctuating feed-in of the RE. In addition, natural gas could be replaced by synthetic methane produced by RE in the long run. In consequence, new fossil plants should only be allowed, if they are compatible with fast load changes. Policy makers must take this into account and find suitable solutions and/or penalties.
- Domestic dispatchable plants should be incentivized to encourage local government, business owners, and homeowners to invest in electricity generation for an affordable and adequate source of electricity.
- A European grid for the exchange of RE electricity must be promoted, which will reduce the cost of electricity and also reduce the fluctuations. A common European grid planning and supervision must be established for that.
- Renewable dispatchable power from the North African or Middle East (MENA) region with exceeding solar potential must be included in the electricity system by efficient point-to-point grids to Germany and other EU countries.
- For efficient heating combined heat and power (CHP) will partly be used. Thermal energy storages for

Figure 6: Scheme of electricity demand and fluctuating electricity production.
decoupling of heat and electricity production in these CHP plants must be foreseen.

- Load management of industrial and residential processes will help to adapt the demand-side to the current RE production.
- The expansion of local RE generation and storage units in the medium and low voltage range is important (especially in the south of Germany) to reduce the need for electricity transport capacities.
- Many processes rely on fuels and a seasonal back-up for electricity security is very important. In consequence, security of fuel supply is crucial and should be guaranteed by concepts for the synthetic fuel production of RE methane (similar to natural gas) and hydrogen by RE electricity. Especially the admixing of hydrogen to RE methane, compared to a sole usage of RE methane in the gas distribution system, should be assessed and evaluated scientifically for that purpose.

In the end, Germany can become more energy self-sufficient. Energy imports of currently about 80% could be reduced to about 20%. By that, the dependencies change from long-term stored fossil energy carriers to short term electricity. This change will also reduce the risk of political influences: fossil fuel can be sold months or years later and the exporting countries could repress the delivery to other countries without losing money. For electricity from solar or wind this is not possible, such that the economics raise the inhibition threshold to use energy supply as means for political pressure.

The main items listed above for Germany hold similarly for the U.S. As in Germany, there is regional imbalance of potential and demand. Potential for electricity generation using RE is greatest in the Western U.S., whereas the energy demand is high in both the Eastern and Western U.S. In consequence and analog to the European grid planning, the potential in the U.S. should be unlocked by efficient electricity grids using a HVDC electric power transmission system.

In the U.S., about half of electricity was generated by coal. Out of the domestically produced energy, renewable energy is low at about 11% (DOE/EIA, 2011). By stabilizing the energy grid and increasing the percentage of RE, the dependency of electricity production on coal will be reduced.

One important aspect of balancing electricity is that the RE production technologies must be harmonized and should not be judged by their isolated levelized electricity cost (LEC), i.e. generation costs per kilowatthour. Denholm and Mehos (Denholm, 2011) demonstrated that for the solar case of PV and CSP. They set up a model of the Californian electricity grid to check its ability to include solar electricity production. Without further measures, only about 15% to 20% of the electricity could be generated by PV due to economic and grid limitations, where PV was applied first because it showed lower LEC than CSP.

With the continued growth for the share of electricity produced from solar energy is expected, CSP with its available thermal storage and baseload capabilities must be applied. To this end, the solar share, which consists of half PV and half CSP, could be increased to more than 50%. Since CSP is both renewable and baseload compatible, its share could be increased further. In conclusion, the sole view on current costs and share may not necessarily lead to the most economic overall energy system in the future; therefore, thorough research on electricity balancing must be completed, which then must be taken into account by policy makers.

PUBLIC ACCEPTANCE

Public acceptance is another key condition for sustainable and renewable energies. Sustainable energies supply power to nearly all parts of the community and everyday life. Several sustainable energies have large physical profiles – wind turbines, solar panels and electrical towers (that transfer power) – that are not invisible and their infrastructure becomes part of the landscape. Therefore, these projects must be supported from the society since they are fully visible.

Renewable energies also need public acceptance to ensure continued research in the field and growth. The growth of renewable energies can help to strengthen and stimulate economies by bringing in money and increasing jobs.

One potential hurdle that affects renewable energies is the location of the infrastructure, which is mainly affected by the “not in my backyard” mentality of many people. Other hurdles include public protests along with the public reading “journalism” as facts instead of doing research on their own about the technologies – or vice versa, the very subjective way of commentatorship, which does not want to provide facts. There will always be some negative comments about renewable technologies, but it is essential that the advantages and disadvantages are weighed against each other publicly and as objectively as possible.

In Germany, society has slowly become aware of the importance of having a positive public acceptance in regards to renewable energies. Nearly every large-scale project is debated between the local community and the project supporters, which could include all stakeholders like workers, land owners and the companies that are backing up the project.

A well-known example for a German project which had clear problems with public acceptance is the reconstruction of the train station in Stuttgart, Germany, called “S21". Although plans had been in development since 1994, there had never been a public discussion of the pros and cons of the project. Furthermore, information about bad project planning and rumors of nepotism were published. In consequence, construction works were flanked with massive protests from the locals who hindered the progress of the project. Not before a public mediation with representatives of the protesters and the companies involved, including about 60 hours of live reporting (Handelsblatt, 2011), construction works could be continued.

Other examples in Germany include protests against carbon capture and storage (CCS) projects in Brandenburg or against a pumped hydro power stations for electricity storage in Thüringen. However, these demonstrations do not mean that...
people are against modern energy technologies. When surveyed, 94% of the general public supports the strengthened development of RE according to a survey from the German Agency for Renewable Energies in 2011 (AEE, 2011). Another 65% agree with the construction of renewable energy systems near their residential areas.

The goal of general acceptance is to inform people about the projects and thereby help to avoid protests and delays. This can be done by improving communication between the company and the local populace. The local public should be educated on the benefits to the community from the projects. One good example is the wind farms which are built with investments from the local community. The public participated in all phases of the project including the planning originating stages. These successful projects were called “Bürgerwindparks,” which translates into “citizen wind farms” (WN, 2010).

One case in which public acceptance was improved is the extension of the Frankfurt Airport in Germany. A mediation campaign with a neutral mediator prevented massive protests during the construction of the controversial project (Vieth, 2009). At the beginning, mediation worked better compared to the “S21” project, because communication started much earlier in the process. However, the acceptance of mediation is highly dependent on the shareholders acting as agreed. If they do not do so, mediation will bring no improvement.

Two new approaches for greater public acceptance are shown in the extension of the highway A8 in Bavaria, Germany. To inform residents, a webpage was created to start a process of constant dialogue (Graf, 2011). Early and open communication about the goals and variations of the project were helpful. Up-to-date information is provided on the internet to develop trust and an atmosphere of respect.

In the U.S. it has become a best practice to keep communication lines open, especially when it comes to public acceptance. It is important to have two-way communication to allow both parties to state their position and share what they bring to the table.

South Carolina has worked on public acceptance of fuel cell research through various different methods. Brochures were created along with implementation of other various initiatives to show the public that this state was ready to take the lead in researching fuel cells. In the end, some of these projects were de-funded from the government due to their findings from research (SCDC, 2011). However, the methods for educating the local community were effective in generating community support.

One example in the U.S. where lack of public acceptance hindered a project is the construction of Interstate 476 in eastern Pennsylvania. During the construction of I-476, local community opposition resulted in many public hearings and demonstrations. After many years of court hearings, the Delaware County portion of the highway was built with many compromises. These include a parkway design as well as several miles of four lane highway, when capacity projections called for six lanes. All of the public disturbances caused delays in the project along with a higher price tag (Kitsko, 2011).

Another positive example of how public acceptance has worked in the United States is from the Best Practices from the Midwest Carbon Sequestration (SCDC, 2011). An outreach program was developed to gradually build a foundation of public acceptance for carbon sequestration. Some of the best practices from this study include: good communication (between the local public and the media), development of opportunities for learning and information sharing, and involvement of key stakeholders.

In Conclusion, earning public acceptance can preserve a project's schedule and budget. Involving local communities early in the process can result in a more positive atmosphere. Ideally, strategies for public acceptance should lead to a better understanding and a promotion of a project by the public. This can be achieved by objective information, early involvement, and also by financial involvement in the project.

COST EFFICIENCY AND COMPETITIVENESS

The joint American-German project group does strongly agree upon the ambition that a sustainable energy system must be as cost efficient as possible and competitive at least to the current energy system.

Certainly, there are cultural differences between the two countries that affect the attitude towards the competitiveness of a 100% sustainable energy system. The U.S. is more economy and market oriented than Germany, which traditionally tries to combine the market with a broader health and welfare system and tighter social / political limits. Having already a very broad majority of people supporting a sustainable energy system in Germany, one might think that the competitiveness of such an energy system might play a less important role for Germany than for the United States.

Nevertheless, all beliefs of experts saying that people might accept higher energy costs in exchange for a sustainable energy system undermine the effect that competitiveness and cost efficiency will certainly support the acceptance of renewable energies not only in the U.S. and Germany, but on a global basis.

The competitiveness of a future sustainable energy system is absolutely crucial and therefore one of the four key areas of action for the joint American-German project group.

Besides the insight that a highly efficient economy decreases energy costs and thereof also helps a sustainable energy system being competitive, the project group has worked out several recommendations of action that will help creating a competitive sustainable energy system.

One action should be to speed up transfer of industrial know-how from established industries to the renewables sector. The advancement of standardized and lean production, a connected global supply chain and building strong clusters, especially between small and medium sized companies, for
further R&D will push the competitiveness of the renewable energy sector.

Another milestone on the way to a competitive sustainable energy system is the successful set-up of a market model that integrates renewable and fossil energies. This market model should secure the construction of modern fossil power plants that can interact with the volatile feed-in of renewable energies and the advancement of bigger energy storage capacities in the electricity grid. A revised and working market model could help a lot on the way to establish a smart integration of renewable and fossil energy generation. Part of this could be the implementation of so-called capacity markets in the German model, similar to the one already used in the U.S.

In order to set up a working market that is able to integrate renewable and fossil energy sources in the transition time to a completely sustainable energy system, also the strengthening of the dispatchability of renewable energy sources plays a major role. Actions like the increase of energy storage facilities as well as enhancing the energy high voltage distribution systems to a smart grid will help to increase the dispatchability of renewable energy sources and increase the security of supply and competitiveness of a sustainable energy system.

The dispatchability of renewable energy sources is further strengthened by an overall system approach needed for the effective implementation, as already pointed out in the balancing electricity section. While biogas and concentrated solar power could be used as technologies to balance volatile photovoltaic and wind energy feed-ins, wind energy, photovoltaics and hydro power sources are able to generate “cheap” energy.

Enabling both countries to push harder for new technologies and innovations is another key action that has to be undertaken. Besides giving incentives to invest the necessary money, also the industry structure is of main interest. On the one hand, many small and medium sized companies are doing business in the renewables sector. Support for building local competence clusters would be a successful way to strengthen the joint R&D capacities of smaller businesses. Specific support of research and development, on the other hand, is not only needed in technical and economical, but also in humanistic fields of science, aiming at increasing the competitiveness of the renewable energy system and looking at this aim from different standpoints.

When it comes to the competitiveness of a future sustainable energy system, one thing is definitely specific about Germany. By contrast with the United States, Germany will have to rely on a certain amount of imported energy from renewable sources. Due to its geographic situation, Germany is not able to cover its complete energy demand from renewable sources in a cost efficient way unlike the United States.

Germany has to be enabled to import electricity that is generated from renewable energy sources from neighboring or third countries, including countries outside the European Union.

When looking at the very diverse possibilities to generate energy from renewable sources, the United States will certainly have the chance to cover their complete demand of energy from renewable sources in a competitive manner.

Concluding, one assumption is clear: The conservation of competitiveness of energy-intensive industries is a crucial issue for Germany and the United States and their strong industrial base. The faster the renewable energies become more competitive than fossil fuels, the faster the conservation of competitiveness of these industries can be achieved. Nevertheless, these industries must participate in the rebuilding of the energy system, especially regarding transition costs, such that incentives to save energy are preserved. In Germany this is currently not the case due to exceptions in the EEG.

COMPARISON BETWEEN THE U.S. AND GERMANY

There are lot of issues that could be compared between the U.S. and Germany. Only a few are listed and explained here. Both countries have their specifics, but both can also learn from each other. The exchange of knowledge and best practice experience is therefore a first major step towards a sustainable future.

Similarities
- In principal, both countries could be energy self-sufficient by domestic RE potentials. Only for Germany the provision with cost-efficient and dispatchable power will need to be backed by electricity imports, e.g. from the south of the EU or North Africa.
- The regional potential is not distributed equally along the country. This makes efficient energy transport necessary.
- People are used to traditional ‘handling’ of energy and the current energy system has developed slowly in both countries. But the transition to a sustainable system requires a resolute change of the current habits.
- The four major points discussed in this paper are the same for both countries – and most other industrial countries. Although certain differences exist, the main paths are the same and need country-specific ways of implementation.
- National biomass strategy: Biomass can be used in a variety of sectors like electricity production, fuels for vehicles or planes, or in industrial processes. However, the domestic potential is limited in both countries and demands an overall strategy for biomass utilization – as well as for possible biomass imports that should correspond to the requirements of sustainability in the exporting countries.

Differences
The main differences between the countries for considerations of a sustainable energy system arise from different cultures. The U.S. is very economy and market oriented, while Germany tries to combine the market with tighter social/political limits. This leads to different developments of research funding or RE incentives. The German Renewable Energy Act (Erneuerbare Energien Gesetz,
EEG) funds RE technologies with a constant feed-in tariff for each energy unit (kWh). Differences are made depending on each technology and the already installed capacity to adapt tariffs by reacting on current market conditions. This arises from the opinion, that short-term subsidies are needed to establish a market with various players that can decrease costs by economies of scale and learning curves.

In the U.S. there is no common law like the EEG. Every state can decide on its own leading to a variety of rules and discrepancies in the RE shares of the states. Funding is concentrated on research for demonstration projects or to foster break-through technologies like in the ‘Advanced Research Projects Agency-Energy’ (ARPA-E) programme. These funds can lead to further steps towards the competitiveness of RE technologies.

By the U.S. approach, only the cheapest technologies are deployed, independent from their later use for a sustainable system, and without market development for important future technologies. This partly leads to inefficient investments and causes a delay of the transition phase. By the German approach on the other hand, the overall system could be considered (if a strategy existed), but is dependent on political will and expertise. A mixture of both should be the goal for future energy policy makers.

Regarding the organization of electricity markets, utilities currently operate predominantly inflexible base-load power plants and, therefore, have an interest in limiting the fluctuating feed-in and the expansion of RE. Policy makers must take this into account and find suitable solutions and/or penalties: The idea of the American Renewable Portfolio Standards (RPS) could help. It would define the allocation of a certain share of electricity and heat from RE by each utility. Producing a lower share than prescribed should be highly penalized. The share should then be increased continuously to 100% RE in the long run as an addition to the German RE Law (EEG).

Regarding the size, energy demand, and RE potential, the U.S. seems to be rather comparable to the European Union (EU). Furthermore, the U.S. federal states are more self-contained than the German federal states and more resemble countries in the EU. However, energy structures and major challenges are completely comparable.

CONCLUSIONS

The design and organization of a sustainable energy system is complex and there are many things to work on in parallel. This compilation has been developed by a joined U.S./ASME and German/VDI team of young engineers to illuminate some major parts to tackle and to define a common understanding of the goal. The U.S., Germany and all other developed nations face similar problems when it comes to creating a sustainable energy system. Since in this ‘energy puzzle’ many things are important, our list of conclusions is by far not complete, but exemplary:

- Not one single renewable energy technology can solve the global energy challenge. An overall system approach, which obeys the critical conditions of sustainability, is essential. This requires the implementation of a nationwide energy strategy.
- Without an increase in energy efficiency & conservation, there will be no sustainable energy system. Potentials for these efficiency gains are huge.
- The continuous increase in energy costs will go on with conventional/fossil energy carriers. Only early investments in RE technologies will enable countries to stabilize the costs in the middle to long run.
- The balancing of electricity is the key to integrate growing renewable energy generation into the grid. RE production technologies must be harmonized and should not be judged by their isolated levelized electricity cost, but by their overall system contribution.
- Comprehensive information and early involvement of affected persons will increase public acceptance to create a sustainable energy system.
- Comprehensive enlightenment about chances and risks of technological opportunities and alternatives will become a key responsibility of engineers. To create acceptance for complex large-scale technologies, standardized evaluation factors can help during the process of involvement.
- Binational or multinational joint R&D and manufacturing projects will help to deploy the economies of scale quicker and advance renewable technologies.
- The exchange of knowledge and best practice experience must be fostered international.

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