Roundtable 1:
The emergence of new technologies, particularly those serving the Energy Transition

- Arnulf Grubler, Acting Program Director, International Institute for Applied Systems Analysis
- Carsten Rolle, Head of Department, Federation of German Industries
- Raphaël Schoentgen, Research & Technologies Director, ENGIE

Moderator: Christoph Frei, Secretary General, World Energy Council

Christoph Frei, Secretary General, World Energy Council

The first question we can ask is: What is driving new technologies in energy? The consensus today is that this is not simply opportunity. Rather, there are a number of major factors driving massive change in the energy sector.

The World Energy Council's Issues Monitor identifies high-level issues that affect energy. We asked 1,200 energy leaders in 90 countries to rate those issues in terms of their level of importance, their level of uncertainty, and their relevant time frames.

- Price volatility, economic uncertainty, market design and electricity storage emerged as the top issues that keep energy leaders awake at night.
- Regional interconnection, renewables, energy efficiency and the transitioning of subsidy regimes are the issues that keep energy leaders the busiest.
- Renewables and energy efficiency are seen as the top action for the coming 6 years, having replaced CCS or nuclear in this respect.

- In global terms, resilience issues are ranked relatively low on average, although this varies greatly by region. Cyber threats rank among the top 1-year movers.

When it comes to resilience issues, Chinese energy leaders are most focused on the energy-water nexus. In Germany, cyber threats are rapidly becoming the top resilient issue. In France, however, resilience issues are relatively low on the agenda of energy leaders.

In conclusion, when talking about the energy transition, we can say that it is clearly being driven by three fundamental factors: decarbonisation, new market design and resilience pressures.

I would now like to hand over the floor to our respected panel members.

World exergy flows: Energy end user efficiency

Arnulf Grubler, Acting Program Director, International Institute for Applied Systems Analysis

I am a student of technology history, with a specific focus on the drivers of past energy transitions. Historically, these transitions have never been policy-driven, as it is the case today. These transitions take also a very long time to unfold. They are not driven by one single technology but by interrelated sets of technologies that combine new technologies, new services, and new infrastructures.

The Global Energy Assessment found that technologies and institutions are not created by individual efforts but in a very specific systemic context. To have new and better technologies it is necessary to have new knowledge, and well-coordinated actors and institutions that are the holders of that knowledge. Those actors and institutions are also key in mobilising the necessary resources for technology investments.

In this, it is important to note that R&D is cheap! Globally we invest approximately $50 billion in energy R&D per year. In contrast, we spend $200 million in subsidising renewable energies, and the energy system itself mobilises up to $5 trillion in investments each year. Mobilising resources for innovation is therefore not only about mobilising resources for R&D; it is also about mobilising resources for market creation and to provide incentives for investments into existing technologies and markets.

My main argument today is a very simple one. There is a group of technologies that is marginalised in our innovation system – energy end-use efficiency. Over 80% of our R&D spend is devoted to the energy supply side, and the innovation system is very biased towards supply side technologies in all other aspects as well. We therefore need a renewed emphasis on energy end-use efficiency, and the advantages of such a focus are multiple.

- First, efficiency: By focusing on end-use, we can leverage enormous efficiency gains. From an exergetic perspective, the two greatest losses occur at the level of end-use and service provision. For example, we lose considerable exergy in the conversion of gasoline into mechanical energy in our cars. We lose even more exergy by having a single person sitting in a car that is designed for multiple users. These are therefore the areas with the largest potential efficiency gains in the transport sector.
- Second, a focus on energy efficiency means that there is a much greater multiplier effect due to the greater investments that are mobilised in end-use investments (up to 4 trillion $ per year) compared to energy supply side investments (about one trillion $ per year).
- Third, focusing on end use will help with innovation on the supply side as well. The less energy consumed and the more efficient we are, the more resilient our energy supply will become.
- Finally, the nature of the technology itself. A significant drawback of focusing on energy end user efficiency is its small scale – this is an area characterised by a myriad of projects that are difficult to organise. However, that small scale also means that it is cheap to innovate and the price of failure is also small.

In conclusion, case studies of innovation successes and failures tend to focus only on successes; they hardly ever mention innovation failures. Nevertheless, we know that only 5% of innovation projects actually make it to the market which makes smaller-scale end-use innovation projects much more resilient compared to large-scale, multi-billion Dollar supply-side innovation projects.

Christoph Frei

Which new sets of technologies do you consider are at the forefront of innovation? You emphasised the energy efficiency side. However, in virtually every area in which we touch on energy efficiency, there are three stakeholders that have to be aligned: the owner, the user and the regulator. Can we therefore be hopeful that energy efficiency will realise its potential?

Arnulf Grubler

The key here is organisational innovation. We have to overcome the principle of market segmentation based on the principal agent model – a model that did not exist in the past. For example, during the industrial revolution, it was the engineers working in the coalmines who developed the steam engine. We have now institutionalised this principal agent model, which was very successful for the car industry, for example. Going forward, new business models such as Uber or Prosumers are needed.

There is an old adage in the literature that technological change is difficult but institutional or organisational change is easy. I firmly believe that the opposite is true: it is organisational change that is the most difficult to achieve.

Christoph Frei

We have heard the research perspective and will now turn to a country transitional perspective. What are the innovation drivers that industry would like to see?

The voice of German industry

Carsten Rolle, Head of Department, Federation of German Industries

BDI is the umbrella organisation of the manufacturing industries in Germany. We often talk about the challenges of the *Energiewende* but a study commissioned by BDI shows that the German economy could also benefit in multiple ways from the energy transition. First, it would lead to an increase in revenue potential for German technology producers. Second, it would improve energy independence by reducing the need for fuel imports. Third, it would contribute to climate protection by lowering the volumes of CO_2 emissions in Germany.

Total public energy RD&D budgets are quite cyclical, peaking at $20 billion in 1980 and then declining for the following 20 years. RD&D budgets also vary greatly by country. In countries such as Finland, Norway Canada or France, this has a high priority. In other countries such as Spain, Portugal or the Czech Republic, the energy RD&D spend per capita is much lower. The focus on different technologies has also changed over time and tends to follow policy shifts. In 2014, European utilities increased RD&D expenditures for the first time since 2011, mainly driven by the French utilities EDF and ENGIE.

BDI assessed 27 technology fields related to energy on the basis of four different criteria (weight in %).

- First, the benefits of the technology itself in terms of emissions, resource efficiency, security of supply, and so on (25%).
- Second, R&D effectiveness: the benefits that each euro of R&D would bring (30%).
- Third, economic importance for the German energy system and for the German economy as a whole referring to its global market shares (25%).
- Fourth, societal and political acceptance and relevance (20%).

As a result of that assessment, 10 technology fields were identified as crucial priorities for policy makers: material storage, fuel cells, energy efficient industrial processes, EU super grid, offshore wind, e-mobility, multi-modal systems, smart grids, energy efficient buildings, and PV. Digitalisation was identified as an 11th field that applies to the 10 other fields and is penetrating all areas of tomorrow's

energy world. When it comes to digitalisation, this is a technology-driven trend rather than a policy-driven one. Sector coupling or multimodal systems is one of the 10 fields that is worth highlighting. This is a long-term trend that is rapidly increasing in importance.

We propose taking a strategic approach based on such a *priority* list of technologies, the first of its kind in Germany.

Christoph Frei

Did I understand you correctly that RD&D is not strategic for the state but for private players only?

Carsten Rolle

We do indeed see fields for public spending and the increasing amount of public money spent in the last years is an indicator that it gains more importance strategically. Part of that R&D can be done by private companies but there is a significant amount that should be publicly funded. On the one hand, we want to see that support being technology open, not picking singular technologies by politicians. On the other, it is not possible to support all technologies. It is therefore necessary to set some priorities.

Christoph Frei

In the latest World Energy Trilemma report, which is currently being prepared, we have found that those policies that we would call “measured” policies are not visible after 5 or 6 years. On the research side, is there a call for massive cyclical investment?

Carsten Rolle

We could have done more with respect to climate change issues if we had invested more on energy efficiency. We tend to see flexibility and efficiency as separate factors. However, these two issues should be bound together more closely, especially in times when there is more electricity from volatile renewables produced than we can consume.

Christoph Frei

We have now heard a research perspective and a country perspective, both of which have pointed to the energy efficiency side of this topic. We will now hear from a company perspective that is more focused on the supply side. What are your views of the technology priorities in the energy transition?

The utilities perspective

Raphaël Schoentgen, Research & Technologies Director, ENGIE

I will provide the perspective of utilities, which are in the middle of the energy transition. That transition represents a major shift for a company like ours. In the past, our assets were extremely large systems that required hundreds of talents (engineers, lawyers, finance experts, etc.). The quality of a company such as ENGIE was to be able to deliver new projects on time. That is, it was concerned with the integration of all the different parts, including technology. As regards the technology and technology providers, we have an array of different suppliers that have been involved in this for decades. They identify the best technologies available, and integrate them into their offers. Once they have developed a new solution, it is available on the market for everyone to use. That is the world of energy as it was 5 years ago.

The energy transition means that the relevant systems are divided in terms of size by a factor of 1/1,000. That means that the entry ticket to develop a new energy plant is much lower: with a few million euros it is possible to start to play at any level of the chain. We are therefore seeing the emergence of a new

array of players and a complete shift in the way a company like ENGIE looks at technologies. We are also seeing a shift from very open large systems to a world where technology may no longer be accessible to all.

That has led ENGIE to change its policies with respect to the ecosystem of technologies and innovators in recent years. First, 2 years ago, we created a new venture fund through which we invest directly in new projects. Second, at the Group level, we have decided to push for a portfolio of large tech pilots, for example the Gaia second-generation biomass project. Third, we are exploring the development of new competencies, for example batteries – not with a view to becoming a key player in batteries but in order to better understand battery technologies and their impact on our business. We have also developed a 3-D printing lab that enables us to print pieces in methyl. This transition is therefore a major lead for a group like ours to integrate with technologies in a completely different way.

When it comes to investment levels, the question of the level of intensity is probably not the best KPI to track. The real question is how one connects to innovation ecosystems. The fact that you are connected means that there is a significant return on even limited amounts of investment. The approach of having open systems with closed loops is the new world in which we are living.

I believe that there are 6 major disruptions underway today.

- First, the division of systems by 1/1,000.
- Second, people want green energy and a mix of green energy.
- Third, people are concerned with CO_2 emissions. In this area it is difficult to find technologies that are major disrupters, and CCS remains a major challenge.
- Fourth, for the first time we have an interconnection between the gas system and the power system at the local level, and there are many companies active in this field.
- Fifth, we are seeing the emergence of new energy chains: power-hydrogen-mobility, biomass-biogas-other products, and so on.
- Sixth, digital is everywhere and represents a major transformation. This raises many issues such as cyber security, the development of apps, the Internet of things, and data analytics.

In that context, ENGIE today can be characterised as being extremely open and connected.

Christoph Frei

You referred to the move from large systems to connected systems. What is the unique sales proposition for large companies in that context?

Raphaël Schoentgen

Our unique sales proposition is that we have a large customer base that we know extremely well. That is something that cannot be built up overnight and, without that, no technology is worth anything.

Carsten Rolle

R&D expenditure alone is not the right indicator here. I believe that being connected and implementing innovations from outside into the company is essential. It is also important to be much better at cooperating with other companies. So it is about the innovation culture of the whole company.

Christoph Frei

We all underestimated the speed at which solar technology developed. Why were we all so wrong and what can we learn from our mistakes?

Arnulf Grubler

It was very interesting to see that Raphaël Schoentgen's industrial perspective resonates so closely with the theoretical perspective.

With respect to solar, scenarios that took an alternative view, in which PV was a prototype of a distributed technology rather than a large utility-scale option, were correct: the market conformed to expectations, albeit with subsidies. We are very good at bringing granular technologies to market, and I am often asked about my favourite technologies. From an equity standpoint I very much like bicycles and radio receivers, which are the most widely distributed technologies worldwide. These technologies are used by the bulk of the world's people, including the poorest. Today, we have a third technology that has joined their ranks: the mobile phone, which has grown to 5 billion users in only 15 years. The reason for its spectacular success of all these technologies is their granular nature and the fact that they all represent a value proposition for the consumer and a new combination of knowledge (banking, social media, etc.).

Carsten Rolle

I am not sure that renewables are always decentralised and that traditional power sources are centralised. For example, there is a lot of wind in Germany but it is highly concentrated in a small number of locations. We see different trends, and there are drivers for decentralised systems from the investors' point of view.

Raphaël Schoentgen

One factor here is the capacity to take a given technology and reduce its costs. In this area, the scale effect matters. In the PV field, for example, there was a bottleneck in the production of silicium/silicon, which was in the hands of about 10 companies worldwide. Once the Chinese players were able to do overcome that bottleneck by re-thinking the production process, they were able to flood the market with products and drive prices down. That same principle applies to new technologies – they will only be massively introduced once their prices are driven down. Another factor is the industrialisation of projects. The most successful projects have surfed on the wave of new business models and subsidies. The roll out of a technology is therefore linked to these effects. The next question is the future development of solar after PV.

Christoph Frei

That provides a very good example of how to overcome fixations as presented earlier today by Pascal le Masson.

Arnulf Grubler

With respect to solar, it is clear that scale matters. There are two phenomena of scale that are paramount to the energy sector. First, economies of scale, using larger turbines, larger power plants, and so on. To date, all the cost improvements achieved in wind turbines have resulted from making the turbines bigger and bigger. However, there are limits to unit scales: it is possible to be "too big". It remains to be seen whether a 20 MW offshore wind turbine will not be at the frontier of that economy of scale. Second, the manufacturing scale. Here, ironically, there is no limit to size. There is only one drawback: having a single monopoly manufacturer will dictate prices.
As to the future of solar, I would sum that up in one phrase: too cheap to meter!

Christoph Frei

With respect to rural electrification, the cheap availability of both direct current (DC) technology and mobile financing has led to breakthrough business models in rural electrification. I find that a fascinating coming together of technologies. In which areas do you see the most fascinating clusters of technologies emerging?

Arnulf Grubler

I will answer that with a trick question: What is the largest energy flow in our human system? Waste. That is, it is the most important energy source that could be tapped but one that is being wasted. We now have new technologies on the market that could revolutionise this at the smaller scale. The usual model for innovation is government funded R&D with a strong military component that is then cascaded down into the civilian sector. The only massive way that thermal electric technology has cascaded down into civil society is in fuel-efficient cooking stoves used in developing countries, with a ventilator that works on the basis of a thermo-convection. This allows people to charge their cell phones via the stove. That is a very surprising application of a high technology product into a low technology product, and we could perhaps learn more from this example.

Carsten Rolle

I believe the greatest challenge lies not in the 10 technology fields that I highlighted but in the organisational and innovation management structures within companies. Shifting our companies to more open, risk-taking management cultures is a huge challenge that requires a complete change in mind sets. We also have to find a way to integrate a myriad of decentralised, small-scale solutions into a profitable business model. Managing this range of ideas so as to both allow them to develop and to generate profit is our greatest challenge.

Raphaël Schoentgen

In the field of electrons, artificial intelligence networks are a key driver of energy efficiency. If we want the different devices in a home to “talk” to each other, they need to talk the same language and the same contextual language. They must also be able to *trade* their electrons on the power network. On the basis of weather forecasts, the system would work automatically to optimise energy use and reduce energy bills. What comes next in technological terms are peer to peer sales of electrons on the network that occur without the intervention of the power companies – the *Airbnb* of electrons, if you like.

In the field of gas molecules, Mercedes, for example, is now developing fuel cell manufacturing plants for its fuel cell cars. It is also developing energy related products in those plants. Something similar is underway in the area of hydrogen, and this is an area of interest for the future.

Christoph Frei

Of course, when it comes to artificial intelligence systems, an important question is who will control the associated multiple payment streams and financing. That is a fascinating question for the future.