FUTURE ENERGY MARKET DESIGNS: RESEARCH AND INNOVATION NEEDS

SUMMARY REPORT

An event organised under the auspices of the

Experts' Group on R&D Priority Setting and Evaluation (EGRD)

22-23 October 2018

Berlin, Germany

International Energy Agency (IEA)

The IEA is an autonomous agency established in November 1974. Its mandate is two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply and to advise member countries on sound energy policy. The IEA carries out a comprehensive programme of energy co-operation among 29 advanced economies[1]. The Agency aims to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations, and other stakeholders.

Since the 1980s, the IEA has continued to build good working relationships with countries beyond its membership, in particular major energy consuming, producing and transit countries. Countries with which the IEA seeks enhanced engagement including Accession countries Chile and Mexico, Association countries China, India, Indonesia, Morocco, and Singapore. Co-operation with these and other partner countries cover a wide range of activities, from joint workshops to in-depth surveys of specific energy sectors or data exchange. Combined, the IEA co-operates with more than 69 countries worldwide.

IEA Energy Technology Network

The IEA Energy Technology Network is an ever-expanding, co-operative group of more than 6,000 experts that support and encourage global technology collaboration. At the head of this vast network is the Committee on Energy Research and Technology (CERT).

Committee on Energy Research and Technology (CERT)

Comprised of senior experts from IEA member governments, the Committee on Energy Research and Technology (CERT) considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. Under the guidance of the IEA Governing Board, the CERT oversees the technology forecasting, analyses and the research, development, demonstration and deployment (RDD&D) strategies of the IEA Secretariat, notably through its flagship publication, *Energy Technology Perspectives*, and the series of energy technology roadmaps. The CERT also provides guidance to its working parties and experts' groups to examine topics that address current energy technology, or technology policy, issues. The CERT is supported in its work through four topical working parties, including the EGRD.

Experts' Group on R&D Priority-Setting and Evaluation (EGRD)

The EGRD examines analytical approaches to energy technologies, policies, and R&D on targeted, timely topics. The results and recommendations support the Committee on Energy Research and Technology (CERT), feed into IEA analysis, enabling a broad perspective of energy technology issues.

Executive Summary

Introduction

On 22-23 October 2018, the IEA Experts' Group on R&D Priority Setting (EGRD) held a workshop in Berlin to gain further understandings on research and innovation needs associated with future energy market designs. Technology experts from research entities and leading agencies across the world offered a wide range of perspectives and insights. The event was hosted by Project Management Jülich.

Rationale and Background

The increase in weather dependent renewable energy sources (RES) in the electricity grid has changed the way electricity is generated and transmitted. So to balance supply and demand in real-time, energy storage and demand-side management will play a crucial role. Also managing electricity to and from other energy sectors such as transport, heating, or industries will play a much more important role in the future power system. This technological transition is accompanied by a diversification of the stakeholders leading to a large number of "prosumers" entering the market.

To handle a more complex, dynamic and interdependent energy system requires a legal framework that allows for a more flexible supply. Governments need to focus on a number of policy challenges linked to system integration and market design over the next years. However, there is also important actions government should take related to Research&Development and below the EGRD list some of those.

Key areas for enhanced R&D efforts

Providing flexibility options

To reach the global goals in CO_2-reduction defined in the Paris Agreement a strong effort in the development and deployment of most carbon-neutral energy technologies is needed. A key ingredient are energy technologies that provide flexibility such as energy storage, intelligent grids and demand response technologies.

Efforts must be taken to provide a market value to flexibility which is not always the case in contemporary energy markets. A thorough understanding of possible energy market designs is needed to accelerate worldwide energy transitions.

Towards better markets: price signals, new technologies and services

A well designed electricity market needs to provide the right price signals. Increasingly dominant issues like intermittency, frequency stability and congestion need to be approached by both the supply and demand sides. Getting price signals right helps markets to adapt or push for new solutions. Research is needed to understand the possible impact of different pricing schemes.

Peer-to-Peer technologies such as distributed ledger and blockchain provide a new perspective on energy-trading since transaction costs are low. These create new business opportunities for companies outside the traditional energy supply chain. More research is needed to fully understand the impact of such technologies on energy market designs. To make peer-to-peer energy trading viable, new financial instruments are needed.

Many energy technologies are available on the market, though a number of new technologies are not on track. In particular, more knowledge on cost-efficient installation, implementation, system integration and sector coupling is needed, not least regarding impact on congestion and stability. The perspective is slowly **shifting from "energy" as the main good on the market towards "energy services"**. This will have long-reaching consequences to the market design as well as to the players on the market.

Future energy systems will rely strongly on digital technology. Since large amounts of often personal data are needed in the process, **data security** becomes an important point to consider. Data security should be given high priority in new market designs.

Living Labs for in-depth policy learning

Living labs and showcase regions provide an ideal opportunity to test different aspects of future energy markets, partially by allowing for regulatory exemptions from the existing legal framework in a "sandbox" setting. These allow evaluating the impact for both technologies and frameworks before rolling out regulatory schemes for the whole country. The living labs currently in place worldwide provide a great chance for in-depth policy learning and can be fed back into decision-making for new regulatory frameworks and business models.

Mission oriented RD&D

R&D funding should focus on solution-oriented transition pathways and be mission-driven, providing solutions to the energy transition. Multiple disciplines and multiple stakeholders will necessarily be involved in the process. An important and challenging task is to ensure a high level of security of supply while allowing for new, possibly disruptive, structures in the energy markets.

Recommendations
• A thorough understanding of possible energy market designs will accelerate worldwide energy transitions and should be considered an integral part of future R&D programmes. • Flexible demand is likely to be one of the lowest cost sources of flexibility. A better understanding how to set the right price signals for flexible demand in any energy market is needed. • Distributed ledger technologies can have a high impact on the energy market and can serve as an instrument to provide flexibility on small scales. Block chain and peer to peer technologies should be considered as a possible alternative to traditional market schemes. • Data security should be given high priority in new market designs due to the large amounts of (often personal) data generated across multiple levels and interfaces. • Living labs are needed to test regulatory schemes in a "sandbox" setting and allow for the active participation of consumers. Future R&D programmes should allow for temporary exceptions from current regulatory frameworks to analyze their impact. • Lessons learned from showcase regions provide valuable insights for in-depth policy learning and should be fed back into into decision-making for new regulatory frameworks and business model. • RD&D should be mission driven, providing solutions to the energy transition. Multiple disciplines and multiple stakeholders will necessarily be involved in the process.

To access the full report please contact Birte Holst Jørgensen (bhjq@dtu.dk) or Johannes Tambornino (j.tambornino@fz-juelich.de).

Proceedings

On the following pages a more detailed overview of the workshop's key findings and results is given and the main messages discussed in each session are summarized. Each presentation is briefly summarized, the full slides can be found on the workshop's website.

Introduction

The workshop was opened by Johannes Kerner from the German Ministry for Economic Affairs and Energy. Germany has ambitious goals on its way towards an environmentally sound energy system which is at the same time secure, reliable, affordable and cost-effective. Within the 7th energy research programme, which was published in autumn 2018, a broad and systemic approach is followed. Besides accelerating the development of energy technologies the programme specifically aims at transferring innovations into the markets. A key element of this research strategy are living labs as a bridging instrument toward market uptake of technological innovation.

1. Challenges, obstacles and risks on the way to a low-carbon society

Observations and key messages of Session 1
• Most energy technologies are not on track to achieve a sustainable future: substantial RD&D efforts are needed to fulfill the CO_2-reduction goals • Government policy, market design and R&D will be instrumental to spur innovation, development and private investment. • Optimizing overall system flexibility is the key to cost-effective reliability • Flexible demand is likely to be the lowest cost, the most readily available and the least well developed among the many possible sources of flexibility • The locational value of electricity needs to be adequately priced

Summary and Discussion

To reach the worldwide goals in CO_2-reduction strong efforts in the development and deployment of most carbon-neutral energy technologies is needed. This includes several renewable energy technologies as well as technologies that provide flexibility such as energy storage, intelligent electricity grids and demand side management. On the regulatory side, efforts are needed to provide a market value to flexibility which is not always the case in contemporary energy markets. The locational value of electricity needs to be adequately priced, e.g. by nodal pricing systems. Cooperation amongst various stakeholders will be an important aspect to solve the current problems. Future markets should be designed considering a balance between optimal regulation and competitive markets allowing some degrees of freedom in energy production and utilization.

Presentations

According to the recent IEA-report Tracking Clean Energy Progress (TCEP) 2018 presented by Carrie Pottinger, the deployment of most energy technologies is not on track to achieve a sustainable future and substantial RD&D efforts are needed to achieve a global temperature stabilisation within a range of 2°C of today's level. Although the worldwide renewable power generation grew by 6% in 2017, important innovation gaps still exist. Among all renewable energy technologies only solar photovoltaics – with a record growth of 34% in 2017 - is considered to be on track, whereas on-shore wind lost its on-track-status recently. To integrate the large scale renewables into the energy system, technologies that provide flexibility are needed. These include energy storage, smart grids, demand response, hydrogen etc. A huge potential remains and energy system costs can be substantially reduced. Worldwide, investments in clean energy technology development are increasing: 2017 recorded the highest clean energy public R&D investment after a few years of stagnation. The agreed upon doubling of RD&D investments within Mission Innovation has a clear impact, but still more investment is needed, the public and private sector alike.

In his presentation "Insights on planning for power system regulators power" Andreas Jahn pointed out that a key ingredient to a RES-based energy system is a market design that considers the value of flexibility which is not always implemented in today's energy only markets. The market needs to be designed to provide reliability while at the same time minimizing the overall costs. Many concurring sources of flexibility are available. It is expected that contemporary market structures will change due to the development of RES costs and will shift the required revenue streams in the system from capacity to energy services. To achieve system security and resource adequacy at the least possible costs, flexibilities such as ramping, storage, balancing area enhancement and dispatch intervals are the keys. The locational value of electricity has to be properly priced e.g. by bidding zones or ultimately nodal pricing designs. However, the transition from one market system to another is difficult as well as expensive and therefore needs to be carefully planned.

2. New technologies and future business models

Observations and key messages of Session 2
• A shift in perspective can be observed: "energy" is replaced by "services" as the main good. • Distributed ledger technologies such as block chain can have a high impact on the energy market and can serve as an instrument to provide flexibility on small scales • The changing energy market provides many business opportunities for new companies outside the traditional energy industry • Data security will become an important factor

Summary and Discussion

New technologies and business models for future energy markets were discussed with a strong focus on peer-to-peer and distributed ledger technologies. The regulatory challenges associated with peer-to-peer energy trading are challenging. Distributed ledgers technologies have the potential to democratize the energy markets as innovative flexibility is introduced with low transaction costs, making the trading of small amounts of energy profitable. Still, the question remains how to socialize the cost of the grid infrastructure if more and more customers become autonomous prosumers. The argument was made that peer-to-peer trading schemes can work only if they are 'consumer-led'. To make peer-to-peer energy trading viable new financial instruments are needed, especially in developing countries where conventional financial markets are not strongly developed.

The perspective is slowly shifting from "energy" as the main good on the market towards "services" and this might have long-reaching consequences to the market structure as well as to the players on the market. Monitoring, collection and analysis of energy data (often private of confidential) will be an important part of future energy markets. On the one hand this brings up opportunities for new business models and new players on the energy market. On the other hand, data security becomes an important issue.

Presentations

Fumiaki Ishida presented on VPP and P2P power transaction using blockchain technology. Kansai Electric Power Company, the second largest power utility company in Japan, launched a virtual power plant (VPP) project in 2017 to serve as a living lab for novel power distribution technologies.

The largest demonstration project in Japan using novel approaches like control value grasp and feedback control was created, attracting even more partners afterwards. Roughly 25 MW of distributed power resources (such as residential batteries, BEV, DSM, …) are linked together and made controllable by a central aggregator. On top of it, direct trading between different actors is possible using a blockchain approach. For Kansai Electric this project gives valuable insights into the future of the power business when the traditional role of utilities shrinks due to a massive introduction of RES and new business models have to be explored. Monetization and deregulation are seen as the biggest challenges in P2P trading.

David Shipworth presented on P2P energy trading using distributed ledgers. A supply-led energy system with bidirectional flows at the grid edges requires demand-supply matching already at the local level. This could be realized through local markets using digital technologies, one option to keep transaction costs low are distributed ledger technologies. First attempts are currently made by Electron[1], a British company that uses a blockchain to release value through collaborative trading of DSR as a non-rival good. However, regulatory challenges are tough on national as well as European levels. EDF Energy R&D UK has recently launched the "CommUNITY project" as a regulatory sandbox to create a P2P-trading platform that aims to allow residents in urban areas to source their energy from local renewables and trade that energy with their neighbours, increasing self-consumption of low carbon energy and reducing overall energy costs. Here legal questions such as P2P-contracting, data privacy and the legal status of the "prosumer" can be explored.

Armin Wolf gave a presentation on Demand response tools and new business models for energy cooperation. The three-year EU project FLEXcoop was launched in 2017. It focuses on the introduction of innovative flexibility-based demand response tools and novel business and market models for energy cooperatives. The overall objective of the project is to provide advanced hardware and software solutions, ICT services and innovative business models for stakeholders involved in electricity markets that deal explicitly with demand response. More specifically, the project strives to provide three solutions: 1) tools that empower prosumers to actively participate in the energy markets, for example by enabling aggregators to segment individual flexibilities and cluster aggregated volumes in order to offer balancing and ancillary services; 2) interoperability based on open standards, a so-called end-to-end interoperable automated demand response optimization framework; and 3) value chain empowerment allowing a fully automated solution which segments, classifies and clusters demand and storage assets as aggregates. Solutions will respect prosumers' privacy and applies with the EU General Data Protection Regulation. In conclusion, FLEXcoop enables energy cooperatives to fulfil the role as aggregators and their members to become active prosumers in the energy transition.

Georg Erdmann presented the Innovation for Cool Earth Forum (ICEF) fintech solutions. ICEF is an annual event in Tokyo with more than 1,000 participants from ~80 countries that convene to discuss technological and social innovations in order to achieve the ultimate goal of achieving "net zero CO_2 emissions". There are two categories: A for technologies foreseen by 2050 and B for business model transformation. Regarding fintech innovations, these include blockchain, Internet-of-things, data mining, artificial intelligence, mobile payment systems and micro finance and crowd funding. Important to notice is that fintech solutions will only be successful if providing better solutions than the conventional financial solutions. Also the primary goal is not GHG reductions, which rather are

[1] www.electron.co.uk

unintended side effects. Such case is the replacement from old 2-stroke tricycle to a new, more efficient 4-stroke tricycles financed through a financial scheme that by means of MCCS can deactivate the engine if the financial obligation is not fulfilled. Another case is the TRINE Fintech company that closes the gap between private capital in developed countries and solar companies in emerging markets, offering an alternative finance solution to off-grid solar projects through a novel crowdfunding model.

3. Energy transition: showcase regions

Observations and key messages of Session 3
• Living labs are needed to test regulatory schemes in a sandbox setting and allow for the active participation of consumers. • Lessons learned from these showcase regions provide valuable insides for in-depth policy learning and can be fed back into into decision-making for new regulatory frameworks and business model • The living labs do not replace the need for traditional large scale demonstration labs where failures are allowed and solutions tested beyond their normal operational limits

Summary and Discussion

Four different examples of showcase regions from Austria, Denmark, Germany and the Netherlands were presented. Within these showcase regions different aspects of future energy markets are tested and researched upon, partially by allowing for regulatory exemptions from the existing legal framework in a sandbox setting.

Living labs are needed where solutions are exposed to real life challenges also those not foreseen. This includes the test of regulatory schemes which may facilitate new business models and allow for the active participation of consumers (residential as well as industrial). Living Labs allow for evaluating the impact for both technologies and frameworks before rolling out regulatory schemes for the whole country.

The living labs currently in place in different countries of the world provide a great chance for in-depth policy learning. Results of showcase regions and experimental cases and their evaluation are of high value also for other countries and can be fed back into decision-making for new regulatory frameworks and business models.

New market design: The experiments or regulatory sandboxes may have unintended consequences for the liberalized energy market where suppliers and distributors are unbundled. Giving some stakeholders (e.g. collectives) favorable conditions for peer-to-peer production and distribution may jeopardize the existing business model of others (e.g. aggregators providing flexibility to grid operators, project developers etc.). The question whether such bottom-up activities will lead to re-bundling of the electricity markets has to be intensively monitored.

The living labs currently in place do not replace the need for traditional large scale labs, which are still needed for traditional large scale labs where failures are allowed and solutions tested beyond their normal operational limits.

Presentations

Dutch experiments with law and governance were presented by Imke Lammers and Lea Diestelmeier from University of Twente respectively University of Groningen. They go back to 2012 where 12 IPIN[2] pilot projects were launched with financial support from the Dutch government. Also a Crown decree was implemented that allowed the projects owners to investigate novel organisational forms for renewable distributed generation at local level, utilize the local grid more efficiently, engage the consumers much more actively and finally evaluate the outcomes and possibly adjust the legal framework in 2019. In short three exemptions were introduced: Firstly, the legal monopoly of DSOs was exempted as collectives could carry out distribution at the operational level; Secondly, collectives automatically would receive supply license; and thirdly, the network tariff approval was exempted as collectives could establish dynamic tariffs. The evaluation of the projects revealed that there was a risk of re-bundling as the new governance form might impose restrictions for other actors and thereby eliminate the competitive market forces. These could be aggregators managing flexibility in the grid or new commercial activities based on storage options. It was noticed that there was little consumer involvement in the pilots. The key message was that the decree was too restrictive and time-constrained for such new modes of governance for a decentralised energy system in real-time setting. If similar experiments are undertaken in the EU, this might lead to different perhaps even contradictory governance modes in the EU energy union.

The Green Energy Lab was presented by Herbert Greisberger on behalf of Cluster Manager Susanne Supper. The Lab is one of three flagship regions Energy in Austria, which were inspired by the Energy Flagship Region at the Forum Alpbach in Tyrol in 2015 and based on the lessons learned in 15 exploratory projects to bridge the gap between research and market. The other two are NEFI (New Energy for Industry) and WIVA (Hydrogen Initiative). The Green Energy Lab covers 4 federal states and energy suppliers (with much renewable energy – wind and PV) and app. 5 million consumers from both rural and urban areas. Already 100 partners have joined and more are expected to join this open innovation, co-creation process to foster end-user integration in an energy system with up to 100% renewable energy. End-user integration is considered decisive for success and consumers are engaged in sub-projects, in calls, in public open days and tours and through social media. The first projects have just started, including ICT4Smart H&P, ThermaFlex, Blockchain Grid, Second Life Batteries for Storage and Green Energy Lab OpenDataPlatform.

The WindNODE showcase was presented by Marcus, Gräbig, CEA of WindNODE, which is one of five German showcase regions supported by the German SINTEG smart energy programme (German Federal Ministry of Economic Affairs and Energy) with more than 230M€ in 2017-2020 and >500M€ total budget. WindNODE is supported with 37M€ and covers the Eastern part of the country with more than 16 million inhabitants, one control area and more than 70 partners from industry, academia and public authorities. It is also a region with a high penetration of renewable electricity (>53%) and hence focuses on utilizing flexibility to cope with intermittency – technically, economically, digitally and communicatively. More than 20 visitor sites make up the core activities with contribution from the partners, e.g. Battery Farm, Lidl supermarkets in Berlin, grid simulator, power-to-cold exhibit. Showcase regions hence represent the third pillar of the public R&D intervention following basic and applied R&D. They are also regulatory sandboxes (a regulatory

[2] Innovatie Programma voor Intelligente Netten: https://www.rvo.nl/actueel/videos/innovatieprogramma-intelligente-netten-smart-grids-voor-de-toekomst

exemption from the energy laws was put into place in Germany for these projects) where it is possible to align the technical energy capabilities with new viable business models and promote energy transition narratives.

Living Lab for New Energy Technology, the Bornholm case was presented by Jacob Østergaard, DTU. The recent Energy Agreement approved by all political parties in Denmark provides further ambitious targets for the Danish energy systems, including 55% renewable energy consumption and 100% renewable electricity by 2030. As part of the Agreement, test zones are foreseen to bring solutions closer to the market by demonstrating their applicability in an operational environment (TRL 6-7). Already today, there are several living labs, for example the EnergyLab Nordhavn, energy collectives in residential buildings and Bornholm Eco-grid. Bornholm is a Danish island with 40,000 inhabitants and a 100% renewable electricity and district heating system, one cable to Sweden and 100% smart meters roll-out. This award winning demonstration island tests frequency services from demand, consumer behavior, grid integration vehicles (incl V2G), advanced wind turbine control, demand response and flex markets. It provides high reliable simulation, models and data of the energy system, which in Ecogrid 2.0 can provide a new market for flexibility. By allowing for alternative/new regulation schemes, it will be possible to investigate interaction between technology, business models and regulators, to evaluate the impact of such new regulation and emulate different frameworks. It will allow for the active engagement of energy collectives/communities where consumers collectively can optimize the usage of resources, trade lack or excess of energy while still allowing each member of the community to optimize her/his assets in a non-profit virtual node between market and the system operators. In conclusion, living labs are important for maturing the solutions and facilitate collaboration. Regulatory frameworks are perhaps the most important barrier for new innovative solutions and test zones will accelerate such solutions. Traditional large scale labs are still needed to allow for failures and test solutions beyond their operational limits.

4. Energy market design: towards R&D policies and decision making

Observations and key messages of Session 4
• The technology is available, knowledge on efficient implementation and system effects is needed • A redesigned electricity market should provide the right price signals • RD&D should be mission driven, providing solutions to the energy transition and include multiple disciplines and stakeholders in the process. • Security of supply must be ensured while allowing for new, possibly disruptive, structures in the power markets at the same time.

Summary and Discussion

Renewable technologies, storage and smart technologies are available and affordable. However, the implementation highlights a new set of issues on the system level. In addition, the large scale spread requires more cost efficient and coordinated installation to integrate into the existing system, not cause grid problems i.e. congestion and stability, and be most effective. The growth of the Singapore Smart Multi Energy System is a key example of combining several measures of efficiency and renewable energy. Successful operation and cost reductions indicate project success and demonstrate possible system wide benefits.

A redesigned electricity market needs to provide the right price signals. Increasingly dominant issues like intermittency, frequency stability and congestion should be approached by both, supply and demand sides. Getting price signals right helps communicate scarcity to the market which can adapt or find new solutions.

Funding, research and demonstration needs to be conducted on solution oriented transition pathways. RD&D should be mission driven, providing solutions to the energy transition. Multiple disciplines and multiple stakeholders will necessarily be involved in the process. An important and challenging task will be to keep the security of supply on high level while allowing for new, possibly disruptive, structures in the power market.

Presentations

Alexander Zerrahn presented on Solar PV prosumage: pros, cons, system perspectives. The growth of prosumage, distributed producers with storage capacities, is promoted by direct subsidies, falling battery prices and falling LCOEs compared to market electricity prices. In Germany, every other newly installed system under 30kWp PV includes storage. 85,000 systems currently (data for end of 2017) provide 600 MWh of battery capacity with the expectation of a strong increase after 2025, when systems fall out of the fixed feed in tariff schemes.

Modelling a stylized scenario for Germany 2035 indicates that optimal storage capacities increase if prosumagers consume wish for higher shares of self-generated electricity. The effect is moderate up to 65% self-generation and strong beyond 70%. Optimal storage capacities are substantially greater if the DER system is fully integrated in the grid, meaning optimal reaction to spot prices. The additional system costs due to prosumage amount to 170-210 million Euro (0.5-0.6%) of total system costs at 60% and up to 2.9% at 70% self-generation. This cost increase is smaller if prosumagers use their PV and battery installations fully integrated, i.e., in line with current market signals. The model further suggests that if consumers wish for higher levels of self-generation, sector coupling with heat and mobility is beneficial to the system.

Hiang Kwee Ho presented on R&D policies to transform and decarbonise the energy system and markets on the example of Singapore: Singapore has an oversupplied electricity market with 13.6GW of installed capacity and 7GW peak demand.

The Research, Innovation and Enterprise Plan (budget $19 billion for 2016-2020) promotes closer integration of strategies, more competitive funding instead of institutional support, a focus on value creation with public-private research partnerships and better manpower for research. Decarbonisation is a relatively new and important driver. The new National Energy Transformation Office synergizes energy R&D efforts between departments. It will take a holistic market perspective to suggest and initiate activities to cut costs, improve reliability and security and cut emissions.

Measures taken to redesign the Singapore energy market include: further market liberalisation where all customers can choose their retailer, new regulatory frameworks for easier deployment of DER, a carbon tax on power plants and large emitters, intermittency pricing mechanism for spinning reserves and grid modelling at different spatial levels and timescales.

Hans-Günther Schwarz presented on Scalable technologies, business models and societal challenges, why energy R&I requires mission orientation and political vision**:** Innovation was conceptualised in the 1970's and 1980's as a linear model, from basic research to applied research, experimental development and pilot/demonstration phase. This simplified model was defining technology as a systems dimension focussing on economic needs and funding gaps that lead to "valleys of death" in the development process. Modern innovation theory looks at innovation as a multi-dimensional process and innovation in complex systems is described in terms of transition pathways.

While traditional innovation theory promotes an innovation-chain, leading to innovation funding, it has been replaced by a circle thinking leading to multi-dimensional process approach. The question arises if R&D funding should only focus on technology and business cases?

A better approach would be a right choice of dimension and reduction of density. Understanding a complex system requires a set of dimensions, which allows to keep the whole system in view. Our standard scientific disciplines are not necessarily able to adopt a systems view – often they operate within one systems dimension only. Technology, for most systems, is not a systems dimension, it is rather an enabler for solutions

An analysis on Market design and regulation during the transition to low-carbon power systems: policy recommendations was presented by **Stefan Lorenczik**: The IEA's WEO 2017 presented the discrepancy between New Policy Scenarios and a Sustainable Development Scenario, considering varying levels of ambition and technological options. A key challenge are intermittent capacities which will provide 33% of the energy mix globally.

The approach to increasing capacity, needs to focus on costs i.e. the lowest price to incentivise renewables and the right capacity mix. Recently introduced renewables auctions are an improvement over fixed tariffs but system requirements must play a bigger role in a priori technology decisions. The value of generation i.e. generation and demand match, should replace traditional generation cost assessments like LCOE. Grid constraints require a new focus on resource location. Instead of grid capacity expansion location-price signals can help guiding investments.

Increasing discrepancy between generation cost and consumer prices discourage efficient response and innovation. Customer response should be based on the real-time price for power. Considering that most consumers would not want dynamic pricing, it would still be beneficial as intermediaries can harness opportunities and manage customer loads.

Household electricity demand peak is likely to increase from addition of EVs, heat pumps and electrification of household appliances. This will bring new challenges for supply security. Peak demand will increasingly be caused by households, requiring new incentives to smoothen demand. Price signals can regulate consumption which, again, can be facilitated by intermediaries managing customer loads. Further distribution system operators will play a more active role. In addition to grid development, DSOs will need to manage increasing demand side changes like distributed generation technologies.