Sector Coupling – buzzword or future of the energy supply

Wolfgang A. Benesch

Kurzfassung
Sektorenkopplung – Schlagwort oder Zukunft der Energieversorgung

Sektorenkopplung ist heute in der Energiebranche in aller Munde. Kann sie aber das leisten, was sie häufig damit versprechen? Oder gibt es gar noch ungenutzte Möglichkeiten? Was sind die Hemmnisse? So sollen z.B. Produktionsprozesse an das Stromangebot gekoppelt werden. Das heißt aber, dass eine Produktionsanlage, die sonst in der Grundlast fährt, nur zeitweise zum Einsatz kommt. Die Investitionskosten bleiben aber gleich. Können günstige Strompreise das bei den Preisen der Produkte aufwiegen?


Die Beschäftigung mit der Sektorenkopplung verlangt, dass sich Unternehmen wechselseitig mit ihren Prozessen beschäftigen, die bisher gar nicht im engen Dialog standen. Nicht nur technische Hindernisse, sondern auch mentale Hürden müssen genommen werden. Lasse ich es zu, dass ein fremdes Unternehmen Einblick in meine Geschäftsinterne erhält?

In dem Beitrag sollen mögliche Ansätze diskutiert werden um zu erkennen in welche Richtung zukünftige Methoden und Anreize der Sektorenkopplung gehen müssen, um die Energiewende erfolgreich unterstützen zu können.

Sektorenkopplung wird mit weiter wachsendem Anteil volatiler Erneuerbarer Energien immer stärker von Bedeutung sein, gerade wenn man den Gebäudesektor und insbesondere den wachsenden Strombedarf durch Elektromobilität sieht. Wie kann es gehen und wie nicht?

Sector Coupling plays a major role in any discussion about energy turn around. But is Sector Coupling as effective as desired? Or are there other possibilities that have not been considered? What are the constraints? Manufacturing processes should be coupled with the electricity supply. That would mean that a production facility, which is typically running on base load, will only be operated intermittently in the future. The investment in the manufacturing facility remains the same. Could flexible production be compensated by a lower electricity price while keeping the overall product price on the same level?

How flexible is the manufacturing process itself? What is the consequence of intermittent production on product quality? What kind of inherent storage capacity does the manufacturing process offer? Therefore, the time dependence of the production process has to be analyzed carefully.

Are there even unused synergies which could be used with directed efforts, leading to positive results under consideration of „Total Cost of Ownership“? Certainly, it is not easy to find appropriate business models that make such ideas of Sector Coupling attractive to companies.

The evaluation of the Sector Coupling requires analyses of processes of companies that had not been in dialog before. Not only technical hurdles have to be overcome, but also intellectual processes. Do I allow outsiders to look inside my company?

The paper will discuss in which direction future methods of Sector Coupling have to be directed to effectively support the energy turn around.

Sector Coupling will become even more important in the future when buildings and the transportation segments will be implemented. Especially the latter with its increasing electricity demand will be challenging. How can it work and how not?

Sector Coupling is a buzz word in today’s discussion about the energy turnaround. It should solve most of the problems associated with the “energy turnaround”. But is the implementation of Sector Coupling able to deliver what is required? Are there new opportunities? What are the hurdles?

How can the current situation be characterized? CO₂ emissions should be reduced. But between other kinds of energy, electricity is loved. It is predicted that demand for electricity will continue to grow. For instance in Germany, for the last 10 years, the annual consumption of electricity has been stable between 550 TWh and 600 TWh, although efficiency has increased. At the same time new usages for electricity have been added. In future, the consumption of electricity will increase dramatically from current 600 TWh to 900 TWh or even up to 1,200 TWh, depending especially on the role that e-mobility will play.

Currently dispatched conventional power is used for backup and stabilization purposes. But to reduce carbon footprint other ways have to be selected to insure the security of the electricity supply. Sector Coupling could be part of the solution. In addition, raw material loops (C, H₂, O₂ ….) have to be closed. Standalone solutions can be one way to reduce CO₂ and stabilize systems. But is this the most effective way? Reaching these goals by avoiding economic disadvantages and electric shortages is expected.

The power, heat, and mobility sectors have fulfilled their tasks to reduce CO₂ and use of renewables in different ways (Figure 1). Until now the power sector has already done significantly (37,8% in 2018) compared to other sectors and it is still increasing. The latest figures for 2019 show about 43% renewables in the power sector. Figure 1 also shows clearly that a joint development could be of help also for the other sectors.

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Sector Coupling – where and how – an analysis

Deeper analysis of Sector Coupling can be described through four points of view:
From the physical view: electricity, heat, fuels and other chemicals
From the functional view: power; service to households; service to industry, trade,
and commerce; and at least the use in the mobility sector.

From the component view: grids (electricity, heat, gas, communication) and storage devices (electricity, thermal, chemical)

And from the socio-economic view: energy business, energy politics, acceptance of consumers

Besides technology, this shows the importance of factors like public acceptance and politics. Clear communication is needed to describe the pros and cons of the selected technologies. Incentives for different stakeholders should stimulate acceptance.

Examples for the successful coupling of sectors

Sector Coupling is not something new. There are historic examples where experience could be gained. Today, the telecommunication industry covers sectors like telephone, photo and computer. This is only possible with exchange between these sectors, otherwise successful products could not have been developed. Other examples are the steel and coal industries or the well-known classical Sector Coupling of “Combined Heat and Power” (CHP). For many years, coupling of energy generation and construction by using fly ash for the cement industry and production of gypsum has been successfully established in coal based power generation.

These examples teach that Sector Coupling does not happen by itself. It has been developed to overcome various difficulties. Open discussion and even negotiation between the involved partners were of high importance. Looking to these examples, the question may be raised: Is coupling only possible and successful between two partners? Indeed a coupling with 3 or 4 partners seems to be attractive but no doubt it is more complex and can only be managed because of opportunities for digitalization as described later.

New business models

A successful business model is a precondition for the development of Sector Coupling. Again many questions arise in this context:

– Are there unused synergies that can be identified and used?
– Or is the opposite, “dys-synergies”?
– Are there still potentially positive results, considering “Total Cost of Ownership”?
– What is the main product?
– What is the by-product?
– Who is leading a possible partnership?
– What is the benefit for the individual partners?
– Are there macro-economic benefits that cannot be explored by one of the sector partners alone

More or less simple business models existed in the past (e.g., CHP). More complex business models are possible today applying digitalization. New ways of cooperation have to be exercised.

An example for a conflict can be described as follows. Electricity is offered based on availability for a production facility. For the manufacturer, this is a disadvantage when compared to electricity being offered through base load. Production based on availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production. The low availability of electricity forces the manufacturer to part time production.

On the other hand, the electricity generator, having to invest in surplus capacity and storage or other renewable back up power, would suffer economical disadvantages. Therefore, it could result in an electricity price which is no longer attractive to the manufacturer.

There are also technical implications which could occur because of part time operation of equipment, for example, increased fouling of membranes or aging of catalysts. Incalculable interruption of the operation of an assembly line can lead to bad product quality that cannot be corrected. Coloring of cars with interruptions may not look so nice for the customer!

Possible solutions for a partly compensation for the losses are:

– A subsidized lower electricity tariff to offset the described effects
– There are macro-economic effects that are able to compensate for the disadvantages
– Income from CO2 certificates
– Benefits of Sector Coupling itself in the sense of synergies (1+1>2)

Digitalization with its possibilities can attenuate these effects within limits by a more detail forecast, monitoring, and management of the process of fabrication.

An idea for partially compensating the economic disadvantage, from the “electrical view” point, could be by bringing conventional generation like gas combined cycle PP from peak load (2,000 h/a) to base load (6,000 h/a):

2,000 h/a pure electricity
2,000 h/a additional CHP
2,000 h/a additional industrial use
Summing up to at least 6,000 h/a.

An additional aspect that can influence the economics via a related business model is the application of inherent flexibility and storage options. It has to be evaluated in detail how flexible a production process can be in reality. Is interruption of production possible without a loss of quality of the products as mentioned above? “How sustainable is the need of electricity?”

Examples are: Demand Side Management (DSM) (e.g., cold storage houses or district heating networks) – Both can tolerate for a limited time either too high or too low temperatures.

The above shows that a detailed analysis which reveals time dependency of the discussed processes is especially needed – technically and economically.

Sectors in overview

For further understanding of the discussed items, the different sectors to be discussed will be characterized shortly.

Power

Generation of electricity which is the core of the power sector will switch more and more from conventional sources like: coal, nuclear and gas to renewables like: wind, hydro, PV or biomass (Figure 2). For a limited time, conventional generation will act as backup power. A bottle neck is currently occurring in the transmission capacity of electricity for the existing grid, especially from North to South Germany. Coupling of transport grids for electricity and gas can be an option to increase energy
transport capacity. Storage capacity is limited and only available for short term support. Mass storage is not available especially for long term bridging of electricity gaps.

Heat

Combined heat and power (CHP) as a prominent example for Sector Coupling has already been mentioned. But for sure, further extensions of district heating networks are possible. The different structures of district heating networks have to be considered. The German example shows the diverging development in eastern and western parts of Germany in the past. All over the country, differences between metropolitan and rural areas have to be distinguished. Particularly, when discussing renewable generation technologies centralized and decentralized heat generators must be considered.

STEAG can use its comprehensive experience in the district heating sector for expansion of this kind of Sector Coupling (Figure 3). In addition, the development in the building sector should be given attention.

- Reduced consumption – higher efficiency
- Low emission technologies
- Heat pumps
- Solar thermal heat supply
- Extension of district heating networks

Additional options are

- new use of night storage heaters
- electrode boilers for use of surplus electricity in the electrical grid
- simple heating rods to use surplus electricity in PV roofed residential buildings to heat water cheap for the next shower

Industry, Trade, Commerce, Services

Industry, trade, commerce, and services offer a wide field for applications of Sector Coupling. The disadvantage is that often the negotiations are not with one partner but with many. Equipment and solutions that can be used in this sector are:

- Electrification of heating processes
- Heat pumps (development also for higher temperatures)
- Synthetic fuels
- Hybrid systems using electricity and gas or synthetic fuels
- Use of waste heat and extension of waste heat networks

Demand side management (DSM) is an effective tool across the sectors of industry, trade, commerce, and services. Load shifting in industrial and commercial but also private sector must be considered. The effectiveness of this measure depends on the level of the individual load that can be shifted and on the number of participants. In the industrial sector, the applications are few but high load. On the other hand, in the commercial and private sectors, the applications are many but small load. A bundle of small scale applications can be feasible. It is important that there is an incentive for the participants to offer this service. Intelligent management of load, consumption and storage is possible if combined with digitalization.

Mobility

Currently, mobility has the biggest problems regarding the energy turnaround and the implementation of renewables. Regulatory measures will increase the pressure for mobility to reduce emissions. Here the Sector Coupling could be especially of great help. The opportunities to be discussed are:

- Increase of efficiency over the full chain of energy use beyond the energy use of a car
- Battery electric vehicles
- Hydrogen fuel cell vehicles for long distances
- Synthetic fuels

These opportunities require a new infrastructure for storage and transportation. Sector Coupling is beneficial for these developments.

Mobility and the transportation sector have hidden costs which are usually carried by the local community (Figure 4). Increased truck traffic causes elevated emissions. Additional expenses of road maintenance are all born locally.

More local production can have very positive effects avoiding truck traffic. It is a macro-economic decision. More use of synthetic fuels will also have macro-economic effects. These examples show that Sector Coupling cannot only be arranged between direct trading partners because of macro-economic effects. As shown, sometimes a quite long chain has to be considered.

SWOT analysis of Sector Coupling

Figure 5 gives an idea of a SWOT analysis of Sector Coupling. Besides the desired increase of renewables, one of the major
The strengths of Sector Coupling is that it is aligned with current megatrends. Sector Coupling reinforces regionalization and promotes neo-ecology, driving sustainability and efficiency while considering socio-economic effects.

Opportunities, as show above, emphasize the well-established CHP model, but via detailed analysis new opportunities may be developed.

But also the weaknesses and threats are described in this article. These are costs of non-baseload production. The question could be raised: why Sector Coupling not only of 2 but may be 3 or more at the same time. Agreement about the leading partner. Each of these options must make sense and have to be integrated centrally, regionally or decentralized for where to locate this technical equipment: CHP and gas motors – Electrode boilers and heating rods

In a follow-on step, it has to be decided where to locate this technical equipment: centrally, regionally or decentralized for each sectoral partner. Each of these options must make sense and have to be integrated under certain economic boundary conditions.

Sector Coupling is not just pairing partners. It’s a complex system connected through a puzzle of many pieces which must fit together (Figure 6). Changing boundary conditions bring new or modified pieces into the puzzle. Overall, systems are optimized for efficiency. Oversupply of renewable electricity indicates inefficiency in the system. The process has lower value. When the supply of electricity is balanced with demand, the system has higher value. Similarly, a system is more valuable if electricity can be consumed flexibly. Processes that have these characteristics are favored. In addition, new feed stocks should be considered for other uses than waste heat: CO₂, H₂, and O₂. In this context, CCU (Carbon Capture Utilization) becomes a high value system in the energy turnaround puzzle.

For a successful Sector Coupling, the interconnecting sectors interlock together like pieces of a puzzle. Sometimes it is time consuming to find the proper piece.

The mentality question

Besides exchange of technical and economic information, intended partners also must share proprietary and confidential information of their business models to make Sector Coupling effective. It is a risk that partners may not be willing to take. However, because independent views provide different standpoints, breakout solutions

Fig. 4. Mobility and macro-economic effects.

Fig. 5. SWOT analysis of Sector Coupling.

How to complete the puzzle? Digitalization and transformation modules between the sectors

The energy turnaround needs dispatchable back up power. Sector Coupling can smooth out energy supply and demand. Creativity in designing Sector Coupling would lead to options and new solutions. Digitalization then monitors and steers these processes derived from problem solving concepts. Digitalization is the lubricant of Sector Coupling. So it is clear that digitalization and the modern internet would enable successful implementation of Sector Coupling. Clear rules are necessary. But at the same time, electricity consumption of the internet is part of the problem. Consumption of electricity for use of the internet is dramatically increasing. Internet consumption is near 200 TWh a year worldwide today. It represents one third of the overall electricity consumption of Germany. Therefore, special attention should be given to account for the significant portion of electricity use by the internet.

For transformation of energy between the different sectors some more or less complicated and thus costly technologies are necessary. Examples are:

- Simple heat exchangers
- Heat pumps
- Electrolysis
- Methanization technologies

Fig. 6. Missing pieces of the puzzle.
can be achieved. Then, I would ask what point of view should I take? From the electricity, or mobility, or industrial view point? The concern for risk in sharing internal information can be a high barrier for possible partners to implement Sector Coupling. It is a special – non technical – hurdle which varies with the mentality of each partner.

What are these hurdles and the related questions to be answered? What is my business model? What is my benefit? Why am I sharing my internal key figures to an external organization? Could my production or my products be influenced by Sector Coupling? It is my impression that the process of partnering could be compared with a marriage. A couple will never be happy if a spouse is thinking only about personal own benefit. For a long lasting partnership, things are developed jointly through thinking and developing activities jointly. It is meeting the common goals for the benefits of the family. Even in the most developed form of Sector Coupling – combined heat and power – some challenging questions sometimes arise. “If you would use my waste heat can my production process be affected? Can a failure in waste heat utilization have a negative impact on my production?”

The only way to solve these kinds of problems is open communication and problem solving to develop the necessary solutions. Problems include reducing CAPEX and OPEX but also improving or maintaining the quality of the products in a manufacturing process.

**Hydrogen, grids and regulatory framework**

Another piece of the puzzle is hydrogen. In the future, hydrogen will play a more prominent role in Sector Coupling. Already, there is great interest in hydrogen and there are many R&D (Research & Development) projects.

Hydrogen is not a primary energy. It has to be generated in future by renewables but it is currently mostly made by steam reforming. Sector Coupling without hydrogen is not possible. Flexibility and mass storage need hydrogen. As shown in Figure 6, hydrogen could be used directly as a fuel or a feedstock for making synthetic fuels.

Today, hydrogen is produced mainly from natural gas and coal via steam reforming. It is so called grey hydrogen. If CO₂ formed during steam reforming is separated and recycled, grey hydrogen “changes color” and becomes blue hydrogen. Surplus electricity generated by renewables can be transferred via hydrogen (green hydrogen) by electrolysis. Electricity can be regenerated later on again from combustion of hydrogen. It is important to increase the hydrogen generation independently of the source, to gather experience with the infrastructure and use of hydrogen. Economics is currently the biggest hurdle for green hydrogen, instead of grey hydrogen; but an energy turnaround and as well a Sector Coupling are enabled by the use of hydrogen. Related technologies for energy turnaround and Sector Coupling depend on hydrogen as energy carrier and chemical feedstock.

For the German market, plants are needed that can flexibly generate electricity or hydrogen. Depending on the market conditions, the plants can either produce hydrogen or electricity to maximize profitability. EEG must honor not the feed in of renewable electricity but the consumption of renewable electricity. Then it is possible to decide to sell or to store electricity. This would make renewable hydrogen more attractive.

In the context of Sector Coupling, all products and by-products should be used in the future. A key to improving the business model for production of hydrogen by electrolysis is to profitably turn oxygen into a co-product of hydrogen.

Another challenge in using large scale electrolysis to produce green hydrogen is the use of a large amount of water. When talking about electrolysis in huge dimensions not only the electricity consumption has to be considered but also the consumption of treated water. The water consumption to bridge a two week dark doldrum could be like the drinking water consumption of a 200.000 inhabitant city in a year. So this restriction is limiting the hydrogen generation in very sunny regions where sufficient amount of water is typically not available.

Today, hydrogen is used by industry for refining petroleum, treating metals, producing fertilizer, processing foods, cooling electric generators, or driving fuel cells. In the steel industry, a transformation process will happen when hydrogen replaces coke to reduce iron. However, this form of Sector Coupling will be determined by the new world price of steel and the resulting economics.

Hydrogen could play a strong role in energy storage and as grid stabilizer in the future. Surplus electricity from renewables could be used to generate hydrogen via electrolysis. Hydrogen could be transported in the natural gas grid and converted to electricity at a later date. It is also energy for fuel cells. Thus, the sector power can be coupled with the sector gas.

Open Grid Europe (OGE) and Amprion, as transmission system operators to be responsible for the planning, construction and operation of the sector transformer, i.e., the power-to-gas plant. This is intended to be financed through network charges.

A key approach for solving the problem of increasing quantities of electricity from wind and solar that do not always find consumers is to direct this electricity to other sectors – where large amounts of energy are required. This is technically possible by coupling the existing infrastructures of the German electricity and gas system with each other. Power-to-gas systems act as a bridge between the individual systems. Similarly, hydrogen can be a feedstock for producing synthetic methane.

Today, this transformation and transport of electricity takes place within each system separately. For example, in the electricity value chain, power plants feed electricity into the grid. This electricity is then transmitted via transmission lines, passed on to other voltage levels via current transformers and transported on from there to the end customers. Gas transport works in a similar way – from the transport network via the regional network to the distribution network. The power-to-gas approach provides an option to transport energy between sectors. Here, electricity is converted into hydrogen in the power-to-gas system, fed into the gas system and transported on to the respective point of consumption. There are three criteria crucial for Sector Coupling to achieve maximum economic benefits and maximum sustainability:

- **Size**: The power-to-gas plants must be integrated into the electricity and gas system in a suitable dimension and at large scale.

- **Location**: The systems must be installed at suitable contact points between the electricity and gas transport networks.

- **Timing**: It must be possible to coordi-
Thus far Ø, new chain of subsidies? Who should have a incentive to stimulate the process avoiding a benefit? What are the strong drivers? How do we deal with sector transformers to gas is not free of charge. At least we have to avoid the crazy situation that we are not able to erect the necessary electrical transmission lines and instead we switch to the gas grid. We are moving one bottle neck (e.g. transmission) to the next bottleneck (natural gas transmission) or we put the gas even on the railroad and find here a new bottleneck. To say it clearly a positive interaction between the sectors is needed and desired but to pass the buck to the next should not be allowed.

Grids are the backbone of the energy turnaround. Sector Coupling had not been a topic in days of the unbundling discussion. How do we deal with sector transformers electricity to gas and vice versa as described today? How does it fit in comparison to transport and distribution grid? We have to define what the task of electricity grid operators, gas grid operators and plant operators is. The question is what has to be changed if Sector Coupling is considered seriously? Who should get which incentives to stimulate the process avoiding a new chain of subsidies? Who should have a benefit? What are the strong drivers?

Since submission of the EEG 2014 the principle had been hurt that only the last consumer should carry the burden of the EEG. Pure electricity storages are no last consumer. The big efficiency losses in power to gas technology are relieved from the EEG burden which is not in the sense of an efficient energy system.

Sector coupling and the necessary plants are no grid infrastructure and should be established in the competitive part of the energy system including flexibilities and gas and electricity capacities. They should not be in the hand of grid operators. The roles in the more and more complex energy systems have to be split clearly between regulatory and competitive tasks. A clear rule for electricity storages could be that received and returned electricity to the grid at the same location is unlimited free of any royalties. Flexibility, system services and capacity need a value. Price signals should stimulate balancing of supply and demand. The grid will be unburdened if this evaluation will already be done in front of the grid. The liability for the electrical balancing zones has to be consolidated.

In the public discussion, the understanding of the boundary conditions of Sector Coupling is far from the reality. Figure 7 illustrates the case of Germany

How does Sector Coupling react to a dark doldrum

When the wind is not blowing and the clouds are not driven away, also PV is not generating electricity. Mass storages are only the source of power if conventional generation is no longer available. Figure 8 shows a typical situation in the grid in Germany in the last 3 years. This could last up to two weeks in January and February in the last years in Germany

The figure shows clearly the importance of Sector Coupling to avoid black outs caused by dark doldrums.

**Fig. 7. Explaining the reality vs understanding of Sector Coupling.**

**Fig. 8. Electricity generation in Germany January 2019, Dark Doldrum source: Fraunhofer ISE, 50 Hertz, Amprion, Tennet, TransnetBW, EEX, last update: 09 Sep 2019.**

<table>
<thead>
<tr>
<th>Understanding</th>
<th>Reality</th>
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Boundary conditions for Sector Coupling – understanding and reality

### Understanding Reality

1. Electricity generated is unlimited.
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3. Power2Gas is low cost solution for mass storage and gas grid integration.
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### Understanding Reality

1. Due to not harmonized extension of renewable electricity generation and necessary grid extension, temporarily and regionally not needed surplus electricity is generated.
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### Understanding Reality

**Fraunhofer ISE, 50 Hertz, Amprion, Tennet, TransnetBW, EEX, last update: 09 Sep 2019.**
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Conclusion

Sector Coupling is needed to achieve the “energy turnaround”. Examples and further opportunities for Sector Coupling have been described. Identifying an appropriate business model requires a detailed analysis of the sectors and open exchange between partners. The different sectors had been described and analyzed by a SWOT chart. Digitalization is an important lubricant and hydrogen is one key technology to be implemented in many forms of Sector Coupling. Technical wise transformation modules are needed and have to be further developed. Hydrogen can be coupled with grids, but there are gaps in the regulatory framework. There is a mismatch between understanding and the reality about Sector Coupling. Special questions like the reaction to dark doldrums and the national and international experience of STEAG with the related topics have been discussed.

Many questions have been raised. These should not describe the problems of Sector Coupling but highlight possible ways to implement it successfully. It is productive when partners join in finding business models or improving technologies. In general, it is useful to clarify that Sector Coupling is only a part of the solution to achieve “energy turnaround”. It is not the only solution. A big hurdle is not the right technology but the mentality of the participating partners. An open and frank dialog is necessary to find possible good business models and to develop new technologies for Sector Coupling. Consequently, the use of the unpredictable renewables can be widened and storage technologies can be advanced, reducing further the share of conventional generation. Yes, Sector Coupling is a buzzword, but it can be an important part of the future of energy supply.

Increase of renewables is leading to a growing mismatch of generation and consumption. Sector Coupling can close the gaps between power generation and electricity consumption in a more effective way. Cross sectoral use of surplus electricity, which is generated unpredictably, will make energy turnaround more economical. In an increasingly more complex energy system, reform of the current regulatory framework would be necessary to facilitate competition and to increase efficiency in the market. It has to be clearly distinguished between the regulated and the competitive part.

The regulatory framework has to consider macro-economic effects and should not favor special technologies. A sector independent view allows economic benefits for each participant. Detailed analyses of the relevant processes have to be ensured although they are not “mine”.

Production processes which are less sensitive to non-base load operation and / or new economic models for non-base load production have to be identified. Besides economic benefits of coupling within one sector, there should be incentives for companies to consider multiple sectors. A more systemic approach would benefit from use of digitalization. Incentives must be developed for Sector Coupling to encourage communication and to remove unnecessary bureaucracy. Politicians should encourage support a low bureaucratic approach. Economic benefits have to be allocated fairly. Without an open and frank dialogue, positive examples for Sector Coupling will come slowly and costly.
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