FlexInd

Flexibilisation of industries enables sustainable energy systems

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Table of contents

Index of tables

Index of figures

Abbreviations

AbLaV	Regulation about interruptible load (German: “Verordnung über Abschaltbare Lasten”
BNetzA	Bundesnetzagentur
DENA	German Energy Agency (Deutsche Energie-Agentur)
DR	Demand Response
DSI	Demand Side Integration
DSM	Demand Side Management
EEG	German Renewable Energies Law
ESD	Effort Sharing Decision
EU-ETS	European Emission Trading System
GHG	Greenhouse Gases
MR	Minutes Reserve
PCR	Primary Control Reserve
SCR	Secondary Control Reserve
SNL	Fast interruptible Load
SOL	Immediately interruptible Load
TSO	Transmission System Operator
UBA	Federal Environment Agency (German: Umwelt-Bundesamt)

1 Introduction

The current global average temperature is 0.85°C higher than it was in the late 19th century. Each of the past three decades has been warmer than any preceding decade since records began in 1850.[1] Scientists have been able to show a relationship between global warming trends and emissions of greenhouse gases emitted by humans burning coal and gas. In responding, the EU has committed to limiting the mean global temperature rise to 2°C above pre-industrial levels. Therefore the European 2020 strategy that sets three main objectives for climate and energy policy to be reached by 2020 has been worked out:

- Reducing greenhouse gas (GHG) emissions by at least 20% compared to 1990 levels
- Increasing share of renewable energy in final energy consumption to 20%, and
- Mowing towards a 20% increase in energy efficiency

These targets are known as 20-20-20 targets. The main policy instruments to achieve the targets are the EU Emission Trading System (EU ETS) and the Effort Sharing Decision (ESD). Member states of the EU have committed to contribute with own targets. One main focus lay onto the re-building of power generation because of its huge amount of GHG emissions by burning coal and gas. Especially Germany has defined very ambitious goals with its transformation of the energy system, the so called “Energiewende”. Considering this fact this study gives deeper insights into the German transformation of the power generation and its consequences. Even in the context of re-building the energy system Belgium faces some supply challenges in winter times- due to that a specific look is given to Belgium with this study, too.

1.1 Project motivation

To meet the EU 20-20-20 targets the rebuilding of power supply has been started, especially in Germany that aims to reduce its GHG emissions of about 40% compared with 1990 levels. In 2020, 35% of the electrical power shall be generated by renewables in Germany.

Main advantage of burning fossil fuels to generate power is the independency of the fluctuation of wind and sun. Replacing those “conventional” technologies by wind and solar energy in a significant amount entails challenges in terms of security of supply, especially in the point of view of industrial and energy-intense companies that need a base load in energy supply. Production technologies are mostly operated continuously in large production facilities with a high degree of capacity utilization to be able to be competitive in an international environment.

Since the beginning of this century increasing shares of renewable electricity are produced with large volatilities in supply. In 2015, the share of renewable electricity production in Germany amounts to 30 % of the gross electricity generation[2] and the share still grows. As storage options are scarce, energy-intensive industrial production capacities and technologies are regarded as an option to deliver demand side response (DR) and demand side management (DSM) as virtual battery/storage site. That presumes an operation mode of

[1] http://ec.europa.eu/clima/change/causes/index_en.htm

[2] http://bmwi.de/DE/Themen/Energie/Erneuerbare-Energien/erneuerbare-energien-auf-einen-blick.html

production facilities lead by the amount of disposable power. Several scientific studies give estimations of the so called “DSM / DR potential” of energy intense productions as e.g. aluminum, cement, chemical, iron/steel and pulp/paper production. These results sometimes seem to be questionable from a point of view of industry – what is in some cases as well due to uncertainties regarding the different categories of potential, as to theoretical, technical and economic potential. The study at hand aims at clarifying the terms of potential, giving a meta-analysis of relevant literature and further to gather deeper insights in DR / DSM: its cost, the capability and willingness of industry to get involved in a flexible production mode for a future production.

1.2 Flexibility versus efficiency?

In recent years, industry in general has already become more efficient than before, moving along the path of 20 % increase in efficiency, as proposed in the EU targets (EED). These targets, however, are not to be reached very easily, but require increased efforts in all branches.

Critical voices are to be heard, that the flexibilisation of industrial processes is expected to contradict the aim of increasing efficiency. As (Kupzog, Roesener, and Palensky 2007) state, conflicts between flexibility and efficiency may arise in many cases, when realizing demand side management strategies.

The following effects are feared to decrease efficiency: operation of processes at a non-optimal operating point regarding load and degree of utilization, full-load hours, higher and more frequent modification of cycles, lower capacity planning of the plant, plant dimensioning etc. If the process control moves from optimized efficiency configurations to such that allow flexibility to a certain extent, the efficiency losses should be kept an eye on.

While indeed the measures linked with enhanced flexibility like the ones listed above can be expected to be contradictive to the increase in efficiency and vice versa, currently no in-depth studies regarding the effect is known. Only very low experience and R&D exist regarding the actual efficiency losses, based on specific plants and processes. Generally, it can be assumed that these losses occur, as experiences with single plants and processes have shown (see case studies in chapter 5.2). Yet, evidence is to be given and the effects have to be quantified for branches.

This conflict is - despite a poor data base - described as one important hurdle in exploring DSM potentials by the industrial partners and is elaborated further in chapter 5.2.

The benefits for the electricity system should be compared to this trade-off to provide an optimized plan for DSM based on ecologic and economic parameters, which is supported by the German government. It may be necessary to accept negative efficiency factors in the industrial production processes if they lead to a higher efficiency of the overall electricity system. However, further analysis is necessary to examine if the overall efficiency gains are sufficiently high to justify efficiency losses on a company level.

2 General overview

This chapter embeds the object of research, namely the DSM / DR potentials in a broader context: Shortly it is explained why there is a need for load management and flexibilities in principle (chapter 2.1), afterwards an overview about the different terms and types of load management characterizing the current discussion is given (chapter 2.2). The relevance of load management in context of other flexibility options is touched on (chapter 2.4).

2.1 Current and future demand in balancing power

The decarbonization of the energy system is one major objective in climate and energy policy in Europe and as well in Germany. “Decarbonization of the energy system” means replacing fossil based power generation (coal, gas, oil or other fossil energy carriers) by power generation based on regenerative energies like sun, wind or biomass. One main objective to reach such decarbonization is the integration of relevant amounts of renewable energies into a supply system constructed for a fossil based electricity supply. According to the current energy and climate political ambitions set by the German Federal Government (BMWi and BMU 2010), the renewable energies shall cover 80% of the gross electricity consumption in 2050 to achieve a reduction of greenhouse gases by 80% to 95% in 2050 compared to 1990.

An electricity system with high shares of renewable energy, such as wind and solar with its strongly fluctuating feed-in structure, is always subject to high requirements in terms of the stability of the electricity system. Furthermore many consumers require a relatively stable load for their energy-intensive productions. With increasing shares of fluctuating renewables, unbalances between supply and demand are likely to occur. The demand for flexibility within the system therefore rises. One of the options to balance supply and demand is to adjust consumers’ loads in accordance with stability needs of the system. Some Industrial companies call relatively high loads in continuous pattern because of production processes that are consuming a lot of energy (energy intensive industries). This implicates that several industrial processes could be able to contribute to integrate fluctuating renewables by offering a more flexible production mode. Thus, high balancing potentials are assigned to the industrial sector by various studies, which are analyzed in detail in the study at hand (see meta-analysis in chapter 3).

In the expert discussion focusing the challenges that accompany the transformation of the energy system it is widely acknowledged that the demand in balancing power increases with a rising share of volatile, renewable power generation. Since higher shares of renewable energies apparently mean a reduction in conventional energy production capacities, additionally the supply of balancing power, which is currently covered to a high share by the conventional capacities, will be reduced. As a result strongly increasing stress on the balancing power market for the future can be expected. But the above named drivers are only one part of a bigger picture. This becomes particularly clear by analyzing the empirical data of the demand in balancing power and increasing shares of renewables in the power sector over the last years. One present study that deals with this subject is (Hirth and Ziegenhagen 2015). The study shows that although the capacity of volatile renewable energies (wind and solar) has almost tripled during the period under consideration (2008 until early 2015), the balancing reserve[3] needed by the transmission system operators was reduced by approx. 15% (compare (Hirth and Ziegenhagen 2015, 11). Looking for the reasons for this correlation, several drivers influencing the demand and supply of balancing power - besides the fluctuating renewable production and attached forecast errors - can be identified. One important reason concerns the energy market: The minimum size of the two balancing products minute reserve and secondary control (see detailed description of products in chapter 4) was reduced and the 15 minute trading in the intra-day market was introduced. This measure has significantly strengthened the market mechanism. Improved quality in forecasts of renewable production as well as load curves and short term power plant deployment planning are factors counteracting the rising demand in balancing power (Energie-Forschungszentrum Niedersachsen Technische and Universität Clausthal 2013, 189). The demand was also reduced by establishing cooperation between the transmission system operators (TSO) in Germany in 2010 with regard to several balancing activities (Netzregelverbund) and also the increasing cooperation with the neighboring TSO is of importance. Furthermore the development of the last years was influenced by a reduced frequency of power plant outages ((Hirth and Ziegenhagen 2015, 12)). Also controllable renewable production plants like biomass and water power became authorized to prequalify to participate in the balancing power market and could be directly market at the same time (Pilgram 2013).

Table 2-1: Current demand in balancing power (average demands for October 2014)

Product:	Average negative demand (MW)	Average positive demand (MW)
Primary control reserve	783	
Secondary control reserve	2002	2057
Minute reserve	2211	1777

Although this overcompensation of the influence of higher shares of renewable energies in the power sector was clearly visible in the last years, one can nevertheless expect an increase in the demand of balancing power in the long run. The additional increase in balancing power market efficiency is relatively small compared to the share of renewable power generation that is aimed at. One study that quantifies the future demand in balancing power is conducted by the German Energy Agency ((Deutsche Energie-Agentur GmbH (dena) and Technische Universität Dortmund / ef.Ruhr GmbH 2014). Here, the demand for minute reserve and secondary control for the year 2033 (each differentiated in positive and negative[4]) is based on the power generation mix formulated in Scenario B 2033 (of the scenario frame work, attached to the network development plan (Netzentwicklungsplan) (see 50 Hertz u. a. 2012)). In this scenario, the share of renewable energies on gross electricity production amounts up to approximately 60% in 2033 (50 Hertz et al. 2012). Under these circumstances, the positive secondary control as well as the minute reserve is thought to increase quite strongly. Assuming constant forecast accuracy for the feed-in of power based on volatile renewable energies, growth of 70% resp. 90% in the demand of negative resp. positive

[3] In this case the balancing reserve includes the secondary and the tertiary control, each the average of the positive and negative reserve.

[4] Positive balancing power: reduce load or increase generation in times of power shortages; negative balancing power: increase load or decrease generation in times of excess power. See also chapter 2.3

minute reserve is estimated compared to the reference year 2011. The increase in the demand for secondary control is relatively small regarding minute reserve: 10% for the negative and 40% for the positive product compared to the reference year. These projections imply the same market conditions for 2033 as we have nowadays. In contrast to this, the authors also examine the demand in balancing control for a changing procedure in dimensioning the demand. Here, the demand in balancing power is not assessed every three month (as it is done today) but for instance on a daily basis. In this case, the demand could be sized following the actual load and generation forecasts. Hence, the increase in balancing power demand could be limited compared to the scenario under current dimensioning conditions (Deutsche Energie-Agentur GmbH (dena) and Technische Universität Dortmund / ef.Ruhr GmbH 2014, 11).

Another study undertaken by CONSENTEC and R2B in 2010 quantifies numbers of future balancing demand. The demand in balancing power is assessed for six different scenarios for the year 2020. The authors consider varying shares of renewable energies in gross electricity production – starting with 25% increasing it in 5% steps up to 50%. They come to the following results: In a power system with a share of 30% or less of produced power based on renewables the demand in secondary control reserve as well as minute reserve is more or less the same as in 2010 (with a share of about 17% on electricity production). An increase in forecast quality compensates the rising demand that would come along with higher shares of renewables (CONSENTEC and R2B 2010, 57). If the share rises above 30%, a significant rise in the demand is described (demand almost doubles considering a share of 50% in 2020).

The scenario of 25% renewables in gross electricity production came to reality in 2014 and the demand in balancing power did indeed not increase, but decrease (see above). But, compared to the main reason named in the study of CONSENTEC compensating increasing demand (which is of improved forecast quality), several additional causes have occurred in reality. A number of regulatory changes, which shall lead to an efficiency gain in production, are not covered in the methodological approach to assess the balancing demand. Hence, the study might overestimate the future demand in balancing power.

2.2 Different terms and types of load management

As mentioned above, load management gains of importance in the context of the energy system transformation. Thus, a lot of research is investigated in this field. But load management is not a new idea. In the following, different types and terms of load management are explained to give a short overview about the historic and current relevance.

In the recent decades, particular the **operational load management** has been of relevance. Operational load management can be regarded as a mean of optimizing energy costs by producing increased amounts of good during times of lower energy prizes and producing decreased amounts of good in times of higher energy prizes. The power of decision of the chosen amounts of production / consumption of energy is at the plant operator. Following DENA, industrial companies are using this measure to reduce cost intensive peak loads in electricity purchase, which arise from the load-related share of the electricity price (Deutsche Energie-Agentur GmbH (dena) 2012, 9).

In contrast to operational load management **superordinated load management** is managed by TSO (transmission system operator). In the second half of the 20th century programs came into action in Germany to prevent peak loads and enable better utilization of base load power plants (Krüger 2011, 1). Klobasa mentions in a short historical classification of load management the term „Least Cost Planning“ which refers to insights and knowledge regarding a resource-saving and efficient power supply gained in the 1990s (Klobasa 2007a, 9) with the focus laying on reducing peak load for a particular grid territory to minimize costs.

In recent years the relevance of superordinated load management rises significantly due to the needed integration of increasing amounts of fluctuating renewable energies like wind power and solar energy. In literature, different terms are used to describe superordinated load management, namely **Demand Side Management (DSM), Demand (Side) Response (DR)** and **Demand Side Integration (DSI)** which are explained in the following.

In general, **Demand Side Management (DSM)** refers to activities that alter the magnitude and/or the time of power demand in order to enhance the overall economic benefits (Charles River Associates 2005, 6). This is usually done by plant operators itself or by interventions of the TSO.

According to this classical definition, DSM covers several strategies to influence the consumers' loads. These are illustrated in Figure 2-1.

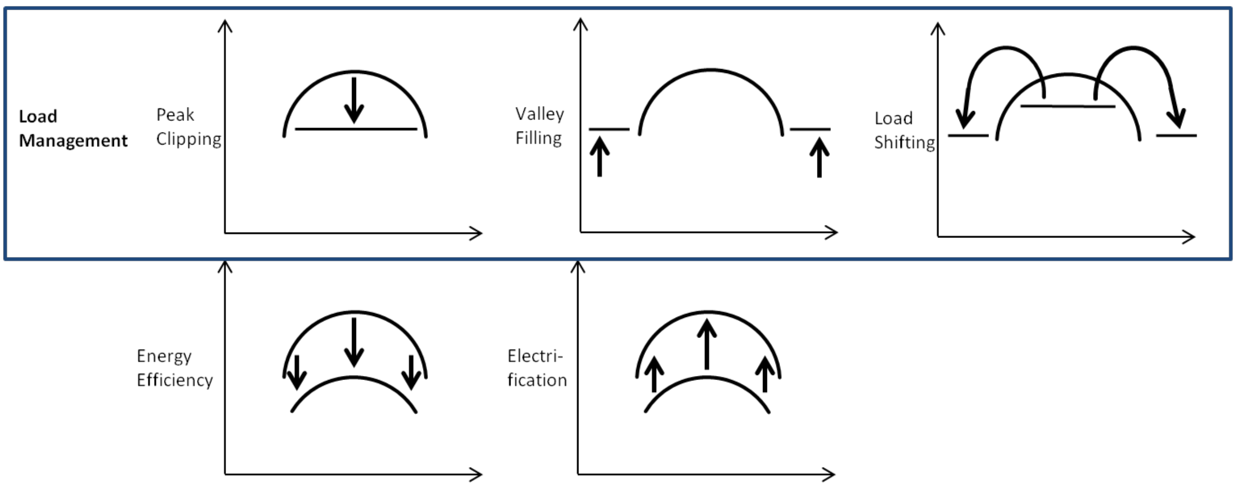


Figure 2-1: DSM Strategies based on (Charles River Associates 2005, 7), (Chamberlin and Barakat 1993)

The common definitions of these strategies include three different types of **load management** (*Peak Clipping, Valley Filling* and *Load Shifting*) that can be used to reach some short-term effects, but also **energy efficiency** that leads to a decreased load within the grid, and **electrification** that leads to an increased load- with potential to deliver control power if applicable. The latter two have rather long term effects.

Peak Clipping describes the reduction of consumers load in e.g. times of peak loads.

In several studies, **Demand Side Respond (DR)** is defined as one subset of DSM that is characterized by a specific control type. It is used to describe all activities that change consumers' loads controlled indirectly by the transmission system operator. As a reaction (or response) of a costumer to an incentive (mostly monetary), the power utilization is economically optimized (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012).

In other current studies DR is not seen as a subset of DSM – it is used as an independent term (see e.g. (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012) (von Roon und Gobmaier 2010 p. 3)). In these studies, DSM is not understood as a superordinate measure for both, direct and indirect control by the TSO. In contrary it is only used for those measures that influence the electricity consumption directly. In this case, **Demand Side Integration (DSI)** is an additional term that is usually used, it serves as an umbrella term for both direct and indirect measures. To avoid confusion due to those different usages of terms, we use the following definition within this study:

DSM is defined as every activity, direct as well as indirect measures, that leads to an adaption of the power demand to the conditions of power generation and power grid**.** Hence it also includes activities that are indirectly controlled by the transmission system operator. **The terms "**Load management" and "Demand Side Management" are understood and used as synonyms.

When discussing the implications of DSM for industrial processes two other terms are of importance as well: If a load reduction is not compensated at a later or an earlier time, the overall energy consumption is lowered. This is called **load shedding**. From the point of view of a producing company it means the renunciation of production units. In case the reduction is compensated by e.g. *Valley Filling* in off-peak times, the combination of the strategies is called **load shifting**. Over a longer time period, the cumulated energy consumption does not change from a theoretical point of view (Kupzog, Roesener, and Palensky 2007, 2). Keeping in mind that there is a specific working point of each production technology where it is operating in an energetic optimum, providing flexibility will lead to losses in the energy efficiency of the process. From an economic point of view as to the national accounts (seen vs. the business perspective of companies) load shedding leads to acceptable costs for the delivered service from the point of view of stabilizing the electricity system (Schwill 2016).

2.3 Different terms and types of potentials

Talking about different terms and types of load management it is also important to have a look at the different types of load management potentials. Generally, it can be distinguished between theoretical, technical, economic and feasible potential, while other categories exist as well. The definition and delimitation between these terms, however, are not always very clear and even less so, transparently applied.

(Gils 2013a) works with the differentiation of theoretical, technical and economic potential and adds the levels of "accepted utilization" and "feasible potential". Doing so, he provides a solid base for discussion. In his terms, the theoretical potential is defined as the sum of all appliances suitable for load management, with the differentiation to the technical potential being the restriction of necessary information and communication technologies and infrastructure (ICT). A subset of the technical potential is the economic potential, which is feasible under an economic point of view under the current market conditions. Additionally to the economic feasibility, the acceptance of the consumer resp. the willingness to offer flexibility is needed to access the feasible potential. This aspect seems to be more important for the sector of households and smaller companies than for large-scale energy-intensive industries. The same definitions are provided by (Grein and Pehnt 2011).

While these definitions provide a solid base for first approaches to potential analysis, intensive dispute with industry actors about their needs and requirements when assessing the possibilities for DSM helped to figure out, that a higher degree of details has to be depicted. For industry actors, the question of the economic potential is the most relevant for the decision for or against further engagement in this field. Yet, the economic potential cannot be quantified without in-depth knowledge about the technical potential. For this, again, concise information about the respective process in question is mandatory, as every plant and every process has to be looked at in a case-by-case-decision. Thus, it is too simple to put the theoretical and the technical potential on a level, as (Gils 2013a) and others suggest.

Therefore, within the framework of this project, an own categorisation of potentials has been worked out, based on, but developing further the works of (Gils 2013a; Grein and Pehnt 2011) and others. The categories are illustrated in Figure 2-2.

Again the theoretical potential serves as starting point. This is diminished by each category, while the reduction is expected to be not in equal steps, but the differences between categories will vary. This is illustrated in the graph, as well (while steps are not to be quantified, only qualitative differences shown).

The categories can be described as follows:

- The **theoretical potential** is defined as the sum of all appliances suitable for load management. For example: a production facility of 50 MW has a theoretical potential of 50 MW of electric capacity.
- The **technical potentials** subsumes all appliances that are basically usable due to the existing necessary information and communication infrastructure as in (Gils 2013a) – minus the electricity for basic maintenance of the plant, e.g. electricity for pumps, electric fans, base voltage that cannot be shut down (not even for a period of time) without closing the site completely. Taking the production facility of 50MW it could be damaged if it is delivering the full theoretical potential of the 50MW. The technical potential in this definition is expected to be only a bit lower than the theoretical potential.
- The **techno-economic potential** follows the same logic: it describes the case that (1) a certain base load needs to be maintained in order to be able to deliver the same quality of products as if the plant would not participate in DSM and (2) the plant is not "damaged" nor will be in a stronger process of ageing (for example ageing of membranes through more modification of cycles, etc.). Both are relevant aspects for the decision of the operators to participate in DSM and could also be subsumed in the category of "accepted utilization" according to (Gils 2013a). They could on the other hand side also fall in the category of the economic potential, as reduced product quality or enhanced plant maintenance are economic aspects to be considered.

  The questions addressed by these factors are really crucial for plant operators, so they are here put in more prominent position. It is not reasonable to consider a technical potential that will never be realised because it requires mayor curtailments in production or in revenues as in case of sooner ageing and higher efforts of maintaining. It is expected, that the step between the described technical and the techno-economic potential is bigger than the one between the theoretical and the technical potential.

- A proper subset of the techno-economical potential is the **economic potential**. It has been defined as what is feasible under an economic point of view under the current market conditions, mostly meaning what cost (variable and fixed costs) occur while apply the flexibilisation options and what the possible revenues can be achieved at the balancing power markets. But especially for a proper calculation of the occurring costs for the plant operator, a variety of factors has to be considered here. The quantification of down stream effects are to be named and numbered: in the case of load shifting, additionally storage facilities can be expected in order to take in the products; for load shedding, maybe the decreased production has to be compensated for further down stream processes. In the plant itself, efficiency losses might occur, further increasing the operational cost.
- The **socio-economic potential** subsumes the effects on human resources: through flexible operation, multi-shift operation could become necessary, more personnel could be needed or the existing staff needs to be trained in a different way. As well, aspects of regulation and frameworks are addressed here, as for example to the question of deployment of further storage facilities that is subject to approval. Acceptance of personnel and residents is as well part of the evaluation of the socio-economic potential.
- Last but not least, it has to be assumed that only a part of the socio-economic potential will be implemented and put into practice, even if all conditions are fulfilled and the framework is set in the right way. Therefore, predictions about the **practical (as well: feasible) potential** should be taken with caution. Experience in other field of potential analysis show that a multitude of aspects might hinder the implementation of socio-economic potentials that are only visible and understandable in a case-by-case analysis. First evaluations of DSM potential in Bavaria and Baden-Wuertemberg in southern Germany by DENA show that the “accepted potential”, as they have evaluated it, is significantly smaller than the technical potential – but not proportional and with high deviations from case to case (Seidel 2016).

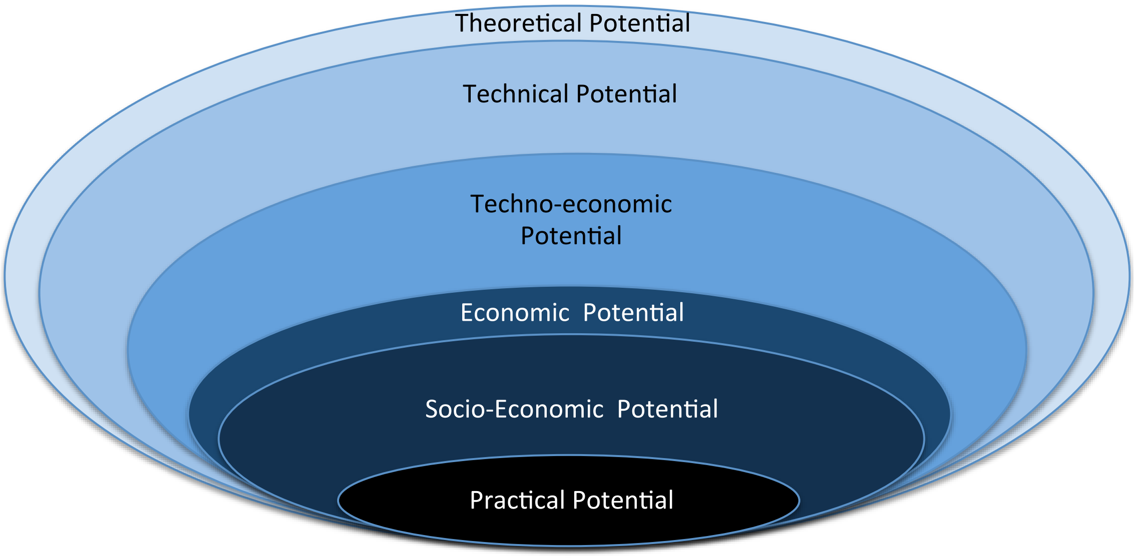


Figure 2-2: Categories of potentials for industrial demand side management (own definition and illustration)

2.4 Relevance of DSM compared to other flexibility options

DSM is not the only possibility to compensate higher fluctuations in the system – an overview about the different options is given in Figure 2-3.

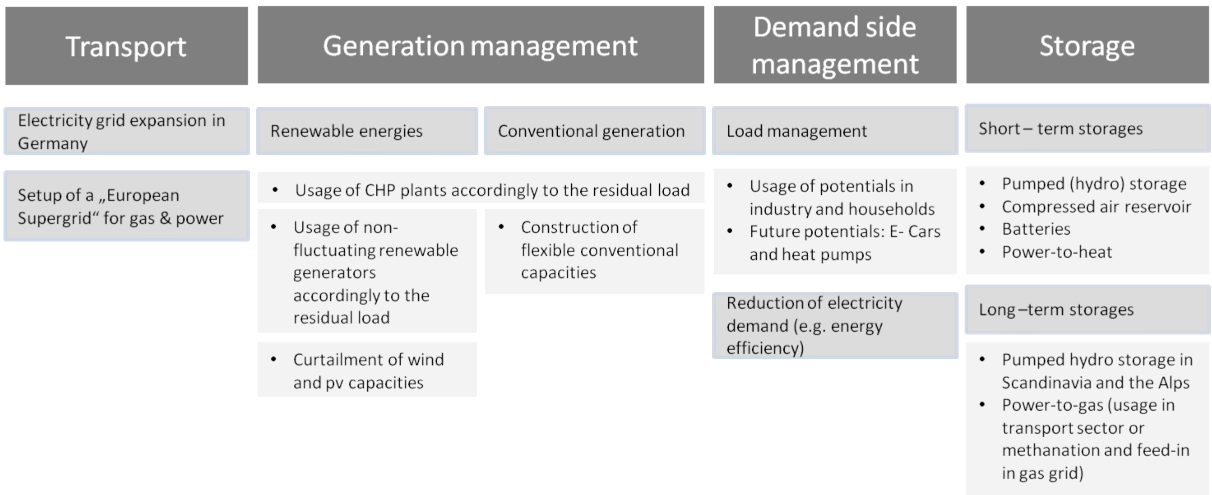


Figure 2-3: Possibilities to integrate high shares of renewables in the German electricity system – an overview (own figure based on (Krzikalla, Achner, and Brühl 2013a) and (Sterner et al. 2010))

Transport: Grid expansion as such supports the integration of renewable energy into the grid. Fluctuations due to weather conditions can better be balanced when several regions with different weather zones are bundled into a control area. By the grid surplus energy can be transported to regions where it is needed. Regarding Europe's landscape a huge amount of different geographical zones and climate zones can be found: regions with a high amount of wind, sunny regions as well as regions with mountains and a lot of snow or rainfall. In a study of the German federal ministry of economy it can be stated that integration of renewables into the power grid can be enabled by a large European transmission network.[5]

Generation management: In times of no wind and solar power conventional power plants are needed to provide energy to support stability of the power grid. As shown in figure 2-3 there are several possibilities to provide power. As one example, flexible conventional power plants can be operated accordingly to the deficits that remain between the load and the renewable production and hence facilitate the integration of renewable energies. The renewables need to become more flexible in terms of electricity production, too: in future system configurations of a decarbonized electricity system they will need to provide control power in order to maintain system stability.

Storage: One additional balancing option of great importance is to store the electricity in times of surplus production and to use it in times of deficits. There are several options to do so, as shown in figure 2-3: storage as electricity with batteries, storage in pumped storage hydro power station, conversion of electricity into heat (kettle), gas (e.g. water electrolysis), or chemicals like methane or methanol.

Demand side management (DSM) is competing to the above mentioned options in terms of its specific contribution and its costs. Goal of this study is to examine the potential of the DSM's contribution- in terms of economic and technical aspects.

Krzikalla, Achner, and Brühl gave an estimation of the future relevance of the different balancing options (Table 2-2). According to the authors (Krzikalla, Achner, and Brühl 2013a, 87), the renewable generation management will be of high relevance from 2030 on. The balancing potential rises corresponding to the share of renewable energies in the power generation. The potentials can either be provided by curtailment in times of electricity surplus or, to provide positive control energy, by running the plants throttled. Since there are no fuel costs for renewable generation plants, the overall operating costs of are low and the control power can be provided at low costs.

Table 2-2: System relevance of different balancing option regarding cost efficiency, potential and degree of technical maturity (based on on (Krzikalla, Achner, and Brühl 2013a, 87))

	2020	2030	2040	2050
DSM	low	medium	medium	medium
Generation management renewables	medium	high	high	high
Generation management fossil power plants	high	medium	medium	medium
Storage	low	medium	medium	high

Because of the limited DSM potential related to existing production plants and further increasing amounts of renewable energy production the system relevance of storage units will arise strongly, following Krzikalla, Achner and Brühl. In 2020, it is still thought to be low whereby in 2050 it is granted a very high importance. The relevance of DSM is described in (Krzikalla, Achner, und Brühl 2013) as arising, too. Its maximum is classified as "medium" of relevance and is already reached in 2030. The potential of storage units is rated higher than the one of DSM because in electricity system configurations with high shares of renewable

[5] Versorgungssicherheit in Deutschland und seinen Nachbarländern: länderübergreifendes Monitoring und Bewertung, consentec, r2b energy consulting GmbH, 06.03.2015

energies, relatively high time-spans with an exclusively positive or negative residual load need to be compensated - for which the time spans to provide control power of DSM are not sufficient. Because of the German strategy to transform the fossil based energy system to one with high shares of renewable energies, power generation based on fossil power plants will play a minor role in the future.

Summarizing it can be stated that the relevance of DSM to compensate fluctuations in an electricity system with high shares of renewable generation will strongly rise in the next decades, whereas it will be relatively small compared to the other balancing options. Nevertheless, a future, decarbonized energy system requires a flexible interaction of all components of the system. The exploitation of consumers balancing potentials will be an important part in the bigger picture “Energiewende”.

3 Technical assessment of flexibilisation options

To assess the future relevance of the different balancing options (Figure 2-3, table 2-2), several flexibility parameters can be compared as it is done in (Krzikalla, Achner, und Brühl 2013). First of all control power can be differentiated between positive control power and negative control power. The type of the control is of high relevance:

Positive and negative balancing power: If the load in the electricity system suddenly rises and the given power supply is not sufficient, **positive** balancing power is needed: additional power needs to be fed into the grid or the load needs to be reduced. On the contrary, the compensation of a supply-surplus at a given load requires **negative** control power: generators need to reduce their feed-in or loads need to be increased in order to maintain system stability.

Furthermore the time span in which control power has to be initiated as well as the time span during which electric work has to be delivered are important. Usually energy-intensive production technologies that are able to be operated in a flexible manner can provide positive control power as well as negative control power from a technical point of view. Production assets that are mainly operated under full load can only provide positive balancing power.

Due to technical restrictions there are many technologies whose load can only be pre- or postponed within a certain time frame (from minutes up to a length of several hours). Therefore duration of control power supply by industrial processes is often limited. Storage devices and most forms of generation management can generally provide the control power over significantly longer time-spans. In regard of activation times, the control power via DSM can be accessed very fast; within a few minutes, the demanded power can be provided by reducing or increasing the corresponding loads whereas conventional power plant react more inertial.

As explained above, flexibilities will become more and more important in context of rising shares of renewable energies in the electricity system - accompanied by volatilities in supply. Currently, the share of renewable electricity production in Germany amounts to 27%. As storage options are still scarce, industrial production capacities and technologies are approached from industry, science and government to make load pattern of production processes more flexible to e.g. serve as virtual battery/storage site and reduce the overall macro-economic costs of the energy system. Within the study at hand, it is focused especially on electricity-intensive processes for aluminum, cement, chemical, iron/steel and pulp/paper production. Several processes in these branches provide flexibility to reduce or increase electricity demand for a certain period of time.

This chapter provides a technical overview of potential processes for flexibilisation for each of these five branches based on a comprehensive literature review, which was commented by industrial experts of the respective branches in single expert interviews as well as in workshops.

3.1 A literature review - approach

This chapter provides an overview about a detailed literature review to assess the technical potential of DSM in the industrial sector. A variety of study is considered to compare potentials, these are shortly presented in chapter 3.1.1. Afterwards, the selected branches and applications are compiled and the different parameters characterizing the DSM potentials that are considered as relevant and that are included in the literature review are described, although many of them are not considered in a variety of the studies taken into account.

3.1.1 Considered literature

The literature research for the meta-analysis mainly focused on the following studies.

Short name (in graphs)	Description of the study (author, year of publication, title, ..)
Agora 2013	Klobasa et al. 2013. „Lastmanagement als Beitrag zur Deckung des Spitzenlastbedarfs in Süddeutschland". Auftragsstudie Endbericht. Berlin: Agora Energiewende.
BET 2015	Langrock, Thomas, Siggi Achner, Bastian Baumgart, Christian Jungbluth, Constanze Marambio, Armin Michels, Achim Otto, und Paul Weinhard. 2015. „Regelleistungsbereitstellung mit regelbaren Lasten in einem Energieversorgungssystem mit wachsendem Anteil Erneuerbarer Energien". Im Auftrag des Umweltbundesamtes.
Buber 2013	Buber, Tim, Anna Gruber, Marian Klobasa, und Serafin von Roon. 2013. „Lastmanagement für Systemdienstleistungen und zur Reduktion der Spitzenlast". *Vierteljahrshefte zur Wirtschaftsforschung* 82 (3): 89–106.
DENA 2010	Deutsche Energie-Agentur GmbH (dena). 2010. „dena-Netzstudie II. Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015 – 2020 mit Ausblick 2025."
D.-Franke 2012	Droste-Franke, Bert, Ruth Klüser, und Theresa Noll. 2012. Balancing renewable electricity energy storage, demand side management, and network extension from an interdisciplinary perspective. Heidelberg; New York: Springer. http://dx.doi.org/10.1007/978-3-642-25157-3.
Gils 2014	Gils, Hans Christian. 2014. „Assessment of the theoretical demand response potential in Europe". Energy 67: 1–18.
Gruber 2014	Gruber, Anna, Franziska Biedermann, Serafin von Roon, und Luis Carr. 2014. „Regionale Lastmanagement-Potenziale stromintensiver Prozesse". In . Graz: Forschungsgesellschaft für Energiewirtschaft mbH. http://portal.tugraz.at/portal/page/portal/Files/i4340/eninnov2014/files/lf/LF_Gruber.pdf.
Hauck 2014	Hauck, Heribert. 2014. „Aluminiumelektrolyse als virtueller Stromspeicher - ein Beitrag zum Gelingen der Energiewende". Trimet Aluminium SE gehalten auf der Plattform Klimaschutz und Industrie – Branchendialog Alu-/NE-Industrie, Düsseldorf, November 25.
Klobasa 2007	Klobasa, Marian. 2007. Dynamische Simulation eines Lastmanagements und Integration von Windenergie in ein Elektrizitätsnetz. Stuttgart: Fraunhofer-IRB-Verl.
Paulus Bogreffe 2009 / 2011	Paulus, Moritz, und Frieder Borggrefe. 2009. „Economic Potential of Demand Side Management in an Industrialized Country - the Case of Germany". In Conference Proceedings. Vienna. Paulus, Moritz, und Frieder Borggrefe. 2011. „The potential of demand-side management in energy-intensive industries for electricity markets in Germany". Applied Energy, The 5th Dubrovnik Conference on Sustainable Development of Energy, Water

	and Environment Systems.
Praktiknjo 2013	Praktiknjo, Aaron. 2013. Sicherheit der Elektrizitätsversorgung: Das Spannungsfeld von Wirtschaftlichkeit und Umweltverträglichkeit. Springer-Verlag.
VDE 2012	VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012. „Demand Side Integration – Lastverschiebungspotenziale in Deutschland“. Frankfurt a.M.
Wille-Hausmann 2009	Klobasa, Marian, Thomas Erge, und Bernhard Wille-Haussmann. 2009. „Integration von Windenergie in ein zukünftiges Energiesystem unterstützt durch Lastmanagement“. Fraunhofer-Institut für System-und Innovationsforschung, Karlsruhe.

Most of the studies refer to the five analyzed sectors, apart from (Buber et al. 2013a) who does not expand on aluminum. The current BET study on load balancing potentials (Langrock et al. 2015) aggregates the industrial branches aluminum and air separation as well as and cement and glass for reasons of data protection. (Hauck 2015), an industrial representative from Trimet brings into focus the potentials in the aluminum industry.

Studies cited very frequently in the discussion are (Stadler 2006), (Klobasa 2007a) (Dena 2010), and (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012).

3.1.2 Selected branches and applications

In most studies the DSM potential of the same six processes (aluminum electrolysis, cement and raw mills, chlorine electrolysis, air separation, electric arc furnace and pulp production) is evaluated. They are regarded as the most promising ones due to their high share of electricity costs in gross value added and their technical possibilities of load shedding or shifting. The motivation to disrupt the production process is higher for these branches compared to branches with a smaller share of electricity costs because of the fact that opportunity costs are higher (M. Paulus and Borggrefe 2009).

The sectors and applications for load management as well as the type of load modification are shown in Table 3-1. In most cases, different types of load management have been looked at, while load shedding is the most common one, followed by load shifting. For many applications, load can as well be reduced as increased.

Table 3-1: Suitable application for each sector based on literature review

Sector	Application
Aluminum	Electrolysis
Chlorine	Electrolysis
Air separation	Air separation
Cement	Cement or raw mills
Steel	Electric arc furnace
Paper	Mechanical pulp production
Cross-sectional technologies	Mills, pumps, compressors, air conditioning,…

Various publications on DSM have included cross-sectional technologies in their analysis. Nevertheless, a quantitative comparison is infeasible because the studies subsume different processes under cross-sectional technologies and different infrastructures of the technologies that influence capability of delivering DSM. The discussion of these findings will be solely qualitatively due to a lack of comparable quantitative data.

3.1.3 Parameters characterizing DSM potentials

There is a variety of parameters characterizing the size of DSM potentials, whereas typically only few are assessed in the majority of the studies. These generally project overall national potentials for industrial sectors resp. single appliances.

The average shiftable load available for flexibilisation represents the most important parameter to describe the size of a DSM potential. Additionally, a maximum amount of DSM called per time unit and the maximum time a potential can be used continuously is frequently examined, and a maximum shiftable amount of energy during a certain period of time is sometimes used to depict DSM potentials. The latter can be calculated by multiplying the average shiftable load by the maximum duration of the DSM activation and the maximum amount of DSM calls in a certain period of time. Nevertheless, a detailed set of parameters was compiled to be able to include any information characterizing the potentials given in the studies. This is described in the following and provides the basis for the literature review.

- **Production capacity and electricity demand**
  As mentioned before, the highest potentials are located in energy resp. electricity intensive processes. Thus, annual production capacities as well as electricity demand of the overall sector and of specific processes are of relevance. Additionally, the specific electricity demand per unit output was considered.
  Electricity use in energy intensive production processes is depending on the production plan. Production is planned for the following month or even for a longer time span. Resulting electricity demand can be estimated on a detailed daily plan for every 15 minutes. The factory owner constantly updates this plan but submits his plan on a monthly basis one month before the monthly production starts. This information is provided to the supplier.

- **Production characteristics / load pattern**
  There is a variety of production conditions restricting the size and the availability of a DSM potential. Many of them are reflected in load patterns used resp. requirements in parameters attached to load pattern. Within interviews with the industrial partners of the project several aspects of importance in context of the load pattern could be figured out for the quantification of a DSM potential. To draw a realistic picture of feasible potentials the following questions should be answered in detail:
  - Which share of the load is available for a load reduction, which for a load increase, with regard to the specific production asset and its production plans?
  - Is there a minimum load that should not be fallen short of?
  - Is the relevant process part of a continuous production, is it located at the beginning of a production value chain with dependencies to following production,

are there daily and/or seasonal load profiles that define a varying size of the flexible load over time or is it driven on demand because it is a precursor?
  - How high is the average load that can be offered for DSM, what is the maximum power consumption when the unit operates under full load and which is the usual utilization level of the relevant processes?

Questions like these help to evaluate if there is potential and if yes, to define its characteristics (e.g. electrical power and work, timespan of reducing or increasing the electrical load, load ramps for reduction and increase of the load) depending on a specific process and its production environment.

In case the utilization level is very high and the production unit operates in full-load, the power purchased cannot be further increased. Hence, only positive balancing power can be offered and it is not possible to catch up on the reduced output that means only shedded load can be delivered. The differentiation between load shedding and load shifting is one of the most important categorization parameters since the opportunity costs for the loss of production is essential for the assessment of the realization for the commercial or rather techno-commercial potential type. Additional parameters to describe production constraints reflected in requirements of the load pattern are the maximum duration of DSM activation, the minimum time in between two DSM calls and the maximum amount of DSM calls per year. Further, for the type of balancing power that can be provided by a specific industrial potential also the time needed for a process to react on control signals and adapt to changing production conditions is of importance.

- **Costs**
  In general upcoming costs can be class-divided into **variable costs**, **fixed costs**, **cost of maintenance**, **investment costs**, and **opportunity costs**.
  Variable costs occur only, when participating in DSM markets and / or delivering control power. They accrue when energy prizes and auctions for control power are checked, DSM potentials of the production assets are evaluated, bids are given and accepted, and control load is delivered.
  Data management systems that enable DSM (for example management systems, control systems (Frontier Economics 2014)) cause **fixed costs**. If additional personal is needed fixed costs accrue, too. Fixed costs are related to the frequency of use of needed resources: the more they are used the lower the costs per unit occur.
  Energy intensive production plants or assets of energy intensive industries are usually constructed in a manner to minimize energy consumption and need of raw materials during continuous operation mode (large scale continuous productions operating without unsteadiness) at a defined operation point or operation window. Requirements of the past did not include fluctuating operation modes adapted to supply of electricity by a power grid fed by renewable energies. Deviant operational modes cause inefficiencies (including product losses and lower product qualities) that are part of the variable costs but they even cause increasing **maintenance cost** because of increased wear. Due to a lack of experience and R&D these additional costs often are not known and cannot be quantified.
  Purpose of an enterprise is the production of goods. Enterprises undertake market analysis, write business plans and plan their production amounts and production capacities according to this. To be competitive, investments in overcapacities generally

have to be avoided. Due to that in many cases only load shedding is possible, because production capacities are scarce. To enable delivering DSM, additional capacities, storage systems, or infrastructural means have to be build and **investment costs** accrue.

Opportunity costs refer to the business purpose of enterprises. Depending on market situation and degree of utilization of capacities it can be of advantage to offer DSM, maybe under renunciation of production. This has to be regarded by the enterprise within the decision-making process.

In general it can be noted that costs of all categories vary strongly depending on branch, kind of production and the production plant itself as well as the specific circumstances in a particular production site of a company (degree of capacity utilization).

- **Energetic impacts**
  As mentioned before, reduced energy, resource and material efficiencies can occur as a side effect of flexibilisation due to a deviation of the ideal usage profile. Thus this aspect is very relevant since it is related to a general contradiction in efficiency and flexibilisation strategies, none of the examined studies assess quantitative numbers for the increase in energy demand caused by DSM usage for the different industrial branches. This is mainly caused by the complexity of this problem: the energetic impacts of DSM usage may strongly differentiate between production technologies as well as different production setting even when comparing the same technology. Of influence may be the age of the plants, the driving mode and the value chains itself that cause different operational modes (the latter being of importance especially for chemical sites).

3.2 Findings for the selected branches based on the literature review

In this subchapter, first an overview of all examined branches is given and the main results are presented. Afterwards, the findings for the single industrial branches are presented in more detail.

3.2.1 Overview of the different branches based on the literature review

As mentioned above, there is a variety of parameters needed to describe DSM potentials. In the literature potentials are described in different levels of detail. Most studies describe only an average value for the flexible load available in the specific processes (compare for example (Dena 2010), (Droste-Franke, Klüser, and Noll 2012) or (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012)), some differentiate between maximum, minimum and average flexible loads (compare e.g. (Gils 2013b)). (Klobasa 2007a) differentiates the flexible load for single appliances according to changing seasonal load patterns (e.g. different values for summer and winter times). A study conducted by Agora (Klobasa et al. 2013) names flexible loads for certain classes of time frames for management (compare while most of the studies do only mention constant (maximum) time frames for management. But there is one study that pursues a very detailed approach: (Stadler 2006) even assesses three-dimensional potential curves for the flexible load available for some appliances– not only dependent on the time frame for management but also on the temperature, which is an important exogenous parameter for appliances such as cold stores or heat pumps. Nevertheless, this study was published almost ten years ago and for industries only the potential of compressed air applications is assessed. Hence, no quantitative data is used in the following comparison from this study.

(Langrock et al. 2015) is one currently published study funded by the Umwelt Bundesamt (UBA), the German Federal Environment Agency that differs from the previous studies in the way of depiction the flexibility potential: Here, the sociotechnical potential is assessed and a classification of the potential according to specific forms of utilizations resp. available products at the electricity markets. The socio-technical potential is here a subset of the technical potential, which takes into account the individual perspective of the companies asked to economic and logistical conditions additional to technical restrictions. It is not part of the quantitative comparison in this overview.

With this overview, two parameters are highlighted from the studies and compared to each other: the annual electricity demand by sector and the average shiftable (and partly sheddable) load available because these parameters are examined in most of the studies.

As mentioned above, the electricity demand of an industrial company is an important criterion for the DSM potential of the considered branches. The higher the electricity demand and hence the load called in a particular branch, the higher is impact for the grid stability that can be generated. Therefore the electricity demand is subject of all the studies taken into account in the literature review. Hence, in the following, the range of given values for the annual electricity demand for each sector is presented in Figure 3-1.

The lowest value of the studies is shown in grey, the highest value in black and the average of all the studies taken is represented by the red dot. It becomes clear that the range is comparatively wide for branches such as steel or chlorine. This may result from the fact figured out in the previous chapter 3.1.3: different processes, companies and plant settings are subsumed under a sector and different categories of potential have been estimated. Individual plant availabilities and plant settings are not necessarily reflected. Following the studies, paper industry has the highest annual electricity demand regarding the average value, followed by chlorine and steel production. Since this parameter plays an important role in the assessment of DSM potentials, this compilation already shows that the DSM potentials assessed in the studies vary strongly.

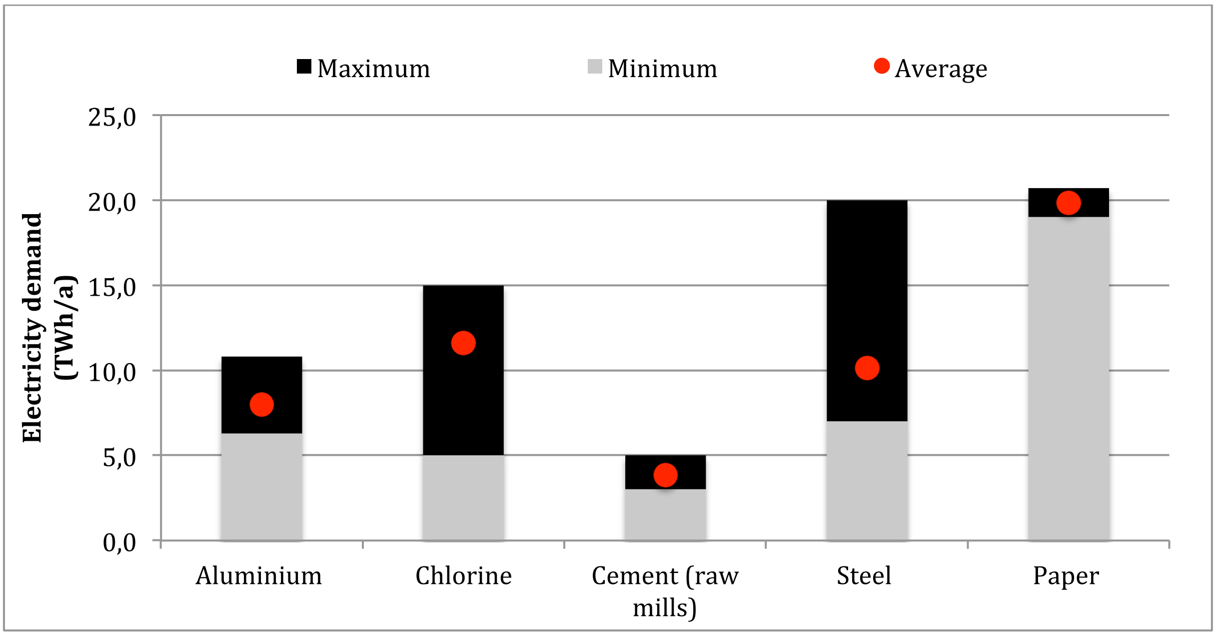


Figure 3-1: Annual electricity demand by sector [aggregated data from literature meta analysis conducted in this study]

An overview of the bandwidth of the maximum load increase and load reduction as the main parameters to describe the height of flexibility potentials for the abovementioned sectors given in the different studies can be found in Figure 3-2. In the studies, the potential mostly is classified as "shiftable load", but according to the discussion of terms (as in chapter 2.2), it is rather named "DSM potential" here. If it would be shiftable load in every case, the positive load should correspond with the negative load, as the shifted production would have to be postponed. Otherwise, it would be the load shedding potential. As mentioned before, the use and classification of terms is not always clear and transparent.

For the purpose of this report, the term "positive" will be taken to describe a load reduction. This is necessary when the demand is higher than the supply. The term "negative" refers to a load increase. This definition applies to the balancing energy market (compare definition in chapter 2.2).

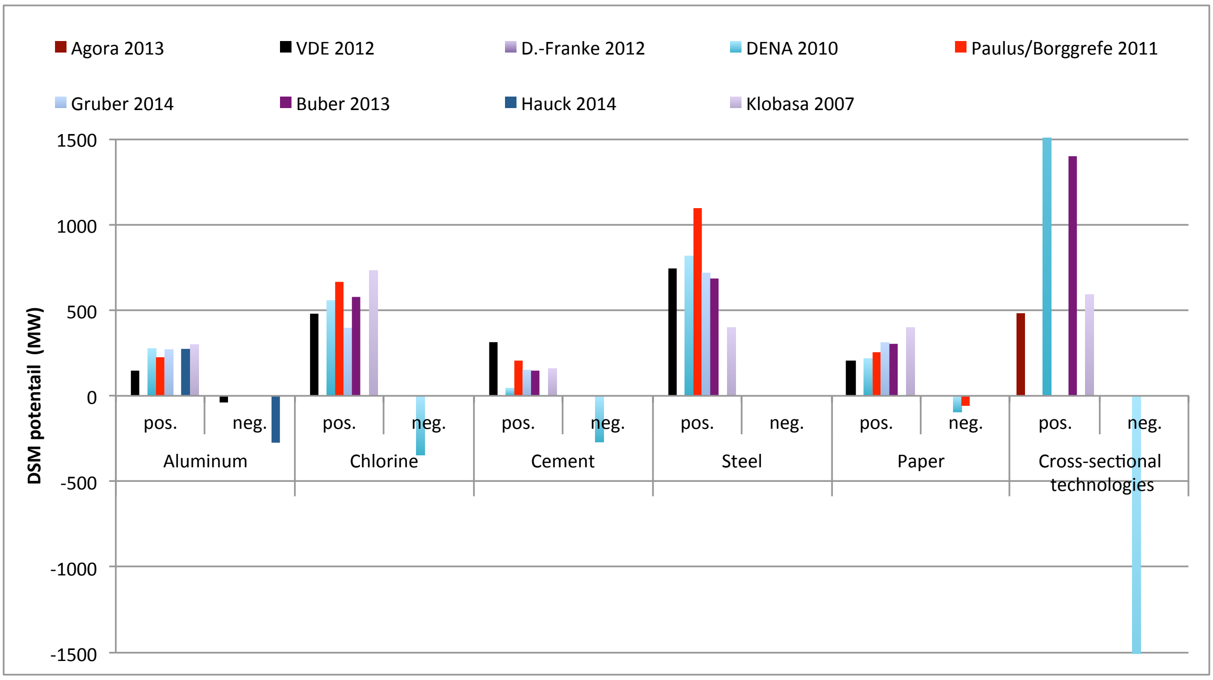


Figure 3-2: DSM potential by sector and study (technical potential) [aggregated data from literature meta analysis conducted in this study]

The highest positive potential can be found in the steel industry due to its high specific electricity demand, while the chemical industry has the highest negative potential due to its good storage options. The negative shiftable load potential of the industrial electricity intensive processes is generally significantly smaller than the positive potential due to the very high utilization levels of the production processes. Unfortunately studies seem to be suffering in differentiation between load shifting and load shedding, as it is seen from an industrial plant operator's point of view. As shown in Figure 3-2, negative potentials seem to be smaller than positive potential. At the first glance it can be assumed that the examined assets are operated in full load, so only positive load can be delivered. This presentation neglects the fact, that load shifting implies that production can be made up and in most practical cases have to be made up for the period of less load. Then capacities to make up for production have to be available *after* delivering positive load - and if they are, there should be potential for negative load as well.

In the case capacities to make up for production units are not available the company has to make the choice between producing goods and delivering DSM. This has a direct impact of the companies' willingness to offer flexibilities and "availability" of the potentials (techno-economic and economic potential).

As indicated above, the range of estimated potentials is comparatively wide. Aside from the varying electricity demand used as one parameter to assess the potentials, various uncertainties and different basic assumptions in the studies contribute to the large differences in the shiftable load shown. As mentioned above, one important reason for the variation of the study results are differing basic assumptions, for example regarding the electricity consumption. Klobasa (10.5 TWh in 2005) and the DENA study (9.8 TW in 2008) use similar values in contrast to the VDE study (5.6 TWh in 2010) basing their estimations on a value nearly half of those studies.

3.2.2 Aluminium Industry

Processes for flexibilisation

The fused-salt electrolysis for primary aluminium production offers a large potential for DSM in non-ferrous metal industry. The bottom of an electrolysis cell serves as cathode, while carbon rods in the cell serve as anode. A direct electric current is generated which converses aluminum oxide into pure aluminium metal via the Hault-Héroult-Process. The process takes place simultaneously in several cells that are electrically connected to each other in series.

The electrolysis process is almost the entire year available for flexibilisation (99.7%) and accounts for a large proportion (9.5 TWh/a) of the total electricity consumption of the sector (10.5 TWh/a) (Hauck 2015). In public studies taken into account, the estimated electricity demand of the aluminum sector ranges from 6.3 TWh/a up to 10.8 TWh/a. (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012, 36). The electricity demand of the process varies between 13.8 and 15.8 MWh/t (see Table 3-2).

Klobasa states that aluminium producers in Germany are under pressure due to energy prizes (Klobasa 2007a, 56). In contrast to that it could be figured out in interviews with aluminium producers that aluminium producers in Germany are competitive with existing wholesale prizes and the existing regulative framework.

Annual production capacity in Germany		**Electricity demand of sector**	**Electricity demand of process**	**Average load called**
Sector	**Process**	**8 TWh/a** *(6.3-10.8 TWh/a)*	**14,900 kWh/t** *(13,800-15,875 kWh/t)*	**1,100 MW** *(1,100-1,300 MW)*
2,240 kt *(1,013-4,400 kt)*	**665 kt** primary alu *(650-680 kt)*			
Average *Range*				

Table 3-2: Production capacity, electricity demand and average load called for aluminum [aggregated data from literature meta analysis conducted in this study]

Potentials for DSM

The operation point of the aluminium electrolyzers is extremely sensitive and has to be remained at constant level in order to guarantee the safe operation of the plant and prevent the melt of “freezing”. Therefore the electrolyzers can only be operated in a flexible mode after modification to the process management. Having this modification installed, the electrolysis can be shut down for one to maximum two hours and the performance can be modulated to a small extent (+/- 2-3 %). This background information was given by an industry expert / participant of the study at hand and it should be beared in mind that possibly not all of the studies looked at in the meta analysis have made the following distinction:

In case of severe disturbances in the power grid, it is technically possible to shut down aluminium electrolysis in order to maintain safe operation of the grid. However, opportunity costs for such case are very high as production stops and the plant will possible be damaged, so this is not an option for economically optimisation of a plant through participation at the flexibility market. The potential of a complete shut down should not be calculated as part of the economically accessible flexibility option.

After the mentioned modification of process management, flexible operation of the process operation window is possible, allowing for a modulation of the electrolysis performance of about +/- 25 % around the nominal operation point and a capacity shift of ca. 50 MWh per MW. This virtual storage capacity can be used for economically optimisation of the site operation and offered for use e.g. at the control reserve markets.

As a result of the conducted meta analysis of literature, there are three potential options for load flexibilisation in the electrolysis process: partial-load operation, short-term load increase and load interruption (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012, 37). As the companies operate the plants at almost full capacity nearly the whole year, there is only limited possibility for load increase. The utilization level typically varies between 95% and 100%, 25% up to maximal 40% are available for DSM according to the studies taken into account. The reaction time is only specified in one study to 7.5 minutes.

By means of a voltage tap changer, the voltage in the electrolysis cells can be reduced for partial-load operation. According to (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012) the load management potential for a reduction amounts to 148 MW; other studies assess potentials as high as 300 MW.

Since the utilization level is very high, the potential for load increase is significantly smaller. Several studies even announce that there is no potential for load increase (compare (Deutsche Energie-Agentur GmbH (dena) 2010, 423). According to another study, for a short time load increase is possible at some of the production sides which amount up to 30-50 MW during a time frame of 4 hours ((VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012).

The maximum height of the overall load possibly interrupted is assessed in two studies and amounts up to 637 MW (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012) resp. 859 MW (Gruber, Biedermann, and Roon 2014).

Its maximum time frame is four hours due to “freezing” of the process in case of a power outage of a longer time. The storage capacity is maximum 48 hours due to a limited buffer to assure a continuous supply of the following casting process. Hence, the electricity demand can be shifted for two days by 25%, providing 13.2 GWh of storage capacity. Pre-condition to be able for delivering DSM is an investment for modifying the operating control to enable a flexible operation and a shutdown as well (Hauck 2015).

During accelerating and shutting down of the electrolysis by these 25%, additional heat is created which could be used in order to attenuate the efficiency-loss of the overall DSM operation.

According to expert interviews conducted in context of the VDE study, load interruption can be carried out every 3 days at maximum, while load reduction (of an upgraded production asset) could be applied once a day, if the conversion of the production site to a “virtual battery” as been made (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012, 37).

In recent years, the annual utilization has already been lower than 100%, in 2009 even less than 50% (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012, 36). This was certainly due to temporary shut downs of production processes and therefore not economically preferable.

First results from experiences with load flexibilisation in aluminium industry indicate an increase of energy consumption - the fact gives prove that efficiency is reduced due to DSM in aluminum electrolysis. The energy demand is increased from about 13.8 MWh/t aluminium up to 14.5 MWh/t aluminium.

Shiftable positive load	Shiftable negative load	Time frame
25% (up to 40%) **250 MW** *(148-300 MW)*	0-25% **70 MW** *(0-275 MW)*	**4 h** *(up to 48 h)*
Average *Range*		

Table -3-3: Shiftable load and time frame for aluminum [aggregated data from literature meta analysis conducted in this study]

Current developments

The family company TRIMET operates three of the four primary aluminum smelters in Germany. It already provides primary reserves for the active regulation of the grid frequency in Hamburg. In order to review and verify the technical and economic estimations for aluminum DSM potentials, the company has launched a demonstrator with an expected storage capacity of +/- 2.2 MW in June 2014 (Hauck 2015).

3.2.3 Cement Industry

Processes for flexibilisation

There are 55 production sites for cement in Germany (Verein Deutscher Zementwerke (VDZ) 2015). The grinding of cement and raw mix in mills is particularly electricity-intensive and a promising option for flexibilisation. Cement production and the required usage of electricity are already rather flexible. The flexibility has as well seasonal as intraday aspects. It is reduced considerably in wintertime as most construction sites are closed. Hence the grinding potential is reduced during that season. Additionally, the height of the DSM potential available changes strongly with the daily load profile: Due to favourable electricity tariffs the grinding takes place mainly during nighttime, whereas during daytime the utilization level is typically lower. Hence, during that time of the day load increase is possible.

The estimated electricity demand of the cement sector ranges from 3 TWh/a up to 5 TWh/a (see Table 3-4). The German Cement Works Association (Verein Deutscher Zementwerke VDZ) predicts an increase in energy consumption of the cement industry due to higher market requirements on performance (Dena 2010) and increasing requirements for environmental protection.

The specific electricity demand of cement is estimated at 90-130 kWh/t cement. Largest part of contribution of about 45 kWh per ton in average is delivered by cement mills. The range of values for annual production capacity is relatively high (11-30 million tones, see Table 3-4). This leads to a wider range of values for parameters that are based on the annual production capacity as well. Seasonal variations (50% - 130% of the average production) lead to a dynamic load demand pattern (Klobasa 2007a). The Research Institute of the Cement Industry expects a constant cement production for the next years, based on the year 2011, as a result of the meta-analysis of (Hoenig, Koring, Fleiger, Müller, et al. 2015).

Annual production capacity in Germany	**Electricity demand of sector**	**Electricity demand of process**		**Average load called**
		Raw mills	**Cement mills**	
21 mio t cement *(11 – 30 mio. t)*	**4 TWh/a** *(3-5 TWh/a)*	**26 kWh/t**	**45 kWh/t** *(30-60 kWh/t)*	**470 MW** *(300-921 MW)*
Average *Range*				

Table 3-4: Production capacity, electricity demand and average load called for cement [aggregated data from literature meta analysis conducted in this study]

The German Cement Works Association (Verein Deutscher Zementwerke VDZ) announced an annual production of cement of 31.1 mio t in 2014, while the overall capacity was 35 mio t.

Potentials for DSM

The utilization level for cement mills is indicated at 60-85% while 40% - 100% of this load can be used for DSM. The maximum time frame for DSM is estimated to 3 to 4 hours. According to the studies analyzed, the potential is available 5000-7500 hours per year.

The mills as well as the furnaces are the most energy-intensive processes in a cement production site (Gruber et al. 2014). Of the four process steps in cement production, only two steps are suitable for load management: the processing of raw material as well as the grinding of clinker to cement.

There are three different processes for production of clinker used in Germany: the dry process in rotary kilns with cyclone preheaters (93.8% of capacity), the semi-dry process (5.1% of capacity) and the shaft furnace process (1.1% of capacity). The continuous high temperature process of calcination and cement clinker burning is performed in rotary kilns. This part of the energy intensive process has hardly any potential for DSM. Also, the exhaust fans have to be operated according to the high temperature process and offer no flexibilisation potential (Verein Deutscher Zementwerke (VDZ) 2015).

Between the process steps, the material is buffered in order to reach a high utilization level of the rotary kiln. Such existing storage capacities could potentially be used for load management. Nevertheless, it is most reasonable to operate the mills together with the rotary kiln process in order to maintain high levels of overall energy efficiency and in order to avoid additional fuel input for drying of the raw material (Schmidthaler et al. 2014; Verein Deutscher Zementwerke (VDZ) 2015).

As a result from the here conducted meta analysis of literature, the positive shiftable load varies between 150 and 300 MW depending on the study, while the negative shiftable load only amounts to 50-269 MW (see Table 3-5). The average of the shiftable load in the studies taken into account is 260 MW positive and 160 MW negative load. One study assess additionally a load shedding potential of 769 MW (Gruber, Biedermann, and Roon 2014).

Shiftable positive load	Shiftable negative load	Time frame
40% - 100% **260 MW** *(148 - 300 MW)*	0%-20% **160 MW** *(50 - 269 MW)*	*3-4 h*
Average *Range*		

Table 3-5: Shiftable load and time frame for cement [aggregated data from literature meta analysis conducted in this study]

The mills can be shut down or ramped up within minutes. The grinding process is based on electricity supply. Its performance can easily be adapted between zero and maximal power. The reaction time is 30 minutes.

To raise the load management potential, additional capacity for silos and mills is required. However, interviews of Paulus and Borggrefe with companies suggest that “utilization levels have almost reached technical limits and that storage capacity is a bottleneck for many cement mills” (M. Paulus and Borggrefe 2009).

3.2.4 Chemical industry

Processes for flexibilisation

In chemical industry, a huge amount of different processes is implemented. Three of the most electricity-intensive processes in this sector are chloralkali electrolysis, air separation, and arc technology for the production of acetylene. The latter exists only once in Europe and is not examined in this study.

Air separation is a potential process for DSM where large amounts of electricity are involved to compress and cool air. This process is undertaken to liquefy the ambient air and to extract nitrogen, oxygen and argon by rectification.

There are approximately 25 plants for air separation in Germany, a quarter of those are situated in southern Germany. The utilization level is 87,7% in average (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012, 39). Partial-load operation of 80% is possible without great effort (Energiewende 2013, 50). The electricity demand of this sector is estimated at 5 TWh/a, while numbers for the electricity demand of the process vary between 0.1 and 1 kWh/m^3, depending on the study. The positive shiftable load ranges from 25 to 170 MW (average: 120 MW) and can be used for DSM activations for a maximum of 2 – 4 hours. Despite the information given above, air separation is of lower relevance in most studies and the lack of sufficient data impedes a comparison with the other processes.

The electricity demand of the chloralikali electrolysis is relatively high with estimations between 5 and 15 TWh/a (see Table 3-6). There are different technologies of chloralkali electrolysis to produce chlorine: Mercury technology, diaphragm technology, membrane technology and some kind of “special” membrane technology where an oxygen reduction cathode is used (ODC technology). The latter needs oxygen for the production process and produces chlorine without hydrogen as by-product by lowering the cell voltage from 3V up to 2V. That means that the energy consumption of the electrolysis can be reduced by 30%.

The mercury process still has a higher electricity demand (3,400 kWh/t in average) than the membrane process (2,700 kWh/t in average) and will be phased out in Europe due to legislation by 11th of December 2017. Actually there are only few plants in Germany. DSM is only limited possible with Diaphragm-technology- therefore only membrane technology will be considered in the following. The estimations for possible operational levels (without decrease of product quality) range from 40% to 88% in the studies analyzed. Therefore the technology offers a good possibility for DSM from a technical point of view. Usually electrolyzers are operated 24 hours per day all year long, with some maintenance intervals of about two to three weeks. Because it is a modular technology, single modules can be maintained when others are still in an operational mode.

Annual production capacity in Germany		**Electricity demand of sector**	**Electricity demand of process**		**Average load called**
Sector	**Process**		**Mercury**	**Membrane**	
4,800 kt *(3,769 – 5,070 kt)*	**2,200 kt** (membrane) **1,200 kt** (mercury)	**11.6 TWh/a** *(5-15 TWh/a)*	**3,400 kWh/t** Chlorine *(3,200 – 3,560 kWh/t)*	**2,700 kWh/t** Chlorine *(2,500 - 2,970 kWh/t)*	**1,000 MW** *(560-1,700 MW)*
Average *Range*					

Table 3-6: Production capacity, electricity demand and average load called for the chloralkali electrolysis [aggregated data from literature meta analysis conducted in this study]

Potentials for DSM for chloralkali electrolysis

The process runs at full capacity to optimize the efficiency of the capital-intensive plants. According to Klobasa, the minimum load required is between 40 and 60% for the membrane process (Klobasa 2007a, 53), the maximum load lays up to 95%. Only one of the studies estimates the share of the load available for DSM significantly lower: The share of the load that is available for DSM assessed in other studies is partly smaller and goes down to 30% (compare e.g. Deutsche Energie-Agentur GmbH (dena) 2010, 442). Flexibility in chlorine production goes hand in hand with the question of storage. Chlorine can be stored easily but due to regulative aspects because of chlorine being hazardous storage capacities should be as small as possible. It seems to be quite impossible to get the permission to store chlorine as a pre-condition to be able to offer DSM. Paulus and Borggrefe consider a reduction of load by 40% for up to two hours as realistic, but neglect the mentioned aspect of storage (M. Paulus and Borggrefe 2009).

In the case of the production of polyvinylchloride, chlorine can be stored as ethylene dichloride - which is an intermediate of the polymer production. In other cases storage as intermediate or final product often is not feasible or even difficult.

Other studies assume a technical possible time frame for load management up to four hours that seems to be very ambitious regarding product qualities. From an industrial point of view product qualities of by-products like caustic soda were suffering when operation the plant is operated below 60% load, too.

The potential is described in the literature to be available in basically all operating hours which amount to 7400 – 7700 hours per year. The activation time of the potential differs between load reduction and load increase: Load reduction is feasible within seconds, while the ramp up takes considerably longer.

The potential for load increase is limited due to the high utilization levels and only mentioned explicitly in a few studies. The highest negative potential is assessed with 346 MW in (Deutsche Energie-Agentur GmbH (dena) 2010, 442). Paulus and Borggrefe mention that in 2009, 8 MW were already offered (although rarely called) as negative balancing potential in the reserve energy market (Moritz Paulus and Borggrefe 2009). In the recently published BET study the socio-technical potential is assessed to zero to 81 MW, depending on the form of usage.

However, load reduction offers a significant potential. One study explicitly differentiate between a positive load shifting (when the load is pre- or postponed) and a load shedding potential: The load shifting potential in this case is assessed with 395 MW (only the membrane process is considered), the load shedding potential goes up to 593 MW (Gruber, Biedermann, and Roon 2014). In another study, the load shedding potential is even as high as 787 MW (VDE - Verband der Elektrotechnik Elektronik Informationstechnik e.V. 2012). As mentioned in chapter 2.2, from macro-economic point of view, load shedding can be an alternative, even if companies do not approve (and therefore the potential might be economic, but not accepted).

Shiftable/sheddable positive load	Shiftable negative load	Time frame
30% - 66% **567 MW** *(484-787 MW)*	0%-20% **130 MW** *(0-346 MW)*	*2-4 h*
Average *Range*		

Table 3-7: Shiftable load and time frame for management for chloralkali electrolysis [aggregated data from literature meta analysis conducted in this study]

Other studies do not always emphasize, if the quantified potential is shifting or shedding potential, but since the utilization level is very high, the potential to catch up on load reduced is comparably small. However, the technical positive potential for load reduction in the other studies is estimated between 484 and 730 MW. The average positive potential mentioned in the studies accounts to 567 MW.

From an industrial perspective this estimation of potential seems to be very high. A rough estimation could be done as follows: The overall capacity for chlorine production, regarding all technologies, is about 5,113 kilotons of chlorine (EuroChlor 2016). Assuming that all of the production units have been produced 7550 hours per year (as average of the literature value 7400-7700 hours), there have been a degree of capacity load of about 86.2 % that means 4,407 ktons of chlorine have been produced. The European average power consumption to produce one ton of chlorine is 2.5 MWh. This means a total consumption of electrical power of about 11.017 GWh. Taking these 7550 working hours result in a load of about 1,459 MW. Referring to the studies, half of the needed load consumed to produce the above mentioned amount of chlorine should be available for DSM. This can only be possible if the degree of capacity lays about 2/3 of the overall capacity, not more than 67%. So a potential between 484 and 730 MW seems not to be realistic. A feasible potential below 200 MW seems to be more realistic (1,459 MW * (100%-86.2%) = 204 MW) with an economic potential that is even smaller.

3.2.5 Iron and steel Industry

Processes for flexibilisation

In general there are two different technologies used in steel production: blast furnace route, which represents the largest fraction in world steel production and electric arc furnace process (EAF). A huge amount of electricity is used in the latter case, where secondary steel is produced from scrap at temperatures of 3,500°C which is furthermore capable of load management measures, as the plants can be shut down and the production process can be postponed.

There are 19 production sites with electric arc furnaces in Germany (Gruber et al. 2014). The steel production is not a continuous process but can be classified as batch production.

The characteristic of EAF is due to the loading of the oven very well suitable for a load management since the start of the melting process can be pre- or postponed and, in case the revenues are very high, the melting process can even be interrupted (Klobasa 2007a, 63).

The estimations of the annual production capacity vary between 13.5 and 13.7 Mt. The electricity demand of the sector shows a wide range with values between 7 and 20 TWh/a (see Table 3-8). The utilization level is only given in one study and is here estimated to 75% (M. Paulus and Borggrefe 2009).

Annual production capacity in Germany	Electricity demand of sector	Electricity demand of process	Average load called
13.6 Mt electric steel *(13.5-13.7 Mt)*	**10 TWh/a** *(7-20 TWh/a)*	**570 kWh/t** steel *(423-790 kWh/t)*	**906 MW** *(741 – 1100 MW)*
Average *Range*			

Table 3-8: Production capacity, electricity demand and average load called for steel production in electric furnaces [aggregated data from literature meta analysis conducted in this study]

Potentials for DSM

The share of the technical load that is available for DSM for EAF ranges from 75% to 100%. The availability of the potential varies between 6,100 and 6,500 hours per year. The production of electric furnace steel can be disrupted short-term, meaning around up to 30 minutes, otherwise the melting process needs to be started again (Gruber et al. 2013).

To tap the potential in EAF, the activation has to be included in production planning. The process with a duration between 50 and 120 minutes can easily be shifted for up to two hours before the start but should not be stopped in progress (Buber et al. 2013a).

The positive shiftable load ranges from 400 MW to 1,100 MW, while the estimations of the negative shiftable load potential do not exceed 25 MW (see Table 3-9). The maximum time frame for a DSM activation is between 45 minutes and 4 hours depending on the study.

Nearly half of the German steel mills have already pre-qualified their processes for the reserve energy market as positive capacity.

Shiftable load (positive)	Shiftable load (negative)	Time frame
75% - 100% **700 MW** *(400 – 1100 MW)*	0% **8 MW** *(0 – 25 MW)*	*45 min – 4 h*
Average *Range*		

Table 3-9: Shiftable load and time frame for electric arc furnace steel production [aggregated data from literature meta analysis conducted in this study]

The future potential in iron and steel production for DSM technologies is limited. Some experts do not see large-scale deployment of EAF for several reasons. The cost-effectiveness needs to be analyzed which could be improved by incentives for DSM availability. Other electric ovens, especially in casting houses provide additional options for DSM.

3.2.6 Pulp and Paper Industry

Processes for flexibilisation

In paper production, there are several processes suitable for load management: grinders, refiners, recovered paper preparation, paper machines and spreading machines.

The processes can be divided in the stages stock preparation, paper machine and finishing. Grinders and refiners are used for mechanical wood pulp production and can be shut down completely for a short period of time.

To produce mechanical pulp from recycled paper, it is first dissolved in water and then processed with pulpers. This process is electricity-intensive and potentially usable for DSM. In the paper machines, the fibre-water-mixture is distributed evenly on a sieve and dried. To use these machines for load management, a long-term production planning is necessary due to a relatively long period of time for ramp-up and shutdown of the machines.

The spreading machines allow a smooth surface of the paper and a uniform thickness. The following data refers to grinders and refiners as here the highest potentials for flexibilities are seen and for other processes no quantifications are made in many studies analyzed.

The estimated production capacity (21-23 Mt) and the electricity demand of the sector (19-20.7 TWh/a) are relatively similar for each study taken into account (see Table 3-10).

The average electricity demand of the processes for wood pulp and refiners are approximately the same (2090-2100 MW), the average load called for both processes is 400 MW.

It is assumed that both processes run 6,100 hours per year. The utilization is estimated at 60% - 90%. The share of load that can be used for DSM is quantified with 80% - 100% in the studies analyzed.

Annual production capacity in Germany	**Electricity demand of sector**	**Electricity demand of process**		**Average load called for both processes**
Sector		**Wood pulp**	**Refiner**	
22 Mt *(21-23 Mt)*	**20 TWh/a** *(19-20,7 TWh/a)*	**2.090 kWh/t** *(2.000-2.090 kWh/t)*	**2.100 kWh/t** *(1.850-2.640 kWh/t)*	**400 MW**
Average *Range*				

Table 3-10: Production capacity, electricity demand and average load called for mechanical pulp production [aggregated data from literature meta analysis conducted in this study]

Potentials for DSM

According to Dena study, only the stock preparation has potential for DSM. Spreading machines and calenders are not taken into consideration due to their low power requirements. The activation time for paper machines is more than 12 hours (Dena 2010). Klobasa remarks that a high utilization of the capital-intensive paper machines is favored, leading to scarcely any potential for load shifting but the throughput of the machines could be reduced (Klobasa 2007a).

The grinders and refiners can be shut down within minutes. However, a certain period of time is necessary between ramp-up and shutdown in order to reduce wear off of the parts (M. Paulus and Borggrefe 2009). Mechanical wood pulp can be stored for a limited period of time before deterioration, offering a significant potential for load shifting.

Shutting down one by one allows a fine graduated partial-load operation (in MW-steps). The needed time for advance notice is less than one hour (Buber et al. 2013a). The electricity consumption of pulp grinders can be shifted for up to 2 hours (Buber et al. 2013a). The positive shiftable load ranges from 200 MW to 400 MW, while the negative shiftable load ranges from 62 MW to 153 MW (see Table 3-11).

Shiftable load (positive)	Shiftable load (negative)	Time frame
80% - 100% **280 MW** *(200 - 400 MW)*	5%-20% **95 MW** *(62 - 153 MW)*	*1,5 – 4 h*
Average *Range*		

Table 3-11: Shiftable load and time frame for mechanical pulp production [aggregated data from literature meta analysis conducted in this study]

3.2.7 Cross-sectional technologies

Several technologies that are applied in most branches, so called crosscutting technologies or cross-sectional technologies, deliver additional potential for DSM. These include among others the following appliances:

- electric ovens for metal production
- grinding mills
- heat pumps
- electrical heating
- air pressure within pumps, compressors,…
- ventilation
- cooling (process cooling, air conditioning)

The studies subsume different processes under the term “cross-sectional technologies”, therefore it is difficult to compare the different figures or to plot them in one graph.

Klobasa assumes a shiftable load potential of 450 – 570 MW for chilling and freezing processes, especially in the nutrition industry. The share of the electricity for refrigeration in this industry is 4-5 TWh/a (Klobasa 2007a). However, the seasonal variations need to be taken into consideration.

The Agora study assumes a shiftable load of up to 480 MW for one hour for cooling and ventilation processes (Klobasa et al. 2013).

The shiftable load potential for not process-relevant ventilation and air-conditioning is 320 MW (Klobasa 2007a). Examples for branches are mechanical engineering and vehicle construction.

Buber and his colleagues estimate the average shiftable load for cross-sectional technologies at 2,800 MW for 5 minutes, 1,400 MW for one hour and 600 MW for 4 hours (Buber et al. 2013a).

The Dena-study estimates a potential of 1,598 MW, 1075 MW, 572 MW and 1,478 MW positive shiftable load as well as 2,680 MW, 141 MW, 0 MW and 703 MW negative shiftable load for compressed air, ventilation, air-conditioning in the chemical industry and air-conditioning in the nutrition industry respectively (Dena 2010).

Advantages of the use of cross-sectional technologies for DSM are the often low costs, good transferability from/into other sectors, a high temporal availability and a good regional distribution.

3.3 Intermediate Results

Basically, some technologies especially established in so called energy intense or energy intensive industries are technologically feasible to be used in a flexible operational mode. That means they could be used to stabilize the electricity grid by delivering negative and positive load. Generally, production processes are dimensioned to operate mostly under full load and the operational mode is optimized in terms of energy efficiency. A production set not oversized, operating in an efficient manner is pre-condition to realize economies of scale and act successfully in a strong international competitive environment. As a consequence, DSM for a continuous load pattern and very high utilization levels (such as aluminum and chloralkali-electrolysis, pulp grinders and paper machines) generally means a loss of production, if the production reduced cannot be postponed or shifted. The load pattern for electric arc furnaces is discontinuous regarding one production cycle (hourly ramp-up and shutdown), while the cement mills are discontinuous regarding day-/nighttime operation.

From a company's point of view, production volume is driven by market demand - because of that the willingness to cease production units to deliver DSM is rather small. Returns of DSM often are not sufficient to compensate revenue loss due to non-produced units under the precondition that size of production capacity is too small for load shifting. This could be one of the reasons why DSM is not offered in a huge amount by industrial companies despite of named huge - technical - potentials in different studies. Furthermore the range of values is relatively broad for some parameters due to different approaches, methods, basic assumptions and limitations. Nevertheless, the potential for DSM for those industries is apparent.

The analysis of industrial flexibilisation is a complex, multi-dimensional problem, where the assessment of potentials for an overall industrial branch is related to a high degree of uncertainty. Different parameters are branch-, application- or site-specific and interrelated. Detailed case studies offer a good opportunity to address this complex problem by narrowing the analysis to one production site only.

To get better insight and solid knowledge about the realistic potential of DSM, at that state the following recommendations should be taken:

- The terms and classification of potentials as suggested in chapter 2.3 should be applied in order to get more transparency in the scientific debate as well as a more solid base for the interested industry actors (differentiation especially from technical, techno-economic and economic potential).
  Furthermore, a more careful differentiation of load shedding and load shifting would be helpful
- It is necessary to further expand on the time constant of the relevant process that is suggested for DSM. For a company, it is highly relevant whether load is reduced for a few minutes or several hours and how frequently it is demanded. Furthermore, size of loads demanded should fulfill capabilities of companies.
- R&D efforts dealing with storage systems (power, steam, educts, intermediates, products) as well as its implementation have to be conducted. Here, a differentiation of further production processes and products has to be considered. For example: the element chlorine cannot be stored for security reasons but the chlorine-product PVC can easily be stored. This storage capacity has great influence on the load management potential. Some studies do not draw these distinctions.

The data found in the studies was presented and reviewed with experts from industry in a workshop in May 2015: Mr Hauck (Trimet, aluminium), Mrs. Perrey (Covestro Deutschland AG, chemical), Dr. Ruppert (VDZ gGmbH, cement) and Dr. Stumpfe (ThyssenKrupp, steel). The feedback of the industrial partners was a useful supplement to the literature-based analysis.

4 Economical assessment of flexibilisation options / market analysis

The economic assessment of some studies show that load management measures can be cost-effective compared to other balancing or storage options. However, the costs can differ significantly from one production site to another, therefore cost estimations need to be based on examples. Two case studies are presented in the context of the broader analysis on barriers and drivers (see chapter 5.2). The following chapter aims to give an overview on the market conditions and “product” characteristics on the markets for balancing power. Against this background, the possibilities of industrial players of these markets can be roughly qualified.

4.1 General overview over products – *in the German market*

There are three possibilities for commercialisation of DSM potentials in the German market: The spot market (day-ahead or intra-day market), the reserve market, or participation as compensation option in balancing groups. The pre-qualification criteria on the former are less strict than the criteria on the reserve market, simplifying the participation of industries. Especially the long tender periods, the high availability needed and the minimum shiftable load required for the spot market are inhibiting (Dena 2010). The reserve market is divided into primary control reserve (PCR), secondary control reserve (SCR) and tertiary or minutes reserve (MR). These are gradually introduced in the case of deviations in the supply and consumption of electricity. An impression of application and tasks is given in Figure 4-1, while from Figure 4-2 the relevant operation time periods can be taken.

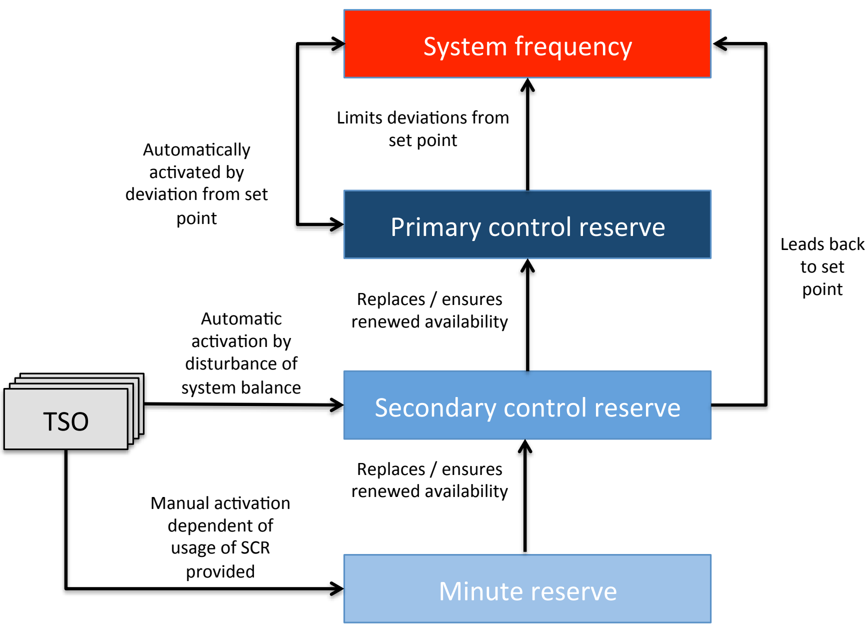


Figure 4-1: Overview over application and tasks of the respective reserve options (translated, according to CONSENTEC Consulting für Energiewirtschaft und -technik GmbH 2014)

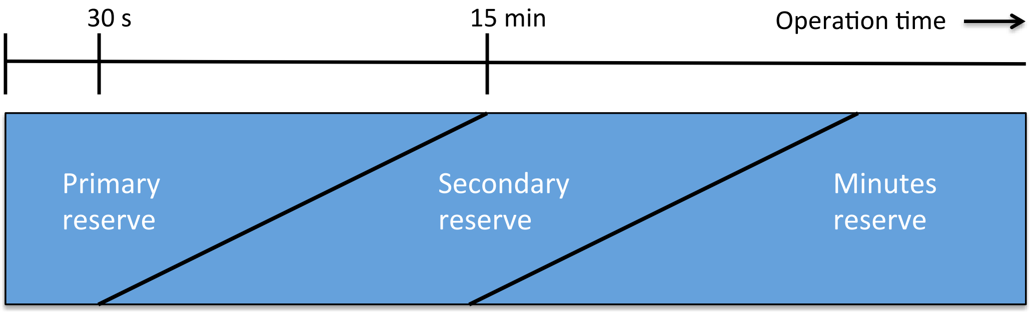


Figure 4-2: Concept of automatic control in the European electricity network (translated, according to CONSENTEC Consulting für Energiewirtschaft und -technik GmbH 2014)

Additionally, the German TSO can fall back (among other options) to the operation of interruptible loads. Here, the two options of immediately (SOL, German "sofort") and fast (SNL) interruptible loads exist that are detailed in the later chapter 4.1.4.

Current tenders regard the characteristics of the reserve products as listed in Table 4-1.

Table 4-1: Summary of product characteristics for reserve options in the German balancing market (BWWi 2015)

	Frequency of tender	**Product period**	**Minimum Volume of product / Increment**	**Pooling**
Minutes reserve (MR)	on workdays	4 hours	5 MW / 1 MW	yes
Secondary control reserve (SCR)	weekly	HT (Mo.- Fr.: 8-20.00); NT (Mo.-Fr.: 20-8.00 & Weekends and holidays: 0-24 h)	5 MW / 1 MW	yes
Primary control reserve (PCR)	weekly	1 week	5 MW / 1 MW	yes

The internet website "www.regelleistung.net" is the platform for trading of reserve products and capacities (50Hertz Transmission GmbH, et al. 2015). It is operated by the four German TSO and data regarding the recent tenders and their results in an anonymized way are provided.

4.1.1 Primary control reserve (PCR)

The primary control reserve has to be able to be activated within 30 seconds. Its duty is to quickly balance disequilibrium in the grid, while the recovery of the set point for frequency is the task of the secondary reserve. PCR is usually provided by large thermal or hydraulic power stations, that can react (due to a storage system for steam) very quickly, but only for a short period of time (CONSENTEC Consulting für Energiewirtschaft und -technik GmbH 2014).

The dimension of primary reserve that has to be provided corresponds to the capacity that would be necessary, if the two biggest power plant units in the regional group of continental Europe would be failing at the same time (BNetzA 2011a). This is numbered as 3 000 MW for Europe, according to approximately 610 MW for Germany in 2011.

The tender for primary control reserve is weekly. It takes place every Tuesday of the previous week, until 15.00 pm. PCR is neither divided in positive or negative load, nor in time slices (Table 4-1). The minimum volume of the product is 5 MW with an increment of 1 MW, but pooling of various suppliers by an aggregator is possible.

Bidden performance prices order the choice beginning with the low priced offer. An exemplary analysis of one week tender from 12th to 18th of October 2015 (taken from 50Hertz Transmission GmbH, et al. 2015) is shown in the analysis (see following chapter 4.3.2).

4.1.2 Secondary control reserve (SCR)

Different form the primary control reserve, that is frequency controlled and automatically activated in case of deviations in frequency, secondary control reserve is activated by the responsible TSO. The task is to reset the deviation of frequency to the nominal value and to completely replace the PCR, so this is available for other disruption cases. The activation of secondary control reserve therefore is a time sensitive process. In Germany, a limit of activation time of five minutes is set (CONSENTEC Consulting für Energiewirtschaft und -technik GmbH 2014). Secondary control reserve is typically provided by thermal power stations that are able to control their capacity or storage power plants (e.g. pumped-storage plants).

Secondary control reserve (as minute reserve as well) is divided in positive and negative control reserve. If the demand of electricity from consumers is higher than the actual production, positive control reserve is required. The TSO needs an increase of electricity, which can be provided by the reduction of electricity demand of industrial consumers. Negative control reserve however means the increase of demand of electricity in order to balance a higher supply than the actual demand. The demand for both, positive and negative secondary control reserve for Germany is about 2 000 MW according to (BNetzA 2011b).

The tender of secondary control reserve is weekly, namely every Wednesday. SCR is divided in two time slices: main time (German: “Hauptzeit”, HT) and low time (German: “Nebenzeit”, NT). Main time is weekdays from 8.00 am to 8.00 pm and low time on weekends, public holidays and during the week from 8.00 pm to 8.00 am (BNetzA 2011b). So, HT is accounting for ca. 35 % of the time of a week (without public holiday) and NT for ca. 65 %.

TSO have to tender their demand of secondary control reserve over all control areas. SCR (as minute reserve) is compensated via performance price (price per kW) and price per kWh. The first award procedure is according to the price per kW, the actual request follows according to price per kWh. Therefore, the awarding follows a Merit-Order system of lowest prices first. Again, as for PCR, the minimum volume of the product is 5 MW with an increment of 1 MW, but pooling of various suppliers by an aggregator is possible.

4.1.3 Minutes reserve (MR; as well: Tertiary control reserve)

Due to the high technical requirements of secondary control reserve, not the whole needed capacity can be (or should be, for practical, as well as for economic reasons) provided at the same time. Part of the demand is offered as tertiary or minutes reserve. Here, the activation time is 15 minutes. Activation occurs not automatically, but it is done by the responsible TSO from case to case and dependent on the foreseeable development of the deviation. The initiation is based on the order of bids. Bids that are accepted are generated automatically following the order of its prizes. As typical suppliers of minutes reserve, gas turbines during standstill, virtual power plants, plants under the renewable-energy-law(EEG) in direct marketing (as biomass plants) and as well as flexibilities on the demand side are listed by (CONSENTEC Consulting für Energiewirtschaft und -technik GmbH 2014).

The tender is daily for the following day with deadline at 10.00 am. Information about the granted acceptance of the offers is at 11.00 am. Minutes reserve is offered in six time slices of four hours respectively (beginning with 0.00 – 4.00 am, 4.00 – 8.00 am and so forth). Each time slice is divided in positive and negative load.

Many details of the tender for minutes reserve follow the regulations for SCR tender:

- Compensation via price per kilowatt (performance price) and price per kWh;
- Tender has to be over all control areas;
- Minimum volume is 5 MW with increment of 1 MW;
- Possibility of pooling via aggregators

4.1.4 Interruptible loads

Aside from the three control reserves, there is the option of offering a product called "interruptible loads" (Verordnung über Abschaltbare Lasten; AbLaV). This regulation has been introduced as measure for the implementation of the German "Energiewende". The period of validity has been limited first to the period of 1st of January of 2013 to end of December 2015, but will be extended for another six month. The benefit and effect of the regulation is seen rather ambivalent: while some industrial players appreciate the additional possibility of marketing their flexibility, some associations for example the Association of Energy Market Innovators (Bundesverband Neue Energiewirtschaft; bne) and the German Trade Association (Deutscher Handelsverband, HDE) criticise it as ineffective and costly[6], referring to an report of the Federal Grid Agency (Bundesnetzagentur 2015).

The regulation aims at big industrial consumers that are connected to the transmission grid (minimum voltage of 110 kV), take high amounts of electricity around the clock and are able to adapt their demand flexible to the requirements of the grid.

There are generally two products foreseen in the AbLaV:

- Immediately interruptible load (SOL, German "sofort") is automatically activated within one second, frequency controlled by deviations in the grid

[6] http://www.einzelhandel.de/index.php/presse/aktuellemeldungen/item/126021-verordnung-zu-abschaltbaren-lasten-nicht-verlängern

- Fast interruptible load (SNL) are activated by the TSO within 15 minutes

Both need a minimum of 50 MW load availability, provided by maximal five units. Three request options exist for both products, detailed in

Table 4-2 below.

Table 4-2: Overview over the request options within the AbLaV (translated according to Fahl and Oertel 2014)

Option	Minimum duration of request	Maximum availability	Break periods
A	15 min	(multiple) 4 x per day (up to 1 h); minimum 4x per week	optionally up to 1 h per day; at maximum daily request minimum of 12 h between 2 requests on subsequent days
B	4 h	1 x per week	48 h
C	8 h	1 x per 2 weeks	7 days

After AbLaV has come to force the first six months were needed for an implementation stage. After these six months the first offer has been made. Until the end of 2015, on nine days 57 calls have been realised and six companies have been pre-qualified and were able to participate, according to (Bundesnetzagentur 2015).

The compensation of supply with interruptible loads is divided in a fixed performance price and a price per kWh. TSO are obligated to compensate their expenses; the shares in cost have to be paid from the final user.

4.2 General overview over products – *in the Belgium market*

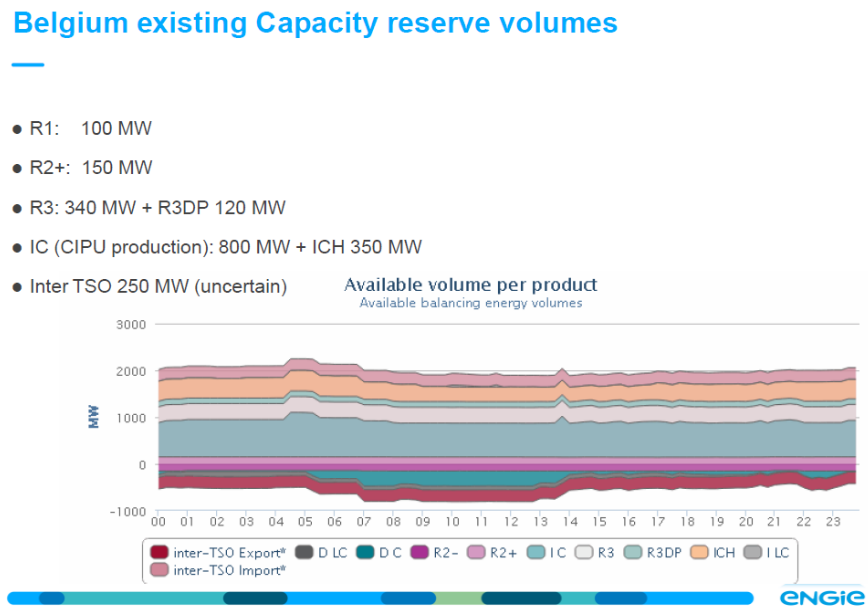
The energy supply system in Belgium is affected via EEX by increasing shares of regenerative energies, too. The Belgian energy mix mainly consists on nuclear power (~5,925 MW) and gas power plants (~5,362 MW). Coal is of minor importance for power generation (~834 MW). Compared to Germany gas-fired power plants become less economic with increasing shares of regenerative energies within Europe (Belgium: ~888 MW). Total electricity consumption in Belgium lays about 84 TWh/a. Belgium is net importer for electricity 16 TWh) (Source: ENGIE).

Demand of control power is rather high, especially in winter times. The responsible TNO in Belgium is Elia. First of all, so called "access responsible parties (ARP)" are obliged to balance their customer portfolio at their access points into the transmission grid on a quarter-houly basis. Where ARPs are unable to balance their customer portfolio the TNO has to undertake necessary steps to balance the control are. Therefore Elia has introduced several products to maintain balance on a national level and to control sudden imbalances between injection and off take:

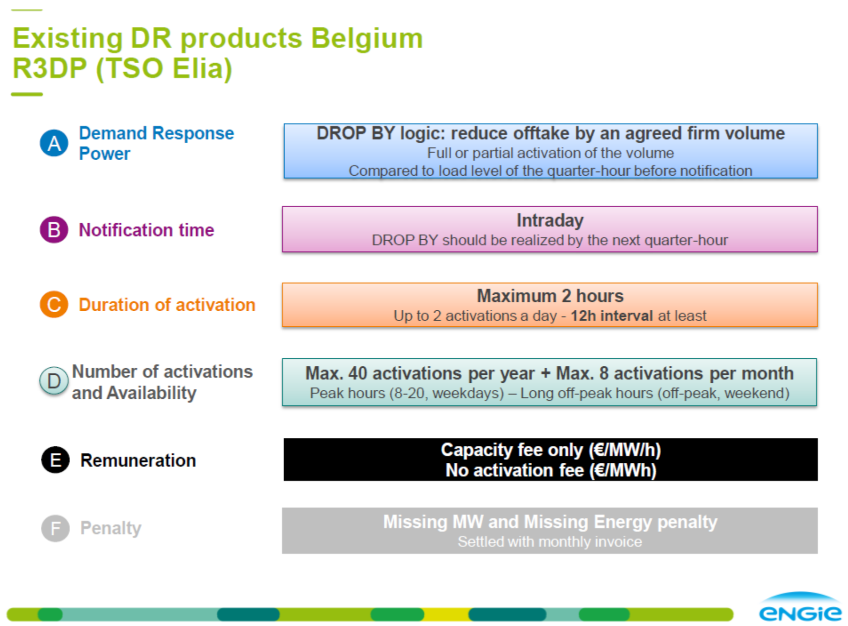
- Primary reserve (R1)
- Secondary reserve
- Tertiary reserve

- Tertiary reserve via sheddable customers
- Uncontracted reserve (“free bids”)
- Reserve contracts with neighboring systems operators

Capacity reserve volumes in Belgium are about 2,100 MW. Its functionality is similar to the types of control power (PCL, SCL, TCL, SOL and SRL) in Germany. But specific product design of loads that could be offered by companies, for example by energy intensive companies are quite different in comparison to German products for the above named types of control power. Main products and its characteristics are:

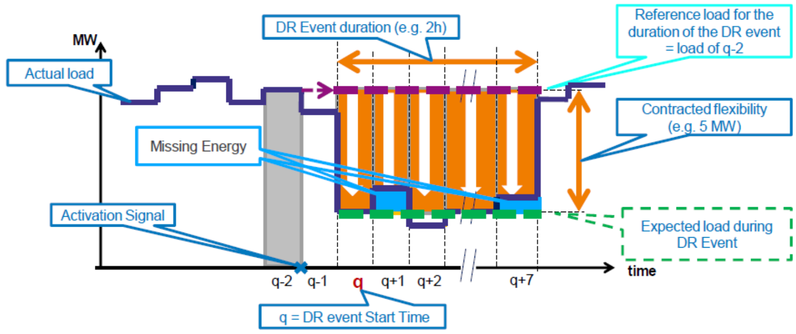


Products at TSO level are R3DP Dynamic Profile, R1 and ICH as well as SDR Strategic Demand Reserve and SGR Strategic Generation Reserve. In comparison to German products, duration and numbers of activation as well as fees are different. The R3DP, the R1; and the ICH product serve as examples to demonstrate this statement:



Existing DR Products Belgium
R3DP

- **Missing MW penalty:** if the contracted flexibility is not available for a particular quarter-hour outside the activation period, a penalty of 130% of the capacity fee is charged.
- **Missing Energy penalty:** if the contracted flexibility is not (fully) delivered during an activation, a penalty is charged, based on the capacity fees and an error rate.



R3DP Specifics

- Minimum power for tendering 1 MW (or else by means of aggregator)
- Unsheddable margin or shedding limit: Minimum power level which is vital for the site, which can never be shedded.
- Verification of compliance: (head meter – shedding limit) has to be bigger than contracted power. → minimal value
- Yearly tendering during summer period
- DSO (if concerned) performs a pre-qualification to check the risks for local congestion problems or other grid stability issues.

- Value 2015: 20 – 25 k€ / MWyear for consumer and about 35 k€ for aggregating company
- (Remark: Real market value is estimated lower)

Primary Reserve (R1)

- R1 for Frequency regulation
- Continuous availability
- Response time within 15 seconds
- Maximum duration is 15 minutes
- Mainly units in generation
- about 30 MW contracted to consumers
- Capacity remuneration (no activation fee)

Interruptible Contract Holders (ICH)

- Limited amount of actiovations per year (4)
- Minimum 5 MW at connection
- Offtake below shedding limit within 3 minutes
- Maximum duration is 8 hours
- No warranty needed and no exclusivity
- 260 MW
- Bidding price (pooling allowed)

The differences between German and Belgian products that fulfill the same function and intend to serve in the same manner to stabilize the power grid show, that certain scope exists for designing products. From a theoretical point of view a design of “energy intensive industry- DSM products” should be possible to encourage industry to engage more powerful in DSM.

4.3 Analysis of practical behaviour of bidders

The platform www.regelleistung.net has among others the function to guarantee transparency in the German market for balancing power and control reserve. The data for the following analysis and interpretation has mostly been obtained from that source.

After a short view on the industry players at the control reserve market, the results of exemplary tenders are evaluated. The prices for kilowatt and prices for kWh are examined as well as the offered capacities. Based on that data, first conclusions can be figured out regarding the business cases conducted in chapter 5. To do so, tenders of PCR and SCR has been evaluated (50Hertz Transmission GmbH, et al. 2015), regarding the week of 12th to 18th of October 2015 that has been randomly chosen. As intermediate result, implications for the industrial players are named.

It has to be stated, however, that the prices and revenues for DMS used here for the randomly chosen week in October 2015 are generally lower than they have been in the previous years (2013-2014). On a long-term perspective it can be stated, that at the same time as the price for electricity has decreased, the DSM revenues have deceased as well.

4.3.1 Industrial players at the market

Because of transparency guidelines TSO have to name the participants of control reserve products. This information is provided with the side www.regelleistung.net, too. Most of the listed companies are energy producing companies that have their core competence in the production and supply of electricity and are therefore not in the focal point of the consideration within this project. Only few industrial companies could be found. These are for example companies from chemical industry, aluminium industry or steel industry.

Furthermore aggregators can be found. Aggregators organize industrial companies by entering into an agreement with the company to market the companies’ control power for a fee. By pooling the control load of several companies the binding character within the pool is not as obligatory as if the company market the control power itself. If issues in terms of production arise another company of the pool can fulfil the aggregators’ obligation. Therefore production of goods still remains the key activity of the company. Furthermore the companies get rid of the administrational efforts of the process of bidding.

In the following evaluation of tender results, all data is anonymized by the provider (50Hertz Transmission GmbH, et al. 2015). It has to be assumed, however, that industry actors are the minority of all players, as the electricity providers dominate the market and set the rules. It can however be stated, that most of the industry players that are not operating via an aggregator are active in the field of offering minutes reserve, while only one company is ready to offer primary control reserve.

4.3.2 Results from tender for primary control reserve

Primary control reserve is compensated via performance price only. For the randomly chosen week in October 2015, the results of the tender are gathered in Table 4-3.

Table 4-3: Results for performance price and capacity from an exemplary tender week in October 2015 for primary control reserve (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

	Performance price [EUR/MW]	Capacity offered [MW]	Capacity awarded [MW]
Average	2.910,58	5,35	5,33
Minimum	2.500,00	1,00	1,00
Maximum	2.983,00	23,00	23,00
Total		**787**	**783**

The range of performance price differs only of about 483 € per MW with the average being close to the maximum. The data suggests some kind of "certainty" in terms of planning returns when providing primary reserve control energy. The graph in Figure 4-3 shows the growth from the beginning price (minimum) to the maximum in a slow increase.

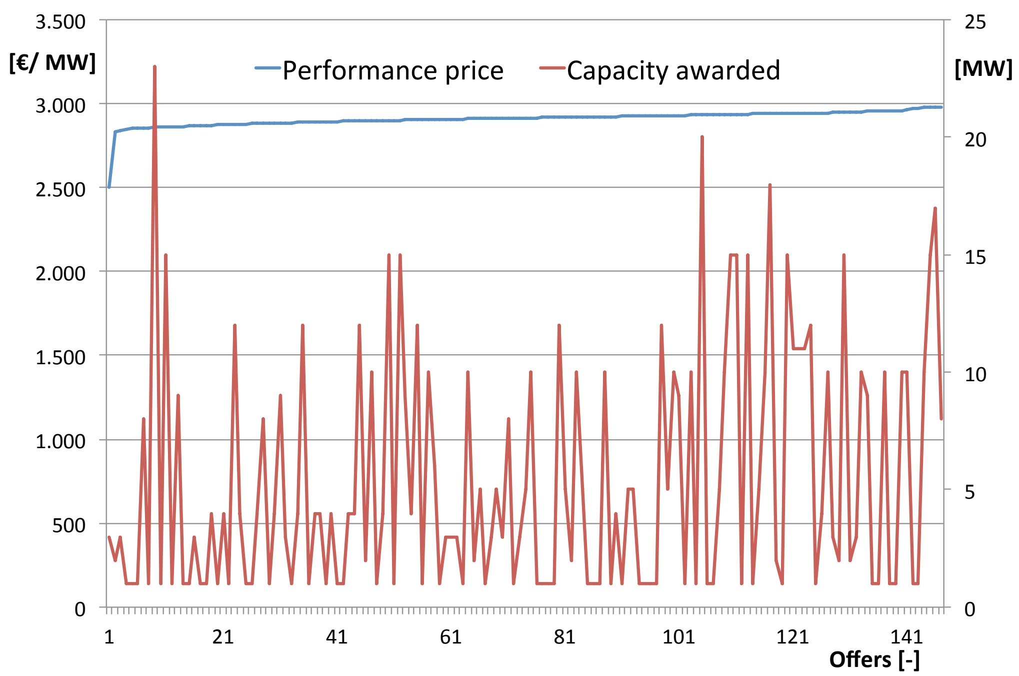


Figure 4-3: Performance Prices paid and capacity awarded for exemplary tender on PCR in October 2015 (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

Furthermore it can be stated that the awarded loads vary mostly between five and ten MW, most of them are below 20 MW with the exception of one bid of about 23 MW. Most of all offered loads have been awarded (Table 4-3 shows a difference between awarded offers of 783 MW and bids of 787 MW).

4.3.3 Results from tender for secondary control reserve

The results from the tender on SCR of the examined week can be seen in Table 4-4. At first, the offers of secondary control reserve are selected via price per Kilowatt. The effectively delivered release order is determined by the prizes of kWh in a second step. SCR is categorized in the two general products of positive and negative load and in time slices of main time (HT) and low time (NT).

From the table it can be stated that the product of positive load at low time is the most expensive one, when looking at the performance price per MW. However, it has to be kept in mind that HT is accounting for only two thirds and NT for two thirds of the time, so the difference is a bit lower when nominating on the same period.

Although the capacity offered is approximately the same between negative and positive load, negative load is offered considerable cheaper than positive, again only looking at the performance prices. So, the reduction of the industry demand of electricity as positive load is compensated higher than a temporal increase of industry demand as negative load. The picture turns around when considering the prices per kWh: here, negative load achieves higher revenues.

For the evaluation of these effects, the behaviour and calculations of the bidders have to be taken into account (see also the following chapter 4.4), for different schemes of behaviour and different intentions exist.

Table 4-4: Results for performance price, price per kWh and capacity from an exemplary tender week in October 2015 for secondary control reserve (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

		performance price [EUR/MW]	price per kWh [EUR/MWh]	capacity offered [MW]
NEG_HT	**Average**	**68,40**	**1.772,16**	**13,94**
	Minimum	46,00	-14,40	5,00
	Maximum	78,00	6.000,00	100,00
	overall capacity			2.007
NEG_NT	**Average**	**105,83**	**1.858,17**	**13,21**
	Minimum	78,00	-7,85	5,00
	Maximum	135,00	6.503,00	50,00
	overall capacity			2.047
POS_HT	**Average**	**305,32**	**1.527,57**	**21,25**
	Minimum	243,00	50,50	5,00
	Maximum	384,00	20.000,00	80,00
	overall capacity			2.061
POS_NT	**Average**	**588,30**	**1.442,87**	**19,69**
	Minimum	475,31	48,86	5,00
	Maximum	857,00	20.000,00	60,00
	overall capacity			2.067

SCR can be offered in a minimum of five MW with an increment of one MW. As can be seen from the average, most suppliers decided for a medium size of volume. The highest volumes have been offered in the last quarter of the range of performance prices (up to 320 – 370 €/MW).

The capacity offered is nearly the same as the overall demand of secondary control reserve, as to few MW in each segment. It can be approximately concluded that all offers have be considered. The majority of bids (app. three of five) have a volume of below ten MW, another ten per cent is below 20 MW. Only two offers meet the maximum volume of 100 MW.

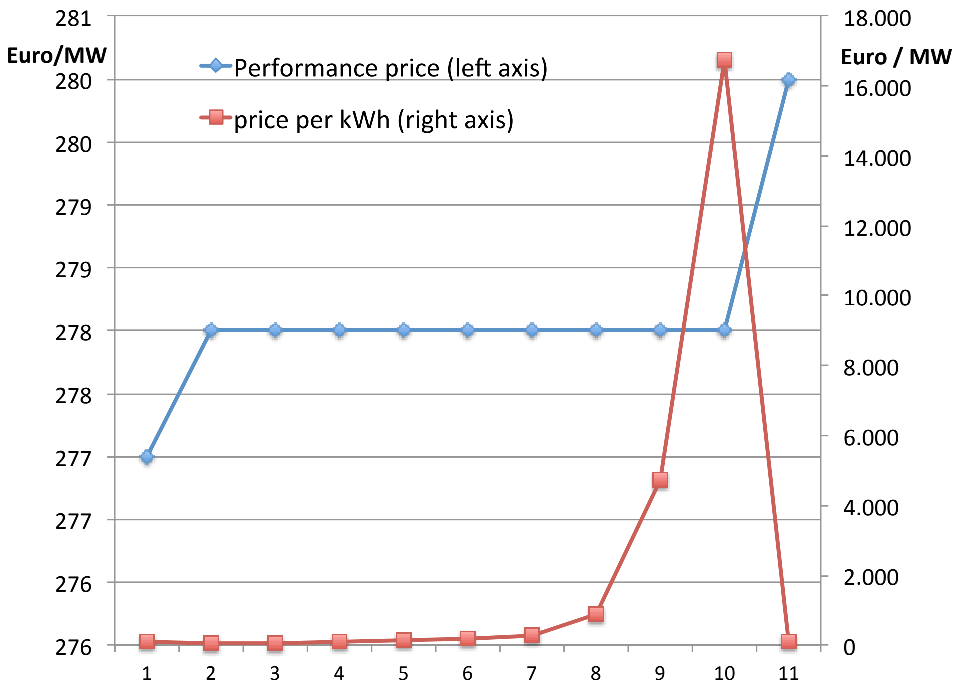


Figure 4-4: Exemplary extract from the tender results of POS_NT, interaction of prize per Kilowatt and prize per kWh (own compilation, data taken from 50Hertz Transmission GmbH, et al. 2015)

The interaction and interdependencies of performance price and price per kWh is illustrated in the extract shown in Figure 4-4. As described above the awarding of bid follows the best prices per Kilowatt at first. All chosen offers get paid in the amount of their bid for their willingness to deliver control power. Performance prices form a stage, if several suppliers offer the same price. The selection of load is then according to the rising price per kWh, following the Merit Order concept. Therefore, the last MW needed at the given performance price can possibly be compensated with considerable high prices per kWh. Unfortunately, a supplier cannot rely on the chance and calculate with these high revenues.

4.3.4 Results from tender for tertiary control reserve

Tertiary control reserve (even named minute reserve) is - as the secondary control reserve - divided in positive and negative load. It can be offered as well in six time slices per four hours, beginning at midnight. The data of the tender of one randomly chosen day (12th of October 2015) are shown in Table 4-5. Like for the other control reserve options, only the awarded offers and their prices are shown.

Table 4-5: Results for performance price, prize per kWh and capacity from an exemplary tender day in October 2015 for minutes reserve (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

		performance price [EUR/MW]	price per kWh [EUR/MWh]	Capacity awarded [MW]			performance price [EUR/MW]	price per kWh [EUR/MWh]	Capacity awarded [MW]
NEG 00-04	**Average**	**0,03**	**128,65**	**9,57**	POS 00-04	**Average**	**0,00**	**123,25**	**8,53**
	Minimum	0,00	0,60	5,00		Minimum	0,00	55,00	5,00
	Maximum	0,15	990	40,00		Maximum	0,00	195	65,00
	overall capacity			2.211		overall capacity			1.792
NEG 04-08	**Average**	**0,03**	**124,75**	**9,66**	POS 04-08	**Average**	**0,00**	**175,68**	**8,24**
	Minimum	0,00	3,60	5,00		Minimum	0,00	88,00	5,00
	Maximum	0,15	990	80,00		Maximum	0,00	317	65,00
	overall capacity			2.212		overall capacity			1.780
NEG 08-12	**Average**	**0,04**	**539,13**	**7,66**	POS 08-12	**Average**	**0,02**	**745,72**	**8,05**
	Minimum	0,00	0,10	5,00		Minimum	0,00	94,00	5,00
	Maximum	0,15	18.800	40,00		Maximum	0,05	4.442	70,00
	overall capacity			2.213		overall capacity			1.780
NEG 12-16	**Average**	**0,06**	**534,81**	**7,73**	POS 12-16	**Average**	**0,00**	**168,36**	**7,42**
	Minimum	0,00	0,10	5,00		Minimum	0,00	86,00	5,00
	Maximum	0,20	20.000	40,00		Maximum	0,00	266	70,00
	overall capacity			2.211		overall capacity			1.780
NEG 16-20	**Average**	**0,02**	**420,84**	**7,46**	POS 16-20	**Average**	**0,08**	**1.323,17**	**8,08**
	Minimum	0,00	0,10	5,00		Minimum	0,00	55,00	5,00
	Maximum	0,10	18.800	40,00		Maximum	0,24	7.986	70,00
	overall capacity			2.216		overall capacity			1.777
NEG20-24	**Average**	**0,00**	**547,41**	**7,98**	POS20-24	**Average**	**0,00**	**224,02**	**8,02**
	Minimum	0,00	0,10	5,00		Minimum	0,00	94,00	5,00
	Maximum	0,01	18.800	29,00		Maximum	0,00	716	70,00
	overall capacity			2.211		overall capacity			1.780

Paid prices for kWh are in average barley above zero or exactly zero in many cases, especially for positive load. The minimal bidden price of the tender is about zero for all products and time slices. The highest offered price paid for positive load is 0.24 €/MW for positive load in the afternoon (POS_16-20). In this segment the biggest prizes for kWh are achieved. Both results present a peak in the overall picture of the time slices, while the highest maximum prices were paid in the afternoon / night with negative load (NEG 16-20 and NEG 20-24).

Contrary to SCR, in the overall picture the compensations for negative control power is compensated with higher prizes than positive load. From a theoretical point of view it seems to be more profitable for suppliers to temporarily increase its demand of electricity in order to reduce the surplus supply in the grid. The awarded capacity for balancing power is a bit higher for negative load with around 2.215 MW than for positive load (around 1.780 MW).

It can be shown (see Figure 4-5) that most bids offer 5 MW, some bids offer 10-25 MW but only few lay above 25 MW. The volume of offer is not getting bigger with higher performance prices.

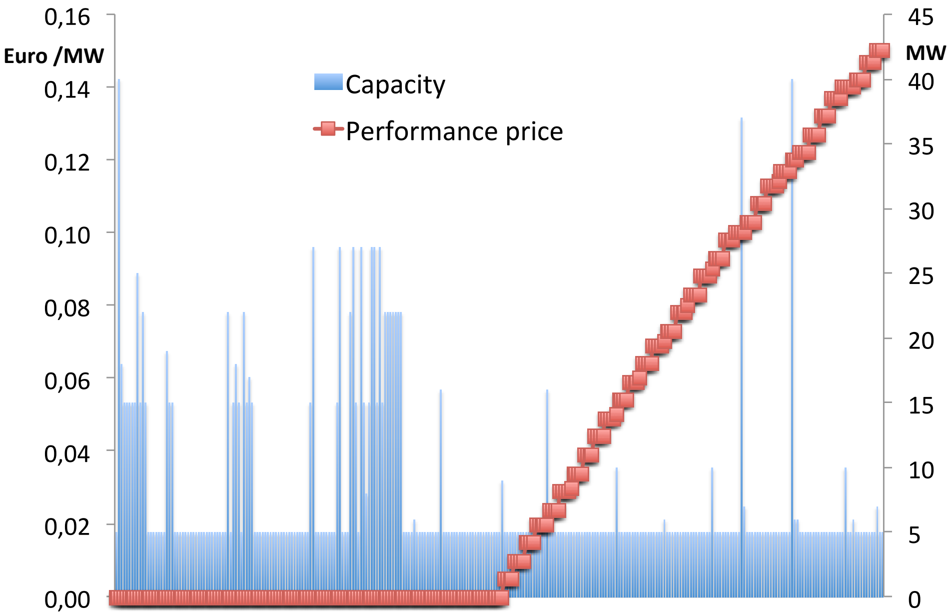


Figure 4-5: Exemplary extract from the tender results: NEG_08-12, performance price and awarded capacity (own compilation, data taken from 50Hertz Transmission GmbH, et al. 2015)

4.3.5 Results from tender for interruptible loads

There are separate tenders for the two products “immediately interruptible load” and “fast interruptible loads”.

The participation of companies in the field of interruptible loads is low in comparison to participation regarding PCR (nearly 150 offers), SCR (about 540 offers), and MR (almost 3000 bids have been awarded, almost twice the number of bids has been offered).

Five offers have been made and accepted for SOL and SNL each in 2015. The results are shown in Table 4-6 and Table 4-7. The price per MW for interruptible loads is fixed by regulation, so the price of kWh is of relevance for the tender. All accepted bids lay in the same range regarding the prize per kWh (395 €/MW for one bid, the other four bids to 400 €/MW).

Table 4-6: Results for performance price, price per kWh and capacity from an exemplary tender in October 2015 for SOL (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

		performance price [EUR/MW]	price per kWh [EUR/MWh]	capacity offered [MW]
POS_00-24	**Average**	**2.500,00**	**395,00**	**92**
	Minimum	2.500,00	395,00	73
	Maximum	2.500,00	395,00	139
	overall capacity			458

Table 4-7: Results for performance price, price per kWh and capacity from an exemplary tender in October 2015 for SNL (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

		performance price [EUR/MW]	price per kWh [EUR/MWh]	capacity offered [MW]
POS_00-24	**Average**	**2.500,00**	**399,00**	**100**
	Minimum	2.500,00	395,00	50
	Maximum	2.500,00	400,00	150
	overall capacity			499

The offered – and awarded – capacities of interruptible loads have bigger volumes than PCR, SCR, and MRL. While for PCR the volumes range mostly between five and ten MW (maximum 23 MW), the volumes in SCR are mainly below 20 MW. Contrarily, the volumes of interruptible loads are all above 50 MW (see Figure 4-6).

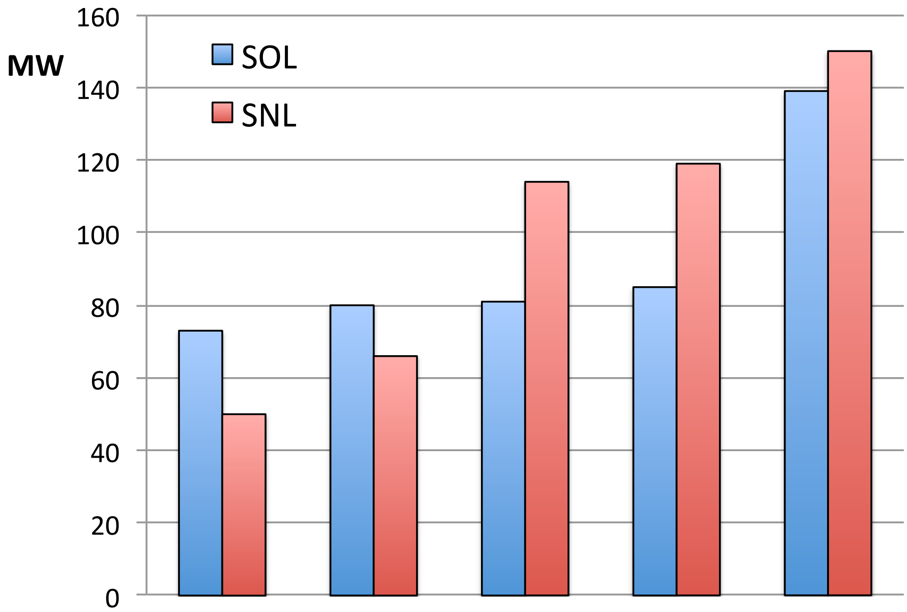


Figure 4-6: Offered and awarded capacities of SOL and SNL, sorted results from tender on interruptible loads in October 2015 (own elaboration based on 50Hertz Transmission GmbH, et al. 2015)

4.4 Implications for industry players on the balancing power market

The already existing engagement of diverse actors on the market for balancing power shows that there are valid and lucrative market models, not only for energy suppliers, but also for industry players. Which plants and processes are available for this market and to what extend capacities are offered is a result of a business assessment and object of internal optimisation.

The presented compilation of tender results shows that there is a calculable range of achievable revenues for each segment. On the other hand, a guarantee for a fixed price does not exist (exemption: performance prices for interruptible loads).

To make a decision for or against participation in DSM market the main question to be answered for the plant operator is, what kind and amount of costs (see also list of costs in chapter 3.1.3) need to be re-financed by the achievable revenue. As part of this optimisation it has to be looked very sharply at the effects to plant or process efficiency, as well. Within this task, the possible and probable shrinks of efficiency have to be quantified ad the effects to the overall economy need to be known. Aside from the business effect on the scale of the single plant or process as well the effects of macro-economic level, as to the overall goal of energy efficiency on national and EU level have to be kept in mind.

From the examined tenders it can be concluded that different motivations or business calculation can lay behind the behaviour of the bidders. This is especially visible from the offers that have not been awarded, as in the case of minute reserve. Obviously, the paid performance prices are in average barley above zero or exactly zero in many cases, especially for positive load, while the picture is quite different for the other segments. For SCR, on the other hand, negative prices for kWh are to be noticed.

The following typical behaviours can be observed:

1) The actor actually wants to be awarded and to have this offer of flexibility used.
2) The actor wants to participate or at least be visible in the market, but does not really want his plant or process to be operated flexible.
3) The actor wants to be awarded and have his plant or process in the market, but does not want to be actually requested.

In the first case, the actor does really mean his offer and is willing to operate his plant or process flexible, as the TSO demands it. The actor therefore chooses his offers in both, performance price as well as price for kWh, in a way that he has good chances of being requested. This means, both prices have to be as low as possible in order to receive the knock, but at the same time high enough to gain a profit of it (bearing in mind all included costs, as explained above). If both prices are set right, the actor can make revenue out of the tender. However, there is no guarantee to that, as the setting of the prices is to a certain extend object of speculation, as the award of contract can be a question of fractions of Euro cents. A good insight knowledge not only of the own plant or process, but also of the market behaviour of the competitors as well as the needs of the TSO is pre-condition. As an example of the strong competition the partly negative prices for kWh in the case of SCR can be named.

The second case is contrary and can indeed be observed at the market: the offer even of performance price is too high to have a chance of being awarded. For example, in the case of minute reserve, performance prices of more than 300 €/MW have been asked for, while even performance prices of zero were not receiving the knock in the same tender, because there were by far enough offers with low enough prices for kWh at a performance price of zero. The fact that there were twice as many offers than have been awarded shows that this behaviour of actors is not unusual. Tender results from other randomly chosen time periods confirm the conclusion. Obviously, the sole participation in the process is valuable for the actors. It can be assumed that the relevant actors are already included in the overall market and their actual effort for the tender is not very big, because it is probably digitized and does not cost a lot of man power. Furthermore it can be assumed that the actor does plan to really participate in one of the next tenders and is therefore remaining in the relevant circles.

The most interesting case with the highest potential of business optimisation is the third case. Here, the actor aims at receiving the offered performance price, but does not want to actually have to respond to the TSO request. Therefore, the offer has reasonable performance prices in order to participate in the overall tender, but the offered prices per kWh are set too high to have a chance to be accepted by the TSO. This high price per kWh can, however, be a compensation for the unrealistic case that the plant operator has to deliver the flexibility offered.

This case is very much speculative and requires a good insight of the market and is more a “playing field” for economists of a certain branch / plant.

4.5 Intermediate result

As intermediate result of this chapter on products and market situations it can be stated, that DSM is not a new concept, but in the given situation (especially in Germany with ambitious goals on fluctuating, renewable energies) it gains of importance. Therefore, industry players develop new interest in the concept, encouraged by governmental policies and intentions, which have already led to the regulation of interruptible loads (AbLaV).

For the industry players, DSM can be seen as a quite complex instrument of business optimisation – be it as part of the optimised charging of electricity for the own plant, as it is already common behaviour in many cases; be it as well as a new opportunity to increase revenues through clever bidding at the control reserve markets. DSM will not, in any case, replace or fully compensate for the core competence of business, the production of goods and products.

In the economical optimisation, the eventual loss of efficiency has to be quantified and considered, of course. This is essential on the one hand for the plant operator in order to calculate the needed revenues for flexibility. Revenues should be at least as large as investments in over-capacities to enable DSM. On the other hand, as well for the national economic accounts and for the ecologic perspective, the effects have to be well known, in order to assess the economic and ecologic sense of the DSM concept.

Only an integrated assessment leads to the formulation of recommendations for actions. These can be different for the diverse actors and levels: industry companies, TSO and electricity market actors and policy makers and financial support givers.

5 Business opportunities for DSM

The previous chapters showed that there is a technical potential for industry to engage in demand side flexibilisation. Furthermore it has been shown that technical potential is not identical with the economic potential and that many studies cited before overestimate what could and will be realized. The purpose of industrial enterprises is the production of goods. Potentials only will be brought to the market if all expected costs - including lost sales if production output could not be caught up at later time - from a DSM driven production will be overcompensated. From the market side, increasing shares of renewable energy in power production will most likely further increase the demand for flexibilisation products. In the future, a higher prize spread of prizes for electricity could be expected with increasing amounts of renewable production in the power mix that could further attract DSM measures for industrial producers.

The products through which balance energy can be offered by differed actors are defined by regulators framework and the current prices achievable for these products were presented in chapter 4. Since these products are regulated and standardised and are thus not industry, branch or company specific, we change the perspective in this chapter and focus on the supply side. By applying the business model canvas, questioning industry actors with questionnaires, conducting a workshop and doing case studies, the view of different industry stakeholders was captured and summarized. After presenting the methods applied (chapter 5.1), we present the results in chapter 5.2. Production technologies of so called “energy intensive industries” like aluminium production, mills in cement industry or chloralkali-electrolysis have been examined in many studies (Klobasa, Marian et al. 2013; Buber et al. 2013b; Gruber, Biedermann, and Roon 2014) with special regard to their potential contribution to stabilize the grid by providing flexibility in production, by DSM. An overview about the conducted meta-analysis of potentials is given in chapter 3.1.

By the interviews it could be figured out that potentials are depending of the specific industrial setting and the production environment. Keeping this in mind in chapter 5.2 we also reflect the business opportunities in light of external conditions. In a last step, we present two business cases, one from chemical and another from aluminium industry to illustrate investment costs needed- that have to be financed by earnings of DSM- in order to establish conditions to increase the flexibilisation potential of their processes or even make it available. Finally, conclusions are drawn on the business opportunities for DSM. They are presented in a SWOT analysis (chapter 5.4).

5.1 Approach to identify business opportunities for DSM

In the following section, the different methods applied for identifying business opportunities for DSM are described in detail. These methods comprise the business model canvas, a workshop, questionnaire and case studies.

5.1.1 Concept of Business models canvas

One methodology for a comprehensive and structured presentation of business models is the business model canvas presented by (Osterwalder and Pigneur 2010). This concept is used to describe, design and analyse business models. This canvas defines nine categories that need to be analysed and described in order to specify a business model. The description can include qualitative as well as quantitative data (depending on the data available and applied) and can serves as basis for discussions on future development and business model innovation. It does offer tools for directly comparing or challenging one model against another (if multiple models are available), but can nevertheless give a good overview on options and alternatives described. The nine steps needed for the description are shortly summarized in the following (based on (Osterwalder and Pigneur 2010)).

For defining the business model there are several starting points. One point is the **Customer segment**. For a business, it is important to define the target group that is to be addressed and to detect their respective needs and requirements. Characteristics that are specified in later steps of the canvas, such as the distribution channel, depending on the customer segment focused and would thus change accordingly. Parameters that need to be defined are e.g. geographical or socio-demographical aspects as well as statistical (or in market analysis identified) consumer behaviour. Examples for customer segments are mass or niche markets and the specialization on elderly people or children. These segments have implications for later specifications of the business model.

In a next step the **value proposition** needs to be described, which indicates what service or product shall be offered and which value is created for a specific customer segment. This value proposition can be innovative or already exist in the market. In any case, it needs to clarify why a customer should choose the specific offer (e.g. design, price, performance). The description could include a unique selling proposition, depending on the product or service offered, the proposition does not necessarily have to be unique and could also resemble the one of a competitor.

Having defined the value proposition, the different **channels** for communication, distribution and sales should be thought about. Questions such as how to raise awareness help customers and deliver the value proposition need to be answered. There are many different possibilities of channels possible: e.g. direct vs. indirect channels that could either be owned or operated by partners.

Connected to the question of channels is the **customer relation** a value proposition requires. The motivation for customer relations could be customer acquisition or retention. While some products do not need any personal relationship other business models rely on e.g. personal assistance through point of sale or call centres.

In the fifth step of defining a business model, the **revenue streams** are defined. In general one or more revenue streams are generated for each customer segment, which can differ in pricing scheme, bargaining etc. These revenue streams can either be generated per transaction (one-time payment), or recurrent revenues. Examples for revenue streams are sales, usage fees or Leasing.

All the above-described categories for describing a business model relate to the external view on the value proposition and to the interaction with customers. The following categories focus on how the business is conducted, and are thus more operative than conceptual questions.

To realise the value proposition and established the channels and relations there are several **key activities** that need to be carried out. These activities are defined in this step. Key activities can be production, problem solving or establishing and offering a platform or network.

In order to plan how to really set up the business, it is necessary to reflect the **key resources** needed for these activities to create and offer the value proposition, operate distribution channels or keep up the customer relations. Different resources such as physical resources (e.g. manufacturing facilities, warehouses), intellectual resources (e.g. patents, knowledge) and human resources need to be reflected.

It might become clear that some activities are not feasible for the company willing to market the value proposition e.g. due to some sort of missing resources. In this case, **partnerships** are relevant. In general four different types of partnerships can be distinguished: strategic alliances, joint ventures, buyer-supplier relationships or competition (strategic partnerships between competitors).

All these factors need to be evaluated according to the costs they induce in order to assess the **cost structure** for operating the business model and assess how it can be conducted profitably.

To apply this framework in the project context, we need to reduce its scope. While the canvas intends to describe a business model for one specific firm, we aim at describing a model that could be adapted by several firms, which differ widely in size, branch and activities. This limitation is especially relevant for the operational factors such as the key activities, key resources and cost structure. Within this project the focus will lay on different "key activities" – enterprises have to make the choice to add DSM as part of key activity or not, depending on its specific situation.

5.1.2 Conception of the workshop "Exchange of experience of industrial DSM"

For offering controllable loads and engaging in DSM there are specific framework conditions that companies need to adhere to. These conditions e.g. relate to the design of controllable load products and energy market presented in chapter 4 as well as to company specific production settings. The aim of the workshop was to bring together actors from industry, the Federal Network Agency (Bundesnetzagentur – BNetzA) and network operators in order to discuss the current framework and preconditions for industries as well as their current experiences with DSM under actual and future perspectives. The discussion aimed to get feedback regarding the suitability of the current framework and changes required in order to make DSM (more) attractive for industry. The focus of the workshop was on the Germany market. For the project, valuable insights for a company's decision of getting involved in DSM should be gained.

The workshop took place on 27th October 2015 from 13:00-17:00 in Wuppertal. All in all, about 20 participants from industry, network operators, BNetzA and academia attended (Table 5-1. During the workshop, three inputs from different actors were given: A. Nebel (Wuppertal Institute, Academia) gave an overview on current possibilities for industries to use DSM and on future developments related to the White Paper (BWWi 2015). A. Neider (Federal Network Agency, Policy) presented information on markets of DSM and focused on the role of load aggregators in this context. The third talk was given by C. Linnemann (50Hertz, network operators) on current practices of DSM from the perspective of a network operator.

The workshop gave room for plenary and bilateral discussions. The latter were organised as learning cafés. Participants were invited to discuss points of interest individually with the speakers for 10 minutes and then change the conversation partner. These discussions were not documented. For further input to the discussion of drivers and barriers, flipcharts have been prepared, at which positive and hindering factors for DSM from industry and network operator side were collected. Furthermore, recommended courses of action for promoting DSM in industry were collected.

Table 5-1: Overview about workshop participants

Speaker		
Name	Affiliation	Topic
A. Neidert	Federal Network Agency	Legislative Framework in practice: Role of aggregators
C. Linnemann	50Hertz	DSM in daily business of network operators
A. Nebel	Wuppertal Institute	Legislative framework – Current state and future trends
Participants (* = Project team)		
Name	Affiliation	
A. Baguette	Federal Network Agency	
R. Enzenhöfer	TransnetBW	
J. Stumpfe	Thyssen Krupp	
M. Sprecher	VDEh – Verein Deutscher Eisenhüttenleute	
M. Principato	HeidelbergCement AG	
J. Ruppert	VDZ gGmbH Verein deutscher Zementwerke- Forschung, Technologie	
N. Schneider	Covestro Deutschland AG	
K. Perrey*	Covestro Deutschland AG	
R. Odenthal	Metsä Tissue GmbH	
H. Hauck	Trimet Aluminium SE	
E. Krott	Engie	
S. Saccani	Climate KIC	
K. Arnold*	Wuppertal Institute	
J. von Geibler*	Wuppertal Institute	
T. Janßen*	Wuppertal Institute	
L. Echternacht*	Wuppertal Institute	

5.1.3 Concept of conducted questionnaire

Previous to the workshop, questionnaires were compiled and distributed to invited industry actors. It can be found in Annex I: Questionnaire. These questionnaires were meant as a preparation for the participants and included several questions on the (current) application of DSM in the company, DSM potential and internal and external barriers and drivers as well as suggestions on how to overcome barriers that could be commented and modified. It was structured as follows:

1) Overview on company and its energy supply
2) Past experiences of company with load balancing
3) Identification of further possibilities of DSM application
4) Barriers for application of DSM in company
5) Suggestions for changes of external conditions

Since the questionnaire was optional, two companies and one agent of an industrial association handed in the requested information. The collection of e.g. barriers and drivers in chapter 5.2 is not meant to be all-encompassing but illustrative and as a starting point for further discussions. The information was nevertheless included in this survey. Part of the questions from the questionnaire was inspired by (Langrock et al. 2015).

5.2 Results on business opportunities

The input collected through the methods above, was processed and summarised according to the underlying research questions. To be able to compare the two defined different business models the information of the workshop and the questionnaires have been analysed and described according to the business model canvas methodology. The results are presented in the following.

5.2.1 Business models for offering flexibilisation

The aim of applying the business model canvas is to describe a business model for companies to market control energy as additional service besides their core business (e.g. producing steel). Whether a company decides to engage in DSM and offer flexibilisation products thus depends on whether the new DSM business model is compatible with the prevailing business model. This question is especially relevant in the categories were competition between the two activities may arise e.g. “key activities” and “key resources”. As will be presented in 5.2.2, the analysis of drivers and barriers also shows: Cost and compatibility with existing processes (i.e. activities) are the most relevant barriers for companies. As stated in the introduction, we present two different business models: One model describing the reference case or “business as usual” in which a company focuses on its core product or service. The other model refers to the option of offering DSM. The business model descriptions will be structured according to the nine business model canvas categories. An overview summarizing the differences is presented in Table 5-2.

The value proposition of the DSM business model is controllable load that a certain industry (or energy producer) can offer. As presented in the previous chapter, there are several forms to offer balancing energy e.g. primary or secondary reserve, depending on the time and duration of delivery. The “customer segment” is highly specialized: The product can only be asked for by network operators required to stabilize and balance the energy grid. Per network, there is only one operator. Referring to the specification of customer relation, the product needs only limited interaction with the customer. Depending on the balancing product, the interaction occurs via a platform (www.regelleistung.net; see also chapter 4.1). After pre-qualification of the company by the grid operator it will be listed for the pre-qualified product (PCL, SCL, MR, SOL, SNL). Bids can be given at an internet platform of the grid distributor by offering a prize for demand and for energy. In the case of SCR, for example, offers will be allocated by the height of the bidden demand prizes until the needed demand is reached.

The willingness of offering DSM by an enterprise depends on the following four categories:

1. Pricing schemes relevant for assessing the possible "revenue stream" and thus possible earnings from DSM – especially when waiving or postponing production of goods. Depending on the specific product and production setting (e.g. capacity vs. operating price) needed revenues to attract DSM can differ.
2. Chosen additional "value proposition": DSM products are defined by the regulatory framework (a description of German products is given in chapter 4.1). Besides the interruptible loads (AbLaV in chapter 4.1), companies can offer their controllable loads in terms of MRL and SCR on the electricity balancing market by an aggregator. While for direct marketing the company directly involves in the load balancing market after a successful pre-qualification by the grid provider, working together with an aggregator the flexibilisation potential is "sold" to the aggregator who bundles the load of several partners and offers this aggregated sum of loads on the control energy market. Therewith, the aggregator enables companies that can only provide small loads to participate in the market. Such an approach is known by the name "pooling".
3. "Key activities": Individual production settings that enable companies to participate in DSM - or not (see chapter 3).
4. "Key resources": resources for e.g. potential needed additional storing capacity, employees for maintenance or energy management. When evaluating the costs, not only cost arising due to additional resources need to be taken into account (compare chapter 3.1.3). Müller (2014) present three types of cost: Costs for initialization include investment costs (Installation of e.g. (automated) control or communication technology, modernization of pricing system with energy supplier) and yearly fixed costs (transaction costs, costs for controlling,…). Furthermore, companies have activation costs that include all variable costs (storage losses, additional costs as pointed out above,…). Another relevant cost factor for variable costs are opportunity costs induced by possibly postponed production, reduced quality or the like. These costs can be considerably high, difficult to assess in advance and may be an important barrier for companies to market their flexibilisation option as will be discussed in the next section.

Table 5-2: Summary of business models

	Categories of business model canvas	**Business model option A: Reference case – Focusing on production as key activity**	**Business model option B: key activity production + DSM**
Pr	Value Proposition	Products	Products and controllable loads

			(negative or positive balancing energy)
	Customer segment	Mass market	Mass market for products and niche market for DSM (network operator)
	Distribution channels	Direct marketing to several clients (companies)	Direct marketing to several clients (companies) for product + direct marketing of loads to network operator
	Customer relation	Product specific	Product specific + Offering loads via e.g. internet platform
	Revenue Stream	Product specific	Product specific; additionally: scheme related to DSM product (capacity vs. operating price).
Company specific	Key Activities	Production and distribution of goods focussed on the customer needs	Production and distribution of goods focussed on customer needs. Reducing/increasing energy demand by controlling a certain process (differing between company and industry) according to demand from network operators
	Key Resources	Existing factories, infrastructure and employees	Existing factories, infrastructure and employees; investment in additional capacities are probably needed
	Key partners	Suppliers, customers	Suppliers, customers and network operator
	Cost structure	Driven by product prizes, prizes of auxiliaries, degree of capacity utilization and product prizes	Driven by product prizes, prizes of auxiliaries, degree of capacity utilization and product prizes and driven by costs of additional wear and loose of efficiency due to DSM measures as well as incomes of DSM measures

The summary in Table 5-2 shows the two business models, option A is the “business as usual” model whereas option B shows a business model in which a company delivers DSM as an additional product. As shown in chapter 3 especially energy intense industries have technical potentials to provide significant flexible loads. Option A reflects the “concentration on core activity” of companies of energy intense industries: Producing goods like chemicals, cement, steel, aluminium, paper and glass.

To be able to offer flexible load as additional product, the company faces two scenarios:

a. Capacities are available to offer DSM as an additional product, which means that the company has (temporarily) unused capacities and is therefore able to offer negative power and can make up for lost production at a later date when offering positive power.

b. There are no capacities to offer load shifting potential because lost production during the delivery of DSM cannot be caught up. Offering DSM in this case means shedding load.

In the case of scenario a, the decision for engaging in DSM is relatively easy. In order to shift production units the company has to have capacities and even storage systems that are available for delivering flexibilities. Under the pre-condition that revenues from DSM overcompensates a fluctuating production mode and its possible consequences (higher maintenance costs due to increased wear; loss of efficiency; higher administrative cost, for example) it will be very attractive to participate in DSM and generate additional income.

Decision-making in scenario b faces more challenges. In this case there are no capacities to offer DSM because the production assets are operated under full load. Consequently, the company has two possibilities: It can waive producing goods and offer DSM instead (b1) or it can waive offering DSM (b2).

Waiving of production units is an option if earnings of DSM are higher than earnings of the production of an additional unit of a good. Based on economic production theory it is commonly assumed that production of goods creates additional value for consumers and national economies. Thus, for scenario b1 added value and effects for national economies has to be examined. What does it mean for national economy if goods, like for example steel and power that are completely different in their economic benefit become “substitutes” from the point of view of a company? Will their prizes in the national economy increase and will these goods be replaced by goods from external (international) markets? Answering these questions, however, goes beyond the content of the project.

Nevertheless, earnings from DSM that are “large enough” to refinance investments in additional capacities could attract companies to invest in building up.

Comparing the two models (business as usual and DSM) shows that offering flexible load means additional effort for a company and that depending on the specific situation of the company investments in infrastructure and / or capacities have to be undertaken to enable the company to deliver flexible load.

5.2.2 Internal drivers and barriers

The questionnaires and the discussions at the workshop as well as business model Canvas revealed several drivers and barriers that companies may face when engaging in DSM. Most drivers we present in the following can also be interpret as “being no barrier” instead of being a real driver. They are nevertheless included in the discussion to present a complete picture.

The main driver is a profitable remuneration, which can be seen as additional revenue stream pairing the core business of a company. As soon as costs for DSM are too high, the businesses will most likely not decide in favour for offering its flexibilisation potential on the market. Thus, the often already existent controlling infrastructure and energy management can be seen as a driver since they reduce the costs. Furthermore, if a company works in continuous operation, no additional wages for e.g. otherwise needed additional shifts are required. A further driver for DSM is that some companies feel a certain pressure to react in order to not fall behind competitors that already enter the flexibilisation business. This pressure to react is connected with the (negative) effect of possibly being distracted from the focus on the core business of the company. Furthermore companies could be driven by regulators to participate in DSM to be granted fee abatement (3.2.3).

As already mentioned, the main barriers named by businesses for offering balancing energy are related to costs and especially opportunity costs. The trade-offs that come along with the discussion of the two conflicting goals of energy efficiency and energy flexibilisation give an indication for the needed remuneration: Prices for flexibilisation products need to not only compensate the costs for delivering balancing energy (initiation and activation costs), but also the money otherwise potentially saved by the increased energy efficiency as well as increased cost for wear.

Companies that offer flexibilisation or would like to expand their potential often need to make some adaption to their production lines as pre-condition. These costs of investment may be perceived as one barrier, especially due to instability and uncertainties of (future) external conditions (detailed discussion in 5.2.3.). Further costs are related to personnel cost needed for additional shifts (in shift operation) when the company needs to make up for the missed production or to engage experts for the implementation of new (flexible) processes. In addition, flexibilisation may lead to a higher wear and additional need of maintenance (both connected to costs). As stated above, opportunity costs are a very important cost category. Examples are the reduced quality of the primary product as well as production downtime.

Besides these internal barriers there are as well challenges for companies related to external e.g. institutional conditions, which are discussed in the next section.

5.2.3 Institutional conditions for DSM business opportunities for industries

The overall systemic developments seem to promote business opportunities of flexibilisation for industries in the future. The topic is on the agenda of several actors (in politics and industry) and the flexibilisation of energy production due to the increasing share of renewable energies call for balancing options. Still, there are (currently) bureaucratic burdens for the integration of small actors for load balancing (on the side of network operators) and from the point of view of the current market situation, the flexibilisation of industry as compared to power plants is perceived to be less relevant.

A crucial factor hindering businesses to engage with demand side flexibilisation is the missing security for investments. The reason for this insecurity is the uncertainty on the overall development regarding the need of industry contribution to balancing options on the one hand and on revenue streams for participants on the other hand. The latter aspect relates to uncertainties with regard to long-term developments of flexibilisation products and prices industry actors can offer to and earn in the control energy market. All in all, this makes it difficult for companies to determine the return on investment, which is important to make investment decisions. To address this issue, it is important to establish a reliable setting and for example consider some sort of fixed prices (as it was done with the EEG to promote investments in renewable energy).

Another issue also related to investments and changes in production processes is that those changes might be as significant that they require the permission of a planning authority. In order to reduce barriers for industries, it would be desirable to reduce related bureaucratic hurdles to a minimum.

Further criticism concerns the design of flexibilisation products, which are not suitable for all industries. Some suggestions for a change brought up relate to those of (BWWi 2015). In general, the time slices for the flexibilisation products should be shortened to 1 hour instead of peak- and off-peak (for secondary reserve) or 4 hours (tertiary reserve). As already done for tertiary reserve, the tenders for primary and secondary reserve shall be published on a daily basis instead of weekly.

Besides these regulatory issues regarding product design, another issue related to the legislative framework has been criticised: the current design of network charges (Netzentgeldverordnung). Industry actors, wished for an amendment of the regulation to exclude the delivery of controllable loads when determining network charges, since companies currently risk costly peak loads (either when providing flexibilisation or when catching up on missed production). Furthermore, flexibilisation options should be considered for determining discounts related to §19 StromNEV.

Last but not least, a major barrier perceived by industry actors is the conflict of interest between energy efficiency and energy flexibilisation, which are both on the political agenda (BMWi 2014), (BWWi 2015)[7]. Higher capacity utilization may for example lead to an increase in the efficiency of a production process. As shown in chapter 2.1.4 producing in a swifting mode to deliver flexibility and producing in a most efficient manner may be contradictory. If the process control moves from optimized efficiency configurations to one that allows flexibility to a certain extent efficiency losses may need to be considered. To promote energy efficiency measures, energy-intensive manufacturing companies aiming for tax compensation (Spitzenausgleich – §55 Energiesteuergesetz, §10 Stromsteuergesetz), are required to define and meet energy efficiency targets and implement an energy management system. Loss of tax compensation results in higher (opportunity) costs for flexibilisation. This contradiction would need to be solved if politics were to set meaningful incentives for industry actors. It has to be stated, however, that to date very low experience and R&D exist regarding the actual efficiency losses. Generally, it can be assumed that these losses occur, but evidence is yet to be given and the effects have to be quantified for each plant and process.

5.3 Case studies

Processes are optimized according to production needs and can thus only realize part of the flexibilisation potential theoretically available. To be able to offer more, investments are needed. The business cases are to demonstrate for to specific examples what investment would be needed and what load specific costs would arise. These costs are then compared to current prices on the German balancing market to analyse the profitability.

[7] BNetzA- Beschlusskammer 6- 23.11.2015, Festlegungsverfahren zur Weiterentwicklung der Ausschreibungsbedingungen und Veröffentlichungspflichten für Sekundärregelung und Minutenreserve- Konsultation von Eckpunkten -

5.3.1 Chlorine Production

Producing chlorine by chloralkali electrolysis (membrane process) has several process steps including

- Sole circuit for dissolving salt (sodium chloride, common table salt) in water up to a defined concentration (=upstream)
- Electrolyser as heart of the process, consisting of several racks. Each rack has an anode, a cathode and a membrane that separates the electrode compartments
- Anolyt circuit for cleaning up and drying the produced chlorine
- Catholyt circuit for cleaning up and pressuring hydrogen (=downstream)
- Circuit for caustic soda, with or without vaporizer
- Transformer-rectifier and
- Process control system

Best chlorine electrolysis technology for participating in DSM is the membrane process. According to this the business case is gathering deeper insights in this technology. Regarding different plants of the same technology (membrane process) for producing chlorine different “settings” of the process steps are possible. Electrolysers can have a different amount of electrolysis cells, transformers can bundle different numbers of electrolysers depending on their maximal current they are dimensioned for and even downstream assets can be built in a way that there are some smaller assets working in parallel or only one big seized asset.

Due to these individual settings of each plant investment costs per additional ton of chlorine vary. In the best case only electrolysers have to be added- in the worst case outside battery limits (transformers as well as up- and downstream assets) have to be adjusted. A rough estimation depicts an investment that ranges between 200 € up to 1,200 € per ton of chlorine. As mentioned before capacities that have to be installed in terms of delivering DSM are not operated with a high degree of utilization because they are “over-capacities”. To avoid lack in product qualities minimum load required is about 60%.

The following case should be regarded:

Assuming a given chlorine plant should be enlarged. Added capacities lay about 160kt/y. Because of existing up- and downstream capacities this can be done for a prize of 200 €/ton:

200 €/t * 160,000 t = 32 millions of Euros.

When DSM should be possible, the dimension has to be enlarged by a factor of ~1.66:

160,000t : 60% *100% = 266,666t

266,666t : 160,000t =1.66

Investment costs rise up to 53,120,000€, earnings of DSM only regarding investment costs are:

53,120,000€ - 32,000,000 € = 21,120,000 €

For a completely new investment of 160kt chlorine per year, 2,000 € per t has to be paid. Earnings of DSM lay about 128 millions of Euros.

Production of one ton of chlorine with membrane technology consumes 2.4 MWh. Average prizes per MWh (based on the investment costs) range between 139 € and 833 € (1,200 €/t: 2.4 MWh/t; 2,000 €/t : 2.4 MWh/t).

Earnings for supply of MWh are hard to calculate because products like SCP and TCP are auctioned- due to that there is always a risk for the bidder not to catch the bid (see chapter 4.4). Planning the revenues and therefore the financing for the investment is of high risk. The actual framework does not incentivize investments for build-up of additional capacities in chlorine producing industry only for the reason of delivering DSM.

5.3.2 Aluminium Industry

As the chemical bonding forces of aluminium oxide are relatively high, a large amount of electricity is required for the electrolysis. A share of 40% of the aluminium production cost results from electricity consumption (Hauck 2015). The resumption of the electrolysis process after a break is very time- und cost- intensive, therefore benefits of DSM for an aluminum smelter need to be high enough to compensate resumption costs.

Current situation

Demand-side management has been used in the aluminum industry in Germany for many years. In particular, the operational load management to reduce peak loads and therefore the capacity price has been implemented already for decades. Therefore, the power consumption of the energy-intensive electrolysis units is automatically reduced in case of high company loads. However, this type of load management represents a major obstacle to the delivery of negative balancing energy since it conflicts the current arrangements regarding cost intensive power peaks and §19.2. Electricity Network Charges Regulation (StromNEV).

In addition some actors may use DSM in form of optimized power purchase on the spot market. But currently the spreads are too small to be able to compensate for opportunity cost of lost production, higher operating costs and increasing wear.

In the following TRIMET as one important Aluminium producer that participates actively in DSM has given some deeper insights of practicing DSM. The company has sold flexible loads particularly at the balancing power market. In Germany, 30 MW primary control power in Hamburg and +20 MW resp. -8 MW secondary control power at the production site in Essen is offered.

Additionally, the company reports very good experiences regarding the sale of flexible loads via the Regulation for interruptible loads (AbLaV) since revenues are high. Currently, flexibility of all electrolysis units in Germany is marketed via this regulation. A similar marketing opportunity exists in France. In Germany, 615 MW interruptible services are made available in this way (mainly by only one company).

Future potential

Additionally to the potential already used, the respective industry player has developed a process, which has considerably larger displacement times of up to 48 h, resulting in substantial shiftable amounts of energy. A power modulation in the range of +/- 25% of nominal power would lead in perspective to a shiftable load in only the German production sites of +/- 170 MW and a shiftable amount of energy of 8,000 MWh in total. The maximum time frame for management of 48h results from the limited availability of the aluminium buffer, which is fed from the molten aluminium in the electrolysis cells. In this way, a continuous supply of the downstream casting processes is ensured. The investment costs for the three aluminum smelters in question in Germany are estimated to € 150 - 170 million. This corresponds to approximately € 1 million / MW or related to the capacity of the virtual battery to € 21,000/ MWh for an assumed shifting time of 48 h. If one assumes a continued use over a period of 20 years at an average number of 25 cycles of use per year, the flexibility would have to be sold for € 42 / MWh in order to cover the investment costs only (data from the FlexInd questionnaire).

The current energy-political framework and its expected revenue streams from the provision of flexibility do presently not guarantee a resilient business case for the investment in flexibility.

As already explained, offering flexibility of industrial production processes often leads to a higher demand for energy due to inefficient modes of operations that occur more frequently. An initial assessment for losses of efficiency in this example is 5% resp. 0.7 MWh per ton aluminium.

5.3.3 Cement Industry

Economic Aspects of DSM in Cement Industry (case study from literature)

A case study of a cement producer in Austria in October 2012 indicates that the costs for DSM are too high compared to the revenues. A cement company examined the meaning of DSM for their production, getting involved in delivering flexibilities for two months. The cement mills and crushers of that company usually run from Monday to Friday, therefore a shift to weekend time was possible and has been undertaken.

In the mentioned project 50% of the peak power could be reduced. However, the additional expenses (mainly human resources as production was shifted to / compensated on weekends, requiring weekend surcharges) exceeded the financial incentives for load management. In the current framework, load management is not economic for cement producers (Schmidthaler et al. 2014). Furthermore, there are indirect costs such as risk premiums and shortage of the life cycle that need to be taken into consideration.

Additional obstacles are the energy efficiency targets of the German Federal Government. Industrial companies are charged a tax on electricity demand. Energy-intensive industries are not required to pay this tax but signed an agreement with the German Federal Government in return that obligates the German industry to reduce their energy consumption in relation to gross value added by 1.3% from 2013 on and by 1.35% from 2016 on every year (Hoenig, Koring, Fleiger, Palm, et al. 2015). Energy efficiency has been in the focus regarding a reduction of production cost for a longer time in cement industry. However, market requirements such as the demand for finer cement or higher environmental standards such as secondary measures for exhaust gas cleaning lead to increasing electricity demand. The Research Institute of the Cement Industry simulated two scenarios and comes to the conclusion that the electricity demand will increase by the year 2030 based on the assumptions made (Hoenig, Koring, Fleiger, Palm, et al. 2015). If DSM should be promoted, the German

Federal Government needs to accept negative efficiency factors as long as they enable significant system efficiency gains in the grid.

5.4 Interim conclusions on business opportunities for DSM

To conclude the discussion of this chapter, we summarize the points in a SWOT-analysis. This analysis arranges the issues according to strengths, weaknesses, opportunities and threats. While the first two categories relate to internal issues helpful or harmful for applying DSM and offering flexibilisation potential, the other two comprise external issues.

	Helpful for applying DSM in company	**Harmful** for applying DSM in company
Internal Issues	**Strengths** • Potential new revenue stream	**Weaknesses** • (Additional) flexibilisation potential requires investments • Competes with core business of company • May induce high opportunity costs
External Issues	**Opportunities** • Competitive advantage for first movers if flexibilisation became mandatory in the future • Potentially increasing relevance of industry contribution due to increasing share of energy production.	**Threats** • Conflicting interests of efficiency and flexibility • Uncertainties with regard to future development of balancing products • Uncertainties with regard to intended role of industry in control energy market

Comparing the business model “business as usual” to the identified DSM business model clearly shows that one of the most relevant factors for engagement in DSM is the availability of capacities. This can be seen as a necessary precondition for offering flexible loads. These capacities can already be existent or be build-up through additional investments. Uncertainties with regard to future development of balancing products and the intended role of industry in the control energy marked as well as conflicting interests between the energy efficiency and flexibility are relevant threats in this respect. On the other hand, investing into capacities for flexibilisation and engaging in DSM can also be an opportunity for companies, since it could lead to a competitive advantage for first movers.

Decision making on company side will have to take into account the needs of (additional) investments, and whether offering flexibilisation potential competes with core business of company and induces high opportunity costs or not. This needs have to be set in relation to the potential new revenues that could be generated.

6 WP 4: Conclusions

As a result of the examination of literature data and data published by TSO it can be stated that there is potential for industry to engage in offering control power by flexibilisation of the operation of plants.

It has been worked out that there are different understandings of the term “potential”. It can be assumed that different usage of the term “potential” within the regarded studies, for example as theoretical potential in one study and as technical potential in another, leads to different conclusions of the industries’ capability to deliver flexibilities. Furthermore it could be stated that analysis of a technology as such is not sufficient to figure out its potential due to the differences of single production plant in terms of their setting, connected infrastructure and its related processes. Furthermore, there is a lack of knowledge when calculating the costs of maintenance. For many processes it is not clear which damages might be caused by adapting operation modes to a flexibilized manner – and even less, in as far these considerations have been taken into account in the analysis of practical or feasible potential itself.

To make potentials of (future) studies comparable a refined classification of potentials for DSM is suggested. Potentials should be classified for theoretical, technical, techno-economical, economical, socio-economical and practical potential. The main difference to already existing classifications is the “techno-economical potential”, which describes the technical potential that is – in short words – economical feasible with regard to the production competence of the plant. It is therefore the potential that can be delivered by still delivering the same quality of products and with the same cycles of maintenance and does not induce enhanced aging of the plant. By not including these aspects in the economic or even “acceptable potential”, as some studies call it, they gain of importance and thus increasing the acceptance of the potential analysis by industry players and therefore the reliability of studies and outlooks.

Although there are only very low assessments of the effects and interactions of efficiency and flexibilisation, this is a topic that is of high interest for the players – from industry as well as from scientific community and politics, as many talks and as well the questionnaires have shown.

There is a trade-off *expected* between load management measures and energy efficiency targets. This is partly due to the fact, that DSM activities often require additional capacities that are only frequently used and therefore increase energy and resource demand. The benefits for the electricity system should be compared to this trade-off to provide an optimized plan for DSM based on ecologic and economic parameters, which is supported by the German government. Here, a broad R&D campaign is needed to investigate these effects without and fixation on the expected result.

It may be necessary to accept negative efficiency factors in the industrial production processes if they lead to a higher efficiency of the overall electricity system. However, further analysis is necessary to examine if the overall efficiency gains are sufficiently high to justify efficiency losses on a company level – once these losses are known and quantified.

Policy has not been in the focus of this project, so no detailed and in-depth analysis has been conducted that could be the base of policy recommendations. The quite intensive talks with the industry players have, however, shown the most relevant fields of concern and insecurities. A major concern of the industrial representatives regarding DSM is the lack of a stable, long-term political framework. Most companies cannot plan sufficiently on the basis of 4-year-periods, especially for larger installations, but need a guaranteed framework for at least 10 years, in order to achieve the amortisation of the plant. In the current framework, an investment is only made if it pays of within the current or the following year[8].

[8] Statement of a workshop participant.

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Annex

Annex I: Questionnaire

Fragebogen zu Flexibilitätsoptionen und Demand Side Management (DSM)

Projekt: Flexibilisation of industries enables sustainable energy systems (FlexInd)

Fragebogen bereitgestellt durch: Wuppertal Institut für Klima, Umwelt, Energie

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Ziel und Struktur des Fragebogens

Dieser Fragebogen dient zur Vorbereitung des Erfahrungsaustausches zu Flexibilitätsoptionen und Demand Side Management (DSM) für Unternehmen im Rahmen des FlexInd Projektes. Durch das Ausfüllen des Fragebogens können Sie zum einen sehen, welche Informationen für die Diskussion zu DSM relevant sind. Zum anderen unterstützt der Fragebogen die gezielte Ansprache von KollegInnen und MitarbeiterInnen zur Sammlung benötigter Informationen. Dabei ist der Fragenkatalog als Vorschlag zu verstehen, der an die Bedürfnisse Ihres Unternehmens angepasst und entsprechend gekürzt, erweitert oder anderweitig verändert werden kann.

Die Fragen gliedern sich in folgende Blöcke:

1) Überblick über das Unternehmen und die Energieversorgungsstruktur
2) Bisherige Erfahrungen des Unternehmens mit Lastmanagement
3) Identifizierung weiterer Möglichkeiten zur DSM-Nutzung
4) Markteintrittsbarrieren für die Nutzung von DMS in Ihrem Unternehmen
5) Vorschläge zur Gestaltung der Rahmenbedingungen

Dem Fragenkatalog ist ein Abschnitt mit grundlegenden Informationen zu DSM vorangestellt. Im Anhang ist außerdem ein detaillierter Fragebogen zur DSM Potentialanalyse beigefügt, der bei Interesse genutzt werden kann.

Hintergrundinformationen zu Demand Side Management (DSM)

Im Folgenden finden Sie einige grundlegende Informationen zu den heutigen Rahmenbedingungen von Demand Side Management, die für einen schnellen Überblick zusammengestellt wurden.

Wofür DSM?

Grundsätzlich werden unter dieser Bezeichnung Aktivitäten verstanden, die auf die Anpassung der Elektrizitätsnachfrage an die Erzeugungs- und Netzbedingungen abzielen. Sie sollen zukünftig eine bessere Integration erneuerbarer (fluktuierender) Energien in das Stromnetz ermöglichen und somit zu einer sicheren, wirtschaftlichen und ökologischen Energieversorgung beitragen.

Welchen Nutzen haben Unternehmen?

Für Unternehmen kann DSM einige monetäre Vorteile bringen. Neben Erlösen durch die Vermarktung von abschaltbaren Lasten/ Regelleistung kann sich eine Kostenreduktion durch die Verringerung der maximalen individuellen Netzlast, sowie durch die Verringerung der maximalen Vertriebslast ergeben. Sollte ein Unternehmen eine Eigenerzeugung betreiben, kann es hier zudem zu einer besseren Koordinierung kommen.

Wie können Unternehmen Flexibilisierung anbieten?

Lasten können momentan über 3 verschiedene Mechanismen angeboten und vergütet werden.

1) Abschaltbare Lasten

Große Verbrauchseinheiten, die am Hoch- und Höchstspannungsnetz angeschlossen sind und nahezu konstant hohe Leistungen abnehmen, können ihr Flexibilisierungspotential (mind. 50 MW) gemäß der „Verordnung über Vereinbarungen zu abschaltbaren Lasten“ (AbLaV) anbieten. Hierbei wird zwischen sofort (frequenzgesteuert innerhalb von Sekunden) und schnell (ferngesteuert durch Übertragungsnetzbetreiber innerhalb von 15 min) abschaltbarer Last unterschieden. Die Verordnung regelt Anforderungen wie z.B. die Präqualifizierungsanforderungen, Vergütungs- sowie Kostenregelungen im Zusammenhang mit den abschaltbaren Lasten. Die Vergütung beläuft sich auf 2.500 EUR/MW Abschaltleistung und einem Arbeitspreis (tatsächliche Abschaltung) von mindestens 100 und höchstens 400 EUR/MWh.

Weitere Informationen: http://www.gesetze-im-internet.de/bundesrecht/ablav/gesamt.pdf

2) Regelleistungsmarkt

Die Beschaffung erfolgt als Ausschreibungswettbewerb am deutschen Regelleistungsmarkt unter Beteiligung zahlreicher Anbieter (sowohl Kraftwerksbetreiber als auch Stromkunden).

Durch die Möglichkeit, technische Einheiten (Erzeugungseinheiten als auch regelbare Verbraucherlasten) zwecks Erreichung der für die einzelnen Regelleistungsarten jeweils geltenden Mindestangebotsgrößen (siehe Tabelle) poolen zu können, ist es auch Kleinanbietern möglich, sich an den Ausschreibungen zu beteiligen. Ein Regelleistungs-Marktgebot besteht aus der angebotenen Leistung [MW] sowie dem geforderten Leistungspreis (Festpreis für die

Bereitstellung [€/MW]) und dem Arbeitspreis (Vergütung für tatsächlich erbrachte Arbeit im Angebotszeitraum [€/MWh]). Die Angebote mit den günstigsten Leistungspreisen erhalten den Zuschlag. Weitere Informationen: https://www.regelleistung.net/ext/

Folgend sind die drei Arten von Regelleistung und ihre wichtigsten Merkmale zusammengefasst.

	Ausschreibung	Mindestangebotsgröße	Zeitscheiben	Aktivierung	Abzudeckender Zeitraum	Vergütung
Minutenreserve (MR)	(werk)täglich	5 MW	4 h (6 mal/ Tag)	< 15 min (teilautomatisch)	15 < t < 60 min pro Störung;	Leistungs- & Arbeitspreis
Sekundärregelleistung (SRR)	Wöchentlich	5 MW	Peak & Off Peak	< 5 min (vollautomatisch)	t <15 min	Leistungs- & Arbeitspreis
Primärregelleistung (PRR)	Wöchentlich	1 MW	1/ Woche	< 30 sec (vollautomatisch)	0< t <15 min	Leistungspreis

Quellen: BMWi (2015): Weißbuch – Ein Strommarkt für die Energiewende, S.67; Veit, M. & Gawel, E. (2014): Implementierung von Demand Side Management im deutschen Strommarkt: eine ökonomische Analyse der Voraussetzungen UFZ Discussion Paper No. 25/2014.

3) Spotmarkt (European Power Exchange)

Durch den kurzfristigen Handel mit Strom am Spotmarkt mit volatilen Strompreisen können Unternehmen beispielsweise durch die Verschiebung von Nachfrage Stromkosten einsparen. Unterschieden wird zwischen Day-Ahead-Handel, worunter der Handel mit Strom für den folgenden Tag und dem Intraday-Handel, der den Stromhandel innerhalb eines Tages bezeichnet.

1. Überblick über Unternehmen und Energieversorgungsstruktur	
Firmenname	
Ansprechpartner	
Branche **Produkte**	
Größe des Unternehmens	Mitarbeiter: Produktionseinheiten:
Anteil der Stromkosten an Gesamt-produktionskosten	%
Stromverbrauch:	Gesamt: MWh/a
Anschlussleistung:	MW
Durchschnittlich bezogene Last	MW
Produktionsverfahren/ **Produktionszeiten**	☐ Batch ☐ Kontinuierlich Sonstiges Produktionszeiten Revisionszeiten/Betriebsferien
Einschätzung bezüglich der zukünftigen Entwicklung des Stromverbrauches und Effizienzsteigerungen	

2. Bisherige Erfahrungen des Unternehmens mit Lastmanagement						
Gibt es in Ihrem Unternehmen bereits Erfahrungen mit Lastmanagement	**Prüfung der Option**		**Teilnahme/ Nutzung**		**Aktueller Stand** (z.B.: Nutzung in welchem Prozess für jeweils welchen Anteil der Last?)	**Bewertung der Erfahrung** (++ sehr gut, + gut, +/o weiß nicht, - schlecht, -- sehr schlecht)
	Ja	Nein	Ja	Nein		
☐ Reduktion der betrieblichen Spitzenlast (Verringerung des Leistungspreises)						
☐ bilaterale Verträge mit Netzbetreibern						
☐ zum optimierten Stromeinkauf genutzt (am Sportmarkt)						
☐ Beteiligung am Regelleistungsmarkt						
☐ Verordnung für abschaltbare Lasten						

3. Identifizierung weiterer Möglichkeiten zur DSM-Nutzung
Welche stromintensiven Prozesse gibt es in Ihrem Unternehmen?
Gibt es welche, die
... a) sich unter Nutzung von bestehenden Speicherkapazitäten zeitweilig verschieben lassen?
... b) grundsätzlich reduziert werden können, und keiner Nachholung bedürfen?
... für die a) oder b) unter Einsatz einer alternativen Technologie in Frage kommen würden? Mit welchen Investitionen wäre dies verbunden?
Gibt es thermische (bisher nicht elektrisch betriebene) Prozesse, die grundsätzlich verschoben werden können? Wenn ja, welche?

Für die detailliertere Analyse befinden sich im Anhang prozessspezifische Fragen, die Ihnen dazu dienen können, die Potenziale in Ihrem Unternehmen einzuschätzen. Für Rückfragen dazu stehen wir Ihnen gerne zur Verfügung.

Über welchen Mechanismus (z.B. Minutenreserve) könnten die oben identifizierten Potenziale derzeit bereits bereitgestellt werden? **Handelt es sich um positives[9] und/oder negatives Potenzial im Sinne des Regelleistungsmarktes?**	

[9] Unter positivem Potenzial (im Sinne der positiven Regelleistung) wird hier eine möglicher Leistungsreduktion verstanden, die gefordert ist sofern die Nachfrage das Angebot übersteigt. Bei negativem Potenzial handelt es sich entsprechend um die Möglichkeit einer Lasterhöhung.

Bedarf eine Bereitstellung der Potenziale zusätzlicher Ressourcen und, wenn ja, mit welchen Kosten wäre dies schätzungsweise verbunden?	
Spezifizierung der Option, über die Flexibilisierung angeboten werden könnte (sollte es mehrere geben, kann diese Tabelle auch mehrfach ausgefüllt werden):	
	Abschätzung der Kostenspanne (z.B. pro MW bereitgestellte Flexibilisierungsleistung – z.B. 20-30€). Sollte keine quantitative Einschätzung möglich sein, ggf. über hoch, mittel, niedrig einstufen und kommentieren.
Know-How? (extern oder auch durch zusätzliche interne personelle Ressource)	
Zusätzliche Anlagentechnik?	
Höhere Anlagenleistung?	
Speicher / zusätzliche Lagerkapazitäten?	
Steuerungsinfrastruktur?	
Kommunikationsinfrastruktur?	
Mitarbeiter zur Wartung und Pflege der relevanten Komponenten etc.?	
Sonstiges?	
Welche variablen Kosten würden im Falle eines Abruf der Potenziale entstehen? (abhängig von Dauer der DSM-Schaltung)	
Opportunitätskosten für Produktionsausfall bzw. verminderte Produktqualität durch Verschiebung	
Lohnzuschläge aufgrund von veränderten Schichtzeiten	
Erhöhter Energiebedarf durch eine Lastverschiebung	
Sonstiges	

4. Markteintrittsbarrieren für die Nutzung von DMS in Ihrem Unternehmen **Unternehmensintern**	
Welche organisatorischen Hemmnisse für die Vermarktung vorhandener Flexibilität gibt es in Ihrem Unternehmen? z.B.: Fehlendes eigenes Energiemanagement, geringe Bedeutung der Stromkostenoptimierung, fehlende Expertise bzw. fehlendes Personal	
Welche produktionstechnischen Gegebenheiten stellen insbesondere Hemmnisse zur Umsetzung dar?	
Welche ökonomische Hemmnisse erschweren eine Teilnahme derzeit? z.B. Verlust von (teil-)gefertigter Produktionsmenge, Einschränkungen in Produktqualität, höherer Personalaufwand, Aufwand von Vorprodukten bei nachzuholender Produktion, Unsicherheit, Amortisation	
Stehen **Flexibilisierung**smaßnahmen Ihrer Meinung nach in Widerspruch zu **Effizienzsteigerungen**?	
Wie sehen Sie die Maßnahmen zur Realisierung von DSM-Potenzialen vor dem Hintergrund von Investitionsentscheidung zur Umsetzung von Effizienzsteigerungsmaßnahmen?	
Wie sehen Sie die Entwicklung von DSM vor dem Hintergrund der **politischen Zielsetzungen zu Effizienzsteigerungen**?	
Unternehmensextern	
Welche allgemeinen Barrieren für die Marktteilnahme sehen Sie? z.B. Mangelndes Informationsangebot, Unsicherheiten insbesondere hinsichtlich des Bestands der derzeitigen Vermarktungsoptionen	
Welche Hemmnisse bezüglich des bestehenden Marktdesigns (für Regelenergie) erschweren die Marktteilnahme z.B. Präqualifikationsanforderungen, Gefahr von Netzspitzen bei Lasterhöhung, Länge der Vorhaltung bei Regelenergieprodukten (z.B.	

12h bei Sekundärreserven), fehlende Investitionssicherheit, gleiche vorgeschriebene Dauer für Lastenanfahr- und Abfahrprozess

5. Vorschläge zur Gestaltung der Rahmenbedingungen für den Energie-Flexibilisierungsmarkt	
Welche der folgenden Vorschläge zur Änderung des Regelleistungsmarktes würden Sie begrüßen?	**Übergreifend:** ☐ Herausrechnen von Regelleistungserbringung bei der Bestimmung der Netzentgelte ☐ Sonstiges: **Sekundärregelleistung:** ☐ Verkürzung der Ausschreibungszeiträume auf einen Tag mit kalendertäglicher Ausschreibung ☐ Ersetzten der Produkte HT & NT durch 4h-Blöcke ☐ Sonstiges: **Minutenreserve** ☐ Vermarktung am Tag vor Lieferung ☐ Verkürzung der Produktscheiben von 4h auf 1h ☐ Sonstiges:
Welche der folgenden Vorschläge zur Änderung des Intraday/Spotmarkt-Designs würden Sie begrüßen?	☐ Verkürzung des Vorlaufs beim Intradayhandel ☐ Flexibilisierung der regulären Netzentgeltstruktur und der Regelungen des § 19 StromNEV ☐ Sonstiges:
Können Sie sich ein von den derzeitigen Vermarktungsprodukten unabhängiges Flexibilisierungsprodukt vorstellen, dass Ihnen bei der Umsetzung von DSM-Maßnahmen entgegen kommen würde?	

Anhang: Fragebogen zur DSM Potentialanalyse:

Der folgende Abschnitt kann jeweils pro identifiziertem Prozess aufgenommen werden.

Prozess	
Art des Lastmanagementpotenzials	☐ verschiebbar ☐ reduzierbar ☐ mit zusätzlichem Technologieeinsatz ☐ mit vorhandener Technologie
Speicher	
Art des Speichers (inhärent, Materialspeicher) **Größe des Speichers** (in m^3, kWh, …)	
Restriktionen des Potenzials	
Welche technischen Restriktionen gibt es? (vor- oder nachgelagerte Prozessschritte, einzuhaltende Temperaturniveaus..)	
Welche produktionsbedingten Restriktionen gibt es (betriebliche Abläufe, Gesundheits- und Arbeitsschutz)?	
Eigenschaften des prozesszugehörigen Aggregats	
Maximale Leistungsaufnahme	MW
Betriebsstunden pro Jahr	h/a
Regelbarkeit	☐ kontinuierlich / in folgenden Stufen
Jährlicher Stromverbrauch	MWh/a
Bedeutung des Prozesses in der Wertschöpfungskette	☐ hoch ☐ mittel ☐ gering ☐ ja ☐ nein
Eigenschaften des Lastmanagementpotenzials	
Wie stark kann die Last zu welchen Zeiten erhöht bzw. reduziert werden?	

Zeitdauer der Schaltung	Minimal	Maximal
Wie lange nach dem Abruf muss spätestens das Nachholen der Leistung passiert sein?		
Minimale Zeit zwischen zwei Schalthandlungen		
Maximale Anzahl an Schaltungen pro Zeiteinheit	pro	
Energieverbrauch Inwieweit erhöhen Schalthandlungen den Energieverbrauch, z.B. durch Teillastbetrieb?		