MSc Program
Renewable Energy in Central and Eastern Europe

Evaluation of the Integration of Demand Side Flexibility into Energy Contracting Services

A Master's Thesis submitted for the degree of

"Master of Science"

supervised by
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October 15th 2016, Vienna

Affidavit

I, **Mag. Ralph Huber** hereby declare

that I am the sole author of the present Master Thesis, "EVALUATION OF THE INTEGRATION OF DEMAND SIDE FLEXIBILITY INTO ENERGY CONTRACTING SERVICES", 73 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

Abstract

The aim of this Master Thesis is to analyse a business model for ENGIE Energie in order to support the newly founded company to position itself as an integrated energy service provider on the Austrian energy market. Therefore the energy contracting business and the participation in power markets by providing available flexibility shall be integrated.

This paper describes the different concepts of energy contracting services and assesses the energy savings potential of such projects, outlines the risks and describes different financing options, as important success factors for energy efficiency projects. In a next step the concept of Demand Side Flexibility will be introduced, categorizing the different market segments and explaining the positive effects it has for the different stakeholders and the energy system as a whole. The integration of both concepts will be analysed on the basis of a case study for a Viennese office building. In addition to the energy savings achieved with an energy contracting project for refrigeration system, the available flexibility of this system shall be used to offer load frequency control.

The findings show that a participation on the balancing market with this refrigeration system would have been economic viable for 2014 and 2015 and could have improved the savings potential of the energy contracting business. Due to a more efficient market functioning and an increasing number of participants in the market the revenue potential for 2016 and onwards is limited. A detailed analysis on a case by case still is recommendable for ENGIE Energie.

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List of Abbreviations

APG	Austrian Power Grid
BRP	Balance responsible party
CAM	Control Area Manager
CEER	Council of European Energy Regulators
CHP	Combined Heat and Power
CO2	Carbon dioxide
CPE	Customer Premises Equipment
CPP	Critical Peak Pricing
DR	Demand Response
DSF	Demand Side Flexibility
DSO	Distribution System Operator
EC	Energy Contracting
EE	Energy Efficiency
EEA	Energy Efficiency Act
EED	Energy Efficiency Directive
EPBD	Energy Buildings Performance Directive
EPC	Energy Performance Contracting
ESC	Energy Supply Contracting
ESCo	Energy Service Company
EU	European Union
EUR	Euro
FI	Finance Institution
GWh	Gigawatt hours
HVAC	Heating, Ventilation and Air Conditioning
IEC	Integrated Energy Contracting
kWh	Kilowatt hours
LFI	Leasing Finance Institute
M&V	Measurement and Verification
MWh	Megawatt hours
NWh	Negawatt hours
QAI	Quality Assuring Instruments
RES	Renewable Energy Sources
RTP	Real time Pricing
ToU	Time-of-Use
TSO	Transmission System Operator

1 INTRODUCTION

1.1 Motivation and Objective of this Master Thesis

During the last decade evolving energy markets and the increasing production of renewable electricity were changing the traditional business of energy utility companies from being energy suppliers towards energy service providers. In my professional occupation at ENGIE Energie (former GDF SUEZ Gasvertrieb) I am currently witnessing the challenges of this changing energy landscape. Selling gas and electricity to industrial clients and large businesses, additional services such as renewable energy supply, flexibility management and energy efficiency improvements are becoming increasingly important. ENGIE is adapting to these circumstances and sees the company as the leader in the energy transition.

Electricity generation from renewable energy sources (RES) and energy efficiency improvements are two major pillars in order to address climate change and global warming. One way to promote energy efficiency is the concept of energy contracting services. Energy supply contracting and energy performance contracting are turnkey services which provide customers with a comprehensive set of measures for the implementation of energy efficiency, renewable energy and distributed generation. In general energy contracting services provide guarantees that savings produced by a project are sufficient to finance the entire cost of such a project. ENGIE Energie is one of the leading companies in Austria offering these services with more than 300 installations under operation in the residential, industrial and commercial sector.

In addition power systems are currently experiencing a period of major evolution. For the past decades electricity has been provided by large centralised power generation units. Following the liberalization of electricity markets and the support of renewable energy production the power system is changing towards a more decentralized organisation. The increasing emergence of RES and the ongoing development and integration of European energy markets result in more intermittent and variable energy flows. This fact increases the requirements on transmission and distribution networks to manage the flows in an efficient manner and avoid constraints. Demand Side Flexibility (DSF) offers one solution to assist the management of the electricity systems. DSF refers to the capacity to change electricity usage by consumers according to price signals or incentive payments which could be market or grid related. (Council of European Energy Regulators 2013)

A viable source of providing this flexible demand response (DR) could be installations which have been realized through energy contracting services such as combined heat and power plants (CHP), electrical heating systems or commercial and industrial refrigeration systems.

The core objective of this Master Thesis is therefore to evaluate the additional economic potential which such installations with flexible demand patterns could have on energy contracting services. In concrete terms this Master Thesis will outline the savings potential of an energy contracting project for a commercial refrigeration system of an office building in Vienna and analyse the potential additional contribution to cost savings through participation in the secondary and tertiary control energy market with this cooling system. The results of this analysis shall build the basis for ENGIE Energie to develop a potential business model and help to position the company as an integrated energy service provider on the Austrian market.

1.2 Methodology and Structure of the Master Thesis

After this introductory chapter outlining the motivation, objective, methodology and structure of this Master Thesis chapter two shall provide the related background information. A description of the ENGIE group on international level, including its history, organisation and new strategy following the rebranding of 2015, will be followed by an overview of ENGIE’s business in Austria. The overview of the Austrian business shall reflect the transition of the company towards an integrated energy service provider. After this institutional background the legislative basis for the topics addressed within this Master Thesis shall be explained. This contains a brief summary of relevant directives of the European Union for renewable energy sources, energy efficiency and energy buildings performance. Concerning the directive for energy efficiency its implementation into Austrian law (Austrian energy efficiency act) will be summarized and shown how this law affects the business of ENGIE in Austria.

Chapters three and four reflect the theoretical background and literature study of this Master Thesis. Following the definition and concept of energy contracting services in general, the well-established business models of energy supply contracting and energy performance contracting will be described in detail. Furthermore a new business model, integrated energy contracting, co-developed by DI Jan Bleyl, a lecturer of this master course will be introduced. To close chapter three potential risks and financing options will be shown.

The concept of Demand Side Flexibility represents chapter four of this Master Thesis. Following the general definition and concept, DSF will be classified according to market-led and network-led signals. This will outline the different market segments DSF can be applied to and the value it has for the different stakeholders involved. A sub-chapter will specifically take a closer look at load frequency control, since the participation in the control energy market is the core of the case study in the following chapter. To close chapter four the potential of Demand Side Flexibility for applications within different industrial sectors will be presented, including an analysis for office buildings.

Chapter five will apply the research performed on the concrete case of an energy contracting project for a refrigeration system of a Viennese office building implemented by ENGIE Energie. Besides showing the cost savings achieved with energy contracting, the economic potential of available flexibility of this refrigeration system shall be quantified and solutions of an integration into the energy contracting presented.

2 BACKGROUND INFORMATION

This chapter shall provide background information both on the institutional context of my professional employment within ENGIE Austria as well as on the legislative background. On the institutional side a short overview of ENGIE Austria will outline the transition from the historical organisation towards a new, more integrated approach of the company in Austria. The legislative background will explain the content of those European directives which shall promote the services analysed and applied within this Master Thesis.

2.1 Institutional Background

2.1.1 ENGIE SA

ENGIE SA is a major stakeholder in the international energy industry, focusing on its three core businesses of electricity, natural gas and energy services to support and develop a new vision of energy for the world - sustainable energy available to everyone. The group has a strong presence at every link in the energy value chain, from low-carbon generation to the provision of energy-efficient solutions for all its customers.

The history of the ENGIE Group is one of merger between many of the biggest names in European industry over a period of more than 180 years. Companies like Société Générale de Belgique, Compagnie Universelle du Canal Maritime de Suez, Société Lyonnaise des Eaux et de l'Éclairage, Gaz de France and International Power. The origins of the Group in the first half of the 19th century were marked by the enormous expansion in transportation, with the rush to build canals, railroads and tramways. The period between 1946 and 1955 was dominated by the need for industrial unity in France, which in turn led to the nationalization of Gaz de France. The discovery of natural gas in 1951 led to the transformation of the group between 1956 and 1967 to become a natural gas transporter, supplier and trader. The 1980s marked the beginning of extensive internationalization of the group's business interests, culminating in the merger between SUEZ and Gaz de France to create a global energy group, called GDF SUEZ.

Today, with a strong presence on every continent, ENGIE applies expertise at every link in the energy knowledge chain based on a simplified regional structure that follows a customer focused approach. The group is adapting to the challenges of a world in which energy is decentralized with a more agile organizational structure rooted at local level and reliant on core business synergies.

As part of succeeding in the challenge to make energy more sustainable and reduce greenhouse gas emissions, around two-thirds of the group workforce is involved in introducing high added value energy efficiency solutions. In total ENGIE counts around 155,000 employees.

ENGIE has been accelerating its own transformation with a new organizational structure consistent with the new corporate plan launched in April 2015. The group now operates through 24 regionally structured business units, 5 core businesses with responsibility for managing sector specific expertise and a new head office designed to ensure cohesion across the business. (ENGIE 2016)

The strategy of ENGIE is based on the aim to become global leader of the energy transitions and therefore focuses on the following four structural trends:

- Decarbonization
- Digitalization
- Decentralization
- Energy Efficiency

2.1.2 ENGIE Austria

ENGIE Austria is part of the Business Unit Northern, Eastern & Southern Europe of ENGIE SA. Following the group’s reorganisation decided in April 2015 and the subsequent rebranding from GDF SUEZ towards ENGIE, also the structures of Austrian entities are in the process of a major restructuration. Until November 2016 ENGIE has been present in Austria with various different subsidies owned by different shareholders. Firstly, COFELY Holding, as owner of Cofely Gebäudetechnik and Cofely Kältetechnik, secondly, Proenergy Contracting as part of COFELY Germany and thirdly GDF SUEZ Gasvertrieb owned by GDF SUEZ SA.

Cofely Gebäudetechnik is active in the fields of planning, constructing, operating and maintaining building facilities.

Cofely Kältetechnik is a specialist for commercial and industrial refrigeration systems, air conditioning systems, heat recovery and heat pumps for example.

Proenergy is one of the largest contracting companies in Austria with more than 300 installations under operation. It covers all major types of energy such as biomass, solar, gas and heating oil.

GDF SUEZ Gasvertrieb is a supplier of gas and electricity for commercial and industrial clients, offering their customers flexible energy contracts, access to energy markets, balance group management and market advisory services.

Before the reorganisation all of the above mentioned subsidies have been operating widely independent and not taken advantage of possible synergies. With the new organization all subsidies will come under the roof of ENGIE Austria GmbH, which will act as a holding for the subsidies below. Furthermore the businesses of Proenergy and GDF SUEZ Gasvertrieb will be merged into the new entity of ENGIE Energie uniting all businesses related to energy supply. ENGIE Energie will consequently be present along the whole energy value chain, from energy markets to energy transformation towards final customer demand, offering an integrated approach to its clients. Below a simplified overview of the organisational structure of the future ENGIE Austria Group:

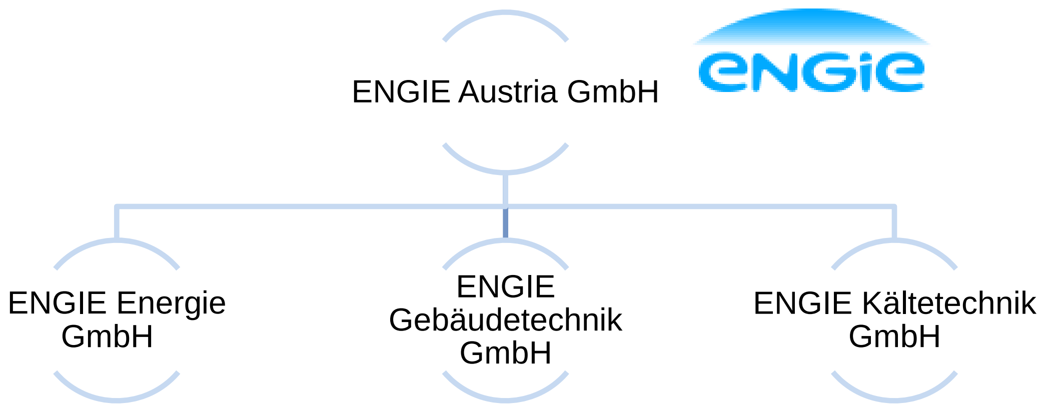


Figure 1: Organisational structure of ENGIE Austria (own illustration)

2.2 Legislative Background

2.2.1 Renewable Energy Sources Directive (2009/28/CE)

The renewable energy directive from 2009 provides a legal framework for each member state of the European Union (EU) in order to deliver its renewable energy commitment. However, the member states have a wide range of policy options to deliver those commitments. Due to the fact that each member state has a different mix of renewable energy sources and that the flows of electricity and renewable fuels across boarders are restricted by the infrastructure in place, there exists significant potential for minimizing costs and optimizing benefits. A close cooperation between the member states and sharing of best practices shall help to enable this process. This directive shall push the development of renewable energy and address the issue that existing energy systems, rules and networks haven been developed for non-renewable energy. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

The directive sets binding targets for the member states with the aim that the EU as a whole will reach a 20% share of energy from RES in gross final energy consumption by 2020 and of 10% specifically in the transport sector. Furthermore a reduction of greenhouse gases of 40% in comparison to 1990 has been outlined. In general the policy framework of the EU aims to reach a more competitive, secure and sustainable economy and energy system of the European Union by 2030. The main areas within this directive cover the following topics:

- Support schemes and cooperation mechanisms
- Buildings and district heating systems
- Training and information
- Electricity
- Networks
- Biomass mobilisation and sustainability
- Renewables in transport
- Guarantees of origin

Concerning demand response or Demand Side Flexibility the directive does not explicitly mention these terms, however, intelligent networks are often mentioned and aim towards the evolution of smart grids. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

Following paragraphs of the directive outline the intuition of integrating RES into the energy system:

§16.1: "Member States shall take the appropriate steps to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities and the electricity system, in order to allow the secure operation of the electricity system as it accommodates the further development of electricity production from renewable energy sources, including interconnection between Member States and between Member States and third countries."

§16.2, c: "Member States shall ensure that when dispatching electricity generating installations, transmission system operators shall give priority to generating installations using renewable energy sources in so far as the secure operation of the national electricity system permits and based on transparent and non-discriminatory criteria. Member States shall ensure that appropriate grid and market-related operational measures are taken in order to minimise the curtailment of electricity produced from renewable energy sources. If significant measures are taken to curtail the renewable energy sources in order to guarantee the security of the national electricity system and security of energy supply, Members States shall ensure that the responsible system operators report to the competent regulatory authority on those measures and indicate which corrective measures they intend to take in order to prevent inappropriate curtailments."

2.2.2 Energy Efficiency Directive (2012/27/EU)

Member states of the European Union are required to use energy in a more efficient way along all stages of the energy chain, from transformation of energy, its distribution toward its final consumption. The Energy Efficiency Directive (EED) shall contribute removing barriers and overcoming market failures that hinder the efficiency in the supply and use of energy. The EED provides indicative energy efficiency targets for 2020 for all member states. It also creates a common framework of measures which shall promote energy efficiency within the EU. Energy generation is one of the key triggers for energy efficiency. Therefore efficiency levels of new energy generation capacities shall be closely monitored, potentials for co-generations and district heating system assessed and corresponding measures be developed. These measure include waste heat recovery and demand side resources.(Joint Working Group from Concerted Action EED / RES / EPBD 2015)

This directive entered into force on 4th of December 2012 and has been expected to be implemented by 5th of June 2014. It clearly promotes energy efficiency measures such as energy contracting services and in particular demand response programs. Regarding DR especially article 15.4 and 15.8 are of importance. Article 15.4 for instance outlines that member state must create regulations and legislation that do not contain barriers for the participation in DR:

§15.4: Member States shall ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response, in balancing markets and ancillary services procurement. Member States shall ensure that network operators are incentivised to improve efficiency in infrastructure design and operation, and, within the framework of Directive 2009/72/EC, that tariffs allow suppliers to improve consumer participation in system efficiency, including demand response, depending on national circumstances.

Article 15.8 states that member states shall encourage demand side resources, especially the access to market with demand side programs. Furthermore the member states also have to create a framework for demand response providers, such as aggregators so that they can participate on those markets and treated in a non-discriminatory way:

§15.8: Member States shall ensure that national energy regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets. Subject to technical constraints inherent in managing networks, Member States shall ensure that transmission system operators and distribution system operators, in meeting requirements for balancing and ancillary services, treat demand response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities. Subject to technical constraints inherent in managing networks,

Member States shall promote access to and participation of demand response in balancing, reserve and other system services markets, inter alia by requiring national energy regulatory authorities or, where their national regulatory systems so require, transmission system operators and distribution system operators in close cooperation with demand service providers and consumers, to define technical modalities for participation in these markets on the basis of the technical requirements of these markets and the capabilities of demand response. Such specifications shall include the participation of aggregators.

The EED builds the legal foundation for removing barriers for DR along the energy chain. Consumer participation can be easily triggered with buildings and appliance technologies in order to stimulate Demand Side Flexibility. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

2.2.2.1 Austrian Energy Efficiency Act

In order to implement the Energy Efficiency Directive of the European Union and to meet the 2020 target of increasing energy efficiency by 20% the Austrian government passed the new Energy Efficiency Act (EEA, Bundes-Energieeffizienzgesetz) in July 2014. The Austrian legislator decided to put the main responsibility on the shoulders of energy suppliers delivering different kinds of energy to end consumers in Austria. This law also applies to foreign energy companies supplying customers in Austria. The law entered into force on 1st of January 2015.

According to section 10 of the EEA energy suppliers are obliged to trigger and prove energy efficiency measures equal to at least 0.6% of their total energy supply to end consumers in Austria in the preceding year. A minimum of 40% of these required efficiency measure have to be implemented at household level. Energy suppliers which are active in the mobility sector may also prove this 40% household share by proving energy efficiency measures in the mobility or public transport sector. Suppliers with an annual delivery of below 25 GWh of energy to end customers in Austria are exempted from the obligations of section 10 of the EEA.

All energy efficiency measures have to be documented and reported to a national monitoring body, run by the Austrian Energy Agency. Together with the reporting of those measures the supplier also has to notify the total quantity of energy supplied in Austria until the 14th of February of the following year. The monitoring body will then decide if and to what extend the reported measures will be taken into account. Measures can also be transferred to third parties.

In case the energy supplier fails to provide the required energy efficiency measures a compensation payment of 200 EUR per MWh becomes due. E-Control, the Austrian regulator, will adjust the amount of the compensation payments each year by taking into account the average marginal cost. However the compensation payment may not be reduced below 200 EUR/MWh.

Furthermore the EEA established harsh administrative fines of up to 100,000 EUR depending on the nature of offence by an energy supplier. Fines may be imposed on suppliers which fail to fulfil their particular obligations on energy savings or which do not pay the compensation amount of 200 EUR/MWh on time.

Many international energy suppliers, such as GDF SUEZ Gasvertrieb (in future ENGIE Energie) have focused their business activities to the industrial and commercial sector in Austria. Consequently it is an additional burden for them to achieve and prove energy efficiency measure of households, a sector which they are not active in.

The way the Austrian government implemented the EEA of course triggered additional costs for energy suppliers. Amendments of existing contracts have only been possible where those contracts included price adjustment clauses or other general provisions for the transfer of additional taxes and costs arising out of the nature of the supply contract. Especially in the business area of industrial customers, where ENGIE Energie is active, the respective margins are significantly lower than the costs of compliance with the EEA. In order to overcome this barrier long and complicated negotiations with existing customers have been held and will be ongoing during the validity of this law.

In a nutshell Austria has chosen a highly complex and sophisticated regulatory system in order to comply with the 20% reduction target set out by the EU. This complexity currently leads to a number of legal and administrative issues for energy suppliers. (Starlinger 2014)

2.2.3 Energy Buildings Performance Directive (2010/31/EU)

The Energy Performance of Buildings Directive (EPBD) is providing the legal framework for EU member states for the optimization of energy performance of buildings. It therefore gives guidelines for the implementation of energy contracting services as well as for Demand Side Flexibility. The EPBD requires member states to set cost optimal levels for the minimum energy performance of new buildings and also of existing buildings which are subject to major renovations.

Even though the EPBD does not clearly mention demand response or energy contracting services it addresses without doubt topics that should trigger the development of both services. Local infrastructure, e.g. district heating systems, accessibility of locally produced energy by RES or combined heat and power plants (CHP) shall be included into the design in order to optimise a new building or a renovation of an existing facility. This could on the one hand be facilitated by energy contracting services and on the other hand include appliances which could provide Demand Side Flexibility.

Building optimisation covers the ability of buildings to move energy demand from periods with lack of energy in the grid to periods with an oversupply of energy and therefore using the ability of buildings to store energy (e.g. heat) and produce energy in local RES systems. Energy storage shall take place with a minimum of inconvenience for building users, for example in terms of decreased indoor thermal comfort. Building designs can influence the ability of buildings to store energy significantly. Usage of building materials with high thermal capacity or installation of storage tanks could be tools to enable buildings to act as an active player in a smart energy grid. An increasing number of buildings include systems for local energy production. Beside local wind turbines, photovoltaic systems and solar thermal systems in the future it will also include CHP systems. These CHP units on the one hand could be financed and realized with energy contracting services and on the other hand enable local networks to harvest the full potential of locally produced electricity and heat with the widespread implementation of smart grid solutions. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

3 ENERGY CONTRACTING SERVICES

3.1 Definition and Concept

Energy Contracting (EC), also referred to as ESCo and Energy Services, is a wide-ranging energy service concept to perform energy efficiency projects in production facilities of industries or buildings. It stands for the contractual relationship between energy-service providers and clients and implicates the outsourcing hence subcontracting of one or several energy related services to a third party. This contrasts with the conventional approach in which an energy user has a separate contract with different suppliers for each commodity, as well as for the supply and maintenance of energy conversion, distribution and control equipment. The energy contracting concept moves the focus away from selling units of final energy and emphasizes on the benefits and services derived from the use of the energy, such as the lowest cost of heating, cooling or illuminating a room.
EC is therefore not restricted to any particular technology or energy carrier. EC is a flexible and modular approach to implement energy efficiency projects, in line with the objectives of a facility owner. (Bleyl-Androschin et al. 2013; Pätäri & Sinkkonen 2014)

An Energy Service Company (ESCo) is responsible for the implementation of a customized energy service package, which includes planning, building, operation & maintenance, optimization, fuel purchase, financing and improvement of user behaviour. The ESCo, depending on the scope of the contract, in general provides guarantees for all-inclusive cost and results. As a general contractor it takes over the commercial and technical implementation as well as the operational risks over the whole project duration. Figure 2 shows the individual components an ESCo coordinates and manages throughout a project and offers to the client at an all-inclusive price. This price includes the functioning, performance and price guarantees for MWh of supplied energy or energy savings NWh ("Negawatthours"). (Bleyl-Androschin & Ungerböck 2009)

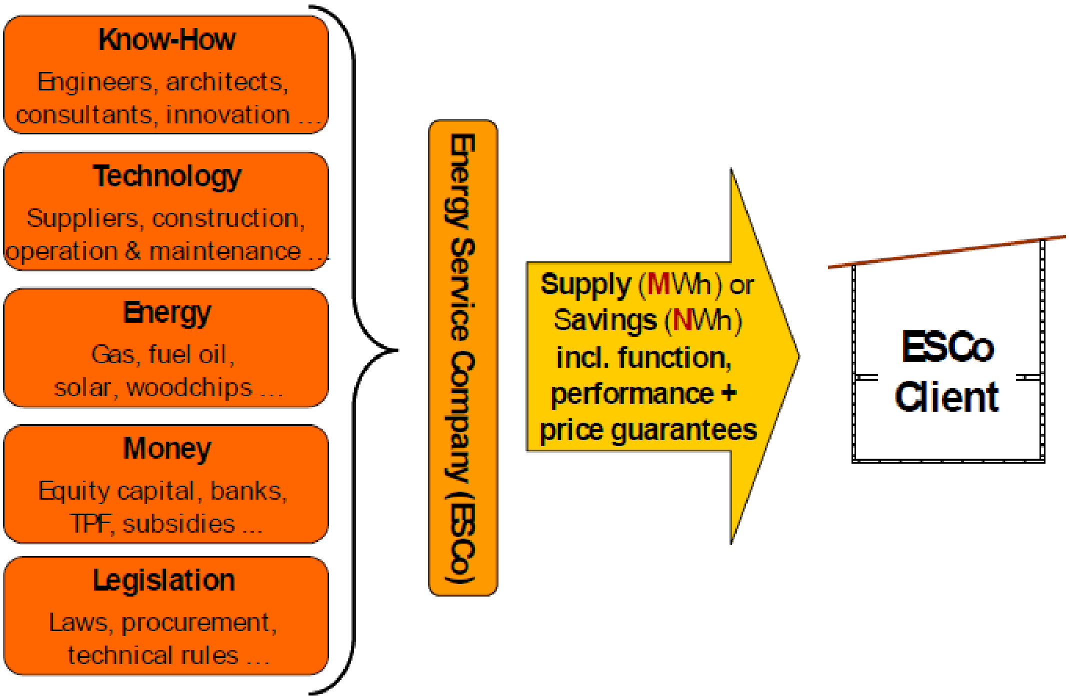


Figure 2: Scope of Energy Contracting Services (Bleyl-Androschin & Ungerböck 2009)

3.2 Contracting Business Models

This chapter shall give an overview of the existing business models of EC. Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC) represent the well-known and mature products, while Integrated Energy Contracting (IEC) stands for a renewed, more complete approach to contracting services, promoted by the Grazer Energie Agentur, under the guidance of Jan W. Bleyl. Figure 3 illustrates the areas of a building in which the different business models usually are applied. All of the above mentioned and in the following sub-chapter discussed business models are performance based and lead to a reduction in final energy demand. Besides environmental benefits through energy and emissions savings EC projects also tend to increase the level of comfort of the building users and an improved corporate image.(Bleyl-Androschin et al. 2013)

ESC projects focus on the efficient supply of useful energy such as heat, cold, steam or compressed air. The measurement of the contracting is based on MWh. This model is comparable to district heating and co-generation supply contracts since it in general also includes the purchasing of the final energy. In case of renewable energy supply contracting, such as solar energy, the contracting will be based on MWh of delivered electricity or heat in case solar thermal. (Bleyl-Androschin et al. 2013)

EPC projects aim to reduce the final energy consumption with energy efficiency measures on the demand side. These include the upgrading of technologies used in distribution systems and energy end-use appliances in an entire building, such HVAC, lighting, compressed air tool, as well as improved user behaviour. This contracting model is based on delivered savings (NWh) in comparison to an ex ante baseline. The term Negawatthours (NWh) has been introduced by Amory Lovins of the Rocky Mountain Institute in 1985. (Bleyl-Androschin et al. 2013)

Integrated Energy Contracting (IEC) combines the two above mentioned concepts and also tries to promote a more simplified approach to measurement and verification (M&V).

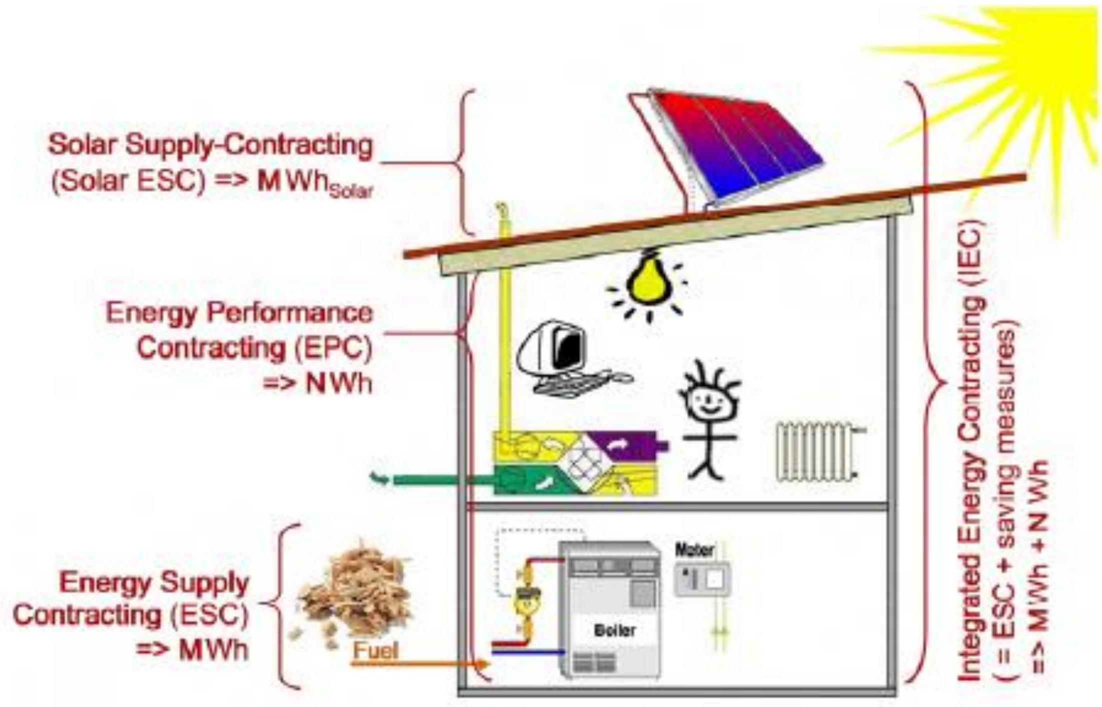


Figure 3: Overview of different EC business models (Bleyl-Androschin; et al. 2013)

3.2.1 Energy Supply Contracting (ESC)

Energy supply contracting is an established instrument to perform energy efficiency measures with modern, environmental protective technologies such as combined heat and power (CHP), biomass or solar thermal plants and other energy supply plants. The ESC approach shifts the attention from primary energy supply towards the use of the consumed energy. The focus of ESC for example can be the optimized supply of hot water, the provision of compressed air at a certain level or the decentralized production of electricity with renewable energy sources (RES) or a CHP. In the majority of projects the ESCo designs, constructs, operates and finances the energy supply facilities and is in charge of purchasing the required energy carrier like gas or biomass. The ESCo supplies the useful energy at a guaranteed price and therefore has an incentive to operate a facility in an efficient way. Figure 4 shows the components of a guaranteed price in the ESC business model. The basic price (also service price) consists of the capital cost, O&M cost, risk provision and profit of the ESCo. The total cost of energy depends on the consumption and the price of the used fuel or final energy. The price components are adjusted to the corresponding indexes. (Bleyl-Androschin & Schinnerl 2010)

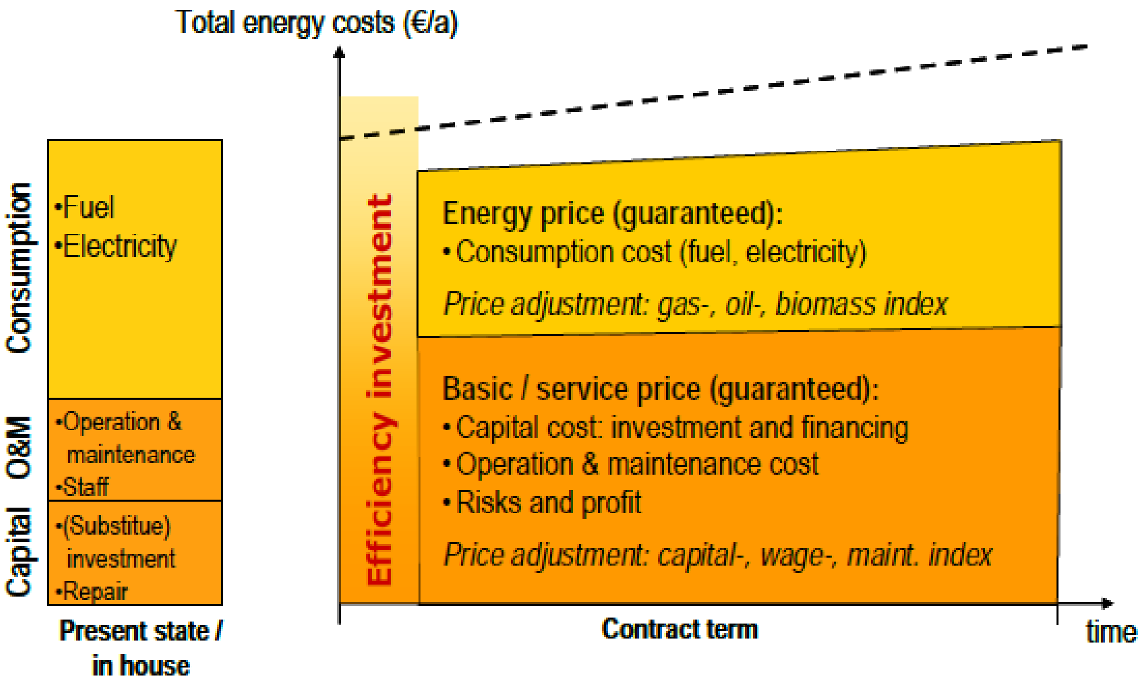


Figure 4: Business Model of Energy Supply Contracting (Bleyl-Androschin & Schinnerl 2010)

3.2.2 Energy Performance Contracting (EPC)

Energy Performance Contracting is a turnkey service which offers customers a set of comprehensive measures for energy efficiency, renewable energy and distributed generation facilities. In general it is combined with guarantees that the achieved savings by a project will finance the full project cycle cost. The business model is based on transferring the technical risks from the client towards the ESCo, who commits to performance guarantees. The remuneration of the ESCo is therefore based on the demonstrated performance, the level of energy savings. EPC is especially interesting for infrastructure improvements of facilities where the owners lack energy engineering skills, manpower, management time, capital funding and understanding of risk. Creditworthy, but cash-poor customers are consequently good potential customers for EPC projects. (EPA 2012; European Commission 2016)

In comparison to the ESC model, the scope of EPC projects is extendible to the entire building including the technical building equipment (e.g. HVAC), lighting and user behaviour. Building envelope measures can also be part of an EPC project with improvements such as insulation of the upper-floor ceiling, window retrofit and in further stage passive solar shading. This can lead until reaching a low-energy building standard, however such projects hardly have been realized under an EPC approach until now. (Bleyl-Androschin et al. 2013)

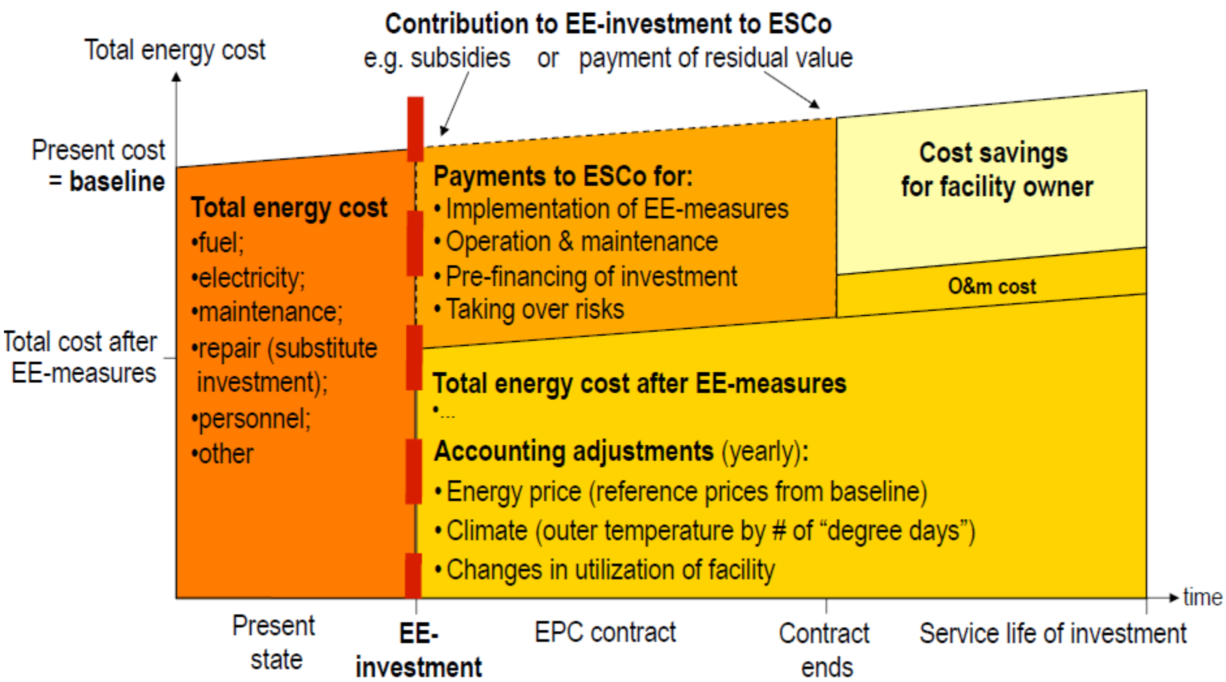


Figure 5: Business Model of Energy Performance Contracting (Bleyl 2016)

Figure 5 illustrates the concept of an EPC project over the life cycle. The contracting rate for the ESCo includes the cost of energy efficiency measures realized, O&M,

the financing cost of the project and the risk provision including the profit. The overall energy cost after implementation of the energy efficiency investment will be adjusted to changing energy prices, climate fluctuations and also change in the utilization of a facility.

Measurement and Verification (M&V)

The main characteristic of the EPC business model is the generation of energy savings in comparison to a historical and into the future projected cost baseline. Therefore the measurement and verification (M&V) of those savings is a very important part of every EPC contract. However, under certain circumstances, this method can be challenging for following three reasons:

1. Savings (NWh) cannot be measured directly but only as a difference between consumption prior and after the realization of the energy efficiency measure. This may lead to two significant difficulties:
   - Lack of availability of historical data (e.g. from bills or meters) may complicate the determination of an accurate baseline
   - Relevant factors in the determination of the baseline can change during a project life cycle. Hence the energy cost baseline is not constant. Elements which influence the baseline are energy prices, climatic conditions (e.g. outside temperature, solar radiation) and changes in the utilization of the facility or process (e.g. operational hours due to different shifts, variable loads, user behaviour, etc.). Particularly changes in the utilization cause significant problems, expenses and uncertainty for both ESCo and the owner in adapting the baseline.
2. High transaction and operational cost to determine and adjust the baseline may cause insecurity and also monetary risk for the project partners. M&V of the savings might therefore cause high expenses in relation to the potential savings of an EPC project. Especially if the savings are generated through a variety of different measures the risk of increased M&V cost is amplified. Since M&V cost are current expenses during the project life cycle it is highly recommended to monitor this process closely in order to avoid a decrease of potential savings during the refinancing period of an energy efficiency

investment. This is especially important for smaller EPC projects. In practice M&V shall not surpass 5 % of the annual savings.

3. Due to above mentioned circumstances ESCos are likely to include safety surcharges in order to protect from the risks of guaranteed saving within an EPC. This can lead to significant additional cost for customers, since the ESCo has to absorb possible increases in energy consumption, e.g. form user behaviour but also inaccuracies in savings calculations.(Bleyl-Androschin et al. 2013)

The transaction cost and cost of M&V of course also exist for ESC, but only play a minor role compared to EPC. Considering the above mentioned points EPC projects very often are only feasible for larger projects. The high efforts of developing, maintaining and monitoring the baseline over the contract duration in EPC have led to a general scepticism with potential client and ESCos. (Bleyl-Androschin et al. 2013)

3.2.3 Integrated Energy Contracting (IEC)

Based on the existing EC business models described in the previous chapters the team of the Graz Energy Agency, under the guidance of Jan W. Bleyl, developed a new, market-based energy service business model, combining energy efficiency and supply. Before introducing this novel model, called Integrated Energy Contracting, Figure 6 shall serve as a summary of the existing business models and lead to this new concept:

	ESC	EPC
End-use markets	Public institutions, residential, commerce, industry	Public institutions (including universities, hospitals, leisure facilities)
Project size: Minimum energy cost baseline	**> € 20,000**/year (=> smaller projects)	**> € 200,000**/year (Ø ESP Berlin: € 1.88 million /year)
Efficiency potentials	**15-20%** (=> limited scope of service)	**20-25%** (up to 30-50%)
Shares in ESCo market	**85-90%**	**10-15%**
Outputs	**Useful energy** (MWh**)** (=> final-energy savings)	**Energy savings** (**N**Wh)
M&V	**Direct**: Energy meters	**Indirect**: savings = Baseline– actual consumption (=> High transaction cost => Baseline risks)

Figure 6: Summary of main characteristics of ESC and EPC(Bleyl-Androschin et al. 2013)

The IEC model promotes an "energy efficiency first" paradigm and combines two objectives:

1. **Energy demand reduction**: implementation of energy efficiency measures in building technologies, building shell and through improves user behavior.
2. **Efficient supply:** the remaining demand for useful energy shall be provided in an efficient manner and preferably from renewable energy sources. (Bleyl-Androschin et al. 2013)

The IEC business model builds on the basics of the widespread and robust ESC model and extends to the savings potentials in the entire building or production plant. In order to assure the correct execution and performance of the energy efficiency measures, the IEC model promotes the use of quality assurance instruments (QAI) instead of extensive, individual M&V measures. The ESco is responsible for implementing and operating the energy service package at its own costs and risks, depending on the specific requirements of a given project. The ESCo in return is compensated for the volumes of useful energy supplied, depending on the actual consumption and with a fixed rate for the energy efficiency measure and a service fee for the O&M. This fixed rate also includes the quality assurance. In case of over- or underachievement of the guaranteed efficiency improvements a system for bonuses and penalties can be included into the contract.

Financing is an additional, modular component of the service package. The business model is drafted in Figure 7. (Bleyl-Androschin et al. 2013)

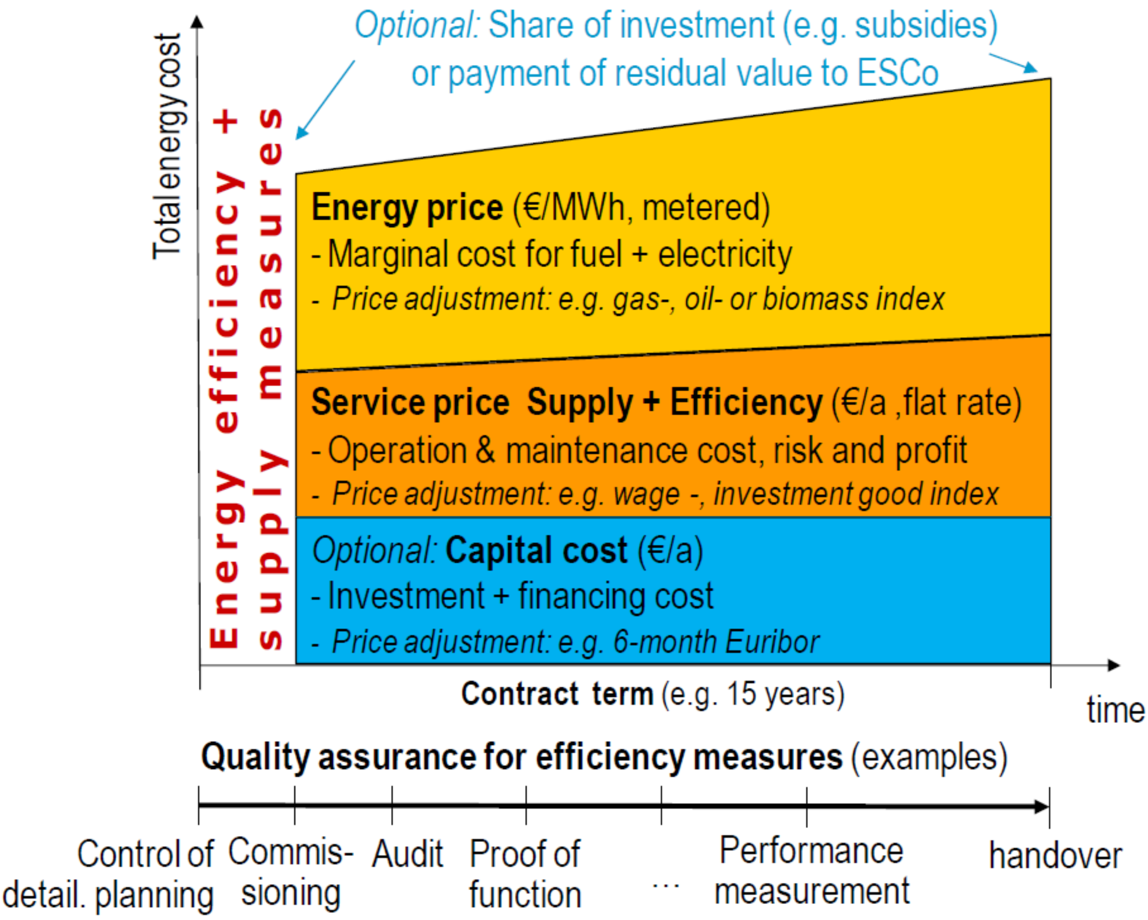


Figure 7: Business Model of Integrated Energy Contracting(Bleyl-Androschin et al. 2013)

The IEC business model suggests that the compensation of the ESCo consists of the following components:

- **Energy price:** covers the consumption related cost of useful energy supplied and is determined per kWh or MWh metered. The price is intentionally set at the marginal cost in order to avoid a consumption related margin and therefore an incentive for the ESCo to sell more energy. Market fluctuations of fuel prices are accounted for with index-linked clauses to relevant statistical price indexed for the fuel used (e.g. biomass index). The risk of changes in the final energy price remains therefore with the client.
- **Service fee energy supply and energy efficiency**: charged as a flat rate it covers the costs related to the operation of the energy supply application. It includes staff, insurance, management, entrepreneurial risk and general

O&M expenses for the energy efficiency measures. Typically the prices are adjusted on a yearly basis by linking them to statistical indices for wages and investment good indices.

- **Capital cost**: Depending on which contract party is financing the EE-measure the capital cost may be part of the service package. In case the ESCo is (co-) financing the remuneration is based on the capital cost minus subsidies and building cost allowances. Adjustments might be linked to financial statistical indices such as the 6-month Euribor.(Bleyl-Androschin et al. 2013)

One major characteristic of the promoted IEC business model is the simplified approach of measurement and verification. The reasoning behind is to make EPC and IEC services also accessible for smaller projects. Compared to the baseline centered M&V approaches of the EPC business model a simplification is achieved by direct measurement of the useful energy supplied and the quantification of energy savings via quality assuring instruments (QAI). QAIs are tests to verify performance and functionality of EE-measures, without validating their exact quantitative outcomes over the entire project life cycle. This results in reduction of concurrent M&V expenses and also eases the ESCo's risk concerning the baseline adjustment.

3.3 Risks of Energy Contracting Services

Energy contracting services, especially EPC projects, present a variety of potential performance and financial risks. After mentioning some of those risks and uncertainties in the previous chapters, this section will present a structured overview in form of Table 1. For each risk category it will show how those risks reveal, which circumstances cause the risk and which consequences these risks might bring along. Finally of course the proper risk management solutions will be pointed out. In general risks of EE projects can be classified into five categories:

- Economic, financial and regulatory risk
- Contextual/contractual risk – concerning project design and installation risk
- Technology risk
- Operational risk
- Measurement and Verification risk(Lee et al. 2015)

Table 1: EC project risks and their management (Lee et al. 2015)

Risks	Manifested as	Risk causes	Risk consequences	Risk management
Economic risk	Construction cost increase	Labour/material cost volatility	Profit reduction of ESCo	Price adjustment based on indices
	Interest rate increase	Interest rate volatility in loan market	Increased financing cost	Interest rate swap
	Fuel cost increases	Commodity price volatility	Reduction in actual cost savings	Hedges; Baseline adjustment of fuel costs
Financial risk (in case of third party financing)	Payment default	Energy saving is not achieved as expected	Inability to service loan and possible termination by banks	Guarantee on energy saving; Performance bond
Project design risk	Insufficient information on facility	Incomplete and poor quality of system operating data	Inaccurate energy baseline; Inaccurate calculation of energy saving	Due diligence; Guided site visit
	Inappropriate design	Improper design and design fault	Shortfall in energy savings	Careful design; design reviews
Installation risk	Completion delay	Adverse weather; shortage of labour; delay in project approval	Delay in commencement of energy savings	Extension of time clauses
Technology risk	Poor System / Equipment performance	Design deficiency	Reduction in actual energy savings	Careful design; acceptance tests
	Wrong equipment sizing	Improper equipment sizing	Equipment frequently operating at part- load condition, resulting in reduction of energy savings	Careful design; acceptance tests

Risks	Manifested as	Risk causes	Risk consequences	Risk management
Operational risk	Degradation of equipment	Faster rate of equipment degradation due to poor maintenance	Consuming more energy to achieve the same performance, resulting in reduction of energy savings	Monitoring and diagnostics
	Faulty operation	Improper system operation (e.g. system is often operating at part load condition)	Reduction in actual energy savings	Operation staff training; Provision of system operational procedure guidelines
	Frequent breakdowns	Improper or lack of maintenance	Reduction in profits of ESCO and disturbance to host	Planned maintenance
	Unexpected consumption pattern	Changes in baseline conditions, such as weather, operating hours, load on system conditions	Change in measured energy savings	Proper contract drafting, especially in considering baseline adjustment factors; Follow established M&V guideline
M&V risk	Poor data quality	Low resolution of operating data; missing data	Increase in uncertainty on energy saving calculation	Prior agreement on the expected quality of data; Carry out investment grade energy audit
	Modeling errors	Incorrect assumptions on technical aspects	The model might be invalid for estimating the baseline energy use after retrofitting, leading to disputes over actual energy savings	Prior agreement on the use of modeling method & assumption
	Inconsistency of data	Improper M&V design (e.g. miss out recording factors which significantly affect energy use)	Dispute over actual energy savings	Proper M&V plan design
	Imprecise/inaccurate metering	Measurement error	Increase in uncertainty in energy saving calculation	Regular calibration; Sub-metering

3.4 Financing Options of Energy Contracting Services

A successful development and implementation of energy efficiency projects depends on various factors. A competitive financing solution is without doubt one of the key success factors of energy contracting projects. Financing for EC investments can be provided by the customer, the ESCo or a finance institution (FI) as a third party.

This chapter shall give an overview of different finance options offered by finance institutions for ESCos and their clients. Namely these are credit financing, operate and lease finance, cession and forfaiting. External finance has a variety of business implications which need to be considered and compared for each finance option before taking a decision. These factors are:

- Direct financing cost
- Legal aspects
- Securities/collateral required
- Taxation implications
- Balance sheet & accounting implications
- Business Management expenditures (Bleyl-Androschin & Schinnerl 2010)

Due to the scope of this Master Thesis not every of the above mentioned criteria will be analysed in detail for each of the finance options in this chapter. Important implications on the business of ENGIE Austria and their clients will however be pointed out, especially who will have to capitalize the investment on its balance sheet.

3.4.1 Credit Financing

Credit or loan financing means that a lender (FI) provides a borrower with capital for a defined purpose and over a fixed period of time. In case of EC, borrowers can be ESCos, real estate owners and companies. The credit has to be settled over this fixed period of time, by re-paying a number of fixed instalments. These instalments, called debt service, cover the borrowed amount, the interest rates and the transaction costs (administrative fees, etc.). In order to obtain a credit the borrower has to prove its creditworthiness and show that he will be able to perform the debt service. In general 20-30% of equity capital is requested by a FI. In credit financing the borrower is both economic and legal owner of the investment and therefore has to capitalize it on his balance sheet. This affects his equity-to-assets ratio, which means less capital to do business with and a reduced ability to get further credits. (Bleyl-Androschin & Schinnerl 2010)

Figure 8: Cash flow in EC projects with ESCo credit financing (Bleyl-Androschin & Schinnerl 2010)

Figure 8 draws the financial flows of an EC project where the ESCo is the borrower. The ESCo is of course responsible for the implementation of the EE measure and refinances the investment with a credit. The contracting rate includes the finance share, which is used by the ESCo to repay its debt. This can be considered as the "traditional" ESCo-Third-Party-Financing model. (Bleyl-Androschin & Schinnerl 2010)

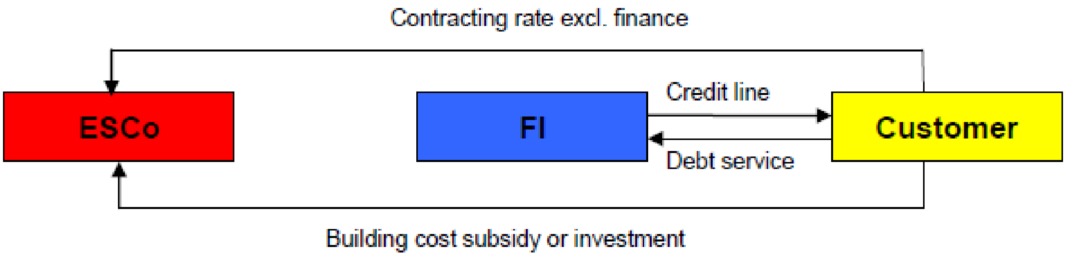


Figure 9: Cash flow in EC projects with customer credit financing (Bleyl-Androschin & Schinnerl 2010)

Figure 9 depicts the customer as borrower of the credit. The ESCo receives financing for the EE investment from the client, who finances itself through the credit and potentially partly from subsidies or from its maintenance reserve fund. This customer finance model is recommendable in cases where the customer has better finance conditions than the ESCo. (Bleyl-Androschin & Schinnerl 2010)

A close coordination between ESCo and customer in terms of financing is advisable, especially in cases where the customer contributes to the investment in forms of subsidies, reserve funds or with equity.

Each and every credit has to be backed with a security, in order to secure the lenders claim against the borrower to pay back the debt. The most valuable securities for banks are land property and personal securities. On average 55% of the credit amount is covered by securities, but ranges may vary from 30% to 80%. Concerning the effects on balance sheets in this case the credit will appear on the books of the borrower.(Bleyl-Androschin & Schinnerl 2010)

3.4.2 Leasing Financing

Leasing is a form of financing in which someone obtains the right to use an asset, without taking possession of this asset. In case of EC assets are the energy efficiency measure or an energy supply plant. Consequently in case of leasing an investment, you do not buy it, but only pay for the exclusive rights to use it.(Bleyl-Androschin & Schinnerl 2010)

A leasing contract is an agreement between the lessor, as the owner of an asset and the lessee, as the user of the asset. The former thereby grants exclusive usage rights of the asset for a defined period of time (basis lease term), in return for the payment of a lease. Typically the lease is paid for in annuities to the leasing finance institute (LFI). As for credit financing the lessee can either be the ESCo or the client.

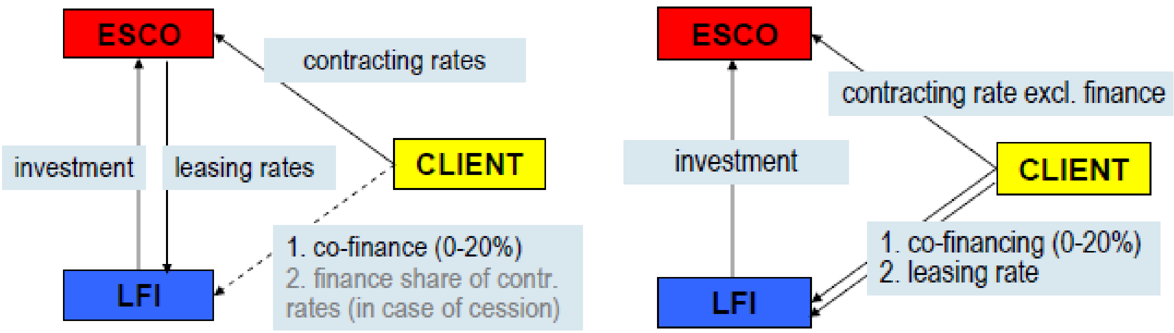


Figure 10: Cash flow of EC projects with ESCo (left) and client (right) as lessor
(Bleyl-Androschin & Schinnerl 2010)

Figure 10 illustrates the cash flows within a leasing agreement, on the left side with the ESCo as lessee and on the right with the client. In both cases the LFI takes care of the financing and the ESCo constructs the EE measure. In general the ESCo arranges the financing agreements, while the LFI in a further step manages potential co-financing options such as subsidies. The leasing rate is in both cases directly paid to the LFI and therefore reduces the contracting rate if the client is the lessor. (Bleyl-Androschin & Schinnerl 2010)

In general there exist two leasing models which are of importance for energy contracting businesses. Operate and finance leasing model, which distinguish mainly in the fact in whose books the EE-measure is accounted for. For finance leasing models the lessee (ESCo or client) has to capitalize the investment in its balance sheet, for operate lease it's the lessor. However rules for operate lease will change in the near future due to new IFRS rules. Operate leasing traditionally is used for cars and goods such as moveable machineries, but also reports an increased use in energy supply service contracts. At the end of the basic lease term the asset has to be re-utilizable and a removal has to be possible without the asset suffering substantial damage. This for example is the case for a container based CHP plant, but not for building insulation measures. This leads to the interpretation that leasing is more suitable for ESC than for EPC projects. Finance lease could be considered as a combination of a credit financing and an operate lease. Except a more project oriented approach on required securities and financing, lot of characteristics are similar to credit finance. (Bleyl-Androschin & Schinnerl 2010)

The following bullet points shall outline some important characteristics of leasing which apply for both the finance and operate leasing model:

- Direct financing cost for leasing often is higher than for a credit. On one hand because the lessor covers a broader range of services (consulting, subsidy management, etc.) and on the other hand because he assumes higher risks with fewer securities compared to credit finance.
- The lessee in general is responsible for the O&M of the asset and also bears the economic risk in case it becomes unusable. Therefore the lessor will oblige the lessee to close an insurance contract for the asset.
- In terms of legal aspects a differentiation between legal and economic ownership is important. Legal ownerships safeguards the control over the asset and functions as security for the lessor. Economic ownership, as already mentioned above, determines who has to capitalize the investment in his balance sheet.
- EC projects often include a transfer of ownership at the end of the contracting period. Leasing financing however legally requires that no automatic transfer of ownership is agreed in the EC contract.

- For lease financing LFIs very often identify fewer risks and tend to accept project based securities such as project revenues (e.g. feed in tariffs for RES). (Bleyl-Androschin & Schinnerl 2010)

3.4.3 Cession and Forfaiting

A cession is a transfer of future receivables, in our case of contracting rates, from a cedent or cessionary (ESCo) to a buyer (FI). The ESCo as original creditor cedes his claims to the FI. The FI as the new creditor gains the right to claim the future contracting rates from the client (debtor).

There exist two basic forms of cession:

- **Cession:** In addition to a credit or a leasing contract ceded contracting rates can be used as further security for the FI. In this case the EC client pays (part of) the contracting rates directly to the FI.
- **Forfaiting:** A cession without an underlying financing agreement. Here the FI purchases the future contracting rates and pays a discounted present value to the ESCo. (Bleyl-Androschin & Schinnerl 2010)

The better known term Factoring is a similar form of cession. However since it used for short term receivables and/or the cession of single invoices it is not applicable for energy contracting services.

Cession

Figure 11 below shows on the left side the cash flows and on the right side the contractual setup in case of cession as security for credit or lease financing. The client pays the on part of the contracting rate directly to the FI and another still to the ESCo. The payment to the FI is used to pay back the debt of the ESCo, while the other part of the contracting rate, paid to the ESCo, covers the operation and maintenance and the risk provision. (Bleyl-Androschin & Schinnerl 2010)

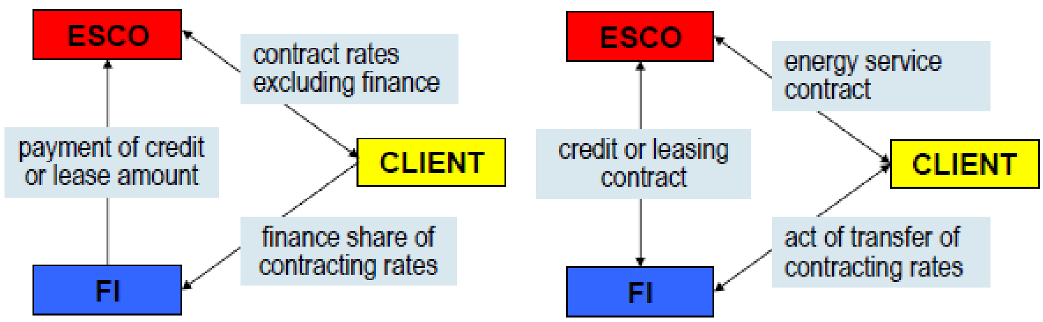


Figure 11: CF (left) and contract relationship (right) for cession (Bleyl-Androschin & Schinnerl 2010)

Forfaiting

FI, ESCo and client sign a so-called “notice and acknowledgment of assignment” in order to seal the forfaiting. Herein the client acknowledges the continued obligation to pay to the FI regardless of any dispute between client and ESCo. Precondition to establish a forfaiting contracting is that the receivables are declared as legal rightful and undisputed. Legal rightful means that the client has to confirm the performance of the EC measure after implementation. Undisputed refers to the fact that contracting rates must be settled independently from the further performance of the ESCo regarding O&M or guarantees. In order to meet these preconditions following EC models could be applied:

- ESC with cession of the basic service price of the rate
- EPC with cession of the fixed part of the rate
- EPC with cession of the total contracting rate combined with a penalty or bank guarantee in the case of nonfulfillment of the ESCo’s performance.

The forfaiting sum should be limited to financing part of the contracting rate. This could be the investment plus capital cost. The remaining share for O&M, energy supply and risk is still paid to the ESCo over the contract term. (Bleyl-Androschin & Schinnerl 2010)

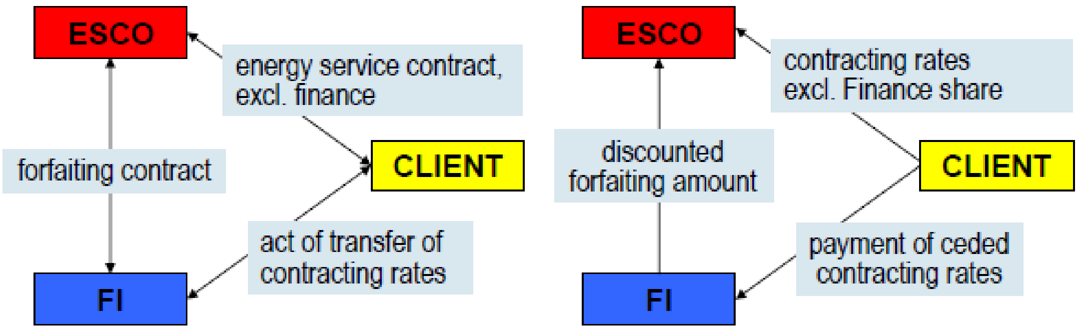


Figure 12: Contractual relationships (left) and cash flows (right) of Forfaiting (Bleyl-Androschin & Schinnerl 2010)

Figure 12 above sums up the contractual relationship of a forfaiting agreement on the left and illustrates the cash flows on the right side. The sum of the ceded contracting rates will be discounted by the FI and payed to the ESCo. The discount consists of the re-financing cost including interest and risk compensation, fees and profit margin of the FI. The client pays the FI according to an instalment plan. In case of forfaiting the ESCo is legal and economic owner of the investment and therefore has to capitalize it in his books. But since he can settle the receivables and liabilities from the project at once, forfaiting has a positive effect for his balance sheet performance indicators and liquidity.(Bleyl-Androschin & Schinnerl 2010)

4 DEMAND SIDE FLEXIBILITY (DSF)

4.1 Definition and Concept

The Council of European Energy Regulators, CEER, defines Demand Side Flexibility (DSF) as follows:

*"**Demand-side flexibility** can be defined as **the capacity to** change electricity usage by end-use customers (domestic and industrial) from their normal or current consumption patterns in response to market signals, such as time-variable electricity prices or incentive payments, or in response to acceptance of the consumer's bid, alone or through aggregation, to sell demand reduction/increase at a price in organised electricity markets. The objective of such market signals is to induce modulation (increase or reduce) of electricity usage and to optimise usage and balancing of networks and electricity production and consumption, for example by consuming less during peak times or by facilitating the integration of electricity from variable renewable energy sources and micro-generation (e.g. behind the meter generation)."* (Council of European Energy Regulators 2013)

Consumers may react in different forms, such as moving electricity demand in time (e.g. delaying demand to avoid expensive prices or benefit from hours with low prices), cutting off their consumption, by shifting fuel (e.g. using gas instead of electricity for heating) or by activating back-up generators which act as demand reduction for the network. DSF also referred to as **Demand Response** (DR) can be driven by market prices, distribution tariffs or reliability signals of the network. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

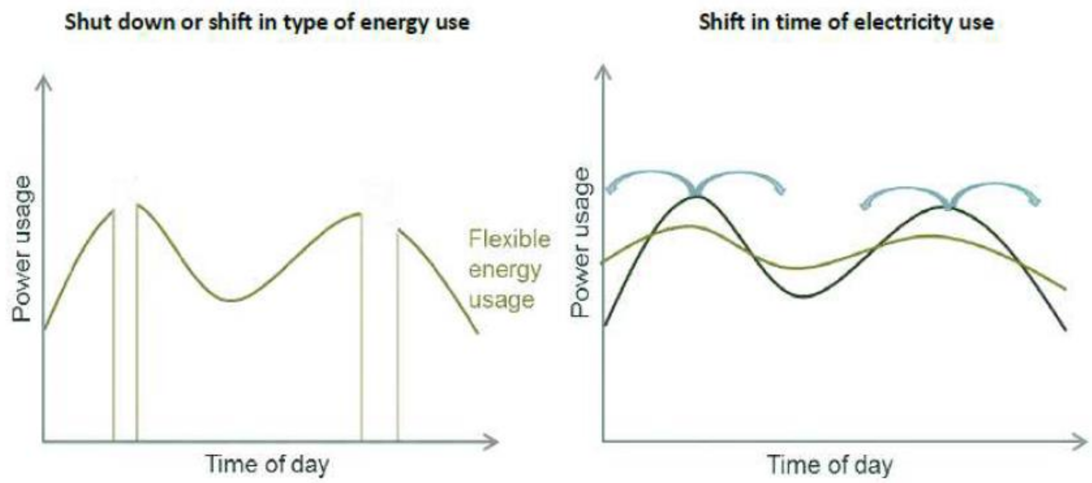


Figure 13: Different type of DSF(Joint Working Group from Concerted Action EED / RES / EPBD 2015)

In the following a list of the different kind of loads which can act as Demand Side Flexibility:

- **Non-curtailment load (Base load):** certain parts of electricity consumption are not changeable. The so-called base load is considered to be inelastic to signals (e.g. alarm systems, IT-applications)
- **Curtailable load:** this part of the electricity consumptions can be turned off at certain times or periods. In this case curtailment happens through reduced take-off (e.g. switching off of decorative lighting in times of high electricity prices) or through fuel shift (e.g. industries use different fuels instead of electricity in times of high electricity prices). This curtailed part of electricity consumption will not be consumed a later point in time.
- **Shiftable load:** this part of electricity consumption can be shifted to a different point in time (earlier or later). In general the overall consumption will remain identical (e.g. charging of electrical car). In cases where the operational changes involve pre-heating or pre-cooling, the overall consumption may even increase due to extra service level or reduced efficiencies. Overall benefits such as reduced CO_2 emissions may still occur in case of total end-user demand increases.
- **Storable load:** this kind of electricity consumption is used at the same moment as usual, but the electricity consumed could be generated, transported and stored at a different moment. Usage could take place in times of high electricity prices or low own production in case of RES. The effect on final energy savings is likely to be negative due to lower efficiencies of storages. Yet in overall primary energy savings and CO_2 reduction can be

achieved for example in cases where the process allows the replacement of electricity from thermal generation by renewable electricity (especially wind and solar).
In times of low electricity prices storable load could also lead to higher consumption of electricity using technologies such as Power-to-Heat or Power-to-Gas.

- **Self-generation:** located at the site of the customer in form of back-up generation (e.g. hospitals or data centres) or micro wind or PV systems. In case of fuel based generation increased CO2 emissions may be recorded due to lower efficiency in comparison to central plants. (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

DSF can lead to different usage approaches and consumption patterns of electricity and as already mentioned does not necessarily lead to energy savings. Increased demand can occur with very low or negative electricity prices and new technologies like storage and fuel shifts (e.g. power-to-gas) will lead to higher electricity consumption. Power prices can be negative on days where high renewable energy production cannot be curtailed and meets low electricity demand. In general negative prices are still uncommon, but in Germany negative prices occur especially on holidays with low industrial demand and high wind and solar generation.

Figure 14 provides examples and a graphical overview of the different load:

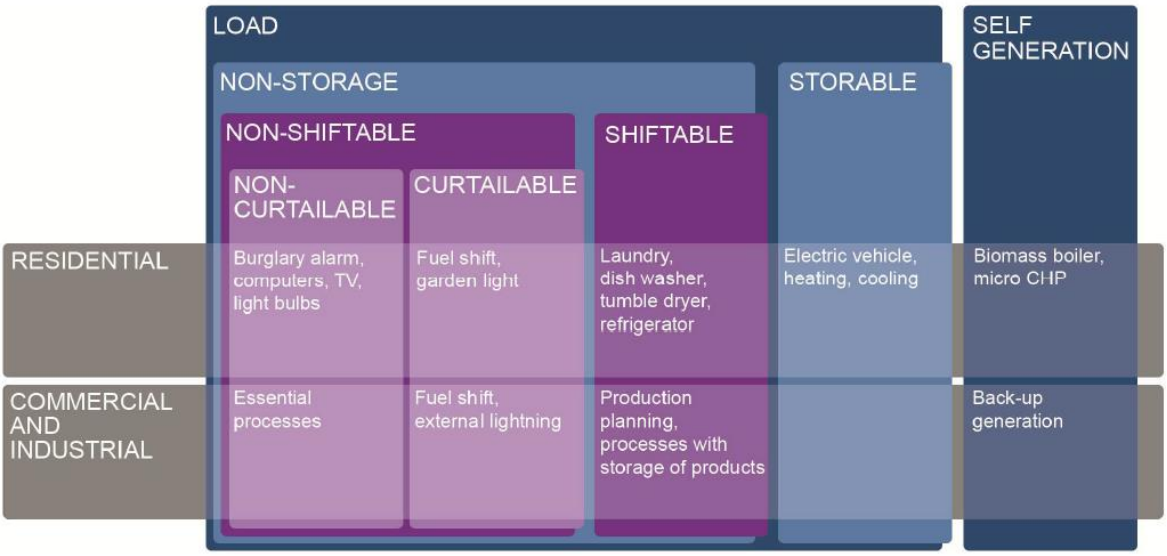


Figure 14: Overview of different load types (Joint Working Group from Concerted Action EED / RES / EPBD 2015)

Since DSF may have an impact on comfort there exist concerns among private customers. They are likely not to respond manually to price signals to reduce or shift energy consumption if an impact on life-style is expected. Nevertheless, in combination with controlled equipment DSF may result in automated response to signals and controllable, minimal impact on comfort. Heat pumps, electric vehicles, radiators, water heaters, refrigerators (without compromising health) or air-conditioning systems may in a short amount of time be curtailed. Laundry machines or dish washers may be set by customers to start later in accordance to parameters set by the customers and depending on price signals. This of course requires that new technological developments in communication technologies are used for home appliances and that electricity tariffs enable and empower such measures on household level. In the future a strong link to the concept of "Internet of things" may lead to large scale application of DSF in households.(Joint Working Group from Concerted Action EED / RES / EPBD 2015)

In case of ENGIE Austria applications in the industrial and commercial sector are currently more within the scope of business. Chapter 4.3 will take a closer look on potential for DSF in industries and office building.

4.2 Classification, Market Segments and Value of DSF

DSF includes different forms of dynamic changes in electricity consumption and has value for various parties in the energy system. Figure 15 illustrates the different segments which benefit through DSF:

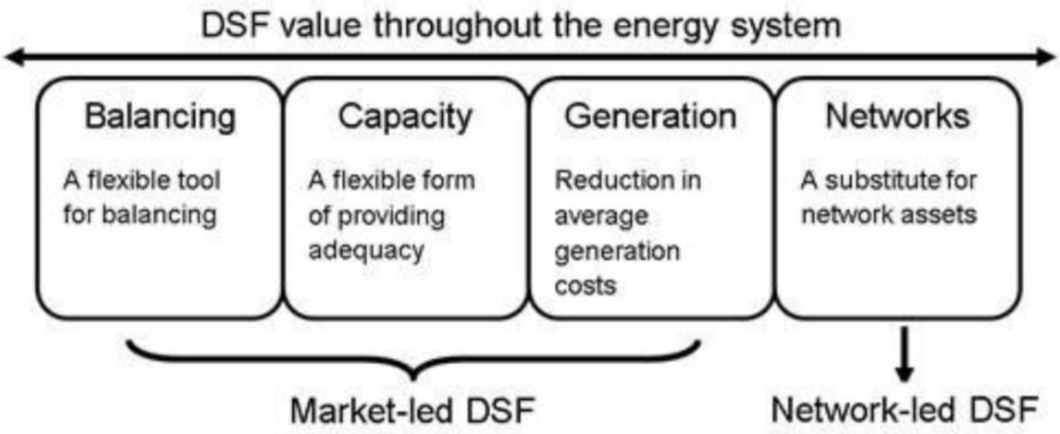


Figure 15: Use of DSF across the electricity system (Council of European Energy Regulators 2013)

In terms of balancing DSF can be used by the Transmission System Operator (TSO) to balance demand and supply of electricity on a real time basis across the system or to support in managing system constraints. Suppliers can use it to balance their portfolio in order to avoid penalties for having long or short positions.

DSF also aims to provide spare capacity to the system reducing the volume of generation capacity required to maintain the security of supply.

So-called peak-shifting, meaning moving consumption from higher demand periods to lower demand periods has the potential to reduce average electricity generation cost by decreasing the need for more costly peaking plants. Flattening the demand curve by demand shifting has furthermore the potential to improve the overall system efficiency for instance by allowing operational plants to run at higher efficiencies. In order to accommodate increased intermittent generation by wind and solar DSF could also be used to increase demand in certain areas. Thereby curtailment of wind farms could be limited and wind power load factors increased.

Finally, DSF can also be applied as substitute for network assets when it defers or avoids investments in network assets. This is the case when it enables Distribution System Operators (DSO) to cope with local network growth without having to build more assets.
The characterization of DSF above could be differentiated between market-led and network-led. However it has to be recognized that a more efficiently operated overall power systems has positive effects on all system participators and consumers. (Council of European Energy Regulators 2013)

Figure 16 shows the interactions between the main participants in the electricity system.

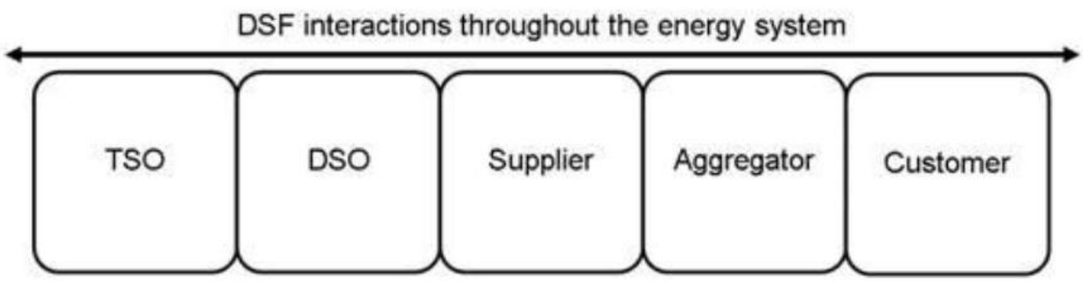


Figure 16:DSF interactions between energy system participants (Council of European Energy Regulators 2013)

In order to play DSF a cost-effective role within the energy systems it is essential that signals are transmitted to customers, both domestic and industrial, in a way that they can react and increase/decrease their consumption accordingly. In terms of signals we can distinguish between price-based signals and incentive-based signals. Any of the above mentioned power system participants could wish to send a signal to customers. Aggregators for example can bundle up individual loads of industrial and domestic customer and offer them for sale or participate in auctions in organised energy markets (e.g. balancing market, control energy). DSF arrangements can be voluntary (e.g. responding to price signals) or mandatory, depending on contractual agreements they may also require exclusivity or be non-exclusive.

Price-based Demand Side Flexibility triggers customer response by price changes which reflect variations in the cost of electricity generation. These time varying tariffs represent an alternative to wide-spread flat rates and empower users to save money on their electricity bill by shifting consumption to times with cheaper prices. Demand response due to price-based signals is an economic decision of the customer and is voluntary at any time. Figure 17 shows that price-based DSF programs can also include time-of-use tariffs (ToU), critical peak pricing (CPP) or real time pricing (RTP). For these forms of price signals smart metering, facilitating short interval metering, is a key pre-condition. The topic smart metering is very broad and complex and will not be addressed in more detail in this Master Thesis.

Incentive-based DSF on the other side is defined by a contractual agreement. Consumers can sign up to such program on a voluntary basis, but once they joined demand reduction or increase is a contractual arrangement. In incentive-based programs participants commit to reduce/increase their electricity consumption or to be curtailed in critical hours. In return they receive a reservation payment or separate incentive payments that are independent from their retail tariff. The following sub-chapter will especially focus on load frequency control energy as part of the balancing mechanism, since it will be applied in the practical example of chapter 5. (Council of European Energy Regulators 2013)

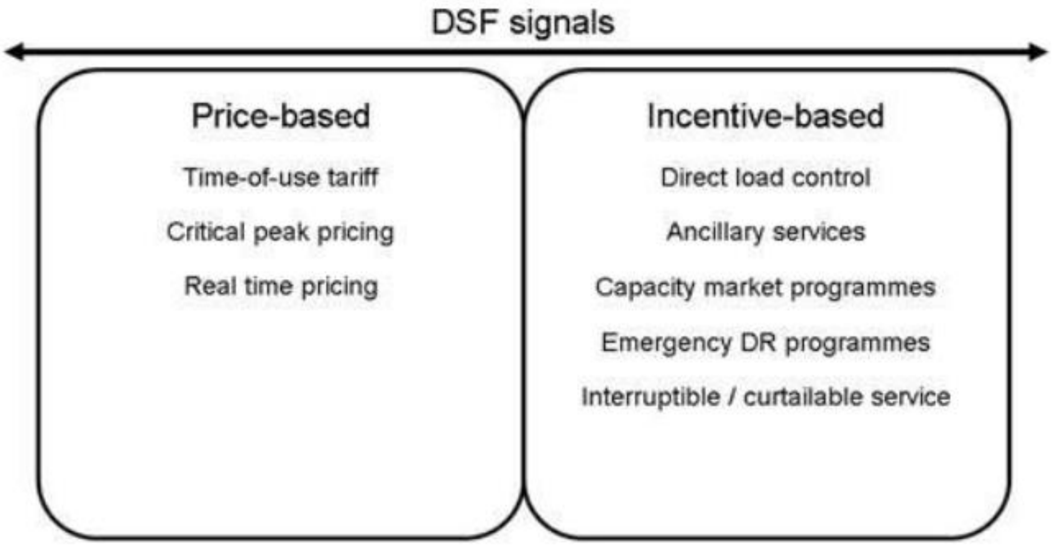


Figure 17: Type of price-based and incentive-based signals (Council of European Energy Regulators 2013)

4.2.1 Load Frequency Control

Load frequency control is used to ensure proper functioning and stability of the power system by keeping the electricity grid balanced at all times. In the European interconnected system the so-called control area mangers (CAM) take care of this responsibility.

There exists certain confusion between the terms of balancing energy and control power. Both have the same purpose of balancing generation and consumption. Deviations from forecasted supply or demand in a balance group cause the need for balancing energy. The netted balancing energy of all balance groups in a control area is the control power which the Austrian Power Grid (APG) has to provide. The total quantity of balancing energy in general exceeds many times the control power, as balance group imbalances may offset each other and generate a portfolio effect. Describing it simply, control power is needed in case of deviations from the forecast in a control area, while balancing energy is caused by deviations from the forecast within a balance group. (E-Control Austria 2013)

In Austria, the TSO, the Austrian Power Grid (APG), assumes the role of the control area manager. To balance the grid the APG applies primary, secondary and tertiary control (minute reserve). The difference between these control mechanisms is the time frame for activation and adjustments. If a major load fluctuation occurs in the

European interconnected system, the primary reserve is activated by APG and provided almost immediately by automatically controled on power production units. Reasons for load variations and deviations from the system frequency of 50 Hz could be a power station outage or unpredictable variations in injection and withdrawal. Contributions of reserve capacity are voluntary and the amounts are based on generation output and expressed by an agreed formula. In Europe primary reserves are handled on synchronous area wide basis. Remuneration is generally paid only for capacity (EUR/MW) and not for energy (EUR/MWh). In 2014 primary control has been dimensioned to handle a maximum deviation of +/- 3.000 MW in Europe. This equalled the simultaneous outage of the two largest generation units in the continental European network. This system thereby maintains the frequency stability. (E-Control Austria 2013; Koliou et al. 2014)

In case of brief power deficit or surplus primary control alone is enough to balance the system again. It is defined as an automated reestablishment of the balance within no less than 30 seconds following the imbalance. After maximum 30 seconds secondary control is activated in order to relieve the burden on primary reserve and liberate it to perform above described function. Secondary control regulates imbalances within a control area while primary control ensures the system stability across control areas in whole continental Europe. Restoring the system may require several minutes. (E-Control Austria 2013)

If it takes longer than 15 minutes to restore the balance between generation and consumption tertiary control takes over or may be activated already alongside secondary control. Tertiary control can be provided automatically or manually but must be ready for dispatch at latest 15 minutes after the imbalance occurs.

For tertiary control there exists a dedicated market where electric energy is traded to re-establish system stability. This balancing market is available to power producers and consumers which have been accredited by APG. Bids for positive and negative balancing energy are placed until 16:00h on a day-ahead basis.

APG, as control area manager has the responsibility to auction tertiary control. Bids are ranked in the merit order list according to various criteria. The merit order list defines in which order participants are informed 10 minutes upfront to start injecting or withdrawing power.

Overlaps between the three control mechanisms clearly exist. The reason behind the differentiation is the fact that only few power plants fulfil all requirements, especially immediate reaction, to supply primary control. Secondary control is covered by plants with short activation times, such as storages or gas-fired plants. Costs for primary control are borne by electricity produces with a maximum capacity of at least 5 MW. The costs are distributed depending on the annual output. (E-Control Austria 2013)

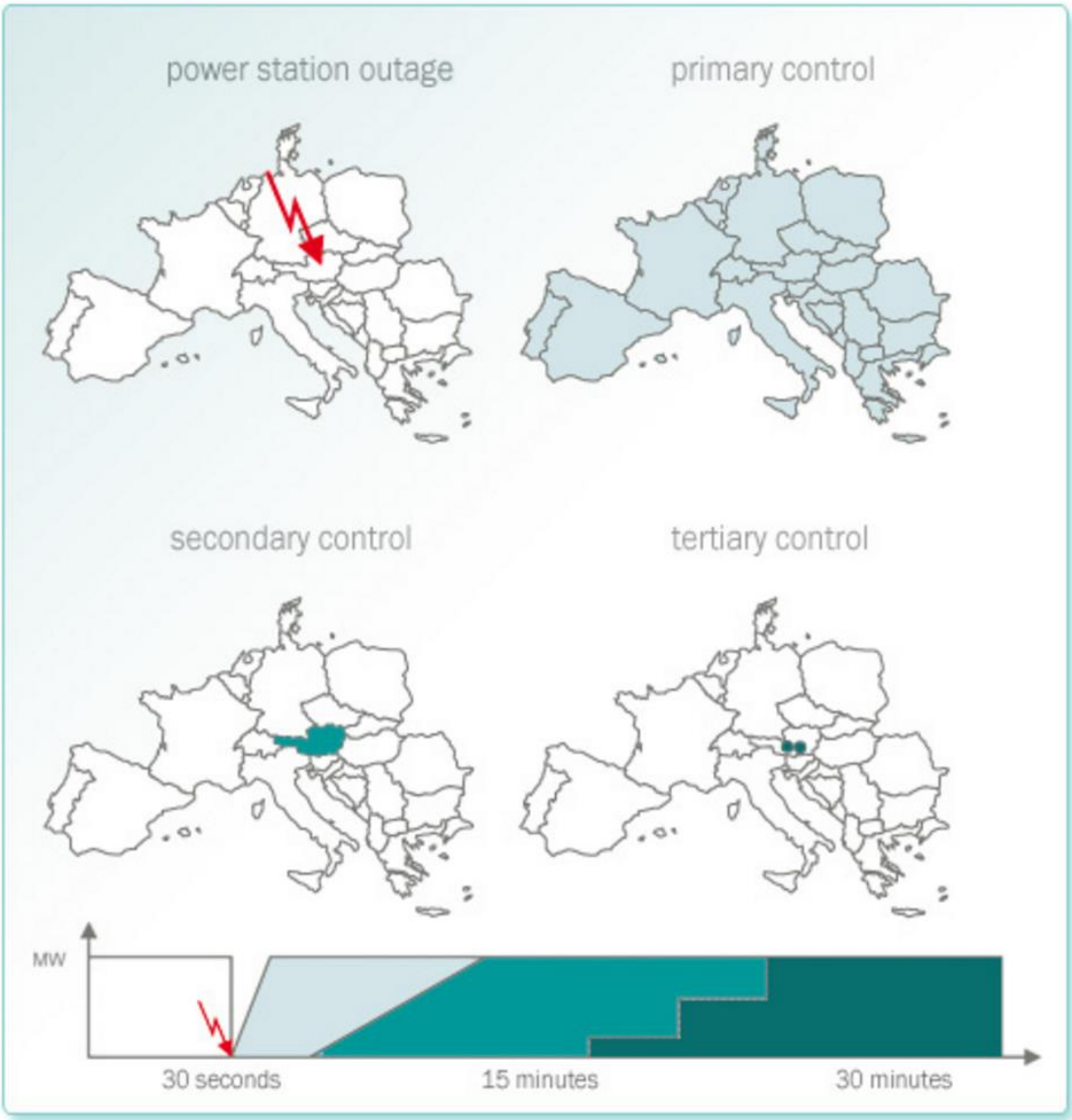


Figure 18: Types of load frequency control (E-Control Austria 2013)

Costs for secondary control are caused by availability of reserve capacity (MW) and by the actual supply (MWh) of control energy. The costs for reserve capacity are borne by producers while the actual used control power is charged to the balance responsible parties (BRP). BRPs such as ENGIE Energie include the risk of this cost in there offers and therefore pass it on to their customers.

For tertiary control power the clearing and settlement agent, in Austria APCS, calculates the costs and charges them the BRPs. Amounts of balancing energy are determined after each month during the clearing, settled by the balance groups and credited to the balancing energy providers. Figure 18 gives an overview of the characteristics of the different load frequency controls:

Table 2: Characteristics of primary, secondary and tertiary control in Austria (own illustration)

Load frequency control in Austria					
Type	**Tender**	**Minimum Bid**	**Activation**	**Time slices**	**Remuneration**
Primary Control	Weekly	1 MW	max. < 30 sec.	1 per week	Capacity price
Secondary Control	Weekly/Daily	5 MW	max. < 5 min.	Peak & Off-Peak / Weekend (12h)	Capacity- & Energy price
Tertiary Control	Weekly/Daily	1 MW	max. < 15 min.	Mo-Fr (4h) / Weekend (4h)	Capacity- & Energy price

For primary control the period in which the primary control power should be provided (tendering period) always extends from Monday 00:00 to Sunday 24:00 (a product over 7 days). The total volume of primary control power must be available in this period without interruption. This means that it must also be continuously reserved by the suppliers in their power plants. The product contains equal amounts of negative and positive primary control reserve. Separate offers for positive or negative primary control power are therefore not possible. The minimum bid is +/-1 MW. Bids in excess of the minimum bid can be placed in full MW increments but must not, however, exceed the pre-qualified power. (APG 2016b)

For secondary control the tendering period is one calendar week (week product). This product is additionally broken down into product time slots:

- **Peak week:** Monday to Friday from 8:00 to 20:00, unless a public holiday, according to the German federal holiday calendar

- **Off-peak:** Monday to Friday from 0:00 to 8:00 and from 20:00 to 24:00, as well on Saturday, Sunday and Holidays, according to the German federal holiday calendar from 00:00 to 24:00

Separate tenders are put out for positive and negative secondary control reserve. Hence, there are 4 week products.

The secondary control power needed in the APG control area currently amounts to +/-200 MW procured in weekly and daily tenders. In the presence of exceptional circumstances, the required volume of secondary control power can be changed by the control area manager. The minimum bid is 5 MW. Bids in excess of the minimum bid can be placed in full 1 MW increments but must not, however, exceed the pre-qualified power. At the end of the bidding period the bids are ranked according to the following criteria and the contracts are awarded:

1. Lowest capacity price
2. In case of several bids with the same capacity price: the energy price will be used as a basis; lowest energy price for positive secondary control, highest energy price for negative secondary control
3. In case of identical power and energy prices: the bid that was placed first wins (time stamp)

Suppliers whose offers are successful will receive the capacity price they quoted, i.e. a "pay as bid" approach is adopted. Once the bid has been accepted, the suppliers are obliged to reserve the corresponding volume of secondary control power. (APG 2016c)

A tender for tertiary control power with capacity price ("market maker tender") is carried out for the coming weekend (Saturday and Sunday) as well as – separately – for the following week from Monday to Friday. These two tendering periods embrace six different product time slots, (0:00-4:00, 4:00-8:00, 8:00-12:00, 12:00-16:00, 16:00-20:00, 20:00-24:00), each of which can be bid for individually. This amounts to 12 different products in the market maker tender.

In addition, there is a short-term tender, a so-call day-ahead tender in which no capacity price is paid for the reserved tertiary power control. In this tender, different energy prices can be bid for the six product time slots on each individual day (e.g. six products per day). These products are identical to the products in the market maker tender, e.g. the bids are ranked in a list which forms the basis for a potential subsequent call. Pre-qualified suppliers of tertiary control can, of course, participate in both tenders, e.g. a supplier who has been accepted in the market maker tender is free to submit further bids (also for the same delivery period) in the day-ahead tender. He can also change the energy price which has already been accepted in the market maker tender.

One block between 1 MW and 50 MW can be offered per supplier and time interval. The power offered may not, however, exceed the amount of the pre-qualified power per supplier. Only full MWs can be offered. The energy price may be positive or negative. If a bid was accepted in the market maker tender, the supplier can change the energy price of this bid up to the end of the day-ahead tender. The energy price originally quoted must, however, not be exceeded in the case of supply or undercut in the case of procurement. (APG 2016a)

For consumers or generators which would like to offer load frequency control but do not have enough capacity to reach the minimum bid size there exists the possibility to join a so-called aggregator. An aggregator is a market participant who offers the service of pooling energy production or consumption from various sources and acts as one single entity towards the grid. This can include local aggregation of supply and demand. Through bundling loads of different sources the aggregator enables also small customers to participate in demand response programs. It is expected that aggregators play an important role in the future power system, controlling multi-fuel, multi-location and multi-owner virtual power plants which can aggregate capacities from distributed energy resources equivalent to the capacity of power plants in order to facility the integration into the physical systems as well as into the market. (Koliou et al. 2014)

4.3 DSF Potential in Industries and Office Buildings

This chapter will provide a non-exhaustive list of applications in energy intensive industries and office buildings which can be used to provide DSF. The list of applications is based on the customer portfolio of ENGIE Energie GmbH and will outline potential processes without going too much into technical details. Participation in Demand Side Flexibility programs such as load frequency control of course depends strongly on the individual processes and circumstances of each company of an industry.

Chemical Industry - Chloralkali Process

For the production of chloride the chloralkali process is an important method. In the chloralkali process a chloride-salt solution is decomposed electrolytically by direct current following this chemical reaction:

$$2NaCl + H_2O \rightarrow 2NaOH + Cl_2 + H_2$$

In general the chloralkali process is executed at maximum capacity to ensure maximum output for this capital-intensive chemical process. Levels of utilization usually range between 80% and 90%. Technically the load of the process could be reduced by up to 40% for up to two hours. However, the potential to shift loads between time periods is limited by the high utilization levels, which makes it difficult to catch-up the curtailed loads. According to an internal investigation by ENGIE a theoretical flexibility potential of more than 3,000 MW exists in Europe for this process. Those 40% of capacity are considered to be already marketed as positive tertiary control power in various countries, such as Austria and Germany. Negative tertiary control power remains currently undeveloped, but is also fairly small due to the high utilization levels. (Paulus & Borggrefe 2011)

Paper and Pulp Industry – Mechanical Wood Pulp Production

The paper industry manufactures a range of different products such as paper, cardboard or sanitary products. Main inputs are recycled paper and pulp. Pulp consists of fibres which get extracted from wood either by a chemical or mechanical process. Due to its high energy intensity the primary DSF potential can be found in the mechanical process for pulp production. The refiners of the mechanical process can be fully activated or shutdown within a matter of minutes. Restrictions are given due to the fact that ramp-up and shutdown should not happen in short intervals in order to avoid an excessive wear of the components. Levels of utilization vary but typically are around 80%. The ability to store the pulp provides significant load shifting potential in the paper industry. Depending on market prices this potential could either be used on the spot market, intra-day market or through positive and negative tertiary control power. (Paulus & Borggrefe 2011)

Aluminium Industry – Aluminium Electrolysis

The process of converting aluminium oxide into aluminium and oxygen through an electrolytic process is called aluminium electrolysis. For activating the electrolysis and raising the process temperature to the correct levels the power demands are significant. Due to the capital intensity of the process the utilization levels range from 95%-98% on an annual basis. Aluminium electrolysis therefore falls under the category of load shedding because hardly any load can be caught up a later time. According to representatives of the industry, the process could be reduced by up to 25% for around four hours before the process runs into danger of stopping. Therefore this process could be used as positive secondary and tertiary control power (reduction of consumption). Bids for calling positive control power might be as high as 1.000 EUR/MW reserved capacity since the value of a lost load is determined by the aluminium price and the risk premium for the technical dangers of destabilizing the electrolytic process. (Paulus & Borggrefe 2011)

Steel Industry – Electric Arc Furnace

Producing steel by melting scrap steel in an electric arc furnace is a very energy intensive process. Heat is generated by an electric arc or induction and melts scrap metal in the furnace. The process can be disrupted immediately, however, if the disruption exceeds 30 minutes the scrap metal will cool down and the melting process needs to be started again. Typically the process takes 45 minutes to melt the scrap steel and another 15 minutes to empty and refill the furnace. Utilization levels therefore are limited at around 75% and difficult to increase. This leads to load shedding as only opportunity for DSF. Steel companies have the option of completely shutting down the process and selling the contracted power on the spot market or on the markets for control power. If the process is disrupted for more than 30 minutes additional costs emerge and should be taken into consideration. (Paulus & Borggrefe 2011)

Cement Industry – Cement Mills

Cement mills crush cement clinker and mix it with other ingredients (e.g. hard plaster) to generate cement with the desired characteristics. Cement mills are the part of cement production with the highest energy intensity and can be regulated in a flexible way. Shutting down and ramping up again is possible within a few minutes. Levels of utilization of cement mills tend to be near the technical limits and storage capacity very often presents a bottleneck for cement mills. Productions dependencies with upstream and downstream process parts often present a hindering factor when it comes to realize load shifting potentials in cement mills. Load shedding therefore is the only viable application for DSF. The determination of the value depends mainly on the cement prices and might vary significantly.

Office buildings

Office buildings have particular energy related needs. Heating for space heating and (optionally) sanitary hot water, cooling for air-condition, ventilation to provide fresh air, lighting, electric power, optionally emergency back-up power.
For heating, a wide variety of heating installations exist like conventional boiler, condensing boiler, heat pump, cogeneration, solar heat, electric heating. Cooling is usually delivered by compression cooling machines but also heat pumps are possible. Ventilation units consist of a supply and exhaust ventilator, optionally equipped with heat recuperation and/or air recirculation. Furthermore, electric power is needed for IT, elevators and other equipment. For some buildings emergency back-up power, a generator on fuel oil or UPS installation provides power to critical elements in case of an incident.

Energy consumption of an office building, heat and power, is influenced and determined by many different factors. Below a non-exhaustive list of influences on a building’s energy consumption:

- **Number of employees and level of occupancy:** the more employees present in a building, the higher its energy consumption;
- **Age of the building and its installations:** older buildings typically are less energy efficient compared to state-of-the-art buildings;

- **Maintenance:** good maintenance follow-up results in more energy efficient installations;
- **Floor surface:** the larger the building, the more heat is needed;
- **Comfort requirements:** a building that is heated, cooled and ventilated all year long will consume more energy compared to a building that is only heated in wintertime;
- **Insulation of the building:** better insulation results in a lower heat and cooling demand;
- **Human behavior:** if a building occupant is attentive to energy consumption and maintains good energy housekeeping, this will generally lead to less energy consumption;
- **Usage of the building:** if for example, a large server room is located in the office building, energy consumption per m² will be higher compared to buildings without a server room.

The energy consumption of an office building is highly case specific. The typical specific power and heat consumption vary between respectively 50 to 350 kWh(el)/m² and 75 and 200 kWh(th)/m². The largest power consumers are lighting, office equipment and ventilation, having approximately equal shares and together representing almost 80% of the building's power consumption. Most of the heat goes to building heating, whereas sanitary hot water represents a rather small part. (Didden 2013)

In terms of Demand Side Flexibility potential applications could be heating installation consisting of a cogeneration unit or heat pump or electric heating, cooling units and air conditioning, ventilation units, lighting and emergency back-up power. The following chapter will analyse the DSF potential in combination with an energy contracting service for a refrigeration system and take a closer look on DSF potentials.

5 INTEGRATION OF DSF INTO ENERGY CONTRACTING SERVICES

5.1 Contracting for Refrigeration System

This sub-chapter describes and analyses an energy contracting project for an office building in Vienna executed by ENGIE Energie. Due to confidentiality reasons the name and the location of this building will not be mentioned. The office building given is located in the city of Vienna. Construction work has started in 1998, with the building completed about three years later in 2001.

The building consists of several parts which can be described as follows:

- Skyscraper with 38 floors with office space and two floors for technological facility equipment in the 39th and 40th floor, and 4 basements with storage rooms and an underground car park
- Low-rise side-building with 4 floors
- Car-park for nearby sports field.

The 40 floors and approximately 165 m high building contains, including the areas of the low-rise building, a rentable area of around 65,000 m². This amounts to a floor area of between 1,500-1,650 m². Beside the skyscraper a so-called low-rise building with an area of approximately 5,150 m² is connected to the building where retail space, conference rooms and a fitness centre are located.

The original cold supply installed during construction of the building consisted of 3 air-cooled compressor chillers with a total output of 1,766 kW and two ice storages with a total capacity of 965 kW. In case of a fully loaded ice storage therefore up to 2,731 kW of cooling capacity has been available, which has been spread over two cold-exchangers in two ascending pipes in the building.

Within the first years of operation it was noticed that the installed generation capacity is not sufficient. For this reason, in 2009 four additional, new chillers, with a total capacity of 1,881 kW_{th}, have been installed in the first basement of the building. The corresponding re-cooling system has been installed outdoors on the roof of an underground car park.

Therefore the installed refrigeration capacity prior to the renovation can be summed up as followed:

1	compression chillers roof	1,766 kW
2	ice storage roof	965 kW
	Installed Cooling capacity roof:	2,731 kW
3	compressor chillers basement	1,881 kW
	Installed Cooling capacity Central UG:	1,881 kW
	Total Cooling capacity	**4,612 kW**

The total annual consumption of cooling energy amounts for 4,255 MWh_{th} for the whole building.

In order to improve the efficiency the owners of the office tower called for the request for proposal for the takeover of the existing refrigeration facilities, renovation of these facilities and the future supply of the building with cold energy (cold water / cooling water) in 2013 with the concept of an energy contracting service.

Due to its Quantum refrigeration concept, the best price to performance ratio and the dedication and commitment of its whole team ENGIE Energie has been awarded the contract. The refrigeration contracting concept of ENGIE represented the most energy- and cost-efficient solution for the office tower and also provided the owners with a projectable and risk-free cost calculation.

The two new chillers weigh around 15,000 kg and are used for air conditioning of the unique "green building" in Austria. The existing cooling system of two ice-storages and a chiller have been replaced by two air-cooled Quantum chillers (cooling capacity of each 993 kW). The cooling system in the basement installed in 2009 has not be replaced. With this upgrade the possibility of free cooling has been realized. The new installed cooling capacity is approximately 4.4 MW and supplies 4.3 GWh cooling energy per year. The reconstruction works were carried out in December 2013 and supply of cooling energy started as of 1st of January 2014.

The contracting concept includes the following services performed by ENGIE Energie:

- Refrigeration including re-cooling, control, monitoring, power supply and metering (cold and electricity)
- Conception and design, planning, execution, installation, modification and commissioning
- Investment
- Operation of the plant
- Service, operation and maintenance, repair
- 24/7 standby
- Measurement

The duration of the energy contracting project is 15 years. After the termination of the contract the ownership of the refrigeration system will again be transferred to the building owners.

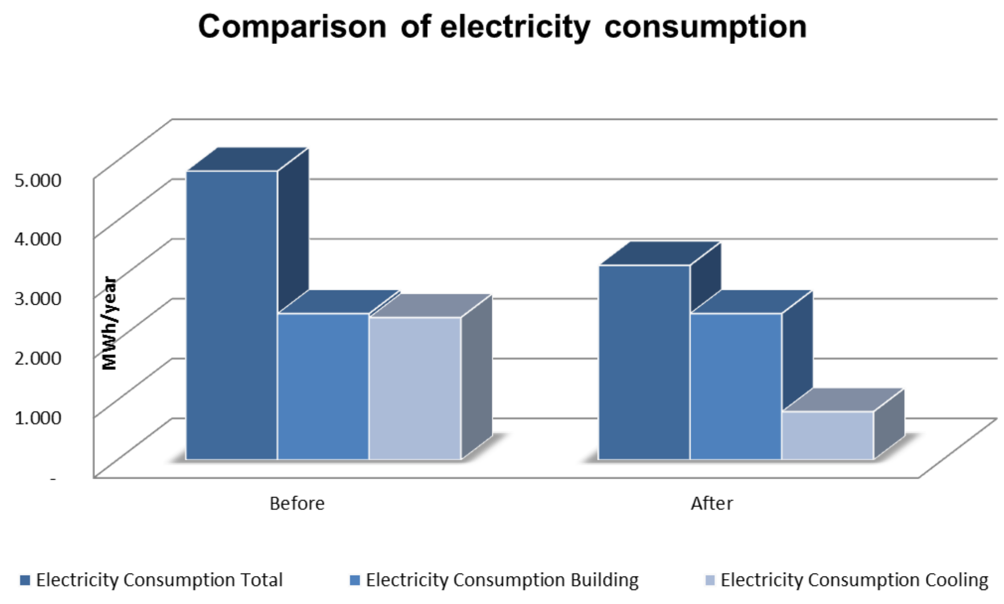


Figure 19: Comparison of electricity consumption before and after implementation (own illustration)

Figure 19 shows a comparison of the electricity consumption before and after the energy efficiency measure. Through the implementation of the above described measurements savings of approximately 1,500 MWh_{el}/year of electricity has been achieved. Before the renovation of the refrigeration system the consumption has been around 2,400 MWh_{el}, compared to around 810 MWh after the renovation. Considering a power price of 100 EUR/MWh, including grid fees and taxes, the yearly savings amount for approximately 150,000 EUR. Taking into account the investment costs of around 1.5 Mio EUR and the duration of 15 years, the economic and energetic potential of energy contracting services is clearly visible.

5.2 Economic Potential of DSF

This sub-chapter will analyse the requirements an application needs to fulfil in order to participate and offer load frequency control in the Austrian power market. The refrigeration system of the office building discussed would comply with the regulations to offer secondary and tertiary control, but not primary control due to short reaction times. The analysis of the requirements and the economic potential will therefore focus only on secondary and tertiary control power.

5.2.1 Pre-requirements

In order to register as a provider of secondary and tertiary control power APG has set a number of requirements which need to be fulfilled for offering this kind of load frequency control. Requirements for technical operation contain various different criteria. The technical unit (in our case the refrigeration system) must have a direct connection to the grid respectively the grid operator. Furthermore the metering point of the technical unit must be assigned to a balancing group. These requirements can easily be met by ENGIE Energie as owner of a balancing group in the Austrian market area. Further technical and operational criteria can be fulfilled together with an aggregator.

New technologies in the field of information technology result in novel ways to reliably transmit data. Taking into account this development APG has defined uniform specifications in terms of technical connection and information requirements for providers of secondary and tertiary control power.

The supplier of control power is responsible for providing the data transmission infrastructure. Secondary and tertiary control power may only be actively marketed by an applicant if the operation of the whole system works stable and error free.

Following points with respect to the data transmission infrastructure need to be complied with:

- **Data transfer points**
  The data transfer points are the serial interface of the CPE (Customer Premises Equipment) of APG in two spatially separated from APG predetermined power stations. The local situation of the candidate is taken into account as far as possible.
- **Remote control system (data acquisition of the applicant)**
  The remote control system is used to record measured values and messages. The candidate has to operate an adequate and effective patch and change management in order to maintain its facilities for the data exchange at a high level of security. Patches classified as critical for suppliers need to be implemented as quickly as possible
- **Redundancy**
  The central control system of the supplier has to operate redundantly. A division into two locations is not compulsory but desirable. The supplier has to ensure an adequate security of its control systems. Automatic switching between the redundant central systems of the candidate has to take place within max. 20 seconds.
- **Connection**
  For data transmission to APG only dedicated point-to-point connections are allowed. Between the control systems of APG and the supplier solutions based on the medium of the internet are excluded. Ethernet interfaces for transferring data to APG must not be used.
- **Protocol**
  For the online date transfer exclusively transmission protocol IEC 60870-5-101 is approved by APG
- **Time span**
  The delay on the entire transmission path (from the data acquisition of the technical unit via the control system to the entrance at APG) may be maximum five seconds.

- **Troubleshooting**

  In case of malfunctioning of relevant components of the control system the supplier must be able to start with the elimination of the fault within two hours.

- **Availability**

  The individual connections between the control systems of the APG and the supplier must at least have an availability of minimum 98.5%.

- **Validation and verification**

  Regular validation or verification of control components and their configuration has to be ensured (automated or manually).

- **Provider of telecommunication services**

  The supplier is obliged to select only those telecommunication service providers which guarantee to inform the supplier of planned maintenance sufficiently in advance. Regardless the supplier needs to take arrangement to meet its obligation to comply with the maintenance and provision of control power. The supplier has to ensure a continuous and transparent monitoring of the availability of the transmission lines.

- **Property protection**

  Appropriate access protection to premises, systems and networks must be ensured at all time (e.g. access and key concepts, authorization management and physical security measures in connection with appropriate instructions).

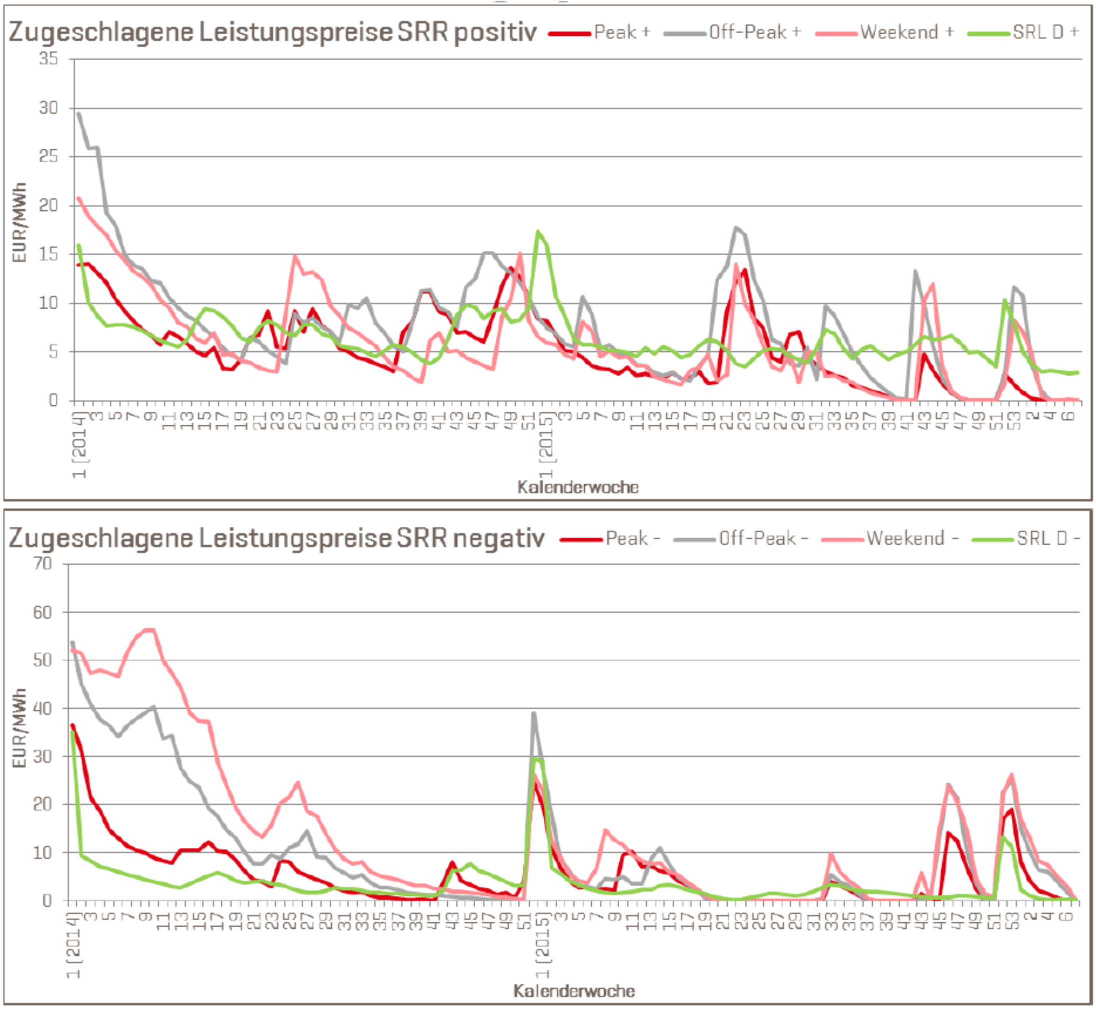
- **Documentation**

  All measures (technical concept, routing, fault clearance, maintenance contracts, etc.) to achieve the required availability have to be presented to APG on request. (APG 2014)

Considering all the above listed requirements it becomes obvious that a considerable workload is necessary to setup a participation in the load frequency control markets. However, working together with an aggregator facilitates an easy implementation. Taking advantage of the knowledge and the systems in place of such frequency control reserve pools seems to be the most adequate solution to start offering flexibility.

5.2.2 Economic Potential Analysis

In order to assess the economic potential first a closer look on the historical development of capacity prices and energy prices of secondary and tertiary control power will be taken. Afterwards the annual revenue potential for both types of control power will be analysed. According to the results of this analysis the economic potential of the flexibility available at the office tower described, will be calculated.



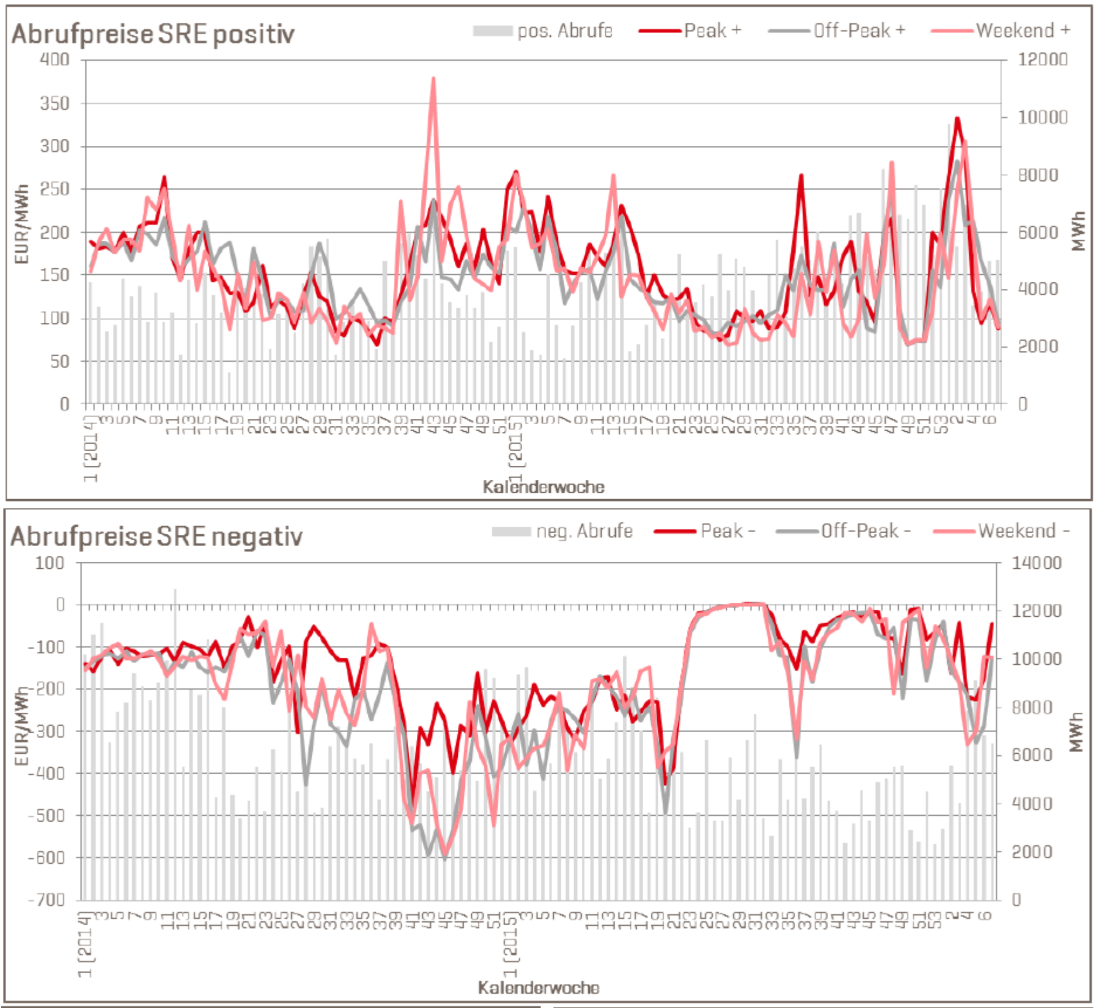
Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	7,63	3,68	0,99
Off-Peak +	10,54	6,06	1,84
Weekend +	8,36	4,02	0,84

Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak -	7,45	3,79	0,50
Off-Peak -	15,25	5,11	1,79
Weekend -	21,61	5,98	2,10

Figure 20: Capacity price development for secondary control power (pos/neg) (APG 2016d)

Figure 20 above shows the development of the awarded capacity prices for positive (upper graph) and negative (lower graph) secondary control reserve for 2014, 2015 and the first six weeks of 2016 on a weekly basis. Higher prices at the beginning of

2014 have reduced afterwards, however volatility especially for positive secondary control is clearly visible. For negative secondary control price variations are not that strong, spikes in prices occur at the end/beginning of a new year. The tables at the bottom of the figure show the volume weighted average price per week and per product. A steady price decrease is visible; especially during 2016 (data until calendar week 33) prices have plummeted.

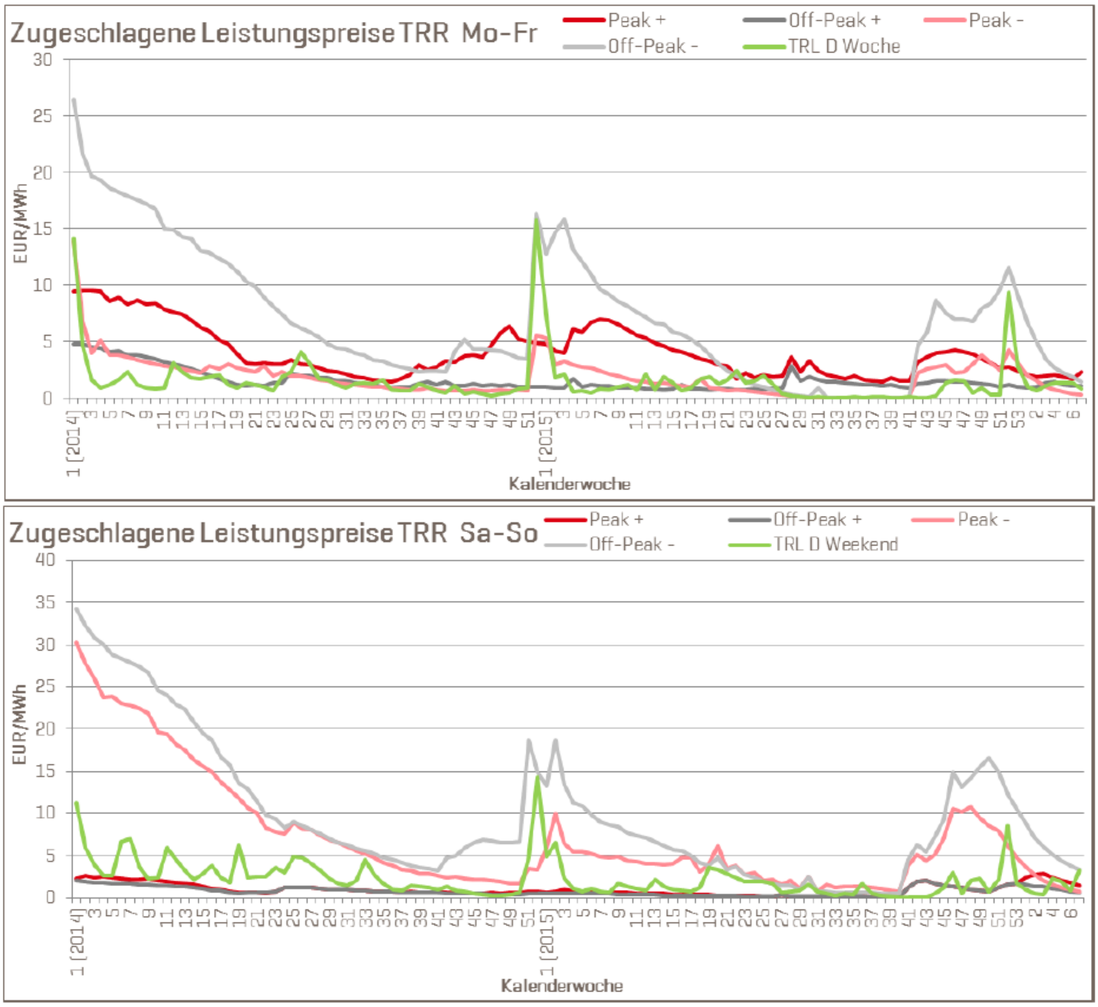


Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	156,23	147,02	100,66
Off-Peak +	155,68	135,12	115,32
Weekend +	157,37	133,51	98,07

Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak -	-163,36	-131,55	-35,67
Off-Peak -	-240,38	-155,63	-54,08
Weekend -	-220,70	-150,55	-73,50

Figure 21: Energy price development for secondary control power (pos/neg)(APG 2016d)

The graphs of Figure 21 show the development of the energy prices for positive and negative secondary control power for 2014, 2015 and the first six weeks of 2016. Again a high volatility can be noticed for both directions. The tables at the bottom also outline a constant decrease in power prices paid for secondary control power. Values for 2016 consider the prices until calendar week 33.



Weekday Mo-FR

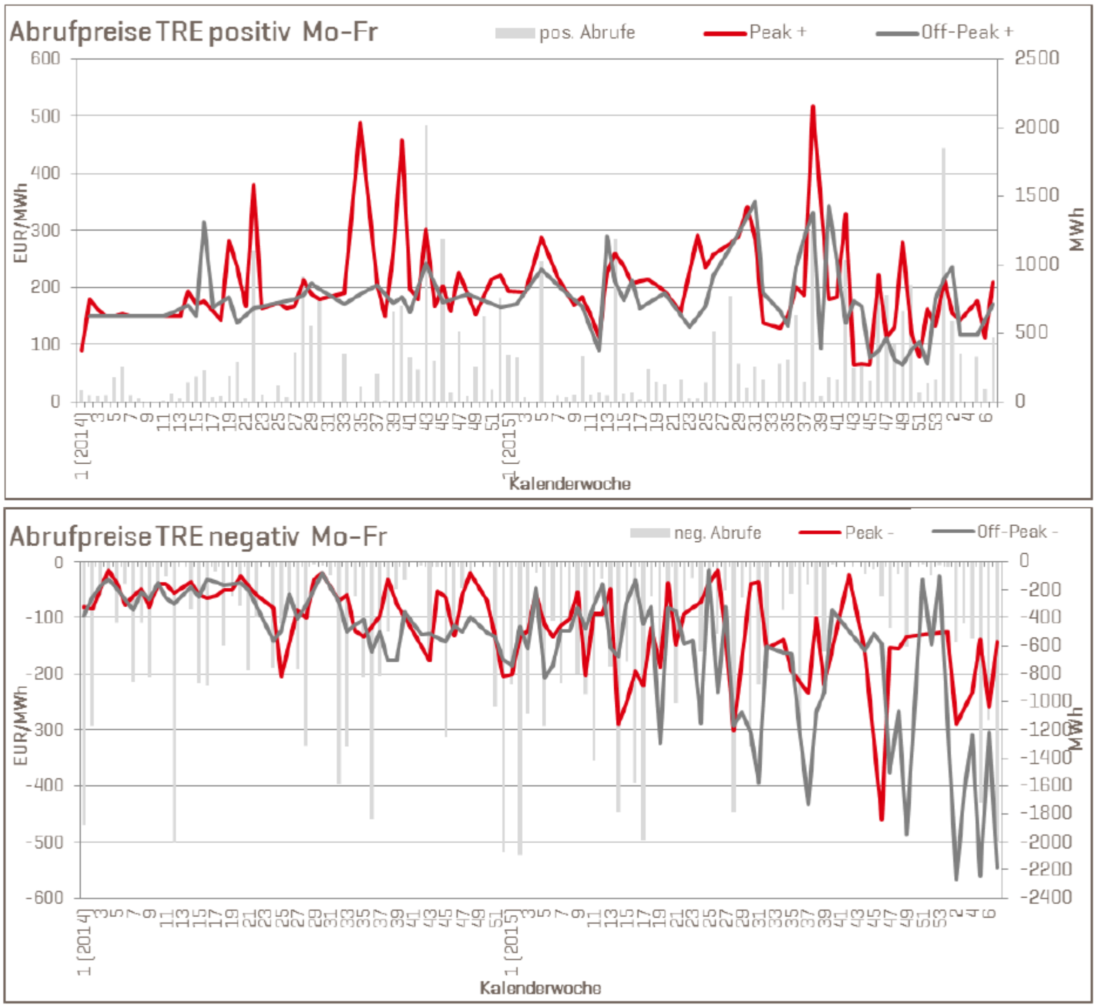
Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	4,78	3,49	1,70
Off-Peak +	2,01	1,13	9,58
Peak -	2,29	1,55	0,61
Off-Peak -	9,24	5,20	9,19

Weekend

Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	1,14	0,60	0,80
Off-Peak +	0,95	0,54	9,07
Peak -	10,41	4,33	1,53
Off-Peak -	13,52	6,41	9,34

Figure 22: Capacity price development for tertiary control power (pos/neg) (APG 2016d)

Figure 22 shows above the graphs for the capacity prices for positive and negative tertiary control reserve. The graphs show a similar development as for secondary control including strong spikes during the last and first weeks of each year. According to experts in the industry this could be a result of high wind output together with low industrial demand during the holidays around Christmas and New Year. The tables at the bottom show a steady decrease of capacity prices for 2014 until 2016 for peak products. On the other hand prices for off-peak products increased during the first half of 2016.



Weekday Mo-FR

Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	202,51	200,84	191,09
Off-Peak +	179,48	179,56	157,80

Ø Preise	2014 [EUR/MWh]	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak -	-74,80	-140,96	-204,95
Off-Peak -	-92,01	-173,06	-256,73

Weekend

Ø Preise	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak +	129,80	168,32
Off-Peak +	135,07	164,59

Ø Preise	2015 [EUR/MWh]	2016* [EUR/MWh]
Peak -	-228,18	-217,09
Off-Peak -	-182,62	-258,81

Figure 23: Power price development for tertiary control power (pos/neg)(APG 2016d)

Figure 23 shows above the graphs for the development of the energy prices for positive (above) and negative (below) tertiary control power for weekdays. Especially for negative control power an increase in energy prices can be noticed starting in the second half of 2015. The tables below tell us that for positive tertiary control power the energy prices remained quite stable, while for negative tertiary control power the prices increased for weekday products from 2014 until mid-2016. Weekend products show a slight increase for positive tertiary control power, while prices for negative tertiary control power increase for weekend off-peak products during 2016.

Table 3 shows that total costs have constantly been rising until end of 2014since opening the market for load frequency control in 2012. Reasons for this increase have been steady increasing capacity in wind power production as well as deficiencies in the market design. In order to stop this cost increase E-Control and APG have taken measures which helped to reduce costs significantly during 2015 and the first half of 2016 (until calendar week 33). Of those measures the most important ones have been the possibility to provide control power through the commercialization of wind power plants and the cooperation with German TSOs.

Table 3: Total cost development of load frequency control in Austria (APG 2016d)

	Gesamtkosten				
	2012 [MEUR]	2013 [MEUR]	2014 [MEUR]	2015 [MEUR]	2016* [MEUR]
PRR	19,6	13,4	13,4	12,6	5,5
SRR	113,3	124,4	159,6	102,2	36,2
ARL	14,0	14,3	6,9	4,6	2,3
TRR	6,9	15,0	17,3	17,8	9,8
UA	3,0	4,8	6,0	5,4	3,3
Summe	156,8	171,9	203,1	142,6	57,2
		9,4%	18,1%	29,8%	*Daten bis KW33

In order to assess the economic potential for Demand Side Flexibility in the secondary and tertiary control power market a variety of different parameters need to be considered. Depending on the strategy and costs of each system different capacity and power prices could be applied. A company who is offering pooling services in Germany and Austria for their clients has developed a model to estimate the revenue potential for the different products of load frequency control.

Table 4 shows the revenue potential for 1 MW flexibility in the secondary control power market for peak and off-peak products for both positive and negative control power. In line with the total system cost described above the revenue potential decreased significantly since 2014. For 2016 the outlook expects a total revenue of only around 10% compared to 2014. Only negative off-peak secondary control still shows a reasonable potential of around 6,000 EUR/year.

Table 4: Revenue potential of 1 MW for secondary control (own illustration; Source: Alpenenergie)

Revenue Potential per 1 MW flexibility Secondary Control Power			
	2014	2015	2016 Outlook
Peak NEG	22 199 €	10 437 €	1 914 €
OffPeak NEG	45 922 €	14 246 €	6 207 €
Peak POS	23 459 €	10 345 €	190 €
OffPeak POS	31 552 €	16 993 €	3 181 €

For tertiary control the development of the revenue potential for 1 MW of flexibility is similar to secondary control. Compared to 2014 the economic potential has decreased substantially, however for some products not to the same extend.

Table 5: Revenue potential of 1 MW for tertiary control (own illustration; Source: Alpenenergie)

Revenue Potential per 1 MW flexibility Tertiary Control Power			
	2014	2015	2016 Outlook
Peak NEG	6 215 €	4 433 €	982 €
OffPeak NEG	26 727 €	15 771 €	3 290 €
Peak POS	14 061 €	10 739 €	5 049 €
OffPeak POS	5 750 €	3 465 €	4 276 €
Weekend NEG	28 298 €	13 622 €	4 057 €
Weekend POS	2 501 €	1 456 €	3 314 €

In order to assess the revenue potential of the refrigeration system of the office building discussed different criteria have to be considered:

- **Available flexible electrical capacity**
  After the renovation of the refrigeration system the whole cooling demand of the office tower is covered by the new installations on the roof of the building. This means that the cooling equipment installed in the basement is currently not used, not even for peak demand hours. This equipment has an electrical capacity of around 500kW$_{el.}$

- **Time slots for offering secondary and tertiary control power**

  Due to the fact that the cooling equipment in the basement in general is not operated the flexibility available could be used to offer negative control power, meaning that electricity consumption could be increased any time. Considering levels of comfort in the building it should only be offered during off-peak hours and on weekends, when users of the building are not present. Theoretically also the cooling equipment operated on the roof could be used to offer Demand Side Flexibility. This would happen in form of load shifting and would provide positive control power, meaning reducing electricity consumption.

- **Costs for fulfilling the requirement of APG**

  In order to comply with the requirements of APG to offer frequency control reserve some additional investment would be necessary. The criteria for information technology would be fulfilled by ENGIE Energie together with an aggregator by providing the entire communication equipment free of cost. In order to guarantee the grid connection and to install the required metering point at the refrigeration system the potential cost depend on the circumstances given at the office building. In an optimal case costs would be limited to a few hundred Euros but could also reach up to 15,000 EUR according to market experts.

Considering above described circumstances and the estimated revenue potential for 1 MW of flexibility Table 6 illustrates the economic potential of the refrigeration system taking into consideration an available capacity of 500kW$_{el}$ for negative control power. Due to the fact that only secondary control or only tertiary control can be offered at the same time with this system an average of both possibilities has been calculated.

Table 6: Revenue potential of the refrigeration system (own illustration and calculation)

Revenue Potential per 500kW flexibilty of the refrigeration system			
	2014	2015	2016 Outlook
OffPeak NEG - Secondary Control	22 961 €	7 123 €	3 104 €
OffPeak NEG - Tertiary Control	13 363 €	7 885 €	1 645 €
Weekend NEG - Tertiary Control	14 149 €	6 811 €	2 028 €
Average revenue potential	**16 824 €**	**7 273 €**	**2 259 €**

Taking into account the annual electricity consumption of around 810 MWh/year of the entire refrigeration system after the renovation and assuming a total power price of 100 EUR/MWh the total annual electricity costs amount to 81.000 EUR. Applying the revenue potentials of Table 6 this would have resulted in electricity cost savings of 21% for 2014, 9% for 2015 and only 3% for 2016. Furthermore it has to be considered that in general the revenues of load frequency control have to be shared between the consumer (as owner of the technical unit) and the aggregator.

5.3 Integration of DSF

The analysis of the previous chapters have on the one hand shown the energy savings potential of energy contracting services, using the concrete case of a refrigeration system of an office building, and on the other hand the revenue potential of this refrigeration system if applied to offer Demand Side Flexibility.

However, an integration of this revenue potential into the energy contracting projects in form of guaranteed savings could be difficult to realize. The analysis has shown that the revenue potential of DSF in load frequency control markets for 2016 is considerably lower than in previous years and is also unlikely to increase in the future. Furthermore revenues are likely to be volatile within a year which makes it even more difficult for ENGIE Energie to guarantee those revenues to their clients.

Even though including the economic potential of DSF into energy contracting projects seems unlikely, nevertheless this additional revenue potential could provide ENGIE Energie with a competitive advantage on the energy contracting market in

Austria. Revenues generated by DSF could still be re-paid to customers at the end of each year on top of the guaranteed savings. In this very competitive market even the smallest contribution of DSF could make the difference. Considering that the ESCo in general is owner of the equipment during the contract period it could also retain these earnings and thereby increase its return on a project. A decision on how to share or handle these revenues should be taken on a case by case basis.

6 RESULTS

The merger between the energy supplier GDF SUEZ Gasvertrieb and the energy contracting company Pronenergy Contracting reflects the strategy of the ENGIE group to position itself as leader in the energy transition. The newly created entity of ENGIE Energie shall help to position the group as an integrated energy service provider in Austria and thereby cope with the challenges resulting from a changing energy sector.

In order to be present along the energy value chain from energy supply to final energy consumption ENGIE Energie is aiming to provide additional value to its customers. One possibility to offer this added value could be the integration of Demand Side Flexibility into energy contracting services.

The energy savings potential achievable with energy contracting services has been discussed in detail and proven on the concrete case of an office tower in Vienna within this Master Thesis. In order to find opportunities to improve the economic potential of energy contracting projects new business models need to be considered at ENGIE Energie. One way could be the integration of Demand Side Flexibility. By providing load frequency control with installations realized with the energy contracting approach, the profitability and economic savings potential of such EC projects could be increased. Participating in the secondary and tertiary control market with a flexible refrigeration system of an office building in Vienna would have resulted in electricity cost savings of 21% for 2014 and 9% for 2015 for the owner of this office tower. However, a more efficient market functioning and an increasing number of participants in the load frequency control market have reduced this economic savings potential down to 3% in 2016.

Despite the fact that the most profitable window of opportunity for including DSF into energy contracting projects seems to be closed, it still is recommendable for ENGIE Energie to investigate the potential of flexible consumption patterns of installations sold to its customers. This could be the load frequency control market or utilization of DSF in other markets. In the challenging and very competitive business environment of the energy sector even the smallest additional savings could be decisive to win a contract and start a long-term customer relationship.

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