Ea Energy Analyses

EKOTERMIJA

Summary Report

& recommendations

Lithuania demand response study

17-08-2018

Published by:

Ea Energy Analyses
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Foreword

This report summaries the findings from a demand response services feasibility study undertaken in Lithuania.

The project was undertaken on behalf of the Lithuanian TSO, LitGrid AB and the DSO, Energijos Skirstymo Operatorius AB, ESO. The project period was from June 2017 to August 2018.

Through the course of the current project numerous aspects regarding demand response have been analysed, including:

- Potential demand response services and technical requirements
- Survey of end users' experiences and views on demand response
- Detailed case studies about demand response, with focus on industrial end users
- Relevant types of electricity demand for demand response have been mapped
- Relevance of EU regulation: Network Code on Demand Connection, Guidelines on electricity transmission system operation and Guideline on Electricity Balancing
- Barriers for demand response

1 Introduction

1.1 Demand response background

Overview and types of DR

Demand response involves reducing electricity demand when the system is in short supply of electricity (which in the Nordic and Continental systems is reflected via high electricity and/or ancillary service prices) and increasing electricity consumption when the system has abundant electricity (i.e. when electricity prices are lower). Demand response (DR) has garnered increasing attention in recent years largely due to the increasing levels of non-controllable renewable energy production, which therefore require sources of system flexibility elsewhere. Widespread cost-effective DR development requires communication and data management, which have seen large advancements and cost reductions in recent years, thus also contributing to an increased focus on DR.

There are essentially four main types of demand response:

- Shifting of electricity demand from one period of time to another. Prime examples include water treatment plants or industry with a number of pumping processes that do not need to run continually and can therefore run during times with low electricity prices, or heating and cooling elements that can adjust their temperature setpoints according to electricity prices and thereby provide additional cooling/heating during lower price periods and less during high price periods.
- Fuel shift. This applies to end-users that can rely on more than one fuel input in order to satisfy their heat and/or electricity needs. An industrial customer may for example have both an electric boiler and a natural gas-based boiler to produce process steam and can switch between the two depending on the electricity and natural gas prices.
- Utilisation of back-up systems. A number of public, commercial, and industrial sites (e.g. hospitals, airports, etc.) have back-up generators in case of situations when electricity supply is interrupted. These units can act as system reserves and also provide demand response.
- Peak shaving/valley filling. Peak shaving refers to reducing electricity demand when prices are high, without using the corresponding amount of electricity at another point in time, while valley filling is the opposite. This last form of demand response is only relevant in rather extreme price situations/circumstances.

“Classic” demand response vs. change in generation

Throughout the current report, the term demand response is used to describe both:
a) what can be referred to as ‘classic demand response’, i.e. altering the amount of electricity that a device or unit utilises based on a signal or price change
b) electricity generation from units that are located at electricity demand sites. This could for example be a large industrial electricity user that has a CHP unit on site and can therefore regulate its net electricity demand by producing more or less electricity itself, and in some situations actually export electricity back to the grid. Another example could be a residential user with a solar PV installation combined with a battery, thus allowing the user to regulate the timing of electricity imports and exports from the grid according to electricity prices. Looking towards the future, another example may become electric vehicles with vehicle to grid (V2G) capability, thus allowing for the EV battery to export electricity to the grid when needed.
Given the growing role that these ‘net exporters’, are likely to play in the future, their potentials and characteristics have been included when discussing the term ‘demand response’ in a broader sense within the current report.

Status of demand response

The volume of realised demand response is growing in all markets. Market rules, new metering systems and procedures are being developed to allow demand to play a role in all markets. Demand response has a clear role in the current EU directives (for electricity market, energy efficiency, renewable energy, buildings), and an even more prominent role in the proposed directives.

Examples for existing demand response activities include Time-of-Use tariffs and reduced tariffs for load that can be disconnected, day-ahead market, regulating power and ancillary services. In many countries, there are still two areas that lack development:

- Small end-users both need smart meters and market procedures that in practise allow demand response.
- Demand can be used as reserves and regulating power, however procedures (including monitoring) are still to a large extent mostly adapted to generators.

Demand response pilot projects

Numerous pilot projects involving demand response have been undertaken in Europe and the general conclusions appear to be:

- Potential for demand response exists in all sectors
- Technology to activate this potential exists or can be developed.
- The demand response impact is typically predictable and realised as expected.

- End-users are willing to participate in pilot projects, and few negative side-effects are reported, e.g. concerning comfort or production.
- For small end-users, automation is necessary.
- A positive side-effect has been that some end-users, enabled by the new monitoring equipment they were provided with, reduced their electricity demand due to a greater awareness of their electricity usage.
- The overwhelming barrier appears to be that the economic benefits associated with participating in demand response are too small. This highlights the fact that:
    - a) transaction costs need to be very small if demand response shall grow in volume
    - b) the full system value of flexibility must be unlocked and distributed to all parties in order to provide the proper incentive to participate.

1.2 Technical characteristics of DR services

There are a number of different markets that demand response services can participate in, with varying technical requirements posed by each market. Two of the most important characteristics in this regard are the activation response time and activation duration. The figure below illustrates these two elements by displaying the ramp rates and timeframes for the various services and markets.

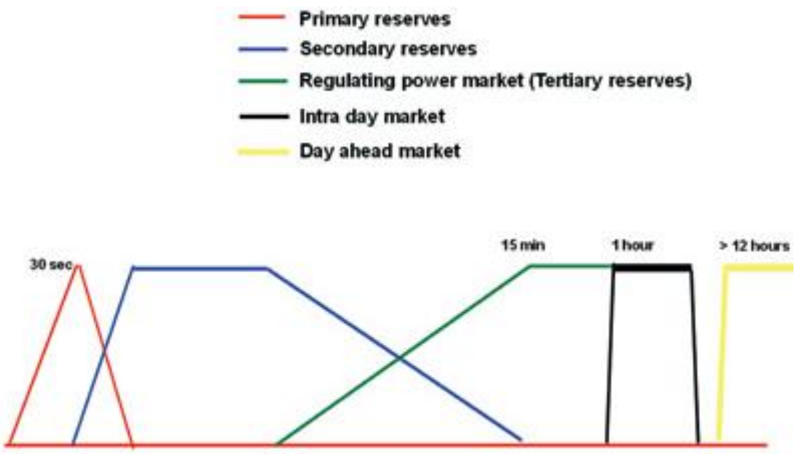

Figure 1: Timeframes and ramp rates for the various reserve types.

Table 1 below summarises the most relevant technical characteristics (start time, duration, regularity, etc.) for the various DR services described today, and estimates for the longer term.

DR Service	Activation time		Activation duration		Bid size / Trade lot		Activation regularity	
	2017	2025	2017	2025	2017	2025	2017	2025
Primary reserve (FCR)	30s	30s	15 min	5 min?	0.3 MW	0.1 MW?	Hourly+	Hourly+
Secondary re-serve (FRR-A)	15 min	5-15min?	contin-uously	60 min?			Hourly+	Hourly+
Tertiary reserve (FRR-M) & (BR)	15 min	5-15min?	60 min	15-60 min?	10 MW	1 MW	Daily+	Daily+
Intra-day	>1 hour	15 min?	15 min	15 min?	0.1 MW	0.1 MW	Daily	Daily
Day ahead	>12 hours	>6 hours?	60 min	30-60 min	0.1 MW	0.1 MW	Hourly	Hourly

Table 1: Overview of the various system services and their technical characteristics.

As can be seen from the table, it is assumed that the technical characteristic for the majority of the markets relevant for DR will be loosened going forward, thus becoming better suited for DR. This includes smaller bid sizes, shorter gate closer times, shorter activation durations, and a range of activation notice times, all of which will allow for DR to play a more significant role going forward. The table above provides a very simplified overview of the technical characteristics of the major DR services. For a much more extensive description please see the report entitled "DR: Technical requirements for DR services".

1.3 Lithuanian power system today

In order to provide some context within which demand response may evolve within Lithuania, a quick overview of the Lithuanian power system is provided below.

Electricity generation capacity

Generation capacity currently dominated by natural gas

As of 2018, Lithuania's installed generation capacity was roughly 3,000 MW, the majority of which is natural gas (Litgrid, 2018). There is over 500 MW of wind power and roughly 60 MW of solar power installed. In addition, there is 900 MW of pumped storage. Plans indicate that in total 620 and 84 MW of wind and solar will be installed respectively by the year 2020.[1]

[1] The current capacity for wind and solar exceeds the minimum goals indicated in the 2010-NREAP, National Renewable Energy Action Plan: 500 MW wind and 10 MW solar. The goal is to have 21% renewable energy

Kruonis pump hydro provides flexibility

The presence of the 900 MW pumped hydro plant (four 225 MW units), Kruonis, means that when compared to other countries, Lithuania has considerably more flexibility on the generation side. While 2 of the 4 units are reserved for ancillary services, the plant can still have a significant impact on prices, i.e. by reducing high prices and guarding against low (or negative) prices. The plant can generate at full capacity for 12 hours when starting from a filled reservoir. The full cycle efficiency is 74%, and in 2017 it generated 574 GWh (corresponding to 638 full load hours). A fifth unit with more flexible operation and higher efficiency (78%) is under consideration (ENTSO-E, 2016).

Electricity generation, import/export and demand

Lithuanian electricity demand largely met by imports

After closure of the Ignalina nuclear power plant in 2009, the majority of Lithuania's domestic electricity consumption has come from imports. This is illustrated in Figure 2, which displays the development in Lithuanian electricity generation, import/export and demand from 2014 to 2016.

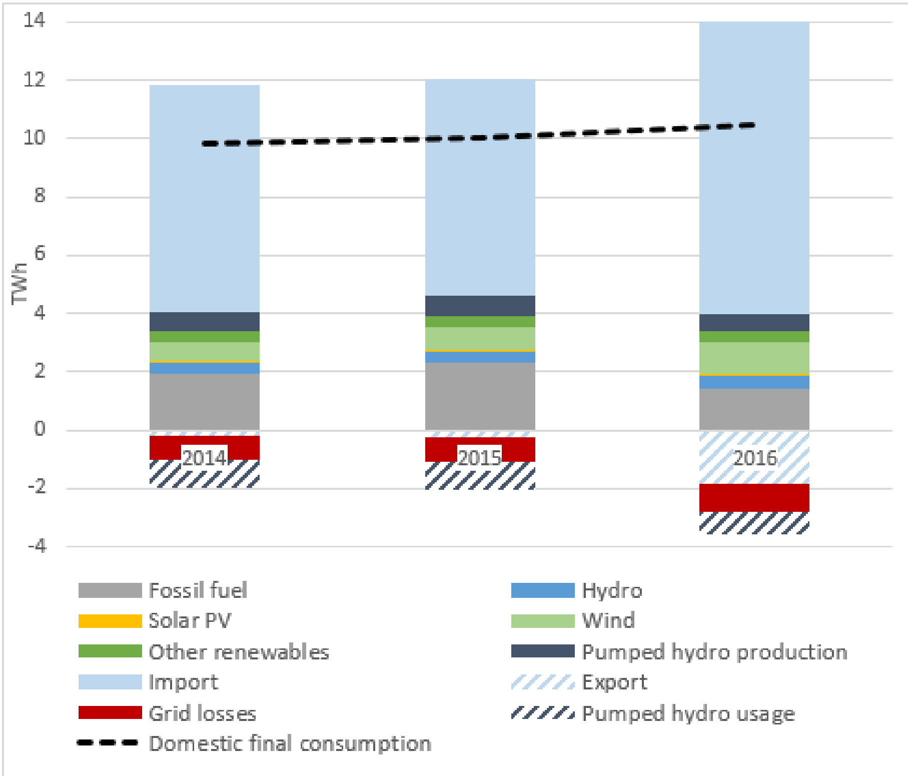

Figure 2: Electricity generation, import/export and demand in Lithuania, 2014-2016 (Vaida, 2017).

in electricity generation. Goals for 2020: Lietuvos Elektros Energetikos Sistemos 400-110 Kv Tinklų Plėtros Planas 2017-2026 M. 2017 m. birželis, Vilnius (page 7). The data for 2020 is interpolated since it is linearly dependent from 2016 to 2026.

Over this 3-year period, domestic final consumption (depicted by the black striped line in Figure 2) averaged over 10 TWh, while the net imports (large light blue portion minus the striped light blue in the figure), averaged 7.7 TWh, with net imports thereby representing over ¾ of Lithuania's domestic final consumption.

In reviewing Figure 2 it is also interesting to note the production from pumped hydro (dark blue), and the larger corresponding electricity demand from pumped hydro usage (striped dark blue). The production from pumped hydro accounted for over 6% Lithuania's domestic final consumption, which seen in an international context is a large share for pumped hydro, and once again reflects the large amount of flexibility in the Lithuanian electricity system.

Electricity transmission

Lithuania is well connected to its neighbours

Given the large role that imports play, it is not surprising that Lithuania is well connected to neighbours, with AC connections to Latvia, Belarus and Russia (Kaliningrad), and DC connection to Sweden (700 MW) and Poland (500 MW).

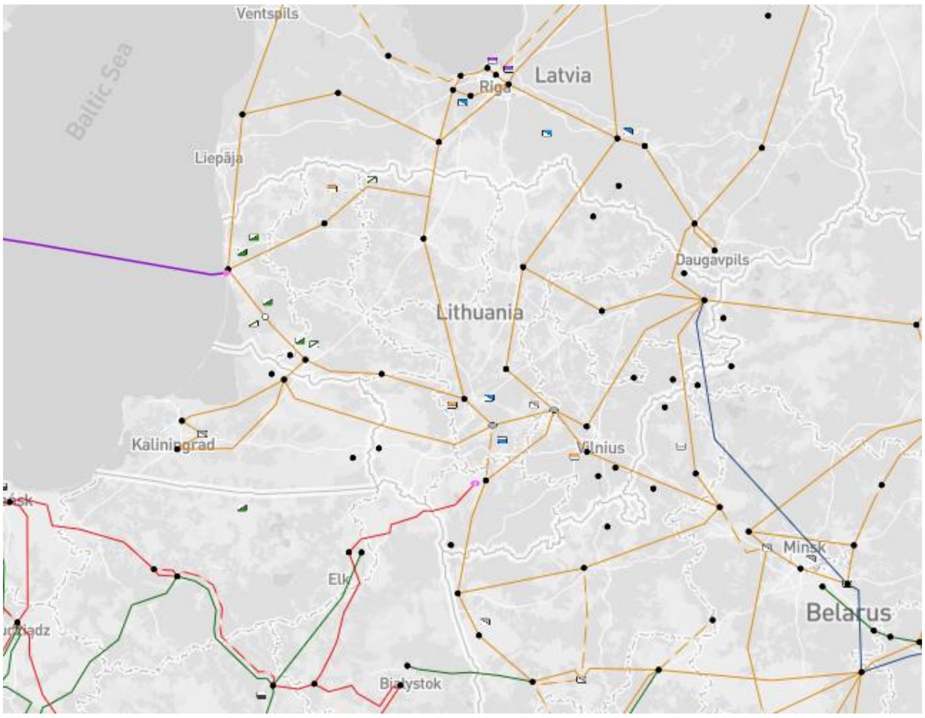

Figure 3: Transmission grid for Lithuanian and its neighbouring countries (ENTSO-E, 2017)

Currently, the Baltic states belong to the IPS/UPS system which is controlled from a dispatch centre in Russia. Primary reserves are supplied by the IPS/UPS system, while secondary control reserve is provided by each control area in BRELL loop with the small part of reserve sharing (100 MW of each Baltic State).

Reserve type	Amount currently purchased	Notes
Primary reserves (Frequency Containment Reserves - FCR)	0 MW	No requirements. The service is delivered by IPS/UPS
Secondary reserve (FRR-A)	100 MW	
Tertiary reserves (FRR-M, RR)	400 MW	Recalculated yearly
Other reserve (12 hours' notice)	484 MW	Recalculated yearly

Table 2: Current ancillary service requirements in Lithuania - Synchronous with Latvia, Belarus, Kaliningrad and IPS/UPS. Please note that short-circuit power, reactive reserves, and voltage controls are not included. (Litgrid, 2017).

1.4 Potential consequences of de-synchronisation

In the longer term, e.g. after 2020 the Baltic countries are planned to be de-synchronised with the Russian electricity system (IPS/UPS).

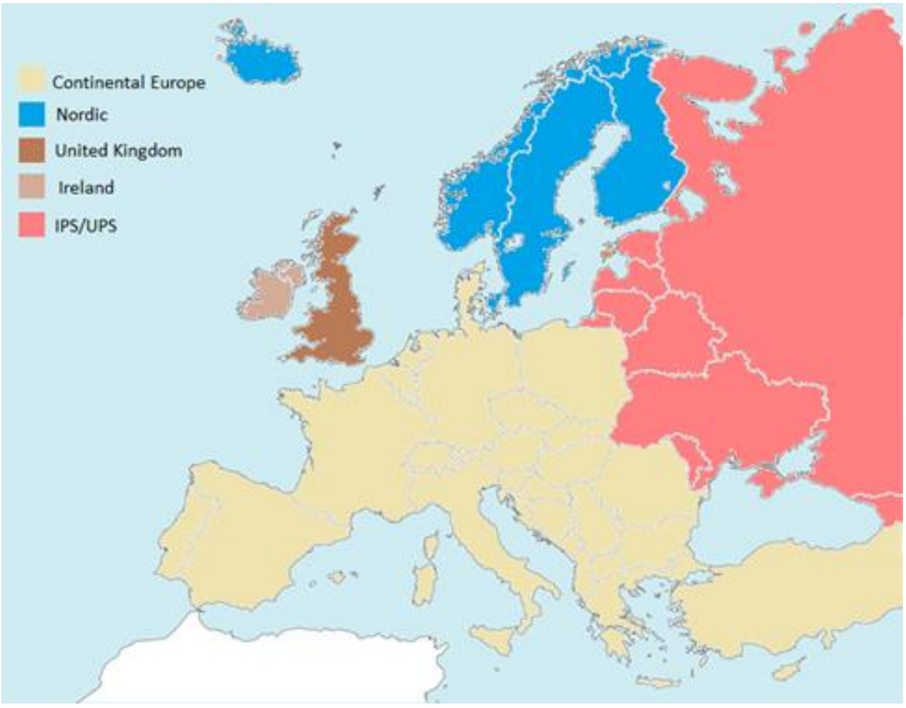

Figure 4: The synchronous grids of Europe. IPS/UPS is shown in red.

This can lead to the Baltic states becoming a separate synchronous area[2], or the Baltic countries can be synchronised to UCTE/Central Europe, i.e. with AC connections to Poland. Both designs would increase the requirements for local reserves. Demand response may deliver part of such reserves.

[2] As described in: (Elering, Pöyro and Ricardo, 2015)

The amount of reserves that must be delivered locally will depend on the future setup. The largest need for reserves would come in a situation where the Baltic countries comprise an independent synchronous system. In this case the needed amount of primary reserves in the Baltic states should correspond to the largest single failure (the failure of a power plant or transmission line). This could be 700 MW. If the Baltic states are instead to be synchronous with the central European system (via Poland), the amount of Frequency Containment Reserves (FCR) can be divided by all the synchronous countries, and the resulting demand for Lithuania could be as low as 10-20 MW.

The amount of secondary reserves should in theory correspond to the largest failure. However, in practice less capacity may be required. E.g. West Denmark (also connected to the Central European system) only has 180 MW of secondary reserves.

	Baltic countries as a synchronous area	**Baltic countries connected to UCTE/Central Europe**
Primary reserve (automatic reserve, controlled by system frequency)	Largest possible fault must be balanced locally, 700 MW today. Capacity must exist locally or by DC-lines.[3]	Must deliver a share of the total of 3,000 MW required in UCTE/Central Europe. The total demand in 2,300 TWh and the Baltic countries (30 TWh) most deliver their share: ~40 MW
Secondary reserve (automatic reserve, controlled by the deviation from the planned exchange to AC neighbours)	Can be a requirement for each of the three countries. May not be needed	Must be able to balance largest possible fault in control area. 700 MW.
Tertiary reserve (manual reserve, also called regulating power)	Reservation of 300 MW up-regulation	Reservation of 300 MW up-regulation

Table 3: Types of reserves needed in two scenarios of new synchronisation of the Baltic countries. Values are indicative. Tertiary reserve in inspired by Danish experience.

Lithuania has a high share of electricity imports and therefore few power plants that can deliver fast reserves. As a result, the pumped hydro plant may in the future play a central role in terms of delivering reserves. Of particular relevance for the current study, electricity demand can also deliver a portion of the required reserves. In Denmark for example, electric boilers in district heating systems deliver fast reserves.

[3] However, if some part of this capacity is reserved in order to get system services from Nordic countries the size of the largest incident should be reduced accordingly.

A 2015 study for example simulated future electricity prices for Estonia and computed the benefits of demand response. It concluded that the benefits of demand side response are modest in the short term, but rapidly increase in the run-up to 2025 when de-synchronisation is scheduled to take place, and Estonia must hold additional reserves.[4] (Elering, Pöyro and Ricardo, 2015). See also (Bertoldi, Zancanella, & Boza-Kiss, 2016).

[4] In this report, the three Baltic countries are assumed to be their own synchronous area.

2 Survey to gauge DR interest and awareness

2.1 Purpose and method

Given that a rather limited portion of demand being flexible can have positive impacts, and that DR is in general a rather new concept, it is relevant to identify electricity users' interest in DR, and the potentials that it may be able to provide in Lithuania in the upcoming years. Conducting a survey comprising a range of electricity users is one way of both identifying interest in DR, but also educating potential DR providers.

In order to estimate the potential reaction to proposed demand response (DR) services, an online survey form was created and sent out to large electricity consuming industries and other users that were deemed to potentially benefit from, and have the ability to participate in, DR services. Each email included an introduction to the proposed service in order to educate consumers on how the service could benefit them, the environment and also the transmission grid.

2.2 Survey response

The email was sent to over 6,300 times to end-users, and the URL was opened 1,432 times. The survey was filled out by 500 different end-users. Over 250 direct calls were made, and there was a large number of responses received after these phone calls were undertaken (see Table 4).

Table 4: Overview of survey respondents

Type	Quantity	%
Private persons	240	43
End-users that explicitly did not wish to participate	58	10
Legal person	260	47
All respondents	**558**	**100**
End-user >10 MW	8	2
End-user 1-10 MW	84	17
End-user 0.1-10 MW	158	32
End-user <0.1 MW	10	2
Private persons	240	48
All active respondents	**500**	**100**
End-user >10 MW respondents not willing to participate	1	2
End-user 1-10 MW respondents not willing to participate	25	43
End-user 0.1-10 MW respondents not willing to participate	32	55
End-user <0.1 MW respondents not willing to participate	0	0
All that explicitly stated unwillingness to participate	**58**	**100**

2.3 Survey findings

Positive towards DR & many TOU contracts

Given that a number of end-users explicitly stated that they did not wish to participate in the survey, the survey results may be slightly positively biased towards demand response. However, even when taking this into consideration, the overwhelmingly positive replies suggest that, generally speaking, the majority of respondents are quite positive towards the concept of DR, and many are interested in assistance to help chart their possibilities for DR participation. The survey indicates that time of use (TOU) tariffs are often used, with only 13% of respondents replying that their electricity price is a fixed price. This is a positive, as a general understanding and awareness that electricity prices can vary from one hour to the next can be seen as a soft introduction to the concept of, and participation in, DR.

Focus on electricity costs

82% of respondents answered that investments that could influence management of electricity consumption were made and/or are planned to be made in the near future. All of the large consumers with capacity exceeding 10 MW are constantly investing in energy efficiency, including equipment. This indicates that the vast majority of end-users are interested in their electricity consumption and are trying to lower their electricity expenses.

Back-up generation

Back-up generation is a prime candidate for DR participation, and the survey results indicated roughly 1/3 of all respondents had back-up generation, and when looking at the largest electricity users, which are often more relevant in terms of providing ancillary services, this grew to approximately 2/3. The survey also highlighted the uncertainties regarding how, and what, respondents classified as back-up generation, which was reflected in the need for the consultants to adjust the back-up generation totals quoted by the respondents. The potential technical capacity of back-up generators was thus estimated at 38 MW, while actual potential of backup generators will depend on DR services prices. Due to the high variable costs of electricity generation in these units, only high DR services prices will enable using back-up generators for provision of DR services.

Heating and cooling

Heating and cooling is one of the most relevant candidates for demand response, because lowering electricity consumption to heating and/or cooling devices during peak load periods will generally not result in significant changes in quality of life and/or services provided. For example, preheating/cooling can be undertaken in industry, retail, or buildings (i.e. the thermal inertia in buildings can be used). In addition, other forms of heat storages or heat generation technologies (e.g. electric boilers) can be utilised.

The results show that 72% of companies use some sort of electrical devices for their heating or/and cooling, and 42% stated that electricity is used for both heating and cooling. These are substantial potential figures, and one finding from the current study could therefore be that this issue should be investigated further in subsequent studies.

DR still a new concept

The survey results highlighted the fact that DR is a new topic for many end-users, as shown by both the responses to the back-up generation (where it was unclear exactly what back-up generation is, particularly from a DR point of view), and heating and cooling related questions. With respect to the heating and cooling replies, when looking at companies, the respondents stated that 72% have some electricity consumption that goes to heating and/or cooling, but when comparing with the questions replied to previously, these same companies indicated that roughly only 20% had some electricity consumption that was controllable. This could suggest that a large number of the companies are unaware that they have some electricity consumption that is in fact technically possible to control.

Assistance seen positively

The previous discussion highlights the fact that additional information and assistance is required in order to help facilitate participation in DR. Given that the survey respondents are overwhelmingly positive towards receiving assistance in evaluation of their technical, economical potential for the Demand Response service, this could be a focus point going forward.

2.4 Key takeaways

Technical potential exists

Respondents were asked if they have the capability to transfer portions of their electricity consumption to other periods of the day, and over 20% of legal companies answered that do have such capability. While 20% may sound like a low figure, from a demand response perspective this is a good starting point, as it is often only a small portion of overall electricity demand during a particular time period that needs to be shifted and/or reduced in order to reduce the costliest aspects associated with a demand peak.

Respondents are willing to participate

The survey indicated that 90% of companies would like to benefit from the management of electricity consumption if technical possibilities were available, while households were the least positive (though still with a 60% positive reply rate). One takeaway from this is that end-users appear willing to alter their electricity consumption habits given that:

a) It is technically possible to do so, which could be understood to mean that the end-user does not actively have to do something (i.e. turn off their television), and thereby their welfare is not altered

b) The end-user is in some way compensated for this flexibility.

Economic incentives

Given that companies are profit motivated, while households are motivated by maximising their general welfare, it is not surprising that larger electricity users express a strong willing to alter their electricity use if there is an economic benefit associated with it, while some households would to a greater extent prefer to use electricity precisely as they see fit, even if this means forgoing a small economic benefit.

This line of reasoning has two takeaways with respect to activating end-users in DSR: For non-household users it is sufficient to provide them with evidence that it is cost-effective to participate, and for households, it is to a greater extent important to assure them that there is both an economic benefit, and that their end-user comfort will not be affected.

Assessment based on user groups

The largest electricity users prefer to buy electricity on fixed price contracts, therefore they have very little incentive to provide price-based demand response services. These users have the largest installed capacities, and technically speaking, could provide ancillary service-based DR services. While only roughly 20-30% of this group states that they have the technical capacity to alter their electricity use, this still results in a large number of MW seen from an ancillary services perspective. In addition, the survey results regarding heating and cooling aspects have illustrated that large users often have a greater potential to alter their electricity demand than they initially suggest.

Users with an installed capacity of 1-10 MW and 0.1-1 MW are primarily using time-varying tariffs and can potentially provide price-based demand response services. 15-23% of consumers have the technical ability to change their consumption pattern, and given their size, would have to be pooled to delivery ancillary services. Therefore, these users can only to a moderate extent be providers of ancillary based DR services.

The smallest legal users and households have indicated the largest willingness to provide DR services, as they have indicated the largest potential to change their consumption pattern according to price variation (40-53%) or upon request from a regulator (30-63%). Involvement of these users in provision of DR services will face technical challenges, as there will most likely be a need for an aggregator, and necessary investments will likely also have to be undertaken by the operators of transmission or distribution systems, something that was also reflected in the survey results, as a great deal of users expect

“Investments by electricity transmission and distribution system operators in the necessary infrastructure”.

3 Illustrative cases of DR in Lithuania

3.1 Background

Illustrative cases from current demand response opportunities can be used to gain insight into complex, real life examples of how demand response is utilised today in Lithuania – or can be activated in the future. The idea is to investigate a limited number of cases (being end-users or aggregators), and both undertake a dialogue about demand response, as well as describe barriers and possibilities.

The qualitative insights from the cases complement information gained from the various pilot projects and studies referred to previously as well as the survey results.

Focus on 5 of the largest electricity users

Five facilities – all with a large electricity consumption – were selected. These companies were selected because they are amongst the largest users of electricity in Lithuania, they all have interval meters, and all have aspects within their electricity demand that can (potentially) provide demand response, e.g. in the day-ahead, intra-day, and potentially, ancillary services markets. In total these five facilities purchased over 740 GWh of electricity during 2016, in addition to producing another roughly 460 GWh for own consumption. This is quite a significant share of total Lithuanian electricity demand, given that 2016 total final electricity consumption in Lithuania was roughly 9.75 TWh (Statistics Lithuania, 2017).

Some of the facilities have onsite electricity production capacity, but even if this capacity was utilised to a greater extent than today, all 5 facilities would still be net utilisers of electricity on an annual basis, and only in extremely rare occasions, net exporters of electricity to the grid. The changes in own production in response to electricity prices and/or ancillary service requests are within this analysis deemed to constitute demand response.

Educative meetings

In person meetings were held with 5 prominent electricity users, as well as three electricity retailers. These meetings are referred to as educative meetings rather than interviews, as each of the participants was provided with an overview of what demand response is prior to the meetings, and the meetings started with a presentation of what demand response was, and how it may be relevant for the company both now, and in the future.

3.2 Selected large consumers

Generally speaking, there is a good deal of flexibility to be found in the 5 facilities visited, some of which is already utilised today, and some that is currently underutilised.

An important element in determining how flexibly a facility is operating is by looking at how it purchases its electricity. For example, if a facility purchases all of its electricity via a fixed price contract, then the facility has no financial incentive to adapt electricity demand to electricity spot prices. The table below provides an overview of the electricity purchase and estimated own generation for the 5 facilities.

Facility	Electricity Purchase				Own production*	Total consumption
	Fixed price	Spot	Time of use	Total		
1		16		16		16
2	86			86	339	425
3	125			125		125
4	309	185		495	124	618
5			21	21	2	23
Total	**520**	**202**	**21**	**742**	**464**	**1,207**

*Table 5: Overview of electricity purchase and estimated own production from the 5 visited facilities in 2016 (GWh). * "Own production" estimates are own calculations based on interviews.*

As can be seen from the table, 70% of the electricity purchased by the 5 facilities in 2016 was done via fixed price contracts, thus not providing any incentive to promote flexibility for this portion of electricity demand.

3.3 Large consumers participation in various markets

Day-ahead market

The simplest and easiest way for three of the five visited actors to provide DR services would be to purchase a greater portion of their electricity via spot contracts. The site facilities have revealed that many of the processes at these three facilities are interlinked, and it is therefore difficult to operate them solely according to electricity prices. However, it became apparent that there is at least some flexibility at these facilities, and perhaps even more importantly, international experiences have shown that when companies are faced with time-varying prices the additional incentive drives investment and/or welfare towards greater flexibility.

Industrial user number 2 in particular would appear to have unused flexibility that could be realised via purchasing electricity in the spot market. This is because the facility produces roughly 80% of its own electricity, and has additional largely unused electricity generation capacity. With this flexibility, and knowledge of spot prices 10-34 hours in advance, it would be possible to largely avoid purchasing electricity during the most expensive hours.

Intraday markets

Given the assumption that a facility is purchasing some of its electricity on the spot market, then all five of the facilities would have an incentive to participate in the intraday market as well. Day-ahead trade involves prices that are known in advance, while intraday trade is different, because the prices are not known beforehand, and the facility must therefore be made aware that there is potentially an attractive offer to increase or reduce their electricity demand/supply.

Industrial user number 4 today, and particularly number 1 after it has implemented its new control systems, are perfectly suited to participating in the intra-day markets as they have flexibility at their disposal, and already purchase electricity on the spot market (and thereby already have staff and commination equipment for monitoring hourly prices).

Regulating power

Regulating power is an increase or decrease in demand (or generation) that can be activated manually by the TSO within 15 minutes. For Lithuania, regulating power has a minimum bid size of 1 MW (from January of 2018).

As a starter, any facility delivering regulating power would likely have to purchase some of its electricity on a-non ‘free volume’ basis (or at least provide their balance responsible with hourly electricity demand plans), thereby making it easier for the balance responsible to document that a regulating power activation has delivered the requested change in electricity demand.

From a regulatory standpoint, it is understood that in order to deliver regulating power, a facility must be a registered electricity producer.
Facilities 1 & 2 are not currently registered as such.

Facility	Regulation potential (MW)		Notes
	Up	Down	
1	1	3	Depends on season (much higher heating demand during winter)
2	10-30	0-10	Depends on season, status of units
3	1	0	Backup diesel generator
4	70	0-10	Depends on status of CHP unit(s), and whether pumping or not.
5	0-1	1-2	Depends on status of CHP unit and pumping

Table 6: Estimated technical regulating power potentials for the 5 visited facilities. Up regulation implies reducing demand and/or increasing own production.

Frequency control reserves

Primary reserves must react in seconds, and this can easily be achieved by certain types of demand, e.g. thermal loads where there is no mechanical inertia. The demand can be active in the complete frequency range, or only at extreme frequencies (e.g. outside the normal frequency range: below 49.9 Hz and above 50.1 Hz).

In terms of providing frequency control reserves, often referred to as primary reserves (Frequency Containment Reserves FCR), it is the consultants' judgement that both facilities 2 and 4 have the technical capabilities to provide FCR if the sufficient financial incentives were in place.

3.4 Retailer and potential aggregator meetings

Electricity retailers act as aggregators for demand response in the day-ahead and intra-day markets. Typical end-users have a contract with free volume (as do the five large end-users in this study), which means that the user does not have to plan or report the electricity demand for the next day. The retailers predict the demand for all of their customers and pay for the relevant amount of electricity hour-by-hour the next day.

Some of the large users inform the retailer regarding changes in production and their electricity needs, but the risk of planning the volume rests on the retailer. The retailer could shift the volume risk to the end user, and thereby reduce the mark-up needed for the contract.

The choice of type of electricity contract is not regulated. Retailer and end-user can construct any type of contract: Fixed price with free volume, fixed price for fixed volume, spot price (plus mark-up) with free volume, spot price (plus mark-up) with fixed volume, time-of-use contract, or any combination thereof.

Name	Share
Energijos skirstymo operatorius [ESO] - regulated consumers	29%
Energijos tiekimas	20%
Electrum Lietuva	14%
INTER RAO Lietuva	13%
Enerty	8%
Enefit	6%
Energijos skirstymo operatorius [ESO] - other consumers	5%
Other	6%
Total	**100%**

Table 7: Retailers and their share of the total demand.

Type of contracts

The retailers spoken to indicate that around 30% of commercial end-users (above 30 kW) have a spot contract. Among the largest users however, the share is lower. For large users it is standard to have a separate contract for baseload, typically with a fixed price. Such contacts are typical tendered yearly, and strong competition exists. The base load can be supplied by one retailer and the remaining electricity by another.

Back-up generation

One retailer had investigated the use of back-up generators for demand response. The variable cost of electricity from a back-up generator (typically an oil-based diesel engine) would be 250-300 €/MWh, however the retailer found that an activation of 2,500 €/MWh was required if only a few hours of activation should cover fixed costs and profit. Neither the spot market nor the regulating power price has been near this value. The highest values in both markets was below 130 €/MWh (first nine months of 2017).

Changes in the regulating market from 2018 (common Baltic regulating power market) may change the prices both in the day-ahead market, the intra-day market, as well as the regulating power market. The retailers anticipate larger price variations as a result.

Potential market participation

Day ahead markets

Once again, the simplest and easiest way for the retailers (as aggregators) to provide DR services would be to sell a greater portion of their electricity via spot contracts. The only technical requirement for end-users to participate in the day-ahead market via their retailer is an interval meter capable of measuring their electricity demand on an hourly basis. These are planned to be fully phased in country-wide by the end of 2021.

In order for the end-users to greater benefit financially from hourly varying electricity prices, some of their electricity demand must also be flexible, and this will require technologies within the home or office to regulate electricity use according to the hourly spot prices which can be acquired the day before.

Intraday markets

Intraday trade differs from the spot market, because the prices are not known beforehand, and the end-user must therefore be made aware that there is potentially an attractive offer to increase or reduce their electricity demand/supply.

The retailer/ aggregator can facilitate the activation of demand response in a number of different ways, for example by having access to direct control of an electricity production or consumption device. Alternately, a concrete offer could be sent out to one more of its customers to increase or decrease its consumption/production. Lastly, a third option would involve sending out an updated electricity price.

Regulating power

Regulating power is an increase or decrease in demand (or generation) that can be activated manually by the TSO within 15 minutes and the required technology to provide regulating power would be very similar to that for the Elbas market, and would again depend on whether it was a direct control set up, or a system where the end-user received an updated electricity price, and then reacted to this price within a very short time frame.

Frequency control reserves

Aggregated demand response can also act as automatic reserves, e.g. primary or secondary reserves. Primary reserves are directly controlled by the frequency. No communication is needed to activate this type of reserve. For example, a refrigerator, heat pump, other heating/cooling devices, or an electric vehicle charger can adjust their electricity demand according to the frequency variation in the grid.

3.5 DSO cases

Case overview

Four of the five facilities described above are connected solely to the transmission grid, with only the clean water facility being connected to the distribution grid. However, In the future, demand response can also be a DSO tool for controlling voltage and to postpone investment in additional capacity (transformers and lines).

A central feature in the design of a grid is the smoothing effect, i.e. end-users do not fully use their allowed demand at the same time. However, new types of demand may challenge the grid, e.g. heat pumps all running at full load in cold weather, or many electric vehicles charging in the late afternoon/early evening.

If demand response is developed to the point where it has a significant volume, demand can also be *coordinated* by the demand response signal and overload the grid, e.g. after several hours of high prices the uptake of demand that has been delayed in order to avoid the expensive hours, may overload the grid (often referred to as the 'rebound effect').

Controlling demand can help maintain voltage within the acceptable limits (typically +/-10%). Reducing demand will increase the voltage, and increasing the demand will decrease the voltage. Challenges with under-voltage can be related to a weak grid (e.g. in relation to an increasing demand), or over-voltage can occur in relation to solar PV installations injecting power into a grid that were not designed for this.

Controlling demand to balance the distribution grid may be a challenge for the end-user. However, depending on the circumstances (mainly the duration of the needed interaction), the total costs associated with local control of demand may lower when compared to the alternative, i.e. investment in additional grid capacity.

DSO case findings summary

Demand response can potentially improve operation of distribution grids, i.e. overloading of lines and transformers can be avoided, and investments may be postponed. Voltage can also be improved by managing the demand.

In the three cases the needed service is only relevant a few hours per year. Therefore, it could be possible for selected end-users to accept an agreement about managing the demand and energy intensive processes could be delayed in these few hours. If the frequency increased over a certain threshold, the end-users would likely prefer a stable supply (obtained by DSO investments).

When it is only a very limited number of end-users that can supply the demand response, it can be a challenge to establish a market based and fair price for the service.

It is the authors' understanding that DSO challenges with voltage and overloading are very specific to the local grid. This is related to the grid design, the type of transformers and nature of the demand. Different types of demand may have different impact on voltage. Also, the potential demand response solutions may be very specific: Is it few or many end-users that need to react to DSO signals?

Solutions for challenges with a high degree of local circumstances can therefore be difficult to implement. Implementation of a more general system, such as time-of-use tariffs, would appear to be more realistic to implement (although less accurate), particularly as Lithuania has extensive experience in using time-of-use tariffs.

4 DR services and provider potentials

4.1 Methodology for DR assessment potential and main drivers

The figure below provides a methodological overview for assessing the DR potential in Lithuania. For electricity demand to be active as demand response, as a first step, it must be technically possible. The technical potential simply describes if a certain type of electricity demand can be used as demand response, e.g. moved in time or shifted to/from another fuel.

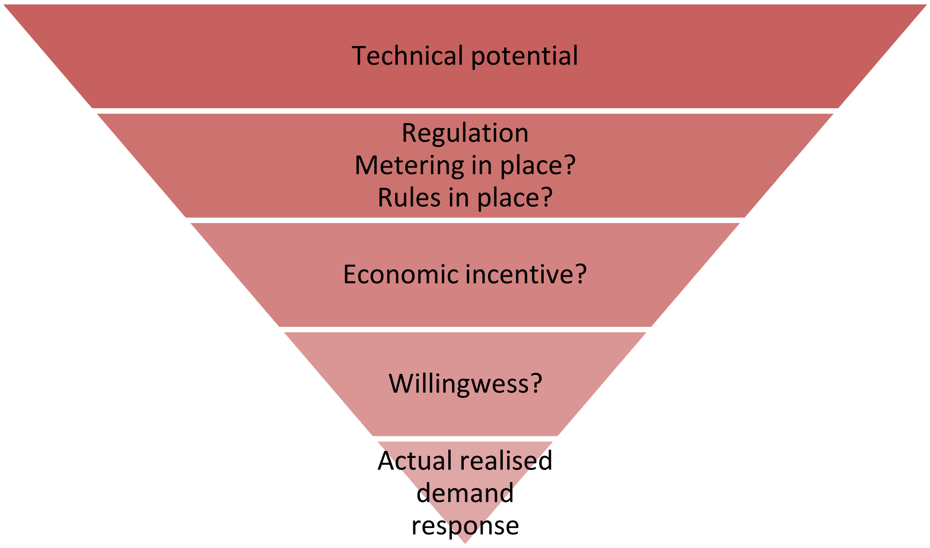

Figure 5: From technical potential to actual realised demand response.

With an estimate of the technical potential, it is then possible to take into consideration the regulations, rules and technical and legal requirements that are necessary to implement DR, which will result in a reduction of the technical potential.

The next question is whether the economic incentive is considered to be attractive, e.g. the current price variation in the spot market may be determined to be too small to make it cost-effective. Finally, it is up to the end-user to decide whether they are interested in demand response. This may include an evaluation of potential side effects of demand response (that may be positive or negative), as well as the willingness to invest time and money in demand response.

In reviewing Figure 5, it should be noted that:

- The technical potential is related to the nature of the demand (some end-uses are more relevant for controlling). The potential can largely be divided into traditional demand response (moving demand in time) and fuel shift/utilisation of back-up.

- Regulation is in the hands of Government, regulators, the TSO and DSOs. Meters and procedures for markets and ancillary services are important. It can be mapped which share of demand (for each main sector) can be active in e.g. the day-ahead market and as regulating power.
- The electricity market, including prices for ancillary services, are the drivers for the size of the economic incentive. The price volatility can the measured by a number of indicators, e.g.:
  - Range (min-max): Will describe the extreme values
  - Average, absolute hourly difference
  - Average, daily max-min difference
  - Number of hours with negative prices. Number of hour with low prices (e.g. below 10 €/MWh)
- Willingness is in the hands of the end-user. In a liberalised market, end-users can give priority to demand response as much (or little) as they find relevant. Willingness is motivated by the economic benefit, but can also be influence by lack of time, prior experience, tradition or personal views, including interest in environment and social issues.

The main drivers for development in the volume of activated demand response is – in the short term – expected to be the regulation and the economic incentive.

4.2 DR services & potential providers

Provision of DR services is mainly related to the potential to quickly alter the consumption pattern of the electric devices in question. The activation time of services can be categorised as follows:

- Demand response time for very fast active power control shall be no longer than 2 seconds and there is practically no artificial delay for activation.
- Activation of FRR providers should be no longer than 30 seconds.
- Activation of RR providers should be done within 15 minutes.
- Constraint Management activation time is not limited and should be based on contractual agreements.

A very rapid change in electricity consumption is possible in inertial processes or energy generating units with the possibility to change generation output. Therefore, very fast active power control services have the least possible types of providers.

A backup generator’s start-time delay is usually 10 seconds, and technically it is possible to program the unit giving a start-time ranging from 0.5 to 30 seconds. It can be complicated to make different start-time settings for provision of very fast active power control services and for cases of loss or failure of the normal power supply. Therefore, backup generators can potentially only be used for services with activation times greater than 10 seconds. In addition, these units can only be used to supply the network with up-regulation, i.e. an increase in production.

Biogas CHP plants usually have a gas engine for power and heat production and can start faster than most other electricity production technologies. For many engines 5-15 minutes are needed. These units can provide up-regulation when not currently generating and can provide down-regulation when they are generating and are able to reduce production. These units can only be used for power regulation or constraint management services.

Technically speaking, industrial, commercial or household users with electrical heating or cooling are capable of providing all type of services, but primarily with respect to decreases of electricity demand, and only to smaller extent for increases of electricity consumption.

4.3 Existing capacities of DR services

Illustrative cases

5 facilities were described in the illustrative cases work, and it was concluded that in particular, some regulating power could be provided by all 5 facilities, while at least 2 facilities could provide frequency control reserves. Two of the facilities would be able to provide DR services mainly using their CHP units, participating in power and frequency regulation. One facility could use its back-up generator and a treatment plant could use biogas CHP providing power regulation. In the case of facility number 1, DR services regulating electricity consumption for heating in a technological process could be provided.

Biogas plants

Opportunities for the water treatment plant in provision of DR services were found via utilisation of a biogas CHP plant in the case work. This can be applied to the other biogas CHP plants as well. These units usually have biogas storage systems that allow for fluctuations in production and consumption, volume changes due to varying temperatures and for stagnating consumption. Conventional storage tanks hold volumes corresponding to gas production of three to four hours. In 2017, installed capacity of biogas CHP units comprised

33 MW, and this capacity with almost no technical constraints could be used for provision of DR services.

Back-up generation

Numerous large end-users or users with critical functions, have their own generators that can act as back-up if the grid fails. The results of the survey found that up to 38 MW of back-up generators are installed at 500 respondents. Since the survey covered both large electricity consumers, healthcare facilities and engineering infrastructure companies, it is likely that the number of back-up generators installed at the remaining users may be higher, but the capacity per generator will be lower. A conservative estimate foresees that up to 2 times more power back-up generators can be installed at the remaining users. It is estimated that about 100 MW of back-up generators are installed in Lithuania.

Other industrial electricity generators

Excluding industrial consumers 2 and 4 from the illustrative cases, there are 9 industrial companies having own electricity generation capacities. These companies have 53 MW of installed electricity generation capacity for own production needs. These are primarily CHP units utilising natural gas or waste energy. It is evaluated that depending on the CHP units' status, almost all mentioned capacity could be able to provide DR services, participating in power and frequency regulation.

Biological Wastewater Treatment

Th electricity demand for treatment of 1 million cubic meters of waste water was estimated to reach up to 17 kW. There are 4 wastewater treatment plants with annual capacities exceeding 10 million m^3 and 5 plants with capacities of 3-8 million m^3. Evaluation of possible capacities of air blowers that could be used for provision of DR services is presented in Table 8.

In the 9 wastewater treatment plants evaluated, the total capacity of air blowers in biological treatment equates to 1.9 MW. In 2015, the total amount of wastewater treated in all wastewater plants amounted to 164.4 million m^3. Therefore, it is assumed that an additional 970 kW of air blower capacity could be found in other wastewater treatment plans. Almost all mentioned capacity could be used for provision of DR services, participating in power and frequency regulation.

Table 8. Wastewater facilities treatment capacities and air blower capacities.

Facility	Wastewater treated, million m^3	Evaluated capacity of air blowers, kW
Vilnius	38	643
Kaunas	26	440
Klaipeda	16	270
Panevezys	12	207
Alytus	4	68
Marijampole	3	48
Siauliai	8	136
Utena	4	65
Mazeikiai	3	48
Total	**114**	**1,924**

Electric heating and cooling

Buildings with geothermal heating systems or with high thermal mass are good candidates for DR because the mass can be used to shift heating or cooling loads and pre-heating or pre-cooling can be effective as part of a DR service.

In the evaluation of consumption patterns, it was estimated that hourly electricity consumption for heating can reach 102 MWh during the coldest day, and hourly consumption for cooling can reach up to 80 MWh during the warmest period. These users are more likely to provide services of reduction of demand (i.e. turn off heating or cooling). Overheating or overcooling of buildings would be possible only for a very short period of time, and only to 10-30% of capacity indicated. Internal heating and cooling regulation systems of buildings will not allow significant increase of heating temperature or decrease of cooling temperature.

All possible evaluated capacities of DR services are summarised in the table below. Higher potential was evaluated for decrease of consumption as it includes capacities of back-up generators. Regulation potential of electric heating and cooling can be used only during a specific period, while the remaining potential in other fields depends more on the status of CHP units than on outdoor temperature.

Table 9. Possible capacities of DR services.

Facility	Regulation potential (MW)		Notes
	Decrease of consumption	Increase of consumption	
Demand units			
Industrial consumer 1	1	3	Depends on season (much higher heating demand during winter)
Industrial consumer 4	4	4	Depends on status of CHP unit(s), and whether pumping or not.
Electrical heating	102	31	During cold season. Depends on outdoor temperature
Electrical cooling	80	24	During warm season. Depends on outdoor temperature
Biological Wastewater Treatment	1.9	1.9	
Generation units			
Industrial consumer 2	10-30	10	Depends on season, status of units
Industrial consumer 3	1	0	Backup diesel generator
Industrial consumer 4	70	6	Depends on status of CHP unit(s), and whether pumping or not.
Industrial consumer 5	1	1-2	Depends on status of CHP unit and pumping
Other biogas plants	33	33	Depends on status of CHP units
Backup generators	100	0	Depends on technical conditions of back-up units
Other Industrial CHP plants	53	53	Depends on status of CHP units
Total demand units	**189**	**64**	
Total gen units	**288**	**104**	
Total	**477**	**168**	

4.4 Locations of possible DR services providers

Possible DR services providers were identified, with the majority being industrial companies and biogas CHP plants. In total more than 50 possible DR services providers were indicated. These capacities reflect only the portion of DR potential that could be used in the nearest future with lowest impact on users' consumption habits.

The largest capacities for possible DR services providers were found in the Kaunas, Marijampolė, Panevėžys, Telšiai and Vilnius regions where the largest industrial companies and biogas plants are located. The potential of back-up generators and electrical heating was not distributed between different regions as these units can be found all over the country. The potential of electrical cooling could likely be divided between the biggest cities where the largest administrative buildings are concentrated. The location of possible DR services providers in different regions is presented in Table 10.

Table 10. Location of possible DR services providers in different regions.

Facility	Regulation potential (MW)	
	Decrease of consumption	Increase of consumption
Alytus region	3.4	3.4
Kaunas region	69.9	50.9
Klaipėda region	9.8	7.8
Marjampolė region	11.8	11.8
Panevėžys region	9.5	9.5
Šiauliai region	6.6	5.6
Tauragė region	0.2	0.2
Telšiai region	70.4	10.4
Utena region	2.3	2.3
Vilnius region	9.8	9.8
Backup generators	100	0
Electrical heating	102	31
Electrical cooling	80	24
Total	**477**	**168**
Total connected to a transmission grid	**141**	**21**
Total connected to a distribution grid	**337**	**147**

Only 10 large consumers are connected directly to the transmission grid and their potential capacity of DR services comprise 2-25% of the total estimated regulation potential. The remaining part of DR potential can be utilised both by the TSO and DSO for power regulation and transmission/distribution constraint management.

5 Obstacles to DR implementation

Based on the findings described the in previous chapters, the current chapter outlines some the most relevant obstacles to DR implementation that must be overcome in Lithuania.

5.1 Regulatory issues

There are a number of regulations that encourage, define, and influence the implementation of demand response. This includes broader EU and national legislation, and more specific guidelines such as network codes. Will many of these regulations seek to encourage demand response, there are also some regulations that can pose an obstacle to DR implantation.

Network Codes

Network Codes are also relevant for demand response implementation and must be complied with and/or adjusted. Brief descriptions of three most pertinent are included below, while more detailed descriptions are provided in the report entitled "DR: Technical requirements for DR services".

The Network Code on Demand Connection (NC DCC) (European Commission, 2016, b) describes how demand response services can be provided to system operation. In this context, demand response services are services that maintain power system stability and resilience, and include: active power control, low frequency demand disconnection, reactive power control, transmission constraint management and system frequency control. The service must be available across a defined range of frequency and voltage (see article 27 to 30).

The Network Code on Electricity Balancing (NC EB) "requires that standard products are defined for the European balancing market (energy and reserves markets) to move towards a single European market with a cross-border regional approach". Meanwhile, the processes for defining these standard products (for example frequency restoration reserves and replacement reserves) are laid out in the Network Code on Load Frequency Control and Reserves (NC LFC & R). (ENTSO-E, 2015).

Regulation of electricity prices

The regulation of electricity prices restricts DR development. All end-users in Lithuania can switch supplier, but only a minority of households have switched supplier. The DSO supplies the majority of households with electricity and the DSO tariffs are regulated. The DSO offers about 6 to 8 plans for consumers that take into account: real time consumption, 1 or 2 time-zones and minimum amounts consumed with a corresponding discount. Critical peak pricing is not yet available (Bertoldi, Zancanella, & Boza-Kiss, 2016).

Removal of regulated prices may lead to more end-users shifting supplier and may lead to new types of tariffs. New tariffs could give less (e.g. fixed prices) or more (e.g. critical peak prices) incentive to demand response.

Independent aggregators

Today, balance responsibles act as an aggregator for end-users when they buy electricity, e.g. on the day-ahead or intra-day markets. This can include management of demand response, e.g. in the day-ahead market.

There is currently no mention in the Lithuanian Electricity Market Act on how to handle balancing responsibility with 3rd party service providers, i.e. aggregators.

Models in other countries include: (Elering, Pöyro and Ricardo, 2015)

- Direct compensation of a BRP by the aggregator at a regulated price (France).
- Bilateral agreements with the BRP or becoming the customer's BRP (e.g. Norway).
- Aggregators have a direct access to customer and BRP's imbalances are not compensated (Great Britain).

Lithuania could also look to Fingrid, which is currently undertaking a number of pilot projects aimed at increasing demand response via third party aggregators. Within this project, Helen, a Finish electricity retailer and producer, will be using reserve power (i.e. back up), for example from data centres, hospitals and shopping centres, to participate in the balancing market. Meanwhile, Voltalis, a France-based company, will aggregate a number of demand-side resources in Finland, including households for use in the regulating power market. (Fingrid, 2018b)

What is particularly interesting about the Helen and Voltalis pilot projects is that they allow for third-party aggregators to deliver regulating power, despite not being the balance responsible party (BRP) for the units that provide the regulation. Referred to as a 'reimbursement model', the pilot project ensures that affected BRPs are compensated after the fact via a trade with the TSO utilising the spot price during the activation hour, and the amount of measured regulating power that was delivered. The aggregator then receives the difference between the spot price and the regulating power price for the amount of regulation delivered. For the BRP, this compensation essentially nullifies the effect of the activation of the third-party aggregator during the activation hour, however, it can lead to imbalances during proceeding hours, as the BRP's end-users may have to adjust their electricity demand accordingly.

How to contract DR for DSO purposes?

Demand response can, at least in theory, be attractive in relation to the operation on distribution grids. Voltage can be managed within the allowed variation, investment in transformers and grid and be postponed – and total costs can be reduced. The types of challenges that can be managed with demand response are illustrated in the illustrative case studies.

The focus in this section is on demand response that is dynamically activated to improve voltage or avoid overloading. The use of static TOU tariffs to change demand is not in focus here. Major challenges exist in practise when DSOs try to realise the benefit of such dynamic demand response.

The main challenge is the local nature of the problem (over loading or voltage deviation). The local nature limits the number of end-users that can deliver the service. It might only be one company that can deliver the needed service. If it is only one or a few end-users that can participate in the service, it is a challenge to define the relevant compensation. It is often impossible to create a market to define the relevant price. There are simply too few providers to create a market price.

With the DSO being a local monopoly, the regulator is likely to require the price to be market based or in other ways clearly defined. This could be as a standard compensation that can be used in many situations.

Another challenge is the different time scales of the two alternatives:

- Investing in infrastructure upgrades. This takes time to prepare and when in place, it cannot be taken back, and has a long lifetime.
- Contracts for demand response may be difficult to make for a long future period. Companies may not be willing to promise to reduce demand for years to come. In some cases, the end-user may require that the reaction is voluntary or only guaranteed for a limited time (e.g. current month or year).

In markets with many participants (e.g. the day-ahead market) is it not a problem that the response in voluntary – other end-users may supply the missing service. However, in relation to demand response in distribution grids the number of relevant users that can deliver the needed service may be limited. In such situations the DSO may need to enter long-term contracts with end-users. If the alternative (grid investments) takes, e.g., a year to implement, this would be the minimum contract length.

5.2 Technical issues

Metering

One of the prerequisites for widespread end-user participation in demand response is the ability to measure end-user electricity usage on an hourly (at a minimum) timescale. This most certainly applies to price-based demand response, but also to many forms of incentive-based demand response if payment is dependent on the quantity of electricity delivered (see text box).

Incentive based vs. price based
Demand response instruments are often segregated into 'incentive-based' and 'price-based' demand response. In incentive-based demand response consumers receive direct payments to change their consumption or generation upon request. They earn from their flexibility individually or by contracting with an aggregator (third-party aggregator or the customer's retailor). In price-based demand response, the consumer adjusts the consumption according to dynamic price signals (not on request). **(Smart Energy Demand Coalition, SEDC, 2017)**

In Lithuania today, companies with a connection above 30 kW have a smart meter and hourly settlement. For smaller electricity users, only a few pilot projects have been completed (ESO, 2017). A mass roll-out of smart meters is expected to start in 2019 and to be completed in 2022, and by 2022 this particular barrier to demand response participating will be removed.

As smart meters are put in place the next years, new forms of demand response can be developed. More advanced tariffs can be developed (more time intervals) and demand can be adjusted to day-ahead prices.

Smart meters will not only allow for more demand response, but may also impact energy efficiency efforts (by making electricity demand more visible) and may also increase interest in selecting an alternative retailer (e.g. by making payment more transparent).

Requirements for ancillary services from small end-users

FCR

Frequency containment reserves (FCR) refer to the active power reserves available to the TSO in order to return the system frequency to the nominal value after an imbalance occurrence. According to GETSO Article 154, each FCR provider has the right to aggregate the respective data for more than one FCR providing unit (power generation or demand unit) if the maximum power of the aggregated units is below 1.5 MW, and a clear verification of activation of FCR is possible. In practice, this means that a large number of small end-users would need to be aggregated. The aggregation of a number of small end-users is unlikely to be problematic from a regulatory point of view, however the requirement of 'clear verification of the activation' may prove to be overly burdensome depending on how the term 'clear verification' is to be understood (see section about real time measurement, below).

Regulating power

There are a number of requirements for regulating power that can prove challenging when the provision of this reserve is done by a number of small units, but there also exist some opportunities.

Activation time

The first requirement for regulating power is activation time. In most jurisdictions (including Lithuania), it is stipulated that the activation must be fully delivered within 15 minutes, and generally speaking, this is to be done in a linear fashion[5].

This particular requirement is not a challenge for regulating power based on a large number of small units, as one of the main strengths of demand response is the ability to respond very quickly, i.e. demand units can be disconnected (e.g. electric heating) within seconds, while larger units (e.g. industrial cooling compressors) would need a few seconds to a minute to start or disconnect.

With automation, with a sufficient number of units in its portfolio an aggregator could deliver regulating power quickly and with the needed profile. The opportunity to utilise a bid with an activation time shorter than 15 minutes likely has higher value for a TSO than a longer activation time, and as such, the acceptance of shorter activation times could be recommended.

[5] The linear reaction is an important feature in order to secure stability and avoid over-shooting. Linear reaction can easily be provided with many small units by making random variation in control parameters. See (Xu, Togeby, & Østergaard, 2008).

Duration of activation

Regulating power bids must currently as a minimum be able to deliver a regulation until the end of the hour in which they were activated (i.e. up to 60 minutes). However, demand response bids vary from conventional fuel-based regulation bids in that the longer duration, the more difficult it is to maintain the activation. Related to this, they also have a maximum amount of time that the activation can last, as eventually consumers will need to start/stop using electricity again. This results in the fact that the marginal cost of providing a demand response regulation increases throughout the activation. Aggregators placing bids based on demand response would therefore benefit from the ability to place bids with varying or alternative maximum activation times. This is not to say that aggregators placing demand response-based bids should be able to have preferential treatment, i.e. deliver bids that other producers/consumers may not. The suggestion here is that the market as a whole would benefit from a wider range of bid types, where all actors would be able to participate. Increasing the bid types and forms would increase the amount of actors that could participate in the market, and thereby provide the TSO with a wider range of options to meet its balancing needs.

Minimum bid size

As was outlined in WP5, the minimum bid size for regulating power varies in Europe from roughly 0.3 to 10.0 MW, as is 1 MW for Lithuania (from January 2018). A 1 MW minimum bid size still requires quite a large number of small end-users (particularly because it cannot be assumed that all can react at any given time), and therefore poses a challenge for aggregators. Reducing this minimum bid size would therefore increase the number of bids in the market, thus providing more liquidity and a more accurate price signal.

With modern IT solutions it can be streamlined for the TSO’s control room staff to active many small bids.

Real time measurement

When a TSO activates a regulating power bid, the planned generation (or demand) for the balance responsible is changed. For example, with 10 MW of up-regulation, the planned generation is simply increased with this effect for the relevant duration. If the realised generation (or demand) differs from the planned, there is a cost associated with the unbalances.

Historically, regulating power has involved a requirement for real time measurement of the generation per each relevant power plant. The measurements documented that the ordered service was delivered. This system has not been problematic, as regulating power has traditionally been provided by large power plants which had such measurement equipment in place. Online measurements do however provide a barrier for small consumption units. From a cost perspective, it would be unrealistic to install online measurements for hundreds of demand units.

Need for aggregators

Electricity demand units are typically much smaller than power plants, and generally need aggregation in order to be activated. How aggregation is undertaken depends on the type of service and the market.

In the spot market, the retailer and the balance responsible typically acts as an aggregator. This is the case without demand response and can also be the case with end-user demand response participation. Without demand response, the retailer predicts the electricity demand for the next day (hour-by-hour) based on historical demand information, weather forecasts, day of the week, etc. In many cases it is relatively easy to predict the demand. The only communication between the end users and the retailer involves a measurement of the electricity used (for individual end-users or for aggregated demand in a network). As unbalances entail a cost, the retailer is motivated to develop a good prognosis. The process involving the development a good prognosis takes time and requires that similar situations have been seen historically. E.g. it is only possible to predict the increase in electricity demand during periods with extremely low temperatures, if such periods of cold weather have occurred earlier. This is a consequence of the described method; whereby historical demand is the basis for the prognosis.

If a retailer's customers are active in demand response in relation to the day-ahead market, then the procedure can be the same. However, an extra parameter should now be included, namely the change in expected demand when prices vary, e.g. during periods with very high or low electricity prices. The Nord Pool spot market has several products that can reflect a price dependent demand. One possibility is simply to indicate a price dependent demand (a downward step curve of demand as function of price). An alternative is the Flexi bid, where an end-user/retailer can offer to reduce their demand during one or more hours if the electricity price is above a certain value. The retailer can e.g. deliver a bid stating that demand can be reduced with 2 MW in three hours, if the price is above 100 €/MWh. Nord Pool computes if this is the case and selects the best hours.

Independent aggregators can be relevant in some cases. However, if there is a significant amount of energy activated as demand response by an independent aggregator, this may create imbalances for the retailer. The independent aggregator may have an agreement with the retailer about how communication and compensation should be arranged. Such agreements may be standardised or may be negotiated individually.

In relation to primary (FCR) and secondary reserves (FRR-A), the volume of activated energy is likely to be small and can thus be ignored. This is particularly the case if the automatic reserve is symmetrical (i.e. involves both up and down regulation, e.g. when system frequency is above or below the nominal frequency). In this case an independent aggregator can interact with end-users that have contracts with different retailers (and balance responsibles) without imposing an imbalance on these parties.

5.3 Market issues

Fixed price contracts

One of the most significant market related issues in Lithuania today is that the largest electricity users currently prefer to buy electricity on fixed price contracts, and therefore they have very little incentive to provide price-based demand response services. Approx. 70% of business consumers in Lithuania used fixed price and 30% spot price contracts (SvK, AST, Litgrid, PSE, 2017).

The large users have the largest installed capacities, and technically speaking, could provide ancillary service-based DR services. While only roughly 20-30% of this group states that they have the technical capacity to alter their electricity use, this still results in a large number of MW seen from an ancillary services perspective[6]. In addition, the survey results regarding heating and cooling aspects have illustrated that large users often have a greater potential to alter their electricity demand than they initially suggest.

The illustrative cases work (WP3) highlighted the fact that simplest and easiest way for three of the five visited actors to provide DR services would be to purchase a greater portion of their electricity via spot contracts. While the facility representatives stated that many of the processes at these three facilities are interlinked, and it would therefore be difficult to operate them solely according to electricity prices, it was also apparent that there is at least some flexibility at these facilities. Perhaps even more importantly, international experiences have shown that when companies are faced with time-varying prices the additional incentive drives investment towards greater flexibility.

[6] The illustrative cases work for example found that the 5 companies in focus alone had the potential to deliver over 100 MW of up regulation and 25 MW of down regulation.

Financial contracts

Financial contracts are a crucial part of a well-developed electricity market. They can assist generators in reducing uncertainty about future electricity price and support traders in offering fixed prices to costumers. However, liquid financial instruments do not exist for Lithuania. Due to a lack of relevant financial instruments, end-users may use fixed prices from retailers as an alternative.

Lack of fluctuation in electricity prices

In recent years price variation in the Lithuanian spot market has been limited. Only a few extreme prices have been realised, and no zero or negative prices. In practise this will reduce the incentive for demand response. If price formation is efficient, with a high level of competition, this is not considered as a barrier that should be removed, but it is a challenge for development of demand response. However, as more wind and solar power enter the system in Lithuania and the neighbouring countries, more price variation is likely to take place.

5.4 Other challenges

Growth of new types of demand

Driven by a desire to reduce CO_2 emissions and fuel imports, and facilitated by rapidly decreasing costs of batteries and electricity production from wind and solar, the coming years will see a growing electrification of the heat and transport sectors. This electrification process entails great opportunities for demand response, but also potential challenges. These are described in greater detail in a report entitled "Demand response: Obstacles, impact assessment and prevention strategy".

Rebound effect

Put rather simply, there are two types of demand response: Fuel shift and shifting of electricity demand in time.[7] With fuel shift, the impact on electricity demand is permanent, i.e. there is not a corresponding increase or decrease in electricity demand at a later time. An example could be an industrial user that has the ability to produce its own heat from an alternative fuel when electricity prices are high, or a district heating plant that can utilise electricity in a boiler when electricity prices are low.

[7] Technically speaking, there is also a third type, i.e. an increase or decrease in electricity demand in response to a low or high electricity price. A very price sensitive consumer may for example accept a slightly lower room temperature during periods with high electricity prices. Alternatively, some households, or commercial customers may dim lights during periods with very high prices if they have automation in place. However, the potential for this type of DR is assumed to be quite low, and therefore disregarded for the purpose of the current discussion.

The majority of demand response potential is however likely to involve situations where electricity demand is instead shifted in time. For example, temporarily halting electricity use for a heating or cooling process delays the electricity demand but will require this demand to be met at a later time, while postponing the charging of an EV will require it to be done later. This phenomenon is in popular terms referred to as the rebound effect, or when referring to heating related processes 'cold load pickup'. The demand after reconnection will typically exceed the prior demand because of 'loss of load diversity'. For example, in IEEE (2009), heat pumps are shown to use twice as much electricity after a blackout, and heat pumps with direct electric heat can use up to five times more if the direct electric heater is activated[8] (see also Lawhead et al, 2006).

Price signals may lead to congestions in local grids

Throughout this report, demand response is hailed as a tool to assist the overall electricity system, i.e. increase electricity demand when prices are low, and reduce it when prices are high. Spot and regulating power prices are determined at the larger price area level, and price-based demand response can therefore be effective in achieving this. However, one potential challenge for price-based demand response is that the economic optimisation of price responsive units may result in an increased correlation of their electricity demand in distribution grids. For example, heat pumps and EVs could potentially overload those distribution grids that don't have a large amount of excess capacity. As such, if electricity demand is developed to be price sensitive the challenges for the distribution grid may actually increase. This may be a particular problem in hours with very low (and sometimes even negative) spot prices. As was noted above, this can also be a challenge after several hours with a very high price; when prices are normalised the pick-up demand from price sensitive demand may be large.

Firstly, it should be noted that the majority of distribution lines are vastly over-dimensioned, so this is unlikely to be a widespread issue. Secondly, there is a degree of smoothing that takes place, for example with respect to when people are at home (affects the home temperature and EV charging, meal preparation, etc).

[8] In the example heat pumps are loaded with 25% of full load before disconnection, while heat pumps with electric heating are loaded only 10% of their full capacity. After reconnection both technologies are loaded 50%.

In the remaining periods and areas where this can potentially be an issue, one potential solution lies in local tariffs (see next chapter), i.e. where the price signal received by the end user has a price area component (spot price and/or regulating power price) and potentially a tariff, as well as a local component, perhaps in the form of time of use tariff, or more advanced form.

A DSO in a problematic area could also potentially work with a local retailer in order to provide the end-users in that area with an incentive not to use electricity during high risk periods, as the cost of providing this incentive during a few hours would likely be much lower than the costs associated with expanding the grid.

Potential exclusion of some resources

There has been a great deal of discussion regarding price-based vs incentive-based demand response with some commentators arguing that only the latter can deliver reliable demand response as this form often entails direct control of an end-user's electricity utilising device. Several demonstration projects, including the Flexpower project (Ea Energy Analyses, 2013), have demonstrated that price-based demand response can deliver reliable and predictable demand response. Going forward it will be important to induce as much demand as possible to participate flexibly, and as some consumers are unwilling to surrender direct control over the devices, but would instead prefer to have the option to react to price signals (or have automation do so on their behalf), it is important to ensure that the rules and regulations governing demand response allow for both forms of demand response. It is the consultants understanding that as long as all end-users are aggregated by the same balance responsible, then there are no additional rules or regulations required to participate in price-based demand response.[9]

Public awareness of DR

The survey results highlighted the fact that DR is a new topic for many end-users, as shown by both the responses to the questions related to back-up generation (where it was unclear to many exactly what back-up generation is, particularly from a DR point of view), and heating and cooling. With respect to the heating and cooling replies, when looking at companies, the respondents stated that 72% have some electricity consumption that goes to heating and/or cooling, but when comparing with the questions replied to previously, these same companies indicated that roughly only 20% had some electricity consumption that was controllable. This could suggest that a large number of

[9] With respect to independent aggregators and EU legalisation, please see discussion previously.

the companies are unaware that they have some electricity consumption that is in fact technically possible to control.

Data on heating and backup generation

Electricity used for heating (space heating and hot water) is relevant for demand response because of the thermal inertia. Electricity supply can be disconnected for a short time without any loss of comfort. It is the consultant's impression that the statistical information regarding electricity use for heating in households could be improved, and this could be a focus area for the Lithuanian government going forward. It is relevant to describe the total electricity used for heating – both where electrical heating is the primary source and where electricity is supplementary to another form of heating.

Electricity costs are a small portion of total costs

Another challenge for demand response (not specific to Lithuania) is that electricity costs are such a small portion of total costs for many of the large end-users. It can therefore be difficult to get the attention of the management, e.g. regarding the pros and cons related to purchasing electricity at varying prices or investing man-hours in developing demand response capabilities.

This issue also applies to household users, as electricity is relatively cheap when compared to the benefit received, and also because the wholesale electricity price comprises a relatively small portion of the total electricity bill.

6 Recommendations based on lessons learned

6.1 Recommendations: Short-term

Develop technology neutral rules and technical requirements for ancillary services

Current requirements tent to favour generation technologies, and updates to contracts, grid codes, and other technical requirements are most likely necessary for all markets looking to encourage greater demand side participation. For example, Fingrid, the Finish TSO, recently altered its contractual language and technical requirements for one form of its frequency reserves (FCR-D), and over 70% of this reserve is now supplied by demand side sources (Fingrid, 2018).

Day-ahead market

Within the day-ahead market*, it is recommended to start with end-users with hourly settlement entering into contracts* with their retailer where the hourly price is equal to the spot price, plus a small mark up. The market system must allow hourly settlement for these users.

This form of price-based demand response does not require an aggregator, and the only technical requirement required to participate in the day-ahead market is an interval meter. In order for the end-user to easily adjust their electricity demand according to the day-ahead published prices, it would also be necessary for the end-user to receive the prices, and/or have some electricity devices that can respond automatically. Examples in the commercial or industrial sectors include heating, cooling, or pumping, while a dishwasher or electric vehicle could be relevant examples for a residential user.

Regulating power

For regulating power, *it is recommended to focus on the largest commercial users first* to deliver price-based demand response. Examples include two of the large industrial consumers as they likely could submit bids above the minimum requirement of 1 MW. Thereafter, focus could shift to medium-large users that could pool their assets under one balance responsible (also referred to as the integrated aggregation model), followed by a large number of smaller users, again with the same balance responsible. It is estimated that the most complex setup at this point in time involves the use of an independent aggregator, because in addition to addressing the technical issues, a fair compensation model would also need be created between different market actors.

In order to live up to coming EU regulation, it may be necessary to establish a payment structure system that compensates balance responsiblies for imbalances that are created via activations from third-party aggregators. It is therefore recommended to follow the evolvement and final wording of the directive of the European Parliament on common rules for the internal market in electricity, and if need be, look to examples such as the pilot projects in Finland that have implemented reimbursement systems.

In terms of technical requirements, as a minimum, participants must have an interval meter, but there are also other required technical requirements, depending on the customer and market set up. There are essentially two different types:

- Price signal: This option requires the BRP customers to be able to receive an updated price signal, and to adjust their electricity demand accordingly. Within industry, heating, cooling, and pumping are all examples that can be adjusted based on incorporating updated price signals into the plant's Supervisory Control and Data Acquisition (SCADA) system. For residential end-users, electric vehicle (EV) and heat pump owners are prime candidates for participating in the regulating power market, as they would simply have to install software that can receive updated price signals, and a simple algorithm and control system could then adjust the electricity demand accordingly.
- Direct control (often an incentive-based form of DR) where the balance responsible/aggregators has control over a specific device. For smaller users, this set up could also be established via a Virtual Power Plant (VPP) system covering many end-users, where the BR could for example control various heating/cooling units according to an agreement entered into with the owner of the unit.

Frequency reserves

Whereas the independent aggregator model is complex for regulating power, it is likely a very viable alternative for the delivery of FCR, and therefore *it is recommended that this form of incentive-based demand response be focused on initially* for the supply of additional primary reserves.

In terms of the technical requirements, communication equipment is not needed, only a simple device to measure the frequency is required. In addition, the end-user must have some form of automation in place that can quickly alter the consumption pattern of the electric devices in question. Industrial process could include pumping, commercial processes include heating and cooling, and residential examples include electric vehicles and heating and cooling.

6.2 Recommendations: Medium to long-term

Increase awareness of demand response

The low survey response rate, and some of the conflicting responses, point to a need for additional practical insights in DR. It is therefore *recommended to undertake initiatives that provide greater awareness regarding demand response,* e.g. via demonstration projects, articles, and educational activities.

Provide relevant technical assistance

The survey also gave a clear indication that end-users are interested in technical assistance to understand their demand response potential. It is *thus recommended to develop the most relevant form of this technical assistance*. It may vary from detailed energy audit for large industrial end-users to general information to households and other end-users with a small of medium electricity consumption. Demonstration projects, e.g. related to industrial heating and cooling processes, could also be relevant.

Continue to develop tariffs for transport of electricity

This could include using the current time-of-use tariffs (TOU) in an even broader scale. New types of tariffs could also be developed, e.g. tariffs where some elements could be activated (dispatched) with short notice. This could be in the form of Critical Peak Pricing (CPP), where a high price level could be announced the day or week before. When all end-users have an interval meter, such advanced tariffs can be tested and implemented at relatively low cost. The goal for such tariff development is to reflect the true marginal costs of transporting electricity. This will as a side impact increase the incentive for demand response.

Electric vehicles and heat pumps

When interval meters have been installed, it is recommended to focus on demand response from electric vehicles and heat pumps. Both technologies have good potentials for demand response. While there is currently only a limited amount of these demand in Lithuania, both are expected to increase in the future.

Increase knowledge about electricity used for heating

Electricity-based space heating and hot water heating is relevant for demand response because of the thermal inertia, i.e. the electricity supply can be disconnected for a short time without any loss of comfort. It is the consultant's impression that the statistical information regarding electricity use for heating (including heat pumps) in households could be improved, and this could be a focus area for the Lithuanian government going forward. It is relevant to describe the total electricity used for heating – both where electrical heating is the primary source and where electricity is supplementary to another form of heating.

Relaxation of rules for demand as regulating power

Two aspects are central when demand (or backup generators) should be activated as regulating power (FRR-M, RR):

- The minimum bid size should be as low as possible. With a high minimum capacity, few retailers/balance responsibles will be active. This is a restriction on competition (entry barrier). However, seen from the end-user perspective, it may also be important that if several retailers offer this service, there will be a variation in the systems used. The end-user will have a choice. Nordic TSO's have demonstrated that systems can be constructed so it is simple for TSO control room staff to order regulating power (from many small units) with a single click with a mouse.
- The rules for monitoring the delivered regulating power must be adapted to the situation with many small units. Use of statistical ex-post methods can document that the delivered service is predictable.

The first of these two aspects has already been partially addressed, as the minimum bid size is now 1 MW. It would be advantageous if this was reduced further, however, at this point *it is recommended to focus on the 2nd aspect, i.e. adapting the existing rules for regulating power*.

Encourage use of demand as primary reserve

Use of large scale demand as primary reserve is well-known in power systems. E.g. in Finland industrial demand planned to be used in relation to the new large nuclear (1,600 MW) plant. Demand can react with practically no notice when frequency is falling. It can also be arranged so the aggregated response to the traditional proportional response is achieved. Random variation of set-points is a way to achieve this.

The main challenge may be related to monitoring of the capacity from demand. It is important to monitor the capacity – the active capacity should be as needed, not significantly higher or lower. With demand combined with an autonomous control system, where frequency is measured locally, and demand disconnected, there is no need for communication. If e.g. electric heating (industrial or in households) was suppling the service, monitoring could include estimating the relevant capacity based on temperature measurements and a few sample measurements (can be standard measurements from the retailer, or specific measurement only covering the electric heating).

It *is recommended to encourage the use of demand as a primary reserve*, and if necessary, relax/revise monitoring criteria to enable use of demand in this regard.

Demonstration project involving demand used for DSO services

The least developed type of demand response service is that needed for DSO purposes, e.g. for control of voltage and local congestion. These needs are local and very time specific, as illustrated in the cases (WP3).

It can be argued that if the DSO only can solve voltage and congestion challenge by investing in new capacity – then less costly demand response options are overlooked. However, work needs to be done to develop systems that can determine a fair price for such local services (with only a few active suppliers).

General capacity challenges can be reduced by use of general DSO tariffs, such as TOU tariffs or CPP tariffs, and Lithuania has extensive experience with TOU tariffs. These will typically be active for larger areas.

It is therefore *recommended that Lithuania consider undertaking demonstration projects with dispatchable CPP tariffs*.

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