Methodological improvements of Resource Adequacy Assessments

Work package 2
Final Report 2

Guidelines and recommendations to determine demand-side response (DSR) potential as input for resource adequacy assessment

Study on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK)

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Guidelines and recommendations to determine demand-side response (DSR) potential as input for resource adequacy assessment

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List of Abbreviations

BTM	Behind-the-meter
CST	Cross-sectional technologies
CTS	Commercial, trade and services
DAM	Day ahead market
DSO	Distribution System Operator
DSR	Demand side response
ENTSO-E	European Network of Transmission System Operators for Electricity
EVA	Economic viability assessment
ERAA	European Resource Adequacy Assessment
EV	Electric vehicles
PtX	Power-to-X
PV	Photovoltaic
RAA	Resource Adequacy Assessment
ToU	Time-of-Use
UCED	Unit commitment and economic dispatch

1 Introduction

Resource adequacy assessments (RAAs) are performed to assess the overall adequacy of power systems to meet current and projected electricity demand. Part of the assessment is to determine the contribution of all resources from the generation-side and demand-side, energy storage, import and export to flexible system operation.[1] For this purpose, it is necessary to assess the current and future potential of demand side response (DSR). While ACER defines fundamental requirements on how to consider DSR in the European Resource Adequacy Assessment (ERAA)[2], a universally accepted methodology to assess the potential and costs of DSR in the context of RAA does not exist. The appropriate and accurate determination of the inherently heterogenous DSR options, although challenging, is however crucial for a comprehensive picture of available resources now and in the future.

ACER's decision to neither approve nor amend the first ERAA (2021), due in part to shortcomings in the current methodology for determining DSR potential, underlines the importance of further developments around DSR potential assessment methods for RAA.[3] ACER found that the ERAA 2021 relies on simplifications and assumptions that likely underestimate the potential of DSR for RAA and suggested relying on a comprehensive methodology for assessing DSR potential and cost parameters in every Member State. The transparency regarding assumptions and modelling of DSR potentials in the ERAA 2022 should furthermore be improved according to ACER.

This underlines the importance of the objective of Work Package 2 on DSR Potential Assessments in the research project. This report aims to contribute to the broader task of improving DSR assessment methods by providing methodological guidelines and recommendations on how to determine the DSR potential of various technologies. The application of the methodological guidelines outlined in the present report within a modelling exercise is not part of the work in this project. The guidelines are therefore intended to be an input for the further development of RAA methods and RAAs conducted by member countries of the Pentalateral Energy Forum and beyond.

More specifically, the goal of the present report is to provide methodological guidelines for DSR potential assessments, which

- consider various technologies (at least 10 technologies);
- consider current and future potential (10-year horizon);
- are in principle relevant for all Penta countries and;
- are useful for load shedding, load shifting, implicit and explicit DSR, in-the-market and out-of-the market DSR.

The work presented here was preceded by a first report providing an overview and evaluation of existing methods to determine DSR potentials. The identified methods were grouped by four "methodological building blocks" among two dimensions: top-down vs. bottom-up approaches and technical-data vs. market-data based analysis. In each of these four methodological building blocks, we identified one methodological approach as being particularly relevant for DSR potential assessments. These were the scaling method, the decomposition

[1] We consider small-scale stationary batteries, battery electric vehicles (BEV) and Power-to-Gas as part of the demand side.

[2] ACER (2020)

[3] ACER (2022)

method, market response analysis and surveys (see report 1, Work Package 2). Nevertheless, all of these methods exhibit strengths and weaknesses. None of the methods can provide all DSR related inputs required by RAAs that aim to be compliant with the ERAA methodology specified by ACER. In most existing DSR potential assessments, regardless of whether they are used for RAA or other use cases, typically a combination of methods is applied. The analysis also highlighted that the appropriate combination of methods is DSR-type specific. Accordingly, the present second WP 2 report describes which combination of the methods can and should be used for a robust assessment of different DSR types, resulting in the definition of all required DSR related inputs for the RAA.

Besides our own work, the input of a first stakeholder workshop on 6 and 7 July 2021 and insights from a second workshop on 3 and 4 May 2022 as well as very helpful remarks from the members of SG2 of the Pentalateral Energy Forum provided the basis for the report at hand.

The report is structured as follows: Chapter 2 outlines the choice of DSR options to be covered by the guidelines presented in the report. Chapter 3 explains the general structure and design of the proposed methodological approach to assess DSR potential illustrated with flowcharts. A deep dive describing the application of a flowchart using the example of DSR in energy-intensive industries is provided in Chapter 4. Specificities of the other considered DSR options are discussed in Chapter 5, while the respective flowcharts can be found in the Appendix. Chapter 6 deals with the analysis of future DSR potentials and plausibility checks to be performed. Finally, conclusions are drawn in Chapter 7. The Appendix includes further material related to methodological guidelines for DSR potential assessments for various technologies to improve the readability of the main report text.

2 Choice of DSR options covered by guidelines

A great variety of technologies and appliances are discussed in the literature and expert discussions as potential DSR options. Technologies and appliances suitable for DSR typically feature one of the following characteristics: heat or cold storage (e.g., space heating), demand flexibility (e.g., ventilation), electrical storage (e.g., small-scale battery storages) or physical storage (e.g., of industrial products).[4]

In Figure 1, we provide a non-exhaustive overview of various DSR options discussed and assessed today.[5] They are categorized on a first level by demand-side sectors – industry, commercial, trade and services, households – and Power-to-X (PtX) and, where applicable, on a second level by technology type. The technology type distinguishes mainly between (1) production processes that are specific to a particular industrial branch, product or process, (2) storages and (3) cross-sectional technologies that cut across the boundaries of different sectors, branches, and processes. In the case of industry, we list the energy-intensive industrial branches and name the processes that are commonly discussed as DSR options in the respective branch.

To select the technologies for which methodological guidelines are developed in this report, we then classified the main DSR options further according to whether they have a high potential today and/or in the future (next 10 years). This classification is based on the results found in literature assessing DSR potential[6] and stakeholder feedback. The classification is

[4] Gils. H. (2014)

[5] Own illustration based on Gils, H. (2014), Heitkoetter, W. et al. (2021), Ladwig, T. (2018), Steurer, M. (2017)

[6] Mainly based on results in Gils, H. (2014) due to the international focus and supplemented by more current results from Heitkoetter, W. et al. (2021)

illustrated in Figure 1. We identified four technologies (or processes) and five industry segments with corresponding processes that have a high technical and achievable potential today. For seven other DSR options, we see an increasing relevance in the future. Data centres promise great flexibility potential in the future. However, a distinction must be made between the process-specific DSR potential that data centres might offer, which is seen as less relevant, and the much greater potential of back-up systems and cross-sectional technologies such as air conditioning that are used in data centres.[7] Since these latter technologies are covered elsewhere, no distinct methodological approach for data centres was proposed. Stakeholders have also mentioned back-up battery systems in the commercial, trade and service sector as a DSR option that will be relevant in the future. These are not yet considered in the literature reviewed, but in Ch. 5.5 we outline how the flowchart on behind-the-meter storage in the residential sector could be used to assess the potential of back-up batteries.

The 20 DSR options highlighted in Figure 1 are covered by the guidelines for DSR potential assessments in RAA outlined in this report. It must be noted, however, that the relevance of individual DSR options may differ from country to country. While some of the DSR options we identified as relevant today or in the future may not be present in some countries or may be present only to a limited extent (e.g., electric heating or cooling depending on climatic conditions or certain industrial processes depending on industrial structure), other DSR options which we identified as being not so relevant may indeed have some relevance in other countries. In any case, the principal approach of flowcharts which we propose can also be adjusted to options which were not analysed in detail.

[7] BloombergNEF (2021)

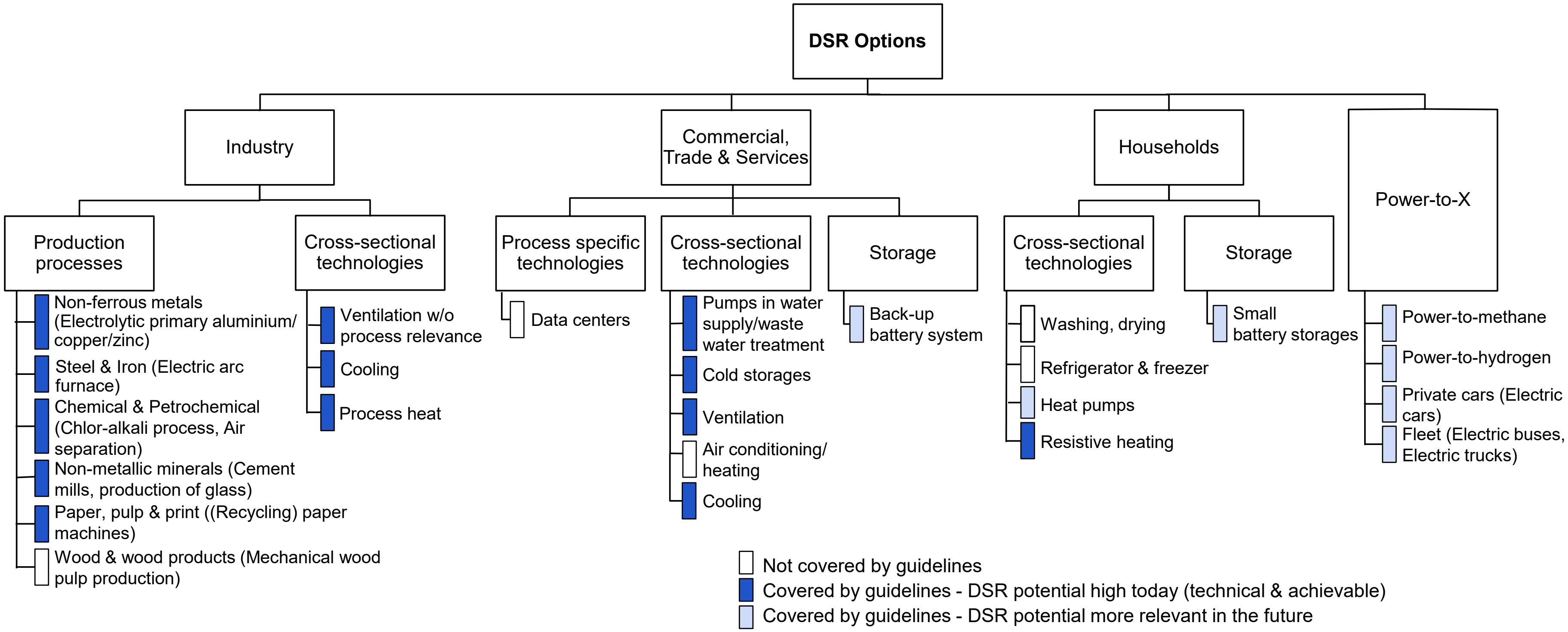


Figure 1: Overview of DSR options, classification of their relevance and consideration in the guideline

For the selected DSR options, existing technology-specific methodologies for assessing their DSR potential were investigated, compared and methodological guidelines derived. Some technologies or processes were deemed similar enough to be grouped together. As a result six different methodological approaches, shown as flowcharts, are proposed to cover the selected 20 DSR options. Table 2-1 indicates which technologies are covered by each of the six flowcharts. While the different flowcharts reflect the key differences between the technologies, they all follow the same structural design and process, which is described in the following chapter.

No	Flowchart	Covered technologies
1	**Energy intensive industry – production processes:** *Main differentiator between the technologies is the load profile: constant or dynamic*	**Constant load profile:** – Non-ferrous metals (electrolytic primary aluminium/ copper/zinc) – Steel & Iron (electric arc furnace) – Chemical & Petrochemical (chloralkaline process, air separation) – Paper, pulp & printing ((recycling) paper machines) **Dynamic load profile over the year:** – Non-metallic minerals (Cement mills)
2	**Industry and commercial, trade & services – cross-sectional technologies** *Main differentiator between the technologies is the load profile: temperature dependent or temperature independent*	**Temperature dependent load profile:** – Air conditioning/heating **Temperature independent load profile:** – Process heat – Cooling – Cold storages – Pumps in water supply/ wastewater treatment
3	**Power-to-X – Electric vehicles**	– Private cars (EVs) – Fleets (e-buses and e-trucks)
4	**Power-to-X – Power-to-Gas**	– Power-to-Methane – Power-to-Hydrogen
5	**Households – cross-sectional technologies**	**Temperature dependent load profile:** – Heat pumps/resistive heating
6	**Behind-the-meter battery storage**	– Small-scale battery storage – (Back-up battery storage systems in commercial, trade & services)

Table 2-1: Overview of derived flowcharts to cover selected DSR options

3 Overview of the methodology for DSR potential assessment

To provide implementors of DSR potential assessments with methodological guidelines in a concise manner, we employ flowcharts to describe methodological steps for the assessment of DSR potentials of various technologies. A flowchart describes the process of DSR potential assessment for a given group of technologies by pointing out its main steps and their connections. Thus, by reading the flowchart left-to-right and top-to-bottom, it enables the user, i.e., the modeller, to understand and implement the assessment by following the steps outlined and considering the modelling choices highlighted in the flowchart. To consider constraints that might limit the time and resources available for assessments, options on best practice vs. must-have approaches are highlighted. The following paragraphs provide a step-by-step guide for the use of the flowcharts.

To assess the DSR potential, in general, the modeller needs to select suitable sources for input data, process these parameters, and finally calculate the result, the DSR potential. Thus, the main elements of the flowchart are data sources (*light green waved boxes*), calculation parameters (*light green parallelograms*) as well as interim and final results (*light green and dark green rectangles*), as depicted in Figure 2.

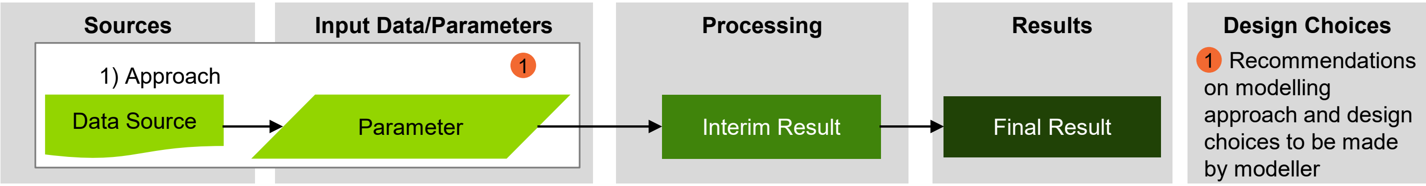


Figure 2: Flowchart legend

The assessment of DSR potential is structured in four steps, as shown in Figure 3. The modeller starts the assessment with a broad definition of DSR potential and in a stepwise manner takes further restrictions into account to refine the DSR potential.

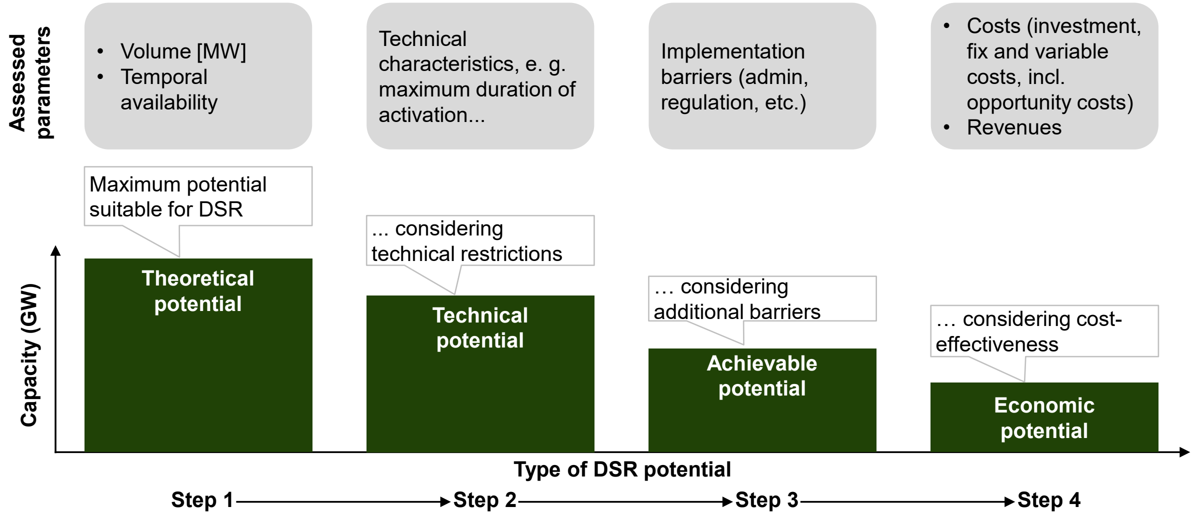


Figure 3: Categories of DSR potentials[8]

For some of these steps: there are several modelling approaches available (represented by a white box in Figure 2). These approaches differ e. g. in the used input data and complexity as well their suitability for different types of DSR options.

[8] Own illustration based on Dranka, G., Ferreira, P. (2019)

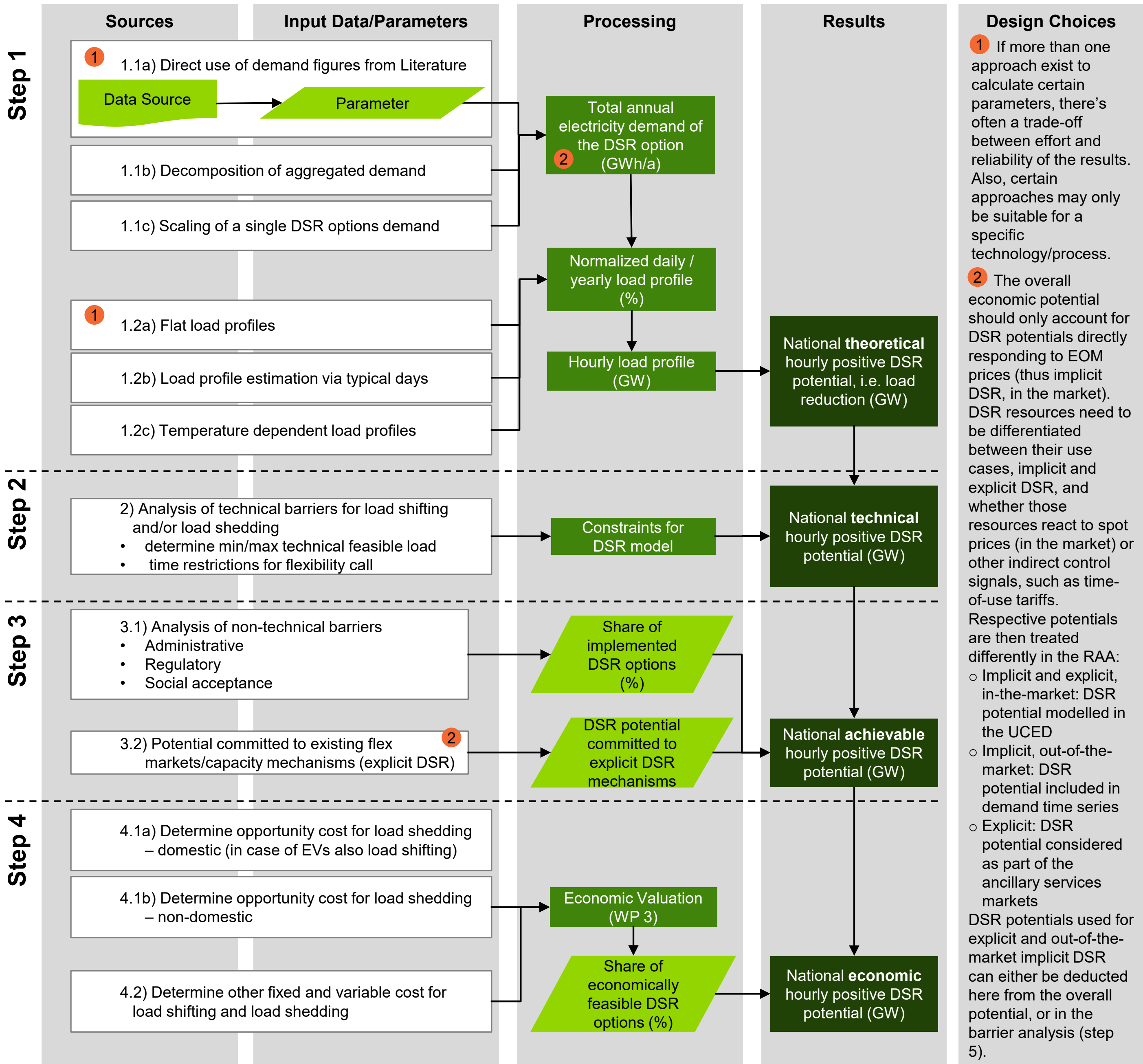


Figure 4: DSR assessment methodology - Overarching approach

The four steps of assessing DSR potential from technical to economic potential are further detailed in the generic flowchart, Figure 4, and described below. Here, we provide a high-level overview on the assessment steps. Details such as data sources will be discussed later:

1. In the first step, the modeller considers the **theoretical potential** of the DSR option, i. e. its load (or capacity). To do so, the overall energy demand of a certain DSR technology option, e. g. a type of industrial process, is derived either through literature review, decomposition or scaling and used to scale the DSR option's load profile. The load profile is either modelled as a flat profile, by using typical days or by considering the temperature dependency of the load.
2. In the second step, the **technical potential** is derived by additionally considering the technical characteristics of the respective DSR option, which constrain load shifting and load shedding. For technologies for which both load shifting and load shedding

can be considered, some technological parameters (e.g. max. shifting time) must be defined for both of these DSR cases. The most important technical characteristics to be considered are the technical restrictions for minimum and maximum load (e.g. decrease of load of Power-to-Heat appliances in industrial processes could be restricted according to the allowable temperature range of the process) and time restrictions for the flexibility activation. Here, the modeller should consider that not an individual DSR resource is assessed but rather a pool of all flexible resources of the same type within a country. Thereby, it may be reasonable to relax technical constraints at pool level in comparison to an individual asset (e. g. ramping constraints or the duration of activation).

3. In the third step, non-technical implementation barriers are assessed to derive the **achievable potential**. These additional barriers are of an administrative or regulatory nature or related to the acceptance of flexibilization measures by flexibility providers such as electric vehicle (EV) owners or industrial plant operators.
4. Lastly, the **economic potential** is derived by accounting for the economic viability of DSR resources. To do so, the modeller needs to estimate cost parameters (fixed, variable cost) for load shifting and load shedding. Only for load shedding, the opportunity costs (e.g., of production that cannot take place during the time load is shed) must be considered. These parameters can be used as input for the economic viability assessment (EVA).[9] As part of the EVA the various revenue streams for DSR resources stemming from different DSR mechanisms are considered. For the DSR potential assessment itself, however, these revenue stream can be neglected.

Handling of design choices

In cases where more than one approach exists to calculate a certain parameter, the modeller must decide which approach to use. One approach may be easier to implement because it requires less data research, but it may be less accurate. The implications of choosing either of the possible approaches are outlined in the text. If the required data is available, we recommend using the simpler approach as the must-have option. The plausibility check and sensitivity analyses proposed in step 5 can ensure a reliable assessment even with the simpler approach.

In addition, the modeller needs to consider various design choices, when performing a DSR potential assessment. These design choices are highlighted in the flowchart (numbered red ball in Figure 2) and concern e. g. the handling of in- and out-of-the market DSR resources. Differentiating between these in- and out-of-the market potentials, as well as implicit and explicit potentials are of particular importance. Depending on the type of DSR resource considered and the setup of the RAA, there are several options for which results from the DSR potential assessment should be used as input for the RAA. [10]

The first distinction can be made between **implicit and explicit DSR resources**. Implicit DSR resources respond to static or dynamic price-based signals by adjusting their normal or current consumption pattern on a voluntary base. This change can be self-directed or directed by an energy service provider. Examples for incentives for implicit DSR include time-of-use electricity tariffs which encourage households to shift their demand to off-peak times.

Explicit DSR resources, on the other hand, participate in organised markets or classical load control programs to offer their flexibility. They are activated by a control signal, making them a dispatchable resource from a system operator's perspective. The different implicit/explicit DSR options are illustrated in Figure 5.

[9] See separate report on the EVA within RAA.

[10] See also report 1 on WP 2. Therein, also definitions for in-the-market/out-of-the-market resources are given as well for implicit and explicit DSR.

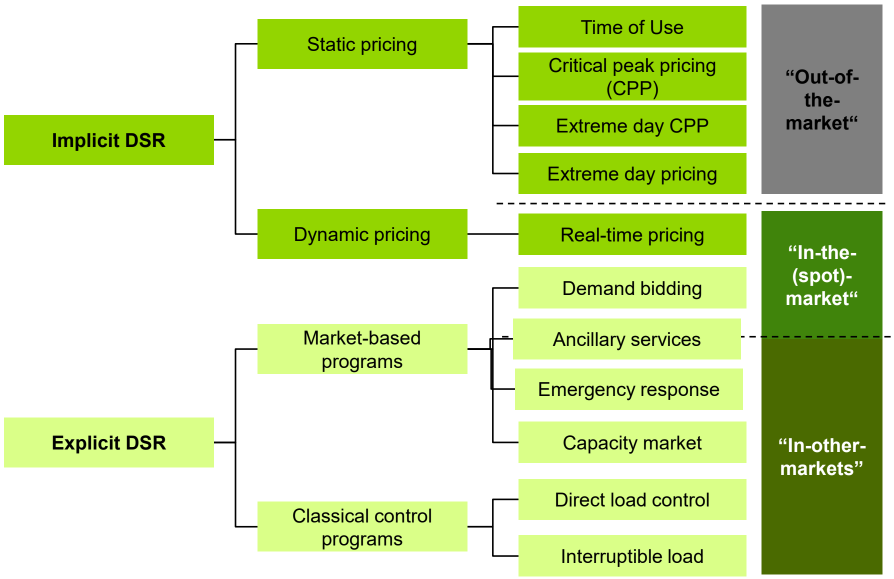


Figure 5: Relation between implicit vs. explicit DSR and in-the-market vs. out-of-the-market DSR resources[11]

Figure 5 also shows how the categorization of implicit and explicit DSR relates to another important differentiation for DSR, namely the differentiation between **out-of-the-market and in-the-market DSR resources**. In the following, we address the different modelling options for out-of-the-market and in-the-market DSR resources for RAA:[12]

- **Out-of-the-market DSR** reacts to static price signals, i.e. price signals that are not directly linked to spot market prices (e.g. EV charging based on Time-of-Use tariffs, peak shaving from small-scale batteries). These resources are included in the demand time series and used as fixed input for the RAA. Respective input data for the RAA in the form of hourly load profiles is derived in step 1.
- **In-the-market DSR** is directly linked to spot market prices, i. e. respective resources react to real-time electricity tariffs. These resources can either be modelled exogenously and used as fixed input for the RAA or modelled endogenously within the RAA.
    - To model DSR resources exogenously, a unit commitment and economic dispatch (UCED) model is used that is linked with the RAA model through the price time series. Based on the results of the UCED model an economic valuation can be done. The exogenously determined economic potential is used as fixed input (demand time series) for the RAA.
    - To model DSR endogenously within the RAA, the theoretical potential as well as techno-economic parameters are used as input. The economic potential is then derived by the EVA as part of the RAA. Notably, the technical and achievable potential are not calculated separately since respective constraints are considered in the EVA as well.

[11] Own illustration based on Albadi, M. H., El-Saadany, E. F. (2007) (see also report 1 of WP 2).

[12] ACER (2020) defines "out-of-market capacity" as any resources that are not wholesale market-based including strategic reserves. For DSR, this relates to DSR resources that change their demand behavior either based on static price signals or direct activation by a third party. Since the modelling of these "out-of-market" DSR options can be handled differently, we further differentiate between DSR options "in-other-markets" (activation by third party) and actual "out-of-market" (reaction to static price signal). The reaction to real-time prices and demand bidding refers to DSR participation in day-ahead and intraday markets and falls into the "in-the-market" category.

For balancing markets (FCR, FRR), being the most important mechanism within the category “in-other-markets”, two options exist to model explicit DSR resources in the RAA:[13]

- Units committed to balancing markets could be modelled in the RAA with a capacity reduced by the amount of capacity reserved for that mechanism. That means, that the respective unit is split into an implicit and an explicit part in the DSR potential assessment. Whilst the former is modelled as an in-the-market-resource, the latter is deducted from the available supply.
- However, if units in the balancing market are represented in the RAA by an increased demand (i. e. conventional demand plus reserve needs), it is not necessary to differentiate between implicit and explicit DSR resources in the potential assessment. Instead, the full capacity of a unit can be considered as an in-the-market resource.

Further ancillary services and capacity markets (“in-other-markets”) are not considered in the unit commitment and economic dispatch (UCED) modelling. However, these other markets may provide additional revenue streams to units active in the market. Therefore, they should be considered within the EVA[14].Whilst the order of steps 2 to 4 is somewhat interchangeable in the sense that in each step further constraints are taken into account, we chose this particular order to reflect the needs of the RAA modelling. The estimation of the economic potential needs to be the last step in the assessment since this type of potential assessment will be realized as part of the RAA itself, by means of the EVA.

Due to the great variety of DSR options, the modeller needs a wealth of data to perform a DSR potential assessment. Several typical data sources should be considered:[15]

- **Literature** provides data such as techno-economic parameters on many DSR options and can be a starting point for the analysis.
- Statistical **data bases**, industry associations, market size assessments or original equipment manufacturers (OEMs) such as EV or heat pump producers are a good source for the data needed to estimate the overall energy demand of a certain DSR resource.
- **Interviews and surveys** are cumbersome to implement but provide insights where other data sources are missing.[16]
- **Aggregators** and flexibility service providers have in-depth knowledge on the flexibilities they market (incl. market size, techno-economic parameters, operation modes) as well as non-technical barriers to flexibilization. Moreover, they are often active in several countries. Therefore, aggregators are uniquely positioned to contribute data and insights to DSR potential assessments.

In general, literature and statistical data bases require less research effort than interviews and surveys. Statistical data bases are especially relevant to perform top-down analysis for a certain DSR option. A bottom-up approach, on the other hand, will most likely require interviews and surveys due to the level of detail required. We also recommend conducting interviews to determine the achievable potential. The flowcharts provide a prioritization of data sources related to which approach we propose to use to determine a particular parameter and suggests the most pragmatic approach. Nevertheless, the sources can be considered complementary. Details on the implications of using the different data sources and how they can complement each other are described in Ch. 4. For any data source, the modeller

[13] See ACER - Methodology for the European resource adequacy assessment, Art. 4 (6) g

[14] See report of work package 3 on the methodology for the EVA.

[15] An in-depth assessment of available data sources for RAA, including the DSR potential assessment, is provided by the report on WP 1 and therefore not part of this report.

[16] See also report 1 on WP 2 for a description of various DSR potential assessment methods including interviews/surveys.

should be aware of the uncertainty incorporated in the data and perform a sensitivity analysis (see Ch. 6), if necessary. Sources for uncertainty are:

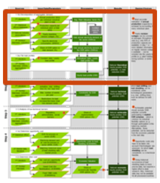
- **Diversity of technologies:** Even within a specific type of DSR resource differences in techno-economic parameters as well as operation modes exist. Within the DSR potential assessment not a single DSR resource is considered but rather the full stock of all resources within a country. Consequently, modellers need to assess and describe an average DSR resource. Deriving average figures is usually done by considering only a small set of resources and not the full stock, and thereby incorporates uncertainty. To better reflect the differences within a certain type of DSR resources, modeller may differentiate between archetypes of a DSR resource in his assessment (e. g. EVs could be distinguished in EVs charged at home, EVs charged on public charging points, EVs within a fleet).
- **Prior knowledge of interviewees:** Due to a lack of prior knowledge on the topic of flexibilization interviewees and survey respondents may not be able to properly assess flexibility potentials or techno-economic parameters of their DSR resources. Therefore, interviews should be preferred over surveys since interviewers may guide the interviewees and establish a common understanding of the topic before the interview. Unsupervised surveys should only be performed with knowledgeable survey respondents such as aggregators to avoid unusable data outputs.
- **Transferability of data:** Whilst there is a relatively large amount of data available for some countries there may be a lack of literature and data on DSR in other countries. Whilst technical, and to a lesser extent economical, parameters for DSR options can be transferred from one country to another, it increases uncertainty in the assessment.

The flowcharts for relevant DSR technologies are shown in their full detail in the **Appendix** of this report. To illustrate the use of the flowcharts, the following chapter provides a deep dive into a selected flowchart.

4 Deep dive: DSR potential assessment for flexibility options in energy-intensive industries (Flowchart A)

The flowchart for DSR options in energy-intensive industries (Flowchart A – Production Processes) is displayed in Figure 6. It resembles the generic flowchart, Figure 4, and details it for the considered DSR option – in this case, energy intensive industries. The flowchart shown can be used to assess the flexibility of industrial processes with generally flat load profiles, i. e. processes with a very high load factor and constant operation. These processes include pulp and paper production, air separation in the chemicals sector, glass production, steel production and electrolysis processes in the non-ferrous metals industry.

In the following, we will detail each step of our methodological guidelines for the assessment of DSR potential from these industries, highlighting where different approaches may be used by the modeller. Different data sources – as a starting point for different approaches – that might be used by the modeller are listed in the flowchart according to the effort needed to make use of them. The easiest method, usually the literature analysis, is listed first.



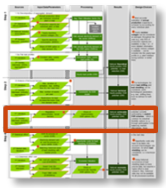
Step 1 – Estimation of the theoretical potential: Initially, we estimate the theoretical potential of the process, by breaking down the industry branch's overall demand into a flexible and non-flexible part (decomposition). The least cumbersome approach is to directly use figures for the overall demand of all industrial plants of a certain industry branch in a country. This energy demand can be combined with the flexible process' percentage share in the energy demand from the literature or statistical databases to calculate the energy demand of the flexible process. More precise, however, is a bottom-up assessment of the energy demand using the production capacity of each individual industrial plant and the specific electricity consumption per ton of good produced. Respective data may be obtained from the national industry association for each industry branch considered. The modeller needs to keep in mind, that when using the production capacity of the plants to assess the overall energy demand, plant downtime (e. g. revision outages, plant holidays) needs to be considered as well. Moreover, a distinction between in-the-market and out-of-the market resources (see Ch. 3) is needed.

Additionally, stakeholder surveys or interviews may lead to more precise bottom-up data than could be achieved through literature reviews. Surveys and/or interviews, however, require greater resources by the modeller. On the other hand, if interviews/surveys are performed they should be used to obtain relevant data needed for the whole assessment process. A compromise is to implement surveys/interviews every few (e. g. 3-4) years, use the resulting data for several years or potentially update figures based on new publications in the years in between.

Next, we use the flexible process' demand to scale the process' load profile, which reasonably can be assumed to be flat, according to relevant literature. However, more precise information on the load profile might be obtained from the DSOs connecting the considered industry plants or aggregators marketing the plants flexibility. We obtain an hourly load profile representing the technical potential of the considered process.

Step 2 – Estimation of the technical potential: Now, we assess the technical barriers restricting load shifting and load shedding for the considered processes – with the latter being particularly important for energy-intensive processes. The results are used as input for the DSR model in the economic dispatch, which gives us the technical potential.

All above-mentioned processes have been analysed in the literature frequently. Thus, direct use of literature values for the technical restrictions is an efficient approach and it can be reasonably assumed, that technical production parameters do not differ between individual countries. Once again, more precise and up-to-date parameters may be obtained from interviews/surveys.



Step 3 – Estimation of the achievable potential: Like the previous step, we can assess the non-technical barriers to flexibilization, e. g. administrative barriers, either through literature analysis or surveys/interviews with industry stakeholders or aggregators. The result of the semi-quantitative analysis is an assessment of the percentage share of flexible assets which participate in DSR mechanisms. As detailed in Ch. 3, the modeller needs to differentiate between flexible assets committed to explicit DSR mechanisms, e. g. balancing mechanisms, and those active in-the-market. Potentials for the former may be obtained from TSOs and should be deducted from the overall achievable potential.

Step 4 – Estimation of the economic potential: Lastly, we estimate financial parameters for the considered DSR options, which will be used as input for the economic valuation and thereby determine the economic potential. Financial parameters obtained from literature are a starting point but can be complemented by data obtained from industry stakeholders and aggregators via surveys/interviews. For example, the experience of aggregators show that cost parameters may be adjusted upwards to reflect the risk aversity of some industry stakeholders. Even if DSR might be economically feasible, respective DSR providers may require a price premium for load shifting/shedding compared to their normal mode of operation.

Here, the modeller should consider including several cost-potential branches, reflecting that higher flexibility potentials can be dispatched at higher cost. At least, low-cost load shifting and high-cost load shedding potentials should be considered. The former requires the estimation of the variable cost of the flexibility use. Whereas the latter requires the estimation of the industry processes' opportunity cost. The opportunity costs are estimated based on statistical data, by relating the industry's gross value added to its energy consumption.[17] Of course, opportunity cost only must be considered for technologies, for which load shedding is a feasible option. An alternative, more cumbersome approach, based on desk research, may analyse recent load shedding events and the spot market prices at which they occur.

[17] For a detailed methodology for the assessment of opportunity cost, see r2b et al. (2014)

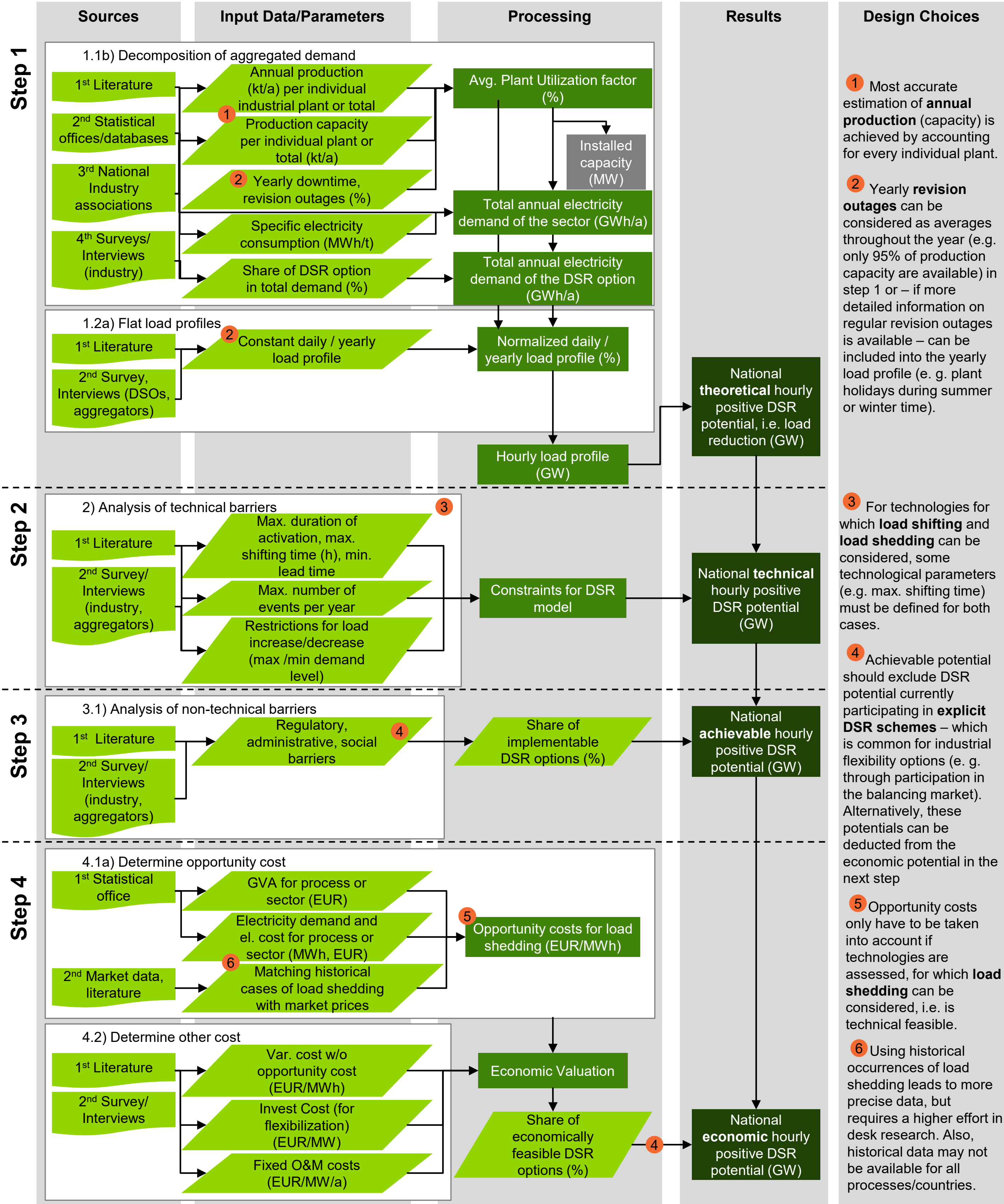
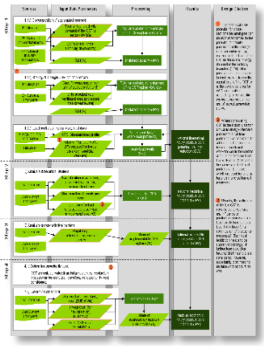


Figure 6: Flowchart A – DSR potential assessment for energy-intensive industries

5 Consideration of specificities to cover different DSR options

Ch. 4 uses the flowchart for energy-intensive industries to illustrate methodological guidelines for DSR potential assessments in this field. Five additional flow charts, all shown in their entirety in the **Appendix** to this report, were created for the assessment of the other technologies introduced in Ch. 2. In the following, we will briefly introduce each of these five flowcharts, focusing on specificities.

5.1 DSR potential of cross-sectional technologies in industry and commercial, trade and services (Flowchart B)

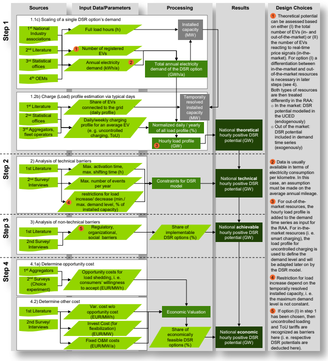


Cross-sectional technologies (CST) are widely applied throughout industry as well as the commercial, trade and services (CTS) sector. CST covered by this flowchart include ventilation, process cooling and heating, cold storage, pumps in fresh water and wastewater treatment. The flowchart covering methodological guidelines for this type of DSR potential is illustrated in Figure 8. Due to dispersed nature, we can reasonably assume that CST follow the same load profiles as the sectors in which they are applied in – flat profiles in industry due to round-the-clock production (see Ch. 4) or standard load profiles for the CTS sector. For the latter, however, a differentiation between typical days is needed (weekend, weekday). For air conditioning, which is dependent on the outside temperature, load profiles would have to be designed in a temperature-dependent fashion, similar to load profiles for heating appliances in the household sector (see Ch. 5.4).

The flowchart shows that there are two principal approaches that could be used to estimate the installed capacity of CST – and thereby the theoretical DSR potential: (1) estimating the share of a specific CST in the overall demand of the sector (top-down decomposition), or (2) estimating the “output” generated by a CST in a certain sector (e. g. the litres of wastewater processed) and scaling it according to the specific energy demand per unit of “output” generated (bottom-up scaling). The latter requires a broader base of input data and more efforts by the modeller, which makes the top-down decomposition approach the simpler approach in terms of data requirements. However, the data needed for the first approach may not be readily available from statistical databases or similar sources. In addition, the scaling approach allows to further differentiate within a certain type of DSR option (e. g. different operating modes or technical setups) and therefore leads to a more precise assessment.

To estimate the technical and economic DSR potential for CST, we assume that the flexibility potential of these technologies is only utilized if it does not affect the overall level of production of the respective industry or CTS branches, e. g. by using the inherent thermal storage capacity within a process. Hence, the flowchart indicates that opportunity costs are not considered for CST in CTS and industry. Consequently, variable cost for using CST flexibility is usually low (e. g. minor loss in efficiency) and can be assumed to be zero. Nevertheless, investment cost must be considered, such as investments for energy management systems to steer the DSR use.

5.2 DSR potential of Power-to-X – Electric vehicles (Flowchart C)



The DSR potential of EVs will be of increasing importance in the future. In contrast to other DSR options, the maximum available capacity for EVs is not constant, as it varies throughout the day with the share of vehicles connected to the grid. The flowchart for assessing their potential is shown in Figure 9.

As illustrated in the flowchart, the theoretical potential (step 1) depends on the annual electricity demand and the charging time, i.e. the (uncontrolled) charging profile. To determine the nation-wide annual electricity demand of EVs, we use a bottom-up approach, i.e., scaling up the DSR option. Data is usually available in terms of electricity consumption per kilometre. In this case, an assumption must be made on the average annual mileage to determine the annual electricity demand per vehicle. For the number of EVs, as shown in the flowchart, the modeller must decide whether (I) the total number of EVs (in- and out-of-the-market) or (II) the number of EVs reacting to real-time price signals including V2G (in-the-market) is considered. For option (I) a differentiation between in-the-market and out-of-the-market resources is necessary in later steps. Both types of resources are then treated differently in the RAA. In-the-market DSR potential will be modelled in the UCED, while out-of-the-market DSR potential will be included in demand time series. Regarding the daily/weekly charging profile a higher accuracy can be obtained if different types of charging profiles are distinguished (e.g. uncontrolled charging, ToU charging).

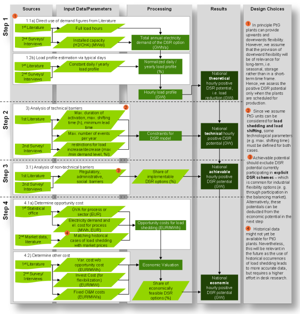
V2G may become a relevant operation mode for EV charging in the future, due to the rollout of suitable charging point infrastructure and EVs as well as changes in the regulatory framework. Therefore, the modeller should assume that a certain share of the EV fleet that is capable of bi-directional charging. For this share of EVs, the technical constraints differ in step 2. In case of discharging, the load would be negative (equal to the maximum capacity of the respective charging point) for the respective hour – instead of zero as it is the case unidirectional charging. The maximum activation time would describe the volume of the storage. Additionally, an efficiency rate should be assumed to account for losses throughout the charging/discharging cycle.

In case option I (assuming the total number or share of the technology) has been chosen, Time-of-Use (ToU) tariffs need to be recognized as barrier in step 3. This ensures that only the share of EVs and related potential that is currently responsive to prices is considered in the RAA. If the number of EVs was already limited in step 1 (by choosing option II), a further reduction of the potential is not necessary to estimate the achievable potential.

The economic potential can also be determined exogenously, without using an EVA. In that case, we would assume that it is no strictly rational decision for all end user (but for some) to flexibilise the EV (investment cost of flexibilization vs. additional savings/revenues), e. g. by installing smart charging infrastructure at home. Rather, based on expert opinion, we would assume a certain share of EVs are using smart charging and thereby react to spot market prices.

If load shedding is considered for EVs, it should be limited to very rare occurrences, since EV aggregators' experience shows that customer acceptance for load shedding (i. e. the induced loss of comfort) is very limited.

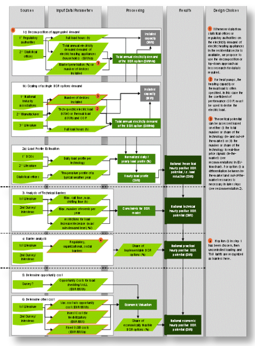
5.3 DSR potential of Power-to-X – Power-to-Gas (Flowchart D)



In addition to EVs, another Power-to-X-technology that is of great importance as DSR option for the future is Power-to-Gas (PtG). This includes PtG plants that produce either methane or hydrogen. We focus on the DSR potential that the plants can provide when they are scheduled for production, and do not consider the case of storage and subsequent re-electrification of hydrogen. The respective flowchart to assess the DSR potential is illustrated in Figure 10.

The flowchart shows that we use the estimated installed capacity and full load hours of the plants to derive the total annual electricity demand of PtG units in step 1. Values for currently installed capacities can be taken from literature, which provides an overview of the status quo of pilot projects or own market research. In the subsequent steps, we handle the assessment of the DSR potential of PtG similarly to that of energy intensive industries and assume the load profile to be constant throughout the day and year[18] (see Ch. 4). Accordingly, the design options/recommendations for estimating the technical, achievable, and economic potential stated for energy-intensive industry also apply to the PtG-case.

5.4 DSR potential of cross-sectional technologies in households (Flowchart E)



In the residential sector, electric heating appliances are particularly relevant as DSR options. This includes resistive heaters (today) and heat pumps (today and with large potential in the future). Both technologies can be assessed using the flowchart for cross-sectional technologies in households with temperature dependent load profiles depicted in Figure 11.

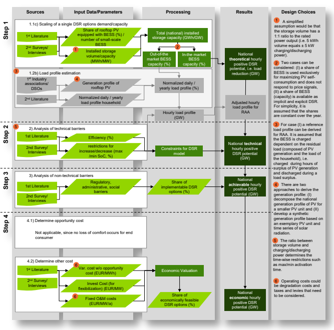
The flowchart shows that there are two approaches to determine the annual electricity demand in step 1. An approach commonly used is a bottom-up approach, i.e., by scaling up the DSR option. Data on technology specific values can usually be found on websites or publications from industry associations and manufacturers. For heat pumps, it is common to specify the thermal load. In this case, the electrical load can be derived with the coefficient of performance (COP). Whenever data from statistical offices or regulatory authorities on the electricity demand of electric heating appliances in the residential sector is available, we propose to use the decomposition or top-down approach as less research for data is required. However, in this case, it must be noted that to determine the future potential, assumptions must be made regarding both the future development of the total annual electricity demand of electric heating appliances and the market penetration of the specific technology. For both approaches, the modeller needs to decide whether (I) the total number or share of the technology (in- and out-of-the-market) or (II) the number or share of the technology reacting to real-time price signals (in-the-market) (see explanations under 5.2) are considered. Lastly, a specificity within this step concerns the annual load profile. For both technologies, this is temperature dependent and hence varies over the year. We propose to use the normalized daily load profiles for resistive heaters and heat pumps published by the distribution grid operators (DSOs). These can be used in conjunction with the temperature profile of a typical weather year to derive an annual profile. In case of a large number of DSOs and hence a

[18] We assume that electrolysers are mainly operated to meet a certain production volume of methane or hydrogen per year (or run the assumed number of full load hours). Nevertheless, as an in-the-market DSR option, the load profile will respond to electricity prices when endogenously modelled in the economic valuation (step 4).

large variety of profiles, we suggest selecting profiles from representative areas within a country. The synthetic load profile then results from the average of the individual load profiles.

In case option I (assuming the total number or share of the technology) has been chosen in step 1, ToU tariffs are recognized as barriers to estimate the achievable potential in step 3. Lastly, in step 4 it is noted in the flowchart that usually only the DSR potential for load shifting is taken into account for electric heating appliances. Without considering fuel switching, the costs for load shedding may be valued at the customer's willingness to accept the induced loss of comfort. Similar to EVs, industry experience suggests that load shedding for electric heating – if considered – should be limited to very rare occurrences.

5.5 DSR potential of behind-the-meter battery storages (Flowchart F)



Also of particular importance as a DSR option are behind-the-meter (BTM) battery storage systems in the residential sector and potentially back-up battery storage systems in the CTS sector in the future. The flowchart focuses on the first case, but with slight adjustments it could also be used to evaluate the potential of back-up batteries. The last paragraph discusses the needed adjustments. The majority of these storage systems are currently installed in combination with a rooftop photovoltaic (PV) system. This also means that the main share of installed BTM battery storage systems are currently operated primarily to maximize PV self-consumption and does not respond to (real-time) price signals. How and at which steps this differentiation needs to be made is outlined in detail in Figure 12.

First, the scaling up approach can be used to determine the installed storage capacity. For this, an average value for volume of small-scale battery storage must be assumed. A simplified assumption would be that the storage volume has a 1:1 ratio to the rated power output. In order to scale this figure, either the number of installed BTM battery storage systems can be used, or an assumption can be made on the share of rooftop PV systems equipped with a battery storage. Especially in light of future developments, the total installed storage capacity should be separated in an in- and out-of-the market share.[19] For simplicity, this share is assumed to be constant over the year. For the out-of-the market share, we show in the flowchart in step 1 how a reference profile for the BTM battery storage can be derived, which in combination with technical parameters is a direct input to the demand time series in the RAA. For the price responsive in-the-market share, we assume that the technical constraints can be used to model the DSR potential within the EVA. The theoretical potential of batteries is restricted by the round-trip efficiency and the advised minimum and maximum level of State of Charge.

Finally, the flowchart shows that there is one more specificity to be considered in step 4. We do consider the load shedding as not applicable for this case. Since we are assuming a use case here where the battery is optimized according to market signals, there is no loss of comfort for the end consumer in providing the flexibility.

[19] Currently, the requirement in ACER (2020) foresees that small-scale batteries behind the meter should be considered as "out-of-market" and peak shaving from these assets shall be considered when developing the electricity demand time-series.

For back-up batteries, an assumption must also be made about the number of batteries installed and their average capacity. As different branches (e.g., retail, data centres) within the CTS sector are considered with varying amounts of batteries installed, a differentiation according to branches might be considered. Interviews with aggregators could be helpful to gather data. There are then two options to proceed. Either we exclude a share of the installed capacity of batteries in the first step, because a decisive proportion of their capacity will be reserved for site reliability purposes, or this share is considered as a technical restriction on the next step. In general, however, the in-the-market path outlined in the flowchart can be followed to assess the back-up battery potential.

6 Scenarios and plausibility check for the assessment results

To account for future developments and validate the results, we embed the described main flowcharts in a preceding step 0 and a subsequent step 5.

Step 0 – Scenarios:

- **Analysis of the future DSR potential**: With respect to the target year under consideration in the Resource Adequacy Assessment, assumptions must be made regarding the development of DSR potentials. In order to account for future developments, the parameters named under step 0 in Figure 7 should be adjusted over time. For each technology, it must be decided which parameters are relevant and how they should be adjusted. Of particular importance for the assessment of future DSR potential is the development of the market penetration of a given technology. Special focus should be given to the development of EVs and heat pumps based on future electrification levels, as well as the development of hydrogen, which will determine the market penetration of electrolysers. For small-scale DSR options (EVs, heat pumps), special attention should be paid to the development of regulatory barriers and thus the assumptions of achievable potential in scenarios. Grid development plans can be used as a reference for deriving future scenarios, ensuring consistency throughout different analyses performed by grid operators (e. g. ERAA, TYNDP). National energy and climate plans could be another source for the development of future scenarios. However, these are not yet updated according to the Fit for 55 Package and may differ widely on their level of detail by country. The updated climate and energy goals could be used as supplementary source.

- **Analysis of sensitivities:** Some data are subject to uncertainties. Firstly, because a large proportion of DSR options are not yet active in the market and there is a smaller database, and secondly because DSR options can be very heterogeneous. Even within a certain type of flexible assets strong differences in techno-economic parameters, annual demand and load profile may exist. Therefore, sensitivity analyses should be performed for the input parameters which are subject to great uncertainties and at the same time can have strong influence on the assessment results if they vary. These parameters are the market uptake of new types of flexibilities, the development of non-technical barriers and cost parameters for small-scale DSR options (or for industries that are not yet active on the wholesale market).

Step 5 – Plausibility check: The estimated DSR potential can be validated by comparison with values found in literature or by applying methods based on a top-down approach and the use of market data. The latter can only be used to compare current DSR potentials in the market but adds further validity to the assessment. The results of the market results-based methods should be considered as a lower bound for the results of the proposed technology-based assessment. Therefore, we recommend performing such an analysis for current potentials in any case.[20]

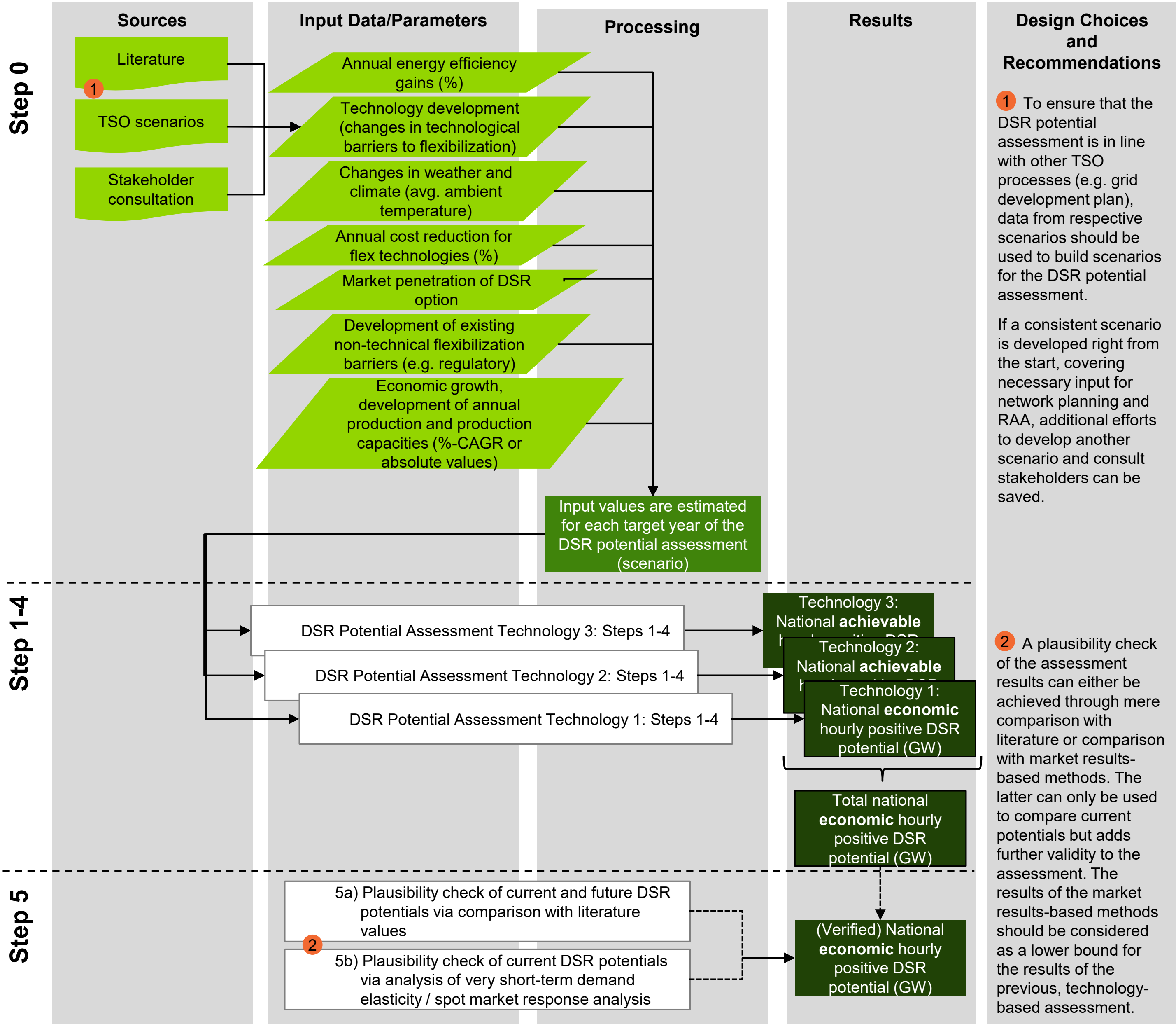


Figure 7: Flowchart for the assessment of future DSR potentials by means of scenario generation and plausibility checks for the assessment results

[20] An overview of relevant literature and more information on top-down market-data based methods can be found in the first report of work package 2.

7 Conclusions

Currently, no universally accepted methodology to assess the potential and costs of DSR exists. The developed flowcharts provide modellers with an intuitive methodology for the assessment of DSR potentials of various technologies. Since a flowchart may be applied for a group of technologies with similar characteristics, we were able to cover 20 DSR options which are of relevance today or in the future with six different flowcharts.

Although we account for technology specific differences with different flowcharts, all of them follow the same technology-independent structure and design. This structure consists of four steps: estimation of theoretical potential (step 1), technical potential (step 2), achievable potential (step 3), and economic potential (step 4). In order to account for future DSR potentials, sensitivities and to implement plausibility checks, the flowcharts are embedded in a precedent step 0 and a subsequent step 5.

In addition to being intuitive and covering a great variety of technologies, the flowcharts provide suggestions on data sources with a classification of which source should be considered first. Furthermore, they provide an overview of different methodological approaches to determine the annual electricity demand and differentiate between more simplified and more complex approaches. Not in all cases (or countries) may the data availability allow to choose the simpler approach. If the simpler approach can be used, it promises less effort for the modeller. However, this choice also has implications (e.g., data accuracy), which are described in the text. With regard to data accuracy, we assume that the described plausibility check and sensitivity analyses in step 5 can ensure a reliable assessment even with the simpler approach. Likewise, we outlined different categories of data sources which could be used by the modeller and discussed the issue of uncertainty in the assessment. The design choices given in the flowchart indicate at which step the modeller needs to make a decision, e. g., regarding the handling of in- and out-of-the market DSR resources. Our comprehensive and clearly structured approach thus takes a decisive step towards an accurate and reliable assessment of DSR in RAA in a transparent manner.

We outline that there are several options and forms in which DSR potentials can be incorporated into the modelling process of RAAs. In principle, this depends on whether in-the-market or out-of-the-market potentials are considered or how the modelling of implicit and explicit resources is dealt with in the RAA. We show at which step the modeller must distinguish between in- and out-of-the market potentials, or implicit and explicit potentials. Nevertheless, we see the need for further research for an evaluation of the different options illustrated. In a more in-depth analysis, the interlinkages between the DSR potential assessment and the RAA may be explored, e. g. the accuracy and computational effort of modelling parts of the DSR potential endogenously or exogenously.

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Appendix – Additional Flowcharts

DSR potential of cross-sectional technologies in industry and commercial, trade and services (Flowchart B)

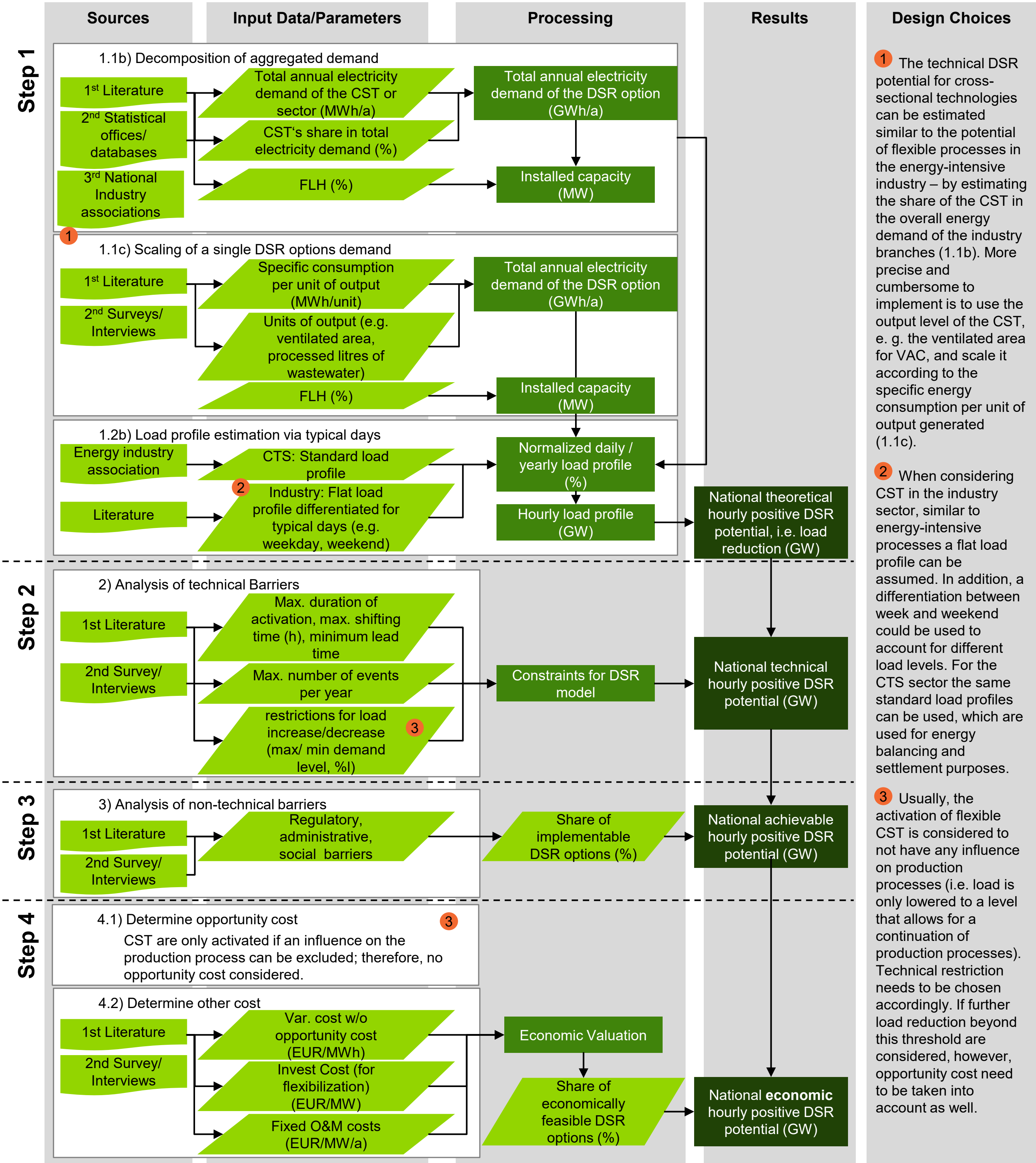

Figure 8: Flowchart B – DSR potential assessment for cross-sectional technologies in industry and commercial, trade and services

DSR potential of Power-to-X – Electric vehicles (Flowchart C)

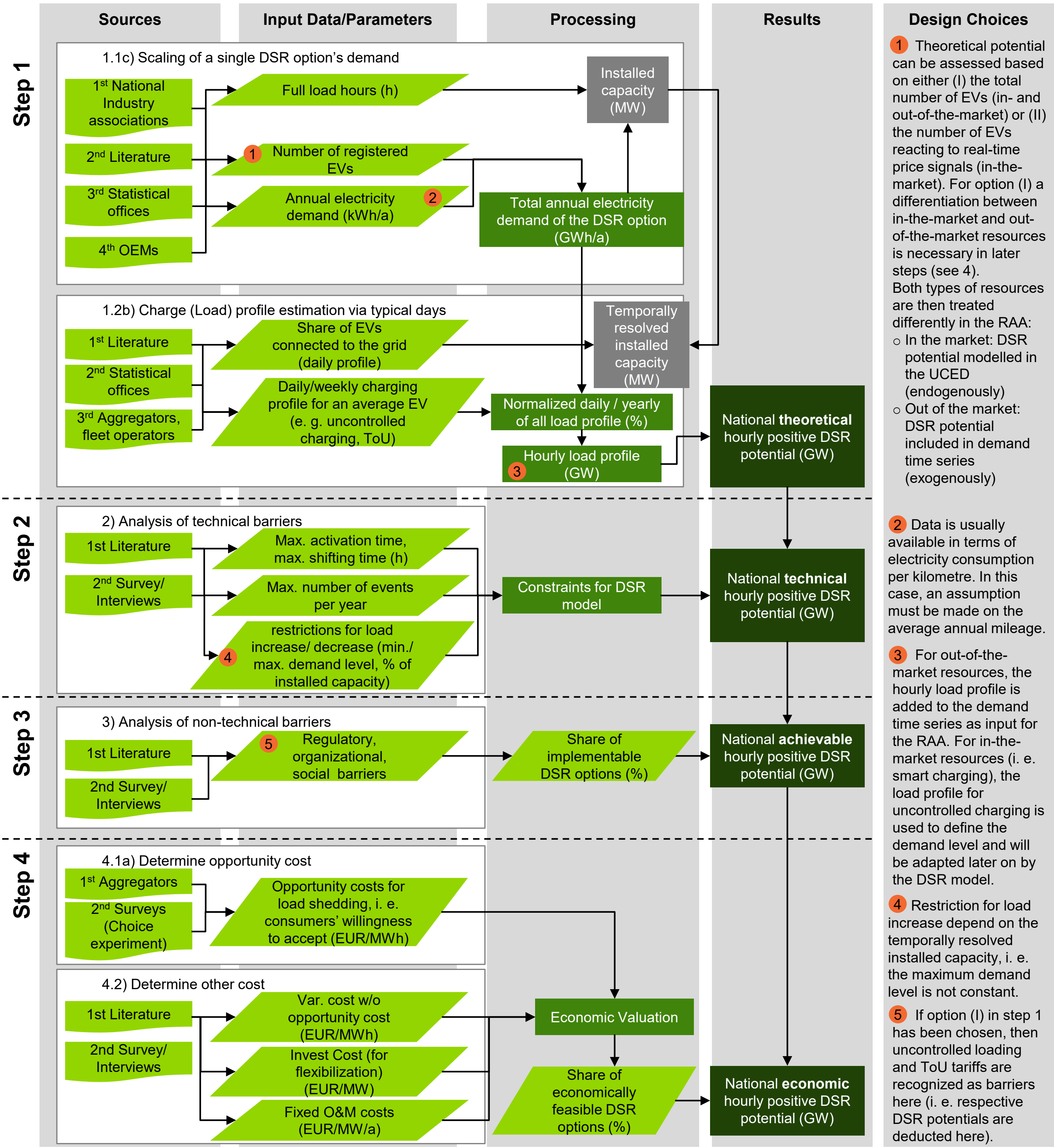

Figure 9: Flowchart C – DSR potential assessment for electric vehicles

DSR potential of Power-to-X – Power-to-Gas (Flowchart D)

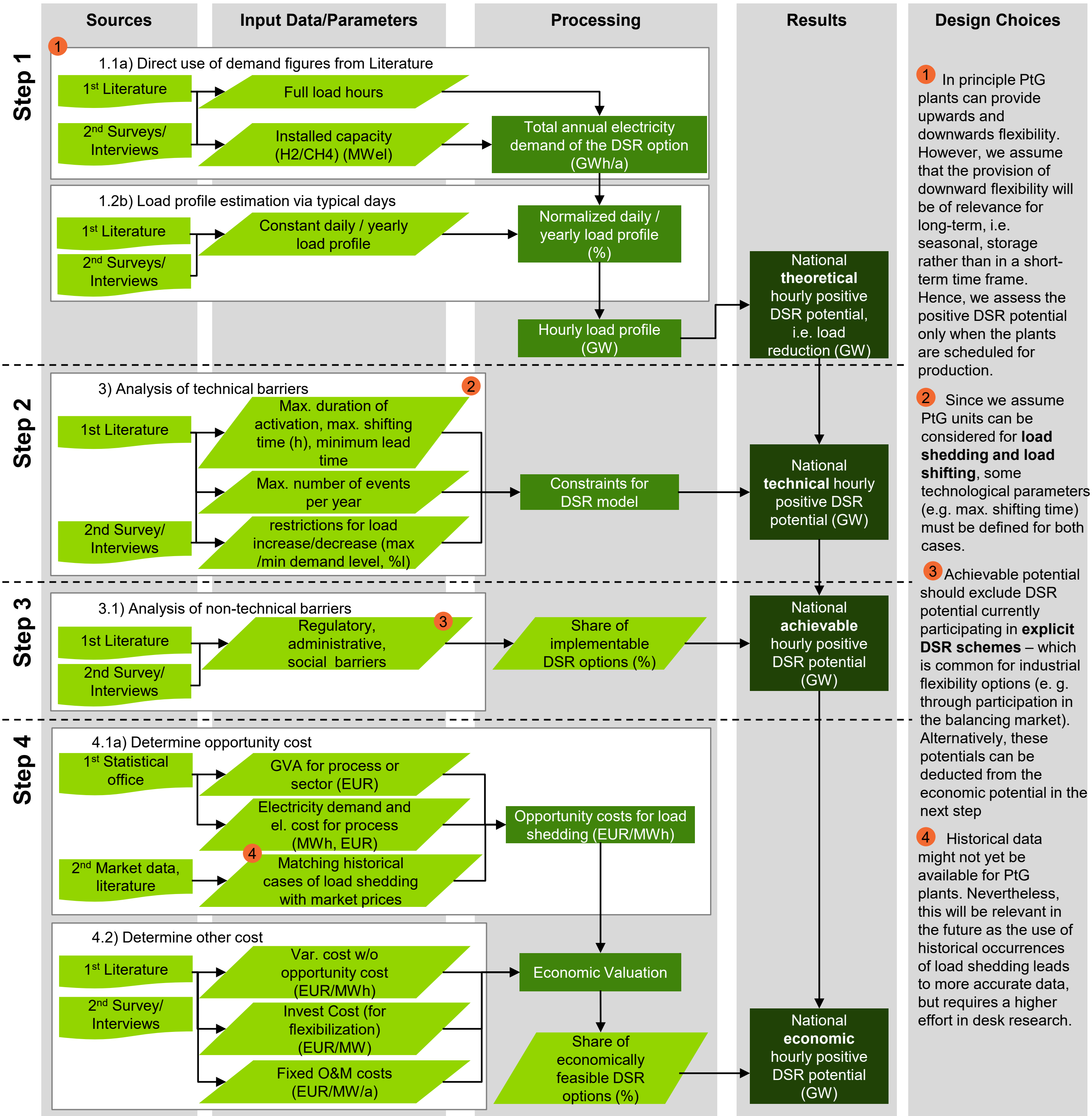

Figure 10: Flowchart D – DSR potential assessment for Power-to-Gas

DSR potential of cross-sectional technologies in households (Flowchart E)

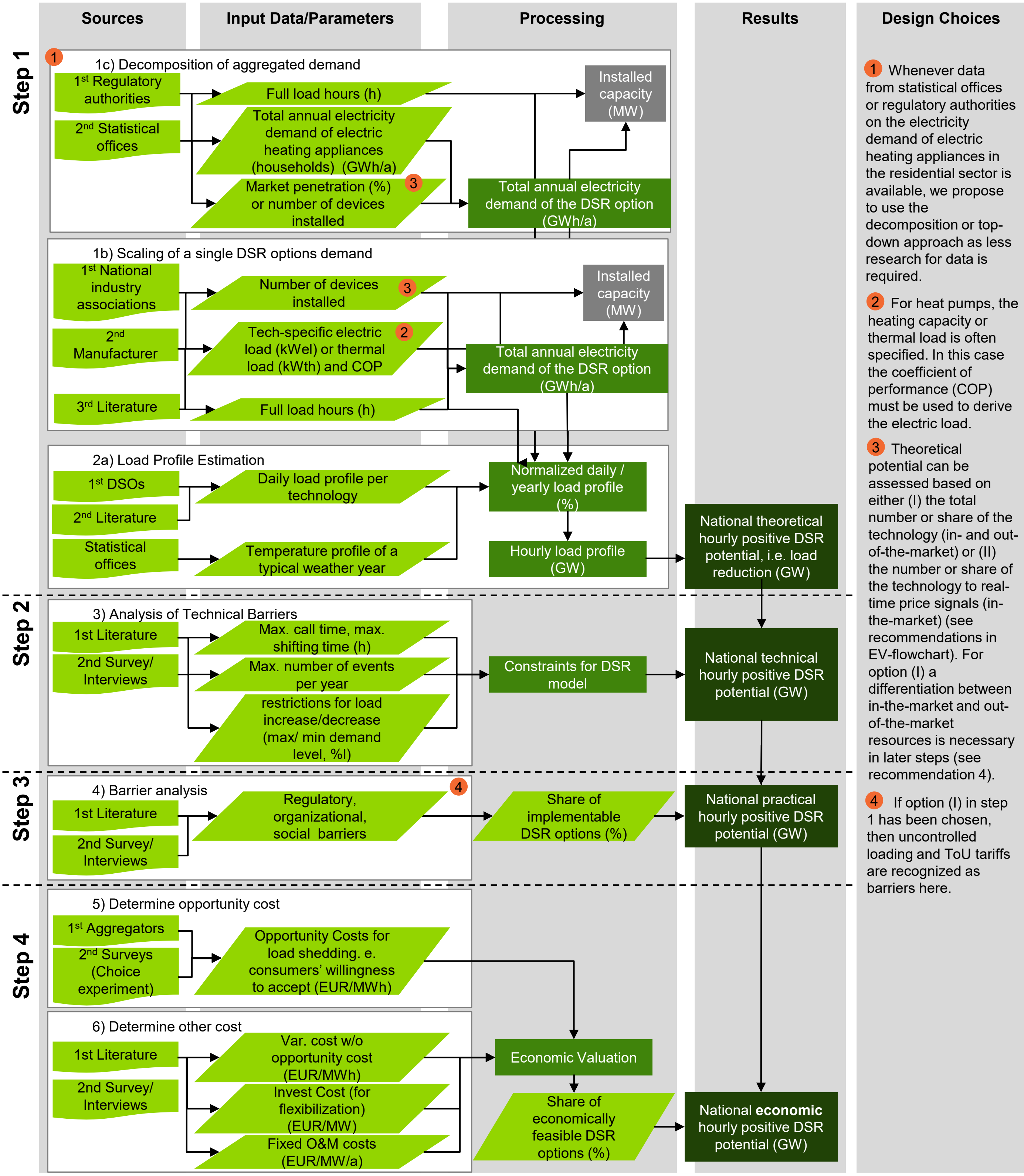

Figure 11: Flowchart E – DSR potential assessment for cross-sectional technologies in households

DSR potential of behind-the-meter battery storages (Flowchart F)

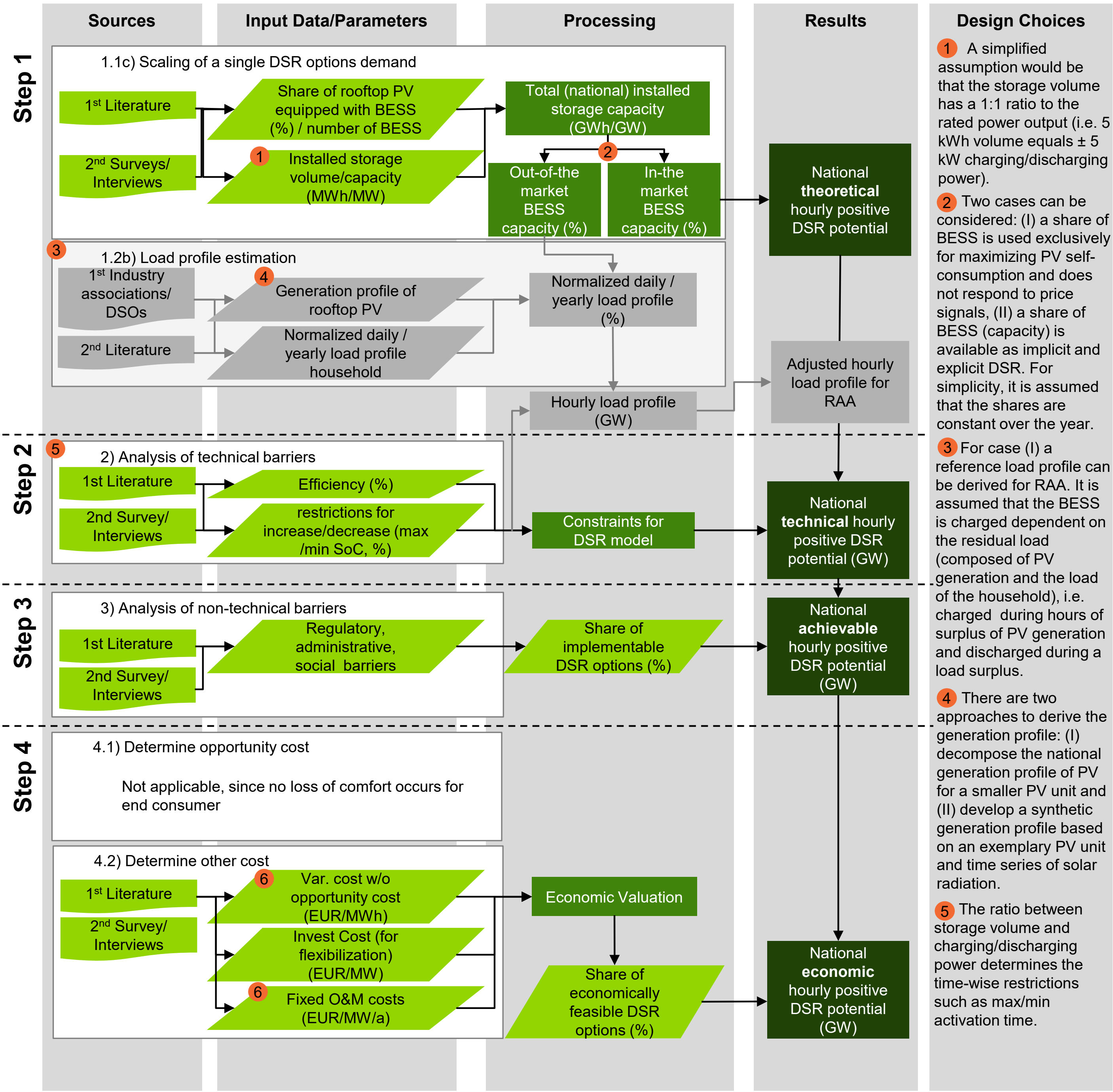

Figure 12: Flowchart F – DSR potential assessment of behind-the-meter battery storages