Flexi-Sync

DEFINITION OF FUTURE SCENARIOS

VERSION 1.0

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Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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EXECUTIVE SUMMARY

Scenarios form an essential part of climate change research and assessment. They help users to understand long-term consequences of near-term decisions and enable researchers to explore different possible futures in the context of fundamental future uncertainties.

The goal of Work Package 2 (WP2) in Flexi-Sync is to analyse the cost-efficient flexibility potential in the local or regional energy system. For this purpose, we design storylines or scenarios in which different sets of future energy system, energy markets and climate and energy policies are described and contrasted. Through scenario analysis in WP2, we will be able to provide the span of results on cost-efficient interactions between the district heating and electricity networks, and the building sector, while identifying the optimal investments in the demonstrator areas of Flexi-Sync by 2050 under different conditions and constraints.

The two scenario framings presented in this report, “100 % RES” and “Maximized flexibility”, have been identified based on a review of several scenario frameworks at international (global), regional, national, and urban (city) levels. The resulting scenario narratives have been fine-tuned with information from the local visions and development plans, as well as with input from stakeholders. The scenarios will later serve as basis for quantitative in-data assumptions for the modelling assessments to be performed in WP2 of the Flexi-Sync project.

1 INTRODUCTION

The goal of WP2 in the Flexi-Sync project is to estimate the cost-efficient flexibility potential in the local or regional energy system. There are three tasks to meet the goal. The first task, summarized in this report, is to define future scenarios in line with ambitious climate targets as well as relevant to estimate the cost-efficient flexibility potential in the local or regional energy systems of the Flexi-Sync demonstration sites. Scenarios form an essential part of climate change research and assessment. They help users to understand long-term consequences of near-term decisions and enables researchers to explore different possible futures in the context of fundamental future uncertainties [1].

Börjeson et al. [2] divided scenario typologies that are used for future studies into three categories and six types. The classification of categories is based on the principal questions that a user may want to raise about the future. These are *"What will happen?"* (i.e predictive), *"What can happen?"* (i.e. explorative) and *"How can a specific target be reached?"* (i.e. normative). Then each category is divided into two groups allowing for increasing the resolution. The categories and groups are presented in Figure 1.

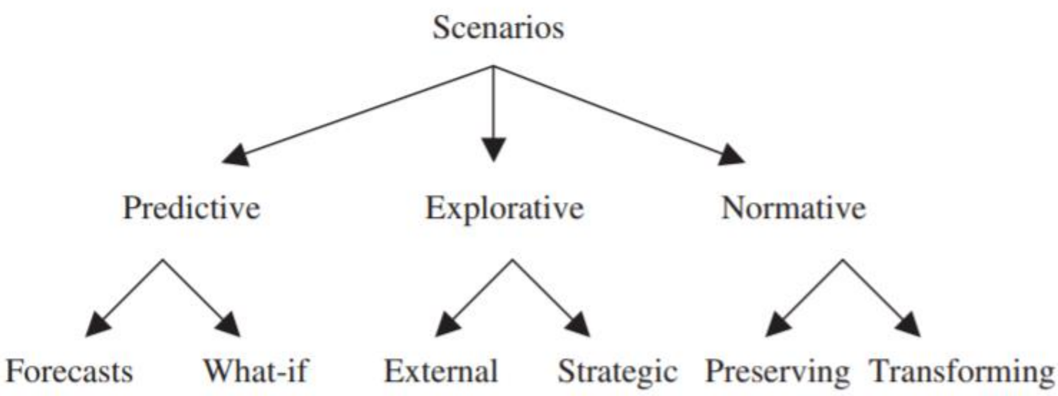

Figure 1- Scenario typology categories and types [2]

The explorative scenarios are divided into two types, external scenarios and strategic scenarios. External scenarios respond to the question *"What can happen to the development of external factors?"* and strategic scenarios respond to the *question "What can happen if we act in a certain way?"* [2].

The aim of explorative scenarios is to explore situations or developments that are regarded as possible to happen. The scenarios are elaborated with a long time-horizon to explicitly allow for structural, and hence more profound, changes. Explorative scenarios can also be used when the user has good knowledge regarding how the system works at present but is interested in exploring the consequences of alternative developments. Thus, explorative scenarios are mainly useful in the case of strategic issues [2].

In the Flexi-Sync project, explorative scenarios will help in the understanding of cost-efficient interactions between the district heating and electricity networks, and the building sector, as well as to identity optimal investments in the Flexi-Sync demonstrator areas by 2050.

1.1 Aim

The aim of this report is to identify a set of scenario framings corresponding to well-known scenarios at different geographical scope and that are of relevance for the assessment of district heating flexibility potential in future 100% renewable energy at the city or sub-national level.

The scenario framings will help to navigate the assumptions for the energy system modelling performed within the Flexi-Sync project; the proposed scenario framings will be further translated into input to the modelling assessments, performed within WP2. The result of the energy system modelling will be presented in D2.3.

2 METHOD

To develop future scenario framings that could be used for assessing the cost-efficient flexibility potential in the local or regional energy systems of the Flexi-Sync areas a method adapted by [3] (presented more in detail in Chapter **Error! Reference source not found.**) has been used. The different steps used in this report is presented in Figure 2. The method applied in this report is primarily focusing on the literature review on scenario frameworks and design as well as a participatory approach, i.e. using input from the stakeholders, to match scenario frameworks with the local development.

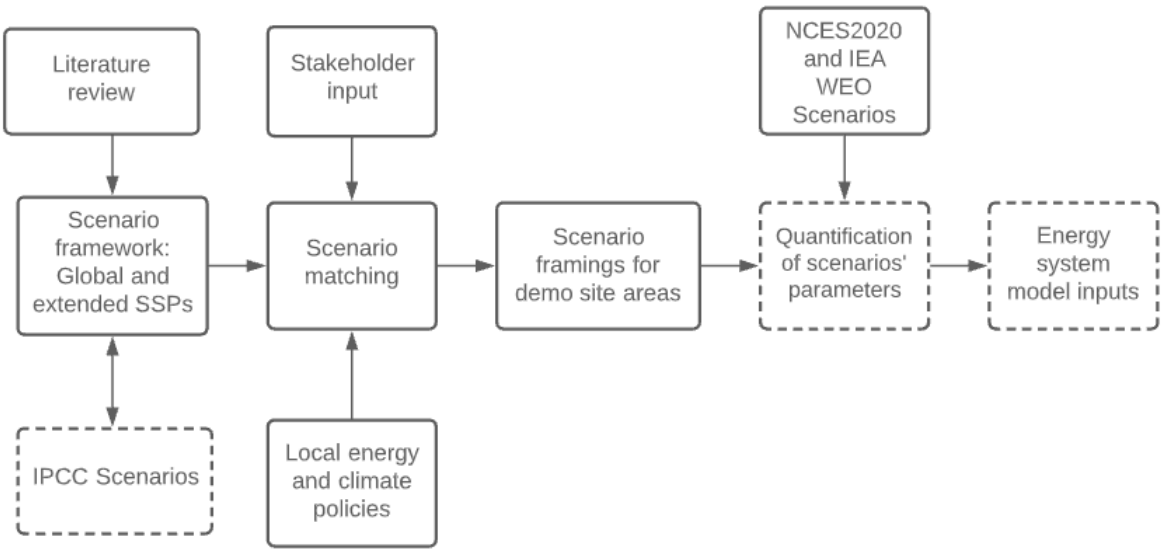

Figure 2 The method used to identify the scenario framings for the Flexi-Sync demonstrator areas. Dashed boxes mean that it is not within the scope of this report. Abbreviations used in the figure: SSPs

(Shared Socio-Economic Pathways), IPCC (Intergovernmental Panel on Climate Change), NCES2020 (Nordic Clean Energy Scenarios 2020), IEA WEO (IEA World Energy Outlook).

2.1 Literature review

For the purpose of the project, the designs of the scenarios are based on existing global and regional scenarios from a literature review. The focus of the literature review has been on Shared Socio-Economic Pathways (SSPs). The global SSPs are used by the IPCC in the Sixth Assessment Report and could be linked to climate assessments, which is being done within another work package of Flexi-Sync.

The literature review was based on searches in Google Scholar using the following keywords: *SSP, extended SSP, SSP and TIMES, regional SSP*. The relevance of the found publications was assessed resulting in around 20 scientific publications. The main findings from the literature review is presented in Chapter 3. The global and regional scenarios found in the literature review have been downscaled to the urban level using the extended SSPs.

As the SSP scenarios found in the literature review does not contain any quantitative parameters, which is needed for the energy system modelling that will be performed within WP2, the scenarios could be fine-tuned and matched with the scenarios in Nordic Clean Energy Scenarios 2020 (NCES2020) and IEA World Energy Outlook. IEA World Energy Outlook scenarios have been used for assumptions for projections of fuel and carbon prices in the previous modelling work, e.g. [3-6]. For the assessment of the future energy system in Nordic countries, three scenarios have been developed in the NCES2020. To be able to use the input from these scenarios, the scenario narratives needs to be matched with the SSP narratives. The main characteristics of the IEA and NCES2020 scenario frameworks are presented in Chapter 3.

2.2 Stakeholder input

To draw the storylines for the two scenarios for each demo site, a participatory approach has been used, in which input from key stakeholders in the Flexi-Sync project (the energy and housing companies involved, as well as other stakeholders) has been gathered via personal communications. The Flexi-Sync project participants have also been given the opportunity to deliver input to the report. Borås Energi och Miljö, Eskilstuna Energi och Miljö, Sampol, Vattenfall Wärme Berlin AG and Agrar Plus (see **Error! Reference source not found.**) have provided information for the storyline assumptions.

Table 1 Input from stakeholders

Stakeholder representative	**Stakeholder category**	**Demosite**
Borås Energi och Miljö	District energy company	Borås, SWE

Eskilstuna Energi och Miljö	District energy company	Eskilstuna, SWE
Sampol	District energy company	Mallorca, ESP
Vattenfall Wärme Berlin AG	District energy company	Berlin, GER
Agrar Plus	District energy company	Maria Laach, AUT

Information has also been gathered from the current local climate and energy policies of the corresponding cities and in addition, national and regional statistic databases (e.g. Statistics Austria database) have been reviewed.

2.3 Matching

The scenario elements found in the literature review have further been matched with the characteristics of the demonstrator areas, identified in the participatory part, to find suitable scenario framings for the demo sites areas of Flexi-Sync. The matching was done to identify two different scenario framing. The resulting scenario framings for the demo site areas are presented in Chapter 4.

3 SCENARIOS

This chapter presents the main results from the literature review on SSPs, complemented with the main characteristic of the Nordic Clean Energy Scenarios 2020 and the IEA World Energy Outlook scenarios. In the following subsections these scenarios are described more in detail.

3.1 Shared socioeconomic pathways - global

A framework has been developed to facilitate the production of integrated scenarios based on combinations of climate model projections, socioeconomic conditions, and assumptions about climate policies [4]. The SSPs describe plausible alternative trends in the evolution of society and natural systems over the 21st century at the global level and large world regions. They consist of two elements: a narrative storyline and a set of quantified measures of development [4].

To help ensure that the set of SSPs developed actually spans a range of outcomes that will allow the characterization of uncertainty in climate mitigation, adaptation, and impacts, an outcome space is defined in which socioeconomic and environmental challenges are represented on two axes: one axis depicts challenges pertaining to adaptation; the other axis challenges to mitigation (see Figure 3).

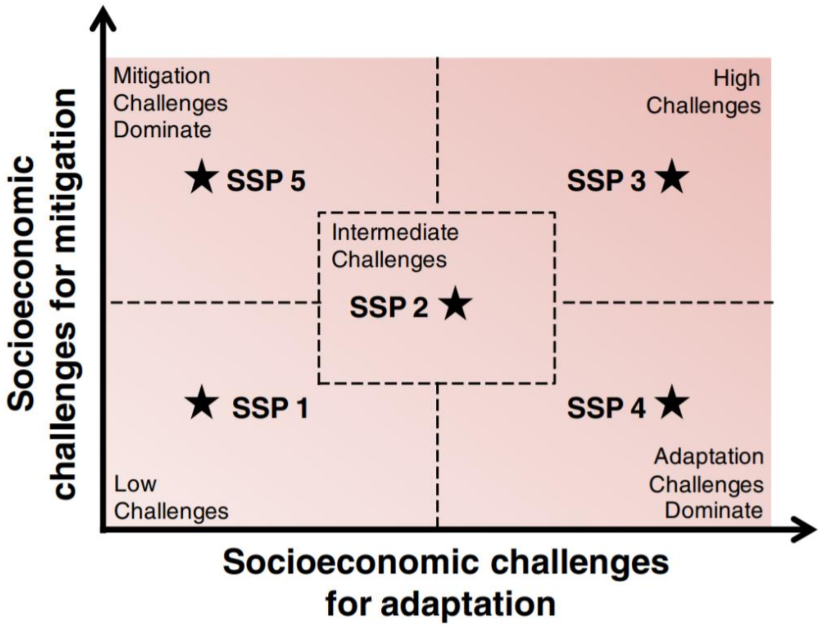

Figure 3 The "challenges space" to be spanned by SSPs [4]

Factors that tend to influence the mitigative capacity of a society include the range of viable technological options, national and international institutions for policy making, the availability of financial resources necessary to support mitigation activities, stocks of human and social capital, and political will for addressing energy and environmental issues [4].

Challenges to adaptation include the limits of autonomous adaptation (i.e. the range of adaptive measures that are readily accessible to individuals and organizations) and the obstacles and constraints to adaptation policies, such as ineffective institutions and governance that impede policy implementation [4].

In Table 2 the initial starting points for the five SSP narratives are presented. SSP1 and SSP2, marked with asterisks in the table below, are identified as the most relevant ones for Flexi-Sync as the narratives involve a relatively fast deployment of renewables.

Table 3 shows possible elements of SSPs relevant to defining challenges to mitigation and adaptation.

*Table 2 Initial starting points for SSP narratives, based on [4, 5]. SSPs marked with * were the scenarios deemed most relevant for the context of the Flexi-Sync project.*

SSP	Challenges	Illustrative starting points for narratives
SSP1*	Low for mitigation and adaptation	**Sustainable development** proceeds at a reasonably high pace, inequalities are lessened, **technological change is rapid** and directed toward **environmentally friendly processes**, including lower carbon energy sources and high productivity of land.
SSP2*	Moderate	An intermediate case between SSP1 and SSP3.
SSP3	High for mitigation and adaptation	Unmitigated **emissions are high** due to **moderate economic growth**, a rapidly growing population, and **slow technological change** in the energy sector, making mitigation difficult. Investments in human capital are low, **inequality is high**, a regionalized world leads to **reduced trade flows**, and institutional development is unfavorable, leaving **large numbers of people vulnerable to climate change** and many parts of the world with low adaptive capacity.
SSP4	High for adaptation, low for mitigation	A mixed world, with **relatively rapid technological development in low carbon energy sources in key emitting regions**. However, **in other regions development proceeds slowly**, inequality remains high, and economies are relatively isolated, leaving these regions highly vulnerable to climate change with limited adaptive capacity.
SSP5	High for mitigation, low for adaptation	In the absence of climate policies, **energy demand is high** and most of this **demand is met with carbon-based fuels**. **Investments in alternative energy technologies are low**, and there are few readily available options for mitigation. Nonetheless, **economic development is relatively rapid** and itself is driven by high investments in human capital. Improved human capital also produces a more equitable distribution of resources, stronger institutions, and **slower population growth**, leading to a less vulnerable world better able to adapt to climate impacts.

Table 3 Possible elements of SSPs relevant to defining challenges to mitigation and adaptation [4].

Category	Scenario element
Demographics	Population, location information (coastal vs. inland)
Economic development	GDP
Resources	Fossil fuel resources and renewable energy potentials
Technological development	Type (e.g. slow, rapid, transformational), direction (e.g. environmental, efficiency, productivity improving) of technological progress Diffusion of innovation in energy supply, distribution and demand
Policies	Development policies, technology policies, urban planning and environmental policies

O'Neill et al [6] further presented narratives as part of "basic SSPs"; which contain enough information to sketch alternative development pathways that are plausible and that enable them to be located in a particular area of the challenges space. For instance, in regards to the above "Technological development" element, assumptions regarding Technology and Environment & Natural Resources elements of SSPs in narratives were further described as in Table 4 [6].

Table 4 Summary of assumptions regarding Technology and Environment & Natural Resources elements of SSPs. Country groupings referred to in table entries are based on the World Bank definition of low-income (LIC), medium-income (MIC) and high-income (HIC) countries, adapted from [6].

SSP element	SSP1	SSP2	SSP3	SSP4	SSP5
Technology					
Development	Rapid	Medium, uneven	Slow	Rapid in high-tech economies and sectors; slow in others	Rapid
Transfer	Rapid	Slow	Slow	Little transfer within countries to poorer populations	Rapid
Energy tech change	Directed away from fossil fuels, toward efficiency and renewables	Some investment in renewables but continued reliance on fossil fuels	Slow tech change, directed toward domestic energy sources	Diversified investments including efficiency and low-carbon sources	Directed toward fossil fuels; alternative sources not actively pursued
Carbon intensity	Low	Medium	High in regions with large domestic fossil fuel resources	Low/medium	High
Energy intensity	Low	Uneven, higher in LICs	High	Low/medium	High
Environment & Natural Resources					
Fossil constraints	Preferences shift away from fossil fuels	No reluctance to use unconventional resources	Unconventional resources for domestic supply	Anticipation of constraints drives up prices with high volatility	None
Environment	Improving conditions over time	Continued degradation	Serious degradation	Highly managed and improved near high/ middle-income living areas, degraded otherwise	Highly engineered approaches, successful management of local issues

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The SSPs are formulated independent of any explicit climate change projections or mitigation and adaptation policies, but rather represent socioeconomic factors that, for any given policy objective, would make mitigation or adaptation more achievable or difficult. The basic SSPs represent socioeconomic boundary conditions for key driving forces [7]. To increase their suitability in sectoral and/or regional studies and their relevance for local stakeholders, the SSPs have to be extended [8]. In other words, the SSPs have been provided a set of scenarios that would be a useful starting point for scenarios development at others scales and for other sectors [9]. For many applications, "extended SSPs" are likely to be required, which would contain additional, more detailed information for particular regions, sectors, or variables or that would be enhanced according to specific needs [6]. Scenario analyses that focus on a particular national or subnational region, or on a particular sector (such as energy), will likely benefit from extending basic narratives and their associated quantitative assumptions. Extended SSPs should use assumptions that are consistent with the basic SSPs, but support modelling and analysis that goes beyond the key variables provided in the basic SSPs.

In the following sections methods developed and used to extend SSPs to regional, national, and city/urban level as well as sector specific scenarios are presented from the literature review. The literature review will serve as a part of the basis for our city level scenarios in the demo city cases of the Flexi-Sync project.

3.2 Extended shared socioeconomic pathways - regional

At the regional level, there are studies focusing on developing extended SSPs in Europe. In one study [9] new scenarios for Europe were developed, at the first step, by mapping the global SSPs into the CLIMSAVE scenarios (existing European scenarios as developed within a project called CLIMSAVE), in order to maintain as much as possible the European and stakeholder-determined flavour. At the second step, a more detailed comparison between the global SSPs and the European CLIMSAVE scenarios was made. For this, a list of so-called main uncertainties that was part of the CLIMSAVE scenarios was used and matched with 'key assumptions' of SSPs, as listed in [6]. At the final step the actual development of the new European scenarios was implemented during an expert workshop [9]. During the expert workshop, the following aspects were discussed and confirmed or agreed upon: First, the initial mapping of the global SSPs into the CLIMSAVE scenarios using the degree of compatibility between the CLIMSAVE and global SSP uncertainties. Subsequently, an outline of new stories for three time slices (2010–2040, 2040–2070, 2070–2100) based on the list of uncertainties, CLIMSAVE stories, and global SSPs. Finally, trends and quantification of key model parameters were estimated for the new EUR-SSPs to match the global equivalent [9]. A summary of the EUR-SSPs is provided in

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Table 5.

Table 5 Example of extended SSPs for Europe [9].

EUR-SSPs	Stories and trends
EUR-SSP1	A high commitment to achieve sustainable development goals through effective governments and global cooperation. Puts governments under pressure to take ambitious measures, including stimulating an energy transition towards renewables and facilitating innovative research Advances in green technologies are further stimulated by international competition leading to a CO2 neutral society by 2050. By 2100, Europe is characterized by a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a strongly regulated but effective multi-level governance structure.
EUR-SSP3	The demand for resources increases, which turns out to be a tipping point for the state of the environment with severe ecosystem failures. Long-term policy planning becomes rare with hardly any money for education, research or innovation. Eventually, the EU breaks down. New alliances with other countries are forged to ensure sufficient energy supply. A high-carbon intensive Europe emerges that is not worse off than the rest of the world.
EUR-SSP4	Substantial proportions of populations having a low level of development, although Europe becomes an important player in a world full of tensions. Sparked by economic crisis and extreme weather events, the EU increases commitment to find innovative solutions to the depletion of natural resources and climate change. In combination with current relatively high levels of social cohesion, energy efficiency, and environmental policy making this initiates a shift towards a high-tech green Europe. Technological development has not resulted in reduced energy prices but has instead established an oligarchy of green business developers that control energy supply.
EUR-SSP5	People place increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. A lack of environmental concern leads to the exploitation of abundant fossil fuel resources. The push for economic and social development is coupled with the exploitation of abundant fossil fuel resources, including large-scale extraction of shale gas. Population across all societal classes adopts a very energy intensive lifestyle. The environment degrades, but the majority of the population is unaware because of successful technological innovation. Towards 2100, the environment is locally seriously degraded as non-renewables are further exploited, which eventually results in a slow re-emergence of investments in renewables.

In another study [8] at European level, a new method to extend the SSPs that makes use of existing scenario studies was developed and applied. The approach lied in a systematic matching of multiple scenario sets that facilitates enhancement of the global SSPs with regional and sectoral information, in terms of both storylines and quantitative projections. The method was applied to develop extended SSPs of human vulnerability in Europe and to quantify them for several key indicators at the sub-national level up to 2050, based on the co-use of the matched scenarios' quantitative outputs [8]. The method consisted of the following steps and details:

1. Selection of existing scenario sets

   The following restricting criteria was applied: the scenario sets had to: (i) focus on Europe; (ii) been developed recently (i.e., post-2010) to ensure their timeliness; (iii) contain at least four different scenarios - in order to increase the likelihood of matching them with the five SSPs; (iv) be related to human vulnerability; (v) contain detailed storylines about future socioeconomic and/or environmental conditions in Europe up to 2050; (vi) be quantified for relevant socioeconomic and/or environmental variables at the sub-national level up to 2050; (vii) be widely accepted by the scientific community; and (viii) not contain any explicit assumptions about future levels of greenhouse gas emissions.

2. Matching method

   Included five steps: (i) identification of domains, elements, and corresponding assumptions; (ii) categorization of assumptions; (iii-iv) pairwise scoring per domain and averaging; and (vi) identification of standout groups of scenarios.

3. Leading scenario sets
4. Consistency check and quantification of the extended SSPs

Results showed that such a method led to internally consistent extended SSPs with detailed and highly quantified narratives that were tightly linked to global contexts. The method also provided multiple entry points where the relevance of scenarios to local stakeholders could be tested and strengthened [8].

3.2.1 In sectoral context

To interpret the basic SSPs in a sectoral context, in one study the extended SSPs have been designed [10]. In the study, the extended SSPs served to qualitatively harmonize several energy models. The extended SSPs provided more detail in three domains of the energy sector:

1. Final energy demand development,
2. Energy conversion technologies including specific mitigation technologies, and
3. Fossil fuel supply.

The approach led to identification of the main points of the extended SSPs with a perspective on the energy sector as they are presented in Table 6.

*Table 6 Extended SSPs with a perspective on the energy sector [10].The SSPs marked with an * are deemed most relevant to the Flexi-Sync project.*

	SSP1* **Sustainability - taking the green road**	**SSP2*** **Middle-of-the-road**	**SSP3** **Regional rivalry - a rocky road**	**SSP4** **Inequality - a road divided**	**SSP5** **Fossil-fueled development - taking the highway**
Energy demand side	Economic value creation decouples from final energy demand.	Energy intensity improvements continue at global historical growth rates.	Fast population growth in developing countries is combined with slow economic growth and income convergence.	Final energy demand is moderately coupled to economic activity.	Energy demand growth is strongly coupled to economic growth, particularly in the transportation sector.
Energy conversion	Technological development, lifestyle changes and policies supporting energy efficiency improvements.	Technological improvements are medium for all technologies.	Slow technological development, and little environmental awareness maintain the strong link between economic activity and final energy demand. Modernization of final energy use is slow and traditional bio-energy use remains important.	In poor countries traditional bioenergy remains important. Technological improvements in conventional oil and gas extraction are high, but policies are restrictive in high-income countries because of local pollution problems. There are significant technological improvements in nuclear power.	Technological development in the fossil fuel sector, including CCS based mitigation technologies, is rapid.
Fossil fuel supply	Social acceptability is generally low for all technologies (particularly nuclear) except non-biomass renewables. The latter is subject to rapid technological improvements, but these are particularly slow in the fossil fuel sector.	No remarkable shifts in the primary energy mix and continued modernization of the final energy mix.	Concerns about energy security and national policies support the use of domestic coal and limit trade in energy.	Investments are risky because of generally volatile markets.	Fossil fuel use. Non-biomass renewables are subject to low social acceptance.

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3.3 Extended shared socioeconomic pathways - national

The basic SSP narratives have been extended to the national level. This allowed, for example, modelers better guidance for the implementation of SSPs into their models. In one study [11], a long-term optimization (TIMES) model was applied to explore the role that biomass can play in meeting the demand for energy and chemicals along with the mitigation of GHG emissions in Brazil up to 2050 [11]. To address the uncertainties about biomass feedstock and conversion technologies, three scenarios were developed. The scenarios were based on the general SSPs which were translated to the scenarios of the study [11] as following:

SSP1: Rapid development towards a sustainable future

> Technological development follows a progressive trend. The environmental policy is based on the national determined contributions agreements of Brazil until 2030. However, to meet the global 2°C warming target more stringent mitigation measures need to be taken by Brazil. The supply potential of biomass assumes a high productivity increase.

SSP2: Middle of the road / business as usual (BAU)

> Technological development follows an intermediate trend. It includes the climate policy actions in the national determined contributions for the Paris Agreement, where the maximum level of annual GHG emission is set at 1.2 Gt CO2-equivalent in 2030 and the share of renewables at 45%.

SSP3: No climate mitigation measures

> Technological development is more oriented towards fossil fuels because the short-term trends and long-term forecasts (without environmental policy) in Brazil shift slightly towards more use of fossil energy. There is no development of CCS in this scenario, except for CCS from conventional ethanol distilleries. Apart from the current biofuel blending targets, no environmental policies are considered. The supply biofuel potential is based on a low productivity increase.

3.4 Extended shared socioeconomic pathways – urban/city

The literature offers examples of methods to develop multi-scale extended SSPs at the local level. For instance, a method was presented and applied to the city and neighborhood levels, using Boston, USA, as a case [12]. The study combined scenario matching, experts' elicitation, and participatory processes to contextualize and make the global SSPs relevant at the urban scale [12]. Figure 4 below shows the method applied schematically.

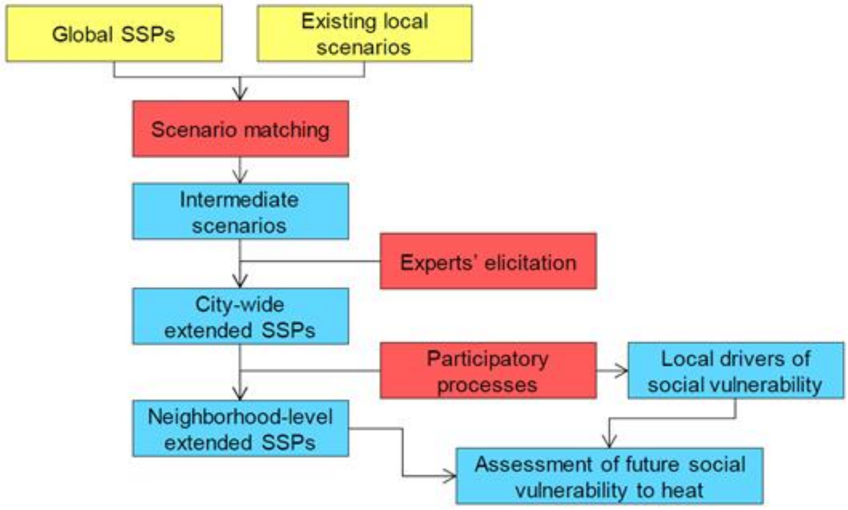

Figure 4- Methodology developed to extend the global SSPs to the urban/city level in Boston [12].

Results from the scenario matching exercise are presented in Table 7. “Stronger Region” and “Status Quo” were the only comprehensive socioeconomic and urban development scenarios for the City of Boston which depict future socioeconomic and urban development paths in Boston up to 2040 [12].

Table 7 Example of extended SSPs to city scale - Scenario matching [12].

	SSP1Boston	SSP2Boston	SSP4Boston	*Stronger region*	*Status Quo*
Economic development	Moderate/high, focus on human well-being	Moderate, uneven	Moderate/low, highly unequal	High	Moderate
Population growth	High	Moderate	Low	High	Moderate
Racial and ethnic diversity	-	-	-	High	Moderate
Favoured households' agreement	-	-	-	Multi-family and multi-purpose homes	Single-family homes
Urban development pattern	Concentrated	Historical patterns	Mixed	Towards a compact city	Continuation of historical patterns
Investments in health and education	Increase	Decrease	Unequal	-	-
Inequalities	Decrease (low)	Persist (steady)	Increase (high)	Decrease	Persist

Results from the scenario matching exercise (Table 7) show that the "Stronger Region" scenario depicts trends that are comparable to that of SSP1, while the "Status Quo" scenario can be matched with SSP2 [12]. In Table 8 selected main drivers of the example of extended SSPs to the City of Boston is presented.

Table 8 Example of extended SSPs to city scale - Selected main drivers [12].

	SSP1Boston	SSP2Boston	SSP4Boston
Name	Sustainable development and social equity	Perpetuation of current trends	Increased inequalities
Socioeconomic and racial equity	Increase	Decrease	Strong decrease
Economic growth	Higher	High	Slower growth, characterized by uncertainty
Population growth	Higher	High	Lower
Diversity	Higher	High	Lower
Housing affordability	Increase	Decrease	Strong decrease
Institutional coordination and response capacity	Higher	Low	Lower
Access to parks and green spaces	Increase (equitable)	Maintained	Unequitable

The global SSPs have been extended to develop Tokyo's long-term socioeconomic scenarios in [3]. In the study, first, important factors and elements were investigated through literature reviews, then a basic theoretical framework was developed. Second, expert interviews were conducted to collect more relevant narratives and elements based on the theoretical framework [3]. Figure 5 below shows the method applied schematically and the development process of the scenarios is presented in Figure 6.

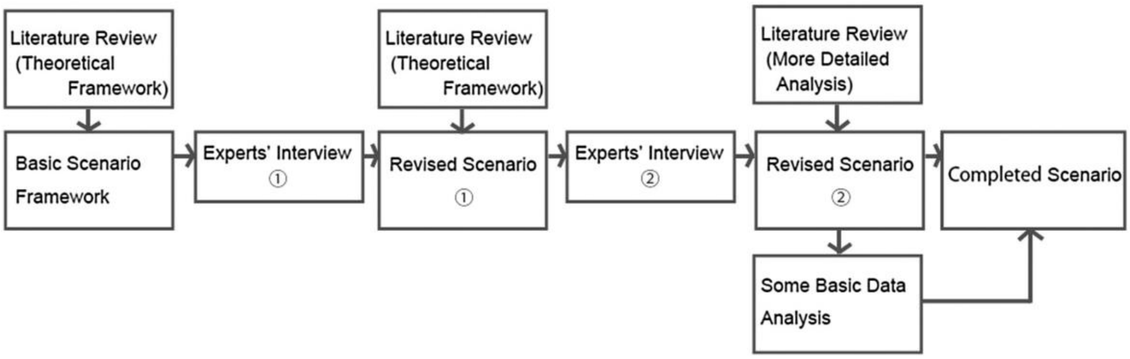

Figure 5 Methodology developed to extend the global SSPs to the urban/city level in Tokyo [3]

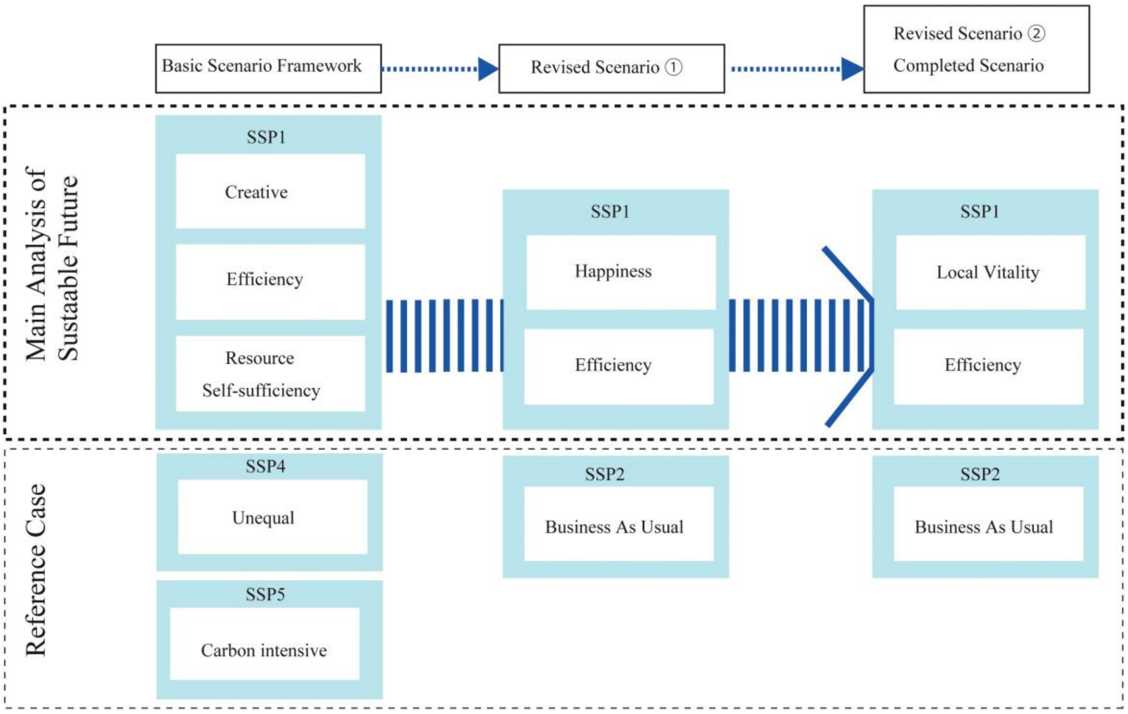

Figure 6 The development process of the Tokyo SSPs [3]

Based on Tokyo's socioeconomic pathways, the future changes in building stock and carbon emissions in Tokyo's building sector were quantitatively analyzed [13].

3.5 Nordic Clean Energy Scenarios 2020 (NCES2020)

Three scenarios have been developed in the NCES2020 project [14] for the assessment of the future energy system in Nordic countries. The scenarios are briefly described in Table 9 below, whereas the key components of the scenarios are presented in Table 10.

Table 9 Narratives of the NCES2020 scenarios

Carbon Neutral Nordic (CNN)	Nordic Powerhouse (NPH)	Climate Neutral Behaviour (CNB)
Carbon Neutral Nordic (CNN) is the central storyline. It develops according to the Nordic countries' national plans, strategies, and targets to reach carbon neutrality. This storyline will not produce a business as usual scenario but rather show what effects stated, but not yet implemented, strategies and targets could achieve. Decarbonization of energy consumption will require fast actions in all sectors. The amount of renewable power and heat production must increase to provide clean energy to end-use sectors. Nordic countries will increase electricity exports to Central Europe, but the amount will not increase much above current projections as electrification of Nordic heating, transport, and industry will require a large supply of low carbon electricity. Biomass imports from outside the Nordics will be limited to current or slightly higher levels to ensure sustainability of bioenergy use. BECCS will compensate some of the most expensive CO2 emissions abatement options. Onshore wind development will be limited below the technical potential due to acceptability and land use issues.	Nordic powerhouse (NPH) is a storyline where the Nordic countries can provide cheaper clean energy than Central Europe and manage to host more low carbon services and industries and increase their exports of low carbon products and energy carriers. In addition to their efforts to reduce Nordic emissions, the **Nordic countries host larger number of data centres, produce more batteries, and manage to increase the exports of electricity,** electro fuels, and carbon free steel and aluminium. All these activities **increase demand for electricity** and/or other energy products. The additional electricity and electro fuels would be produced by offshore wind hubs, **continuing the lifetime of nuclear power plants, ground-based PV power plants, and by onshore wind, assuming high acceptance for onshore wind. There would be more excess heat from industry and services that can be used in district heating generation.**	Climate Neutral Behaviour (CNB) is a storyline motivated by strong political and citizen engagement, and a **rapid decrease in costs of distributed energy generation** and other low carbon technologies. In this storyline, politicians and citizens adopt additional **energy and material efficiency measures** in all sectors that lead to **lower energy demand. In addition, decentralized generation technologies become much more common** and they further cut the energy delivered through grids and lead to **prosumers** and districts as energy suppliers. Energy demand for transport decrease due to modal changes, remote working, car sharing, and lower and more efficient heavy transport of goods. Focus of society in this storyline is not on GDP but on sustainability, circular economy, and securing biodiversity.

Table 10 Key components of the NCES2020 scenarios

	Carbon Neutral Nordic (CNN)	Nordic Powerhouse (NPH)	Climate Neutral Behaviour (CNB)
Emission of GHG	National profiles CO2 neutral before 2050.	National profiles CO2 neutral before 2050.	National profiles CO2 neutral before 2050.
Heavy industry driver	Sectoral GDP. Basis growth.	Sectoral GDP. Increase drivers with 10% in 2050 increasing linear from 2030 compared to CNN.	Sectoral GDP. Reduce drivers with 10% in 2050 increasing linear from 2030 compared to CNN.
Production Industry driver	Sectoral GDP. Basis growth.	Sectoral GDP. Basis growth.	Sectoral GDP. Basis growth.
Data centers driver	Numbers and size. Special projection (Cowi).	Numbers and size. Double the amount of data centres compared to CNN.	Numbers and size. Special projection (Cowi).
Trade and service driver	Sectoral GDP. Basis growth.	Sectoral GDP. Basis growth.	Sectoral GDP. Basis growth.
Households	Basis growth.	Basis growth.	Basis growth.
Freight by truck	GDP. Basis growth.	GPD. Increase tkm with 5% in 2050 increasing linear from 2030 compared to CNN.	Reduce tkm with 5% in 2050 increasing linear from 2030 compared to CNN.
Aviation driver	Travel patterns. Follow historical growth.	Travel patterns. Follow historical growth.	Travel patterns. Growth until 2025 and then decrease to 2015 level in 2050.

3.6 IEA's World energy outlook scenarios

IEA World energy outlook scenarios (Table 11) are global scenarios which have been used for assumptions for assumptions of fuel and carbon prices in the previous energy system modelling studies, e.g. [15-18].

Table 11 IEA World Energy Outlook Scenarios

Stated Policies Scenario	Current Policies Scenario	Sustainable Development Scenario (Extending the Sustainable Development Scenario to 2050)
The New Policies Scenario is renamed as the Stated Policies Scenario (the acronym is STEPS – Stated Energy Policies Scenario). As with its predecessor, this scenario is designed to reflect the impact not just of existing policy frameworks, but also of today's stated policy plans. The name-change underlines that this scenario considers only those policy initiatives that have already been announced. The aim is to hold up a mirror to the plans of today's policy makers and illustrate their consequences, not to guess how these policy preferences may change in the future.	Current Policies Scenario, which only looks at policies in place but from which the effects of announced policies are excluded.	The Sustainable Development Scenario models a rapid and deep transformation of the global energy sector. It is consistent with all the "net zero" goals contemplated today being reached on schedule and in full. The technology learning and policy momentum that they generate means that they become the leading edge of a much broader worldwide effort, bringing global energy-related CO2 emissions down sharply to less than 10 billion tonnes by 2050, on track for global net zero by 2070. This means that the Sustainable Development Scenario is "likely" (with 66% probability) to limit the rise in the average global temperature to 1.8 °C, which is broadly equivalent to a 50% probability of 1.65 °C stabilization. These outcomes are achieved without any recourse to net negative emissions.

4 SCENARIO FRAMINGS FOR DEMO SITE AREAS

We propose the following scenario framings inspired by a combination of the extended SSPs and NCES2020 scenarios presented in Chapter 2. The scenario framings developed built upon the extended SSPs with the energy sector perspective as these provides more detail in three domains of the energy sector (energy demand, energy conversion and fossil fuel supply). Where applicable the extended SSPs are combined with scenarios from Nordic Clean Energy Scenarios 2020 (NCES2020) to make sure that a quantification of parameters needed for the energy system modelling is possible. However, quantified parameters from IEA scenarios could also be needed for further modelling work.

The 100% renewable energy system scenario, called *100% RES,* is inspired by SSP1 (*Sustainability – taking the green road*) and CNB (*Climate Neutral Behaviour*). The scenario representing energy systems that maximize the flexibility potential, called *Maximized flexibility*, is inspired primarily by SSP2 (*Middle-of-the-road*) together with NPH (*Nordic Power House*). There are however some exceptions to this, see the Spanish and German demo sites.

4.1 Borås, Sweden

According to the climate and energy strategy from 2020 [19] the city of Borås has assessed their remaining carbon budget to fulfil the Paris Agreement, in line with this the greenhouse gas emissions in the municipality needs to decrease by 16% per year. The future vision for Borås 2035 is that the citizens are aware of how they can reduce their climate emissions through reduced and well-informed consumption, good choices of transports and smart energy consumption. The municipal sector should be a role model in the work for energy efficiency both in terms of energy use for buildings and transport [19].

Table 12 Scenario narratives of Borås

	100% RES	Maximized flexibility	Vision in the local development plans
GHG emissions	**Low**	**Medium**	**Low**
Energy demand side	Economic value creation decouples from final energy demand.	Technological improvements are medium for all technologies.	Conscious consumption, and smart energy use. A dense and multifunctional city. The municipal administration and companies are role models in energy efficiency both for buildings and transportation.

Energy conversion	Technological development, lifestyle changes and policies supporting energy efficiency improvements. Advances in green technologies lead to a CO_2 neutral society by 2050. By 2100, a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a strongly regulated but effective multi-level governance structure.	No remarkable shifts in the primary energy mix and continued modernization of the final energy mix.	District heating is the main source for heating. District heating is based on biofuels and waste. The proportion of biofuels in the district heating production has increased. Local electricity production has increased based on investments in a combined heat and power plant based on biofuel. The small-scale electricity production is significant and caused by many small electricity producers.
Fossil fuel supply	Social acceptability is generally low for all technologies (particularly nuclear) except non-biomass renewables. The latter is subject to rapid technological improvements, but these are particularly slow in the fossil fuel sector.	Energy intensity improvements continue at global historical growth rates.	It's easy to fuel the car with biogas or other renewable fuels. There are also plenty of charging stations for electric vehicles. The infrastructure for bicycles is coherent and enables inhabitants to use the bicycle as a transport method for both short and long distances.

4.2 Mölndal, Sweden

The largest climate investment made in Mölndal is the biofuel-fired CHP plant. Completely without greenhouse gas emissions, Mölndal Energi supplies district heating customers in Mölndal and electricity customers around the country with renewable energy. Right now, we are also seeing something of a solar revolution. The municipality installs solar at schools and other buildings at a high rate. Solar map, energy and climate advice and investments from Mölndal Energi contribute to increasing small-scale solar production quickly in Mölndal when many choose to make their own renewable electricity. In Mölndal's solar map, you can easily see if solar is suitable for your particular house [20].

The city of Mölndal, like all other municipalities, must both promote the management of energy and work for a safe and secure energy supply within the municipality. It is in this work that the energy and climate plan have an important role. The City of Mölndal will also contribute to sustainable development for transport, energy production and energy use [20].

The energy and climate plan not only cover the City of Mölndal's own activities, but everyone who lives and works in the geographical municipality is affected. It presents the municipality's common energy and climate goals, strategies and priorities [20] (see vision on the local development in Table 13).

Table 13 Scenario narratives of Mölndal.

	100 % RES	**Maximized flexibility**	**Vision on the local development**
GHG emissions	**Low**	**High**	All work to reduce greenhouse gas emissions.
Energy demand side	Economic value creation decouples from final energy demand.	Energy demand growth is strongly coupled to economic growth, particularly in the transportation sector.	Buildings are designed so that the energy requirement is minimized during new construction and remodeling. Densification in the form of a mixed city with a varied range of housing, places, service and culture take place in good public transport locations with acceptable air and noise situation.
Energy conversion	Technological development, lifestyle changes and policies supporting energy efficiency improvements. Advances in green technologies lead to a CO_2 neutral society by 2050. By 2100, a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a	Population across all societal classes adopts a very energy intensive lifestyle Technological development in the fossil fuel sector, including CCS based mitigation technologies, is rapid. Slow re-emergence of investments in renewables.	Heating is done with district heating, renewable energy sources or efficient heat pumps. Small-scale energy production is encouraged and facilitated. By 2022: - An additional 400,000 m2 of heated property will be connected to the district heating network compared with 2012. - The production of renewable electricity within the municipality will increase.

	strongly regulated but effective multi-level governance structure.		
Fossil fuel supply	Social acceptability is generally low for all technologies (particularly nuclear) except non-biomass renewables. The latter is subject to rapid technological improvements, but these are particularly slow in the fossil fuel sector.	A lack of environmental concern leads to the exploitation of abundant fossil fuel resources. exploitation of abundant fossil fuel resources, including large-scale extraction of shale gas.	Efficient energy use and use of renewable energy sources prioritized. By 2022, the distribution of fuel at Riskulla CHP plant will be at least 80 percent renewable and a maximum of two percent oil of total energy supplied. In principle, all oil for normal heating must be replaced.

4.3 Eskilstuna, Sweden

Improved communications have contributed to the expansion of our functional region, as well as the feeling that the world has shrunk. Our mental maps of the surroundings have also changed. All in all, these changes are positive for the development of society as a whole [21]. The scenarios narratives and vision on the local development is presented in Table 14.

Table 14 Scenario narratives of Eskilstuna

	100% RES	Maximized flexibility	Vision on the local development
GHG emissions	**Low**	**Higher**	If we are to be able to halt climate change, emissions must be sharply reduced. At the same time, through various measures, we must adapt society to the climate change that can no longer be avoided. Climate adaptation is not the same as the measures we take to reduce emissions and thus in the long run climate change but should be seen as a complement to that work.
Energy demand side	Economic value creation decouples from final energy demand.	Energy demand growth is strongly coupled to economic growth,	

		particularly in the transportation sector.	
Energy conversion	Technological development, lifestyle changes and policies supporting energy efficiency improvements. Advances in green technologies lead to a CO_2 neutral society by 2050. By 2100, a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a strongly regulated but effective multi-level governance structure.	Population across all societal classes adopts a very energy intensive lifestyle Technological development in the fossil fuel sector, including CCS based mitigation technologies, is rapid. Slow re-emergence of investments in renewables.	Coordination between climate-efficient heating, transport infrastructure and housing planning will be a key issue. The energy system, i.e. heating of premises and homes, accounts for a majority of the municipality's local emissions of carbon dioxide. The form of heating with almost zero climate impact is the wood chip-based district heating, which means that we must create good conditions for district heating homes and premises both in terms of location and building type. The continued development must take place in a resource-efficient manner. In order to manage national goals and interests and be able to plan for sustainable development, regional thinking is required. We want to work for a more sustainable energy supply and energy use. What we plan and build today will remain for a long time to come. We are building for the future. By facilitating efficient transport solutions for both passenger and freight traffic and creating a structure that is designed based on different effects of a changing climate with floods, warmer temperatures or extreme weather, Eskilstuna Municipal Group works for climate-adapted and energy-efficient community planning.
Fossil fuel supply	Social acceptability is generally low for	A lack of environmental	

	all technologies (particularly nuclear) except non-biomass renewables. The latter is subject to rapid technological improvements, but these are particularly slow in the fossil fuel sector.	concern leads to the exploitation of abundant fossil fuel resources. exploitation of abundant fossil fuel resources, including large-scale extraction of shale gas.	

4.4 Berlin, Germany

Two scenarios are described in Table 15. We assume the scenario "100 % RES" is more similar to the framework conditions of SSP1 and "Maximized flexibility" to be more like the framework conditions of SSP5. The vision of the local development is based on Berlin "climate protection" scenario (the Berlin Energy Turnaround Act) [22].

Table 15 Scenario narratives of Berlin.

	100% RES	Maximized flexibility	Vision on the local development
GHG emissions	**Low**	**High**	**Low** Berlin aims to make a significant contribution and to become climate neutral by 2050. Carbon dioxide emissions shall be reduced by 40 per cent by 2020, by 60 per cent by 2030 and by 85 per cent by 2050, all compared to the base year 1990. Over the long term, it is intended to reduce urban carbon emissions in Berlin by as much as 95 per cent by the middle of the century.
Energy demand side	Economic value creation decouples from final energy demand.	High penetration of Flexi-Sync solution.	Public administration to be a good role model. The central and district administrations need to organise their work in a carbon-neutral manner by the year 2030. By

			implementing refurbishment roadmaps, public building stock will be comprehensively refurbished for energy efficiency by 2050. Heat market makes up 47% of final energy consumption in Berlin. District heating is an important lever to decarbonise the inner city of Berlin. New or existing buildings, which are responsible for about half of Berlin's greenhouse gas emissions, need to become more energy-efficient through different approaches. There will also be a shift in the transport sector, towards a city where public transport and cycling are more attractive in order to encourage people to leave their cars at home. Electro-mobility is a key as well.
Energy conversion	Technological development, lifestyle changes and policies supporting energy efficiency improvements. Advances in green technologies lead to a CO_2 neutral society by 2050. By 2100, a high level of sustainability-oriented political and societal awareness, focusing on renewable energy and low-material growth in a	Lead to CO2 neutral society by 2050. Policy support for energy efficiency improvements and use of green technologies. District heating has a high relevance but include the use of other innovative solutions as heat pump combined with excess heat utilization and flexibility options (thermal storages and NODA innovations)	The City of Berlin and Vattenfall has agreed on a roadmap to decarbonise the district heating of Berlin. The coal phase out will be finalised end of 2029 by replacing coal in district heating by natural gas and power-to-heat. In a second phase 2030-2045 fossil gas will be phased out by power-to-gas (H2), excess heat utilisation, power-to-heat, geothermal, solar heat, heat storages and bioenergy. Greening within the city will be extended (including roofs and facades) and fostered in order to make

	strongly regulated but effective multi-level governance structure.		the city more resilient to rising temperatures.
Fossil fuel supply	Social acceptability is generally low for all technologies (particularly nuclear) except non-biomass renewables. The latter is subject to rapid technological improvements, but these are particularly slow in the fossil fuel sector.	High acceptance for renewables technologies and utilization of urban excess heat resources with a clear reduction of fossil fuel supply. flexibility options are fully accepted.	Greener energy supply. More school education on climate protection and clean energy. Greater efforts in adapting to the effects of climate change. Reducing greenhouse gas emissions by cutting energy use and replacing fossil fuels with renewables. The phase-out of coal will lead to a significant reduction not only of carbon dioxide emissions, but also of fine dust, sulphur dioxide or heavy metals and will contribute to better air quality in Berlin in general. Natural gas is only considered to be a bridging technology - if efficiently used in cogeneration.

4.5 Palma, Spain

Palma is a city located in Mallorca, part of the Balearic Islands. Regarding energy forecast, the city elaborated an action plan sustainable energy 2011-2020 (Pla d'acció per a l'energia sostenible de Palma (PAES)) to reduce CO2 emissions from 24% up to 47%, but no future scenarios or energy roadmap published. However, Palma is under the regional regulation (Govern de les Illes Balears) where there is a law in climate change and energy transition (Llei 10/2019, de 22 de febrer, de canvi climàtic i transició energètica). This law translates the national plan in climate change (PLAN NACIONAL INTEGRADO DE ENERGÍA Y CLIMA 2021-2030 (PNIEC)) to the Balearic Islands framework. The objectives of the balearic law are the following:

- 40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990, and 90% by 2050.
- 35% renewable energy in electricity generation by 2030, and 100% by 2050.
- 26% improvement in energy efficiency by 2030, and 40% by 2050.

- Install 1000 electric car charging point by 2025 and 100% of electric cars by 2050.

PNIEC also facilitates the distributed electricity generation, the digitalization and the increase of the renewable sector to become the 1.8% of Spain GDP), creating new and greener jobs.

Pricewaterhousecooper foresees the use of renewables energies from 40% to 70% of the total energy installed in Spain, the presence of nuclear power plants and an unstable electricity supply which can be reduced by the interconnection among countries [23].

A more recent article from Deloitte [24] draws four different scenarios for the demand by 2030:

- Continuist: Spanish demand has not increased significantly, and petroleum products still is the main energy resource, increasing the gas consumption slightly. There is an increase of building efficiency for the equipment renovation.
- Economy electrification: high increase in electrical vehicles (50% of new vehicles) and electrical trains (20% of freight transport), an increase of electricity consumption in the energy domestic share.
- Conventional reduction: this scenario is focus in increasing the performance of the existing technologies and an increase in the use of natural gas.
- High electrical efficiency: Electrical vehicle is 60% of new sales and electricity and gas are present in all sectors achieving with PNIEC objectives by 2030.

Moreover, Deloitte [25] analyses Spanish commitment to fight against climate change until 2050 (reducing GHG emissions by 80%-95%). This would involve:

- Substitute current energy carriers for others with lower emissions.
- Develop a power generation fleet based exclusively on renewable sources
- Introduce energy efficiency measures.

For a specific definition of a future scenario in Mallorca, it is relevant to consider that Mallorca is an island and a tourist destination (the 76.1% of the GDP is from the tertiary sector) therefore its economy has a highly dependency on the airplane and sea transport [26].

Furthermore, last years' energy efficiency and renewable regulations has had low impact so far (electricity demand in the Balearic Islands has increases around the

2% in last years (2015-2019). Renewable energy is near the 5.4% of the electricity power installed [27].

Two scenarios are going to be described, one if the regional policies reach its objectives taking the green road (which we assume is more similar to the framework conditions of SSP1). The other one where they are not able to change the trend with regional rivalry for local energy (which we assume is more like the framework conditions of SSP3).

Table 16 Scenario narratives of Palma

	100% RES	Maximized flexibility	Vision on the local development
GHG emissions	**Low**	**High**	40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990, and 90% by 2050.
Energy demand side	Economic value creation decouples from final energy demand.	Fast population growth with slow economic growth and income convergence.	Energy efficiency and decoupling economic growth from increase of energy demand produces an energy demand reduction.
Energy conversion	Lead to CO2 neutral society by 2050. Policy support for energy efficiency improvements and use of green technologies. Electrical vehicle increasing its penetration in the local transport.	Slow technological development, and little environmental awareness maintain the strong link between economic activity and final energy demand. Modernization of final energy use is slow and traditional bio-energy use remains important.	35% renewable energy in electricity generation by 2030, and 100% by 2050. Install 1000 electric car charging point by 2025 and 100% of electric cars by 2050.
Fossil fuel supply	High acceptance for non-biomass and biomass renewables technologies, with a clear reduction of fossil fuel supply.	Concerns about energy security and national policies support the use of domestic coal and limit trade in energy.	The use of fossil fuel is reduced until eliminated.

4.6 Maria Laach, Austria

The main assumptions of the two scenarios are described in Table 17. Two variants of the SSP1 for the energy sector represent “100% RES” and “Maximized flexibility”. The vision of the local development is based on lower Austria “future image” scenario.

Table 17 Scenario narratives of Austria.

	100% RES	Maximized flexibility	Vision on the local development
GHG emissions	**Low**	**Low**	**Low**
Energy demand side	Economic value creation decouples from final energy demand.	Economic value creation decouples from final energy demand. High penetration of Flexi-Sync solution.	Carbon free and smart energy use. Energy mix between dense urban areas and rural areas
Energy conversion	Lead to CO2 neutral society by 2040. Policy support for energy efficiency improvements and use of green technologies. District heating has a high relevance for heat supply with a predominant use of biomass.	Lead to CO2 neutral society by 2040. Policy support for energy efficiency improvements and use of green technologies. District heating has a high relevance but include the use of other innovative solutions as biogas, heat pump and flexibility options (thermal storages and NODA innovations)	Society, political administration and companies are role models in energy efficiency for buildings. District heating is very relevant as heating source being dominant the use of biofuels or other renewables sources. CHP investments based on biofuel is a fundamental element.
Fossil fuel supply	Medium acceptance for non-biomass and high acceptance of biomass renewables technologies, with a clear reduction of fossil fuel supply.	High acceptance for non-biomass and high acceptance of biomass renewables technologies, with a clear reduction of fossil fuel supply. Flexibility options are fully accepted.	The possibility to be connected to the district heating system or to have access to a carbon free source (heat pump or biomass boiler...) is common. DH networks are smart including energy storages and other demand site management systems

5 CONCLUDING REMARKS

This report defines future scenarios in line with ambitious climate targets as well as relevant to estimate the cost-efficient flexibility potential in the local or regional energy system. The scenarios will help in the understanding of cost-efficient interactions between the district heating and electricity networks, and the building sector, as well as to identity optimal investments in the demonstrator areas by 2050.

The scenarios have been defined based on a review of relevant scenarios frameworks at international, national, regional, and urban levels. The resulting urban narratives have been completed with information form the local visions and development plans, as well as with input from stakeholders. These scenarios will be translated into specific quantitative inputs for the modelling assessments to be performed in WP2.

One scenario is the 100% renewable energy (“100 % RES”) and the other scenario is energy systems that maximize the flexibility potential (“Maximized flexibility”). Based on the literature study the 100 % RES scenario is generally inspired on SSP1 in combination with the CNB scenario of NCES2020. The scenario representing the “Maximized flexibility” scenario is generally inspired by SPP2 together with NPH. For each Flexi-Sync demo case narratives have been described for the scenarios, in these exceptions from the generally mentioned inspirational scenarios may occur to better describe the local preconditions for the demo sites.

The scenario framework in this study will be used as a starting point and give initial input to the modelling assessments performed within WP2 with the models TIMES and ECCABS. The results will be presented in D2.3.

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