Republic of Serbia
Ministry of Finance
Department for Controlling and Financing of EU Funded Programmes
Ministry of Mining and Energy

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#ЕУ ЗА ТЕБЕ

Further Development of Energy Planning Capacity

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Input data for modelling tools

23rd March 2022

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ABBREVIATIONS

BEL	Belgrade
BESS	Battery Energy Storage System
CAPEX	Capital Expenditure
CF	Capacity Factor
CGE	Computable General Equilibrium
CHP	Combined Heat and Power
CP	Carbon Price
CY	Climate Year
DSR	Demand-Side Response
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
EMS	Joint stock company “Elektromreža Srbije”
EnC	Energy Community
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
GVA	Gross Value Added
HPP	Hydro Power Plant
IEA	International Energy Agency
IRR	Internal Rate of Return
MAF	Mid-term Adequacy Forecast
MANAGE	Mitigation, Adaptation and New Technologies Applied General Equilibrium
NACE	Nomenclature of Economic Activities
NECP	National Energy and Climate Plan
NT	Net Transfer
NTC	Net Transfer Capacity
PAP	Pump Accumulation Plant
PECD	Pan-European Climate Database
PEMMDB	Pan-European Market Modelling Database
PSHPP	Pump Storage Hyfro Power Plant
PV	Photovoltaic
RAE	Regulatory Authority for Energy
RES	Renewable Energy Sources
REG	Regulatory-based measures
ROR	Run-Of-River
ROW	Rest of the World
RES tool	High RES penetration market tool
SEMS	Serbian Energy Modelling System
SES	Southeast Serbia
SAM	Social Accounting Matrix
SORS	Statistical Office of the Republic of Serbia
SSP	Shared Socioeconomic Pathways
SWS	Southwest Serbia
TPP	Thermal Power Plant

TSO	Transmission System Operator
TY	Target Year
TYNDP	Ten-Year Network Development Plan
UCED	Unit Commitment and Economic Dispatch
VOJ	Vojvodina
WEM	(scenario) With Existing Measures

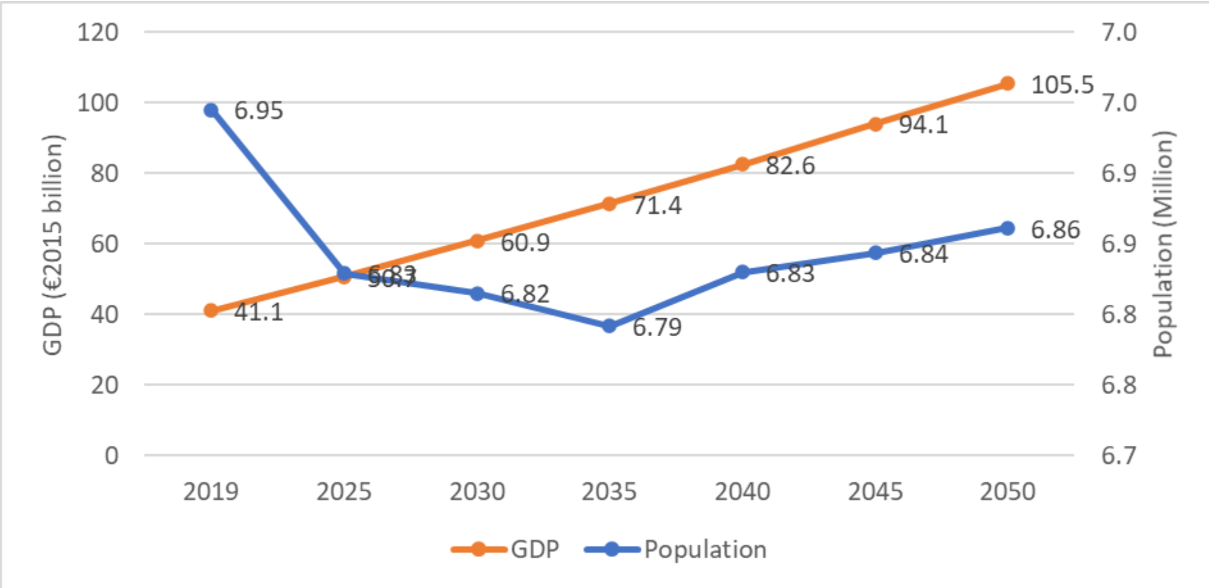
1 DESCRIPTION OF SEMS INPUT DATA FOR SCENARIO ALTERNATIVES

1.1 Projected evolution of main exogenous factors influencing energy system and GHG emission developments

1.1.1 Macroeconomic forecasts (GDP and population growth)

This chapter presents briefly the main input parameters, which are utilised in the formulation of the scenarios for the energy system of the Republic of Serbia. The most crucial parameters, which affect the energy demand, include the evolution of the GDP and the population until 2050.

The projection of population is shown in the following Figure 1 based on the median scenario of the Statistical Office of the Republic of Serbia (SORS) and the projections of GDP, as was discussed and agreed with the working group are also presented.



	2019	2025	2030	2035	2040	2045	2050	Source
Population (million)	6945,0	6829,2	6815,0	6791,7	6830,0	6843,6	6861,3	Medium Scenario from SORS[1]
Number of persons per household	2.89	2.88	2.86	2.85	2.83	2.82	2.80	Projected to decrease to the average of 2.8 by 2050.[2]

1 Statistical office of the Republic of Serbia, table "Population projections, five variants, by region" https://data.stat.gov.rs/Home/Result/180203?languageCode=en-US

[2] Statostical office of the Republic of Serbia is used as a sourve for the year of 2019 (see table 1.1 in https://publikacije.stat.gov.rs/G2021/PdfE/G202114018.pdf). The remaining years are based on the projection assuming that by 2050 it will decrease to the level that Croatia has achieved in 2020 according to Eurostat https://ec.europa.eu/eurostat/databrowser/view/lfst_hhanwhtc/default/table?lang=en

GDP (€ 2015 billion)	41078.7	50689,9	60866,5	71439,2	82595,9	94064,2	105515,0	See Annex 4.1 for details

Figure 1: Evolution of GDP and population until 2050

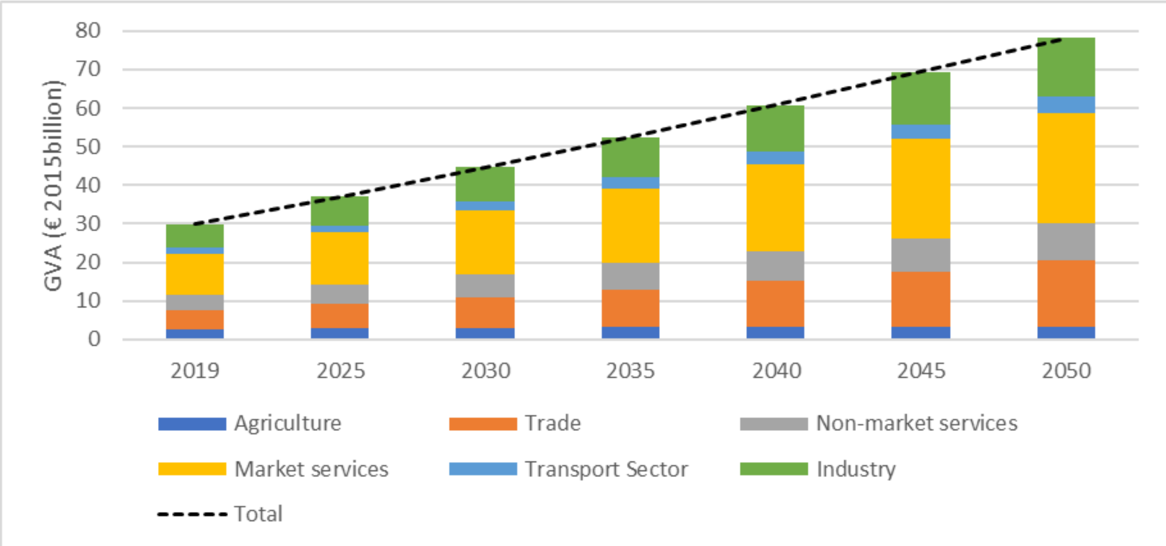


Figure 2: Evolution of GVA for different sectors of economic activities until 2050.[3]
(Source: Projections from the Macroeconomic CGE model consistent with the overall GDP projections)

The projections of the Gross Value Added (GVA) per sector of economic activity, which are consistent with the GDP projections presented above and used in the WEM scenario, are displayed in the Figure 2.
For the energy intensive sectors of cement, iron and steel, copper, lead, zinc, other non-ferrous metals, glass, ceramics and other non-metallic minerals, the physical outputs have been used as the driver for energy demand in each subsector, as can be seen in the following Table. The projection of physical output is used in these energy intensive sectors since the physical quantity is considered as a more realistic driver for energy demand projections compared to the Value Added of the sector, the variation of which can depend on other economic reasons, e.g. changes to the price of the product and not only to the actual change of the output.

Table 1: Evolution of physical output of energy intensive industrial subsectors until 2050

kt	2019	2025	2030	2035	2040	2045	2050
Steel	1664.0	1871.0	2035.0	2290.0	2643.0	2748.0	3033.0
Copper	45.0	80.0	90.0	120.0	140.0	150.0	180.0
Lead	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Zinc	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lithium/Boron and related products	0.0	0.0	600.3	600.3	600.3	600.3	600.3
Other Non-Ferrous	20.6	22.0	22.0	23.0	24.0	25.0	25.0
Cement	2151.0	2695.0	3018.4	3302.1	3569.5	3808.7	4055.1
Glass Recycled	15.2	24.0	29.0	33.0	41.0	47.0	53.0
Glass Primary	26.2	33.0	35.0	36.0	38.0	37.0	35.0
Ceramics	16.8	21.0	24.0	28.0	32.0	36.0	41.0
Other Non Metalic Minerals	10.0	13.0	15.0	17.0	19.0	22.0	24.0

[3] See Annex 4.2 for details on the projection of the Macroeconimoc model used in this project

Source: Projections from the Macroeconomic model and inputs for the new activities in industrial and mining sectors received from the relevant stakeholders.

The table above includes the projected increase in copper production according to the published information and the introduction of new activities in other sectors of industrial production and mining, based on information provided by the key stakeholders.

For the other industrial subsectors, the Value Added has been used as the demand driver and this shown per subsector in the following Figure. These projections are consistent with the GDP projection presented in Figure 1 and the analysis of the Macro-economic model which is used on the present study (MANAGE CGE model).

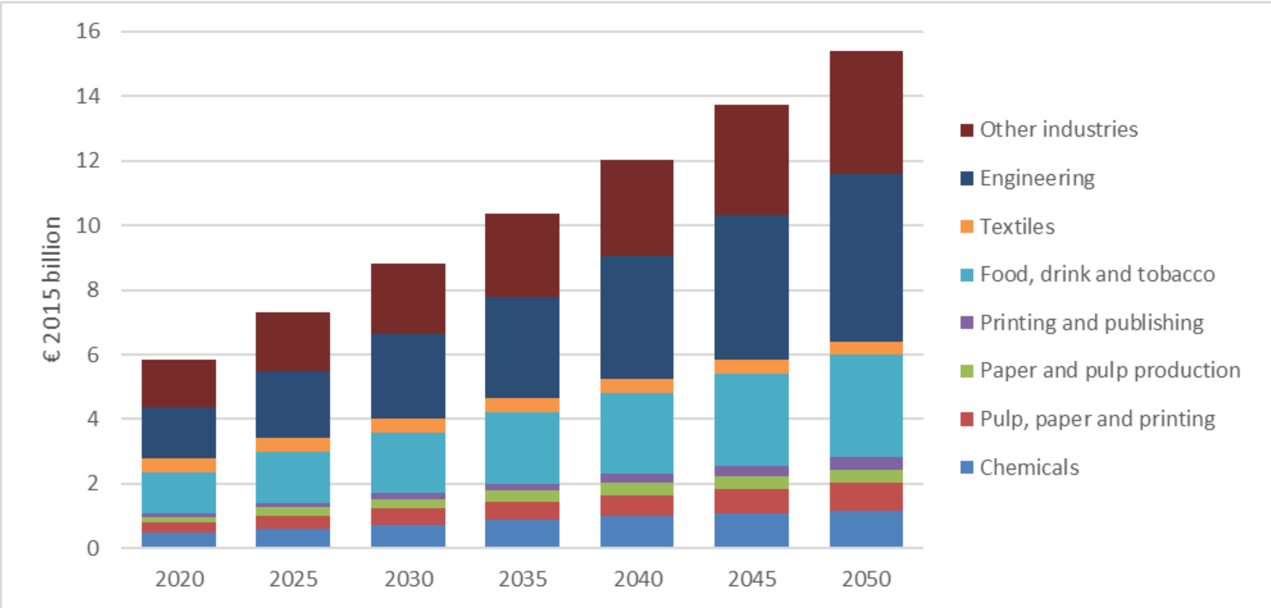


Figure 3: Evolution of value added of other industrial subsectors until 2050
(Source: Macroeconomic model projections consistent with the GDP projections)

1.1.2 Projections of imported energy prices

The projections of the average annual import prices of the main energy commodities are shown in the following table.

Table 2: Energy import prices projections[4]

Euro(2015)	2020	2025	2030	2035	2040	2045	2050
Oil (Euro/barrel)	33.5	63.97	72.2	81.5	87.8	95.2	106.3
Gas (Euro/MBTU)	3.4	5.57	6.24	6.85	8.04	8.71	8.83
Gas (Euro/MWh)	11.59	19	21.3	23.36	27.42	29.71	30.12
Hard Coal (Euro/tonne)	36.53	50.48	64.02	69.36	73.87	77.56	80.85

The prices for 2030 and beyond are based on the “Impact Assessment of the stepping up Europe’s 2030 climate ambition” which is the analysis which has been performed for new Fitfor55 package of the European Union. However, since the price assumptions which were included in the Impact Assessment were too low for the first periods, the 2025 values were increased to 19Euro/MWh.
In order to be easier to compare the prices the following table presented the prices in Euro(2015)/GJ.

[4] European Commission, “Impact Assessment of the stepping up Europe’s 2030 climate ambition”, with a correction of values in 2025, https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2020)176&lang=EN Table 35.

Euro2015/GJ	2020	2025	2030	2035	2040	2045	2050
Crude Oil	5.76	11.00	12.42	14.02	15.10	16.23	17.45
Natural Gas	3.39	5.55	6.23	6.83	8.01	9.31	10.82
Hard Coal	1.70	2.12	2.68	2.91	3.10	3.29	3.50
Coke	2.16	2.69	3.41	3.69	3.93	4.18	4.45

1.1.3 Investment cost of RES technologies.

The projected development of the cost of wind and PV technologies can be seen in the table below. Three cost levels have been included for wind installations to model a "supply curve" for the wind potential.

Table 3: Investment costs projection for wind and PV installations[5]

Euro/kW	*2025*	*2030*	*2040*	*2050*
Solar PV – Plant size	575	550	500	350
Rooftop Solar PV	690	660	600	420
Wind plants Cost level 1	1150	1000	950	900
Wind Plants Cost level 2	1265	1100	1045	990
Wind Plants Cost level 3	1520	1320	1254	1188

The investment costs presented above were based on the background note presented in Annex 4.3.

An additional cost for the connection costs, calculated as an average from the data provided by EMS from existing projects is added to the investment costs presented above, as can be seen in Table 5.

Table 4: Additional connection costs for wind and PV plants installations

Average connection costs per region	*€/kW*
BEL	35.6
VOJ	35.6
SES	53.9
SWS	100.0

(Source: Average values of the connections costs provided by EMS)

The capacity factor for solar PVs is considered to be 15% for plant size installations (reduced by 10% for rooftop installations), while the capacity factor of wind plants varies from 27% in regions Belgrade, Southern and Eastern Serbia, Šumadija and Western Serbia, to 30% in Vojvodina.

1.2 Other input assumptions

1.2.1 Carbon pricing options

The following options were considered regarding the projection of the prices of CO_2 in the time horizon until 2050.

Table 5: Carbon prices projection Options

	a	b	c	d
Projected ETS price Euro2015/tCO2	Option 1 Euro2015/tCO2	Option 2 Euro2015/tCO2	Option 3 Euro2015/tCO2	Option 4 Euro2015/tCO2

[5] For more information see Annex 4.3

2025	60	15	4	4	0
2030	70	35	20	20	20
2035	80	60	30	25	25
2040	90	90	45	30	45
2045	115	115	115	40	115
2050	150	150	150	50	150

The different options presented in the table above correspond to different levels of "free allowances" allocated to the emissions which should be included in the ETS scheme for Serbia as can be seen in Annex 4.4.

The rationale for the prices in the first column of the table is the following. The latest EU Reference Scenario 2020 (published in July 2021) presents the following projection for the ETS prices:

Table 6: Carbon prices projections in the Baseline 2020 scenario of the EU

Year	Euro2015/tCO2eq
2025	26.5
2030	30.0
2040	50.0
2050	150.0

Source: (EU Reference Scenario 2020, July 2021, Figure 8[6]*)*

However, a footnote in the report points out that *"The modelling applies to the ETS policy framework for 2030 as of end of 2019 and was realised before the political agreement on the new climate target of reducing EU's net GHG emissions by at least 55% in 2030, which has very likely affected the dynamics of the ETS price since the end of 2020" (EU Baseline 2020, July 2021, page 41).*

Furthermore, based on the current ETS-price development trends (which are above 50Euro/ton after June 2021), and based on the following comment from the recently **published proposals for the revision of the ETS**[7] (pg34): "*The ETS carbon price in Baseline which only reflects currently adopted policies averages at €29 for the period 2021 to 2030 and €30 for the period 2026 to 2030. Currently observed carbon market prices already respond to the increased GHG target and vary between €40 and €55. Future carbon prices are by nature uncertain and impacted by policy choices and market developments. The policy scenarios modelled project for the period 2026 to 2030 average carbon price ranges between €45 and €70, with projected carbon prices in the year 2030 ranging between €50 and €85. This is broadly in line with external analyses, for which the average of price forecasts for 2030 is €71, with a large range between €42 and €89.".* Therefore the 2030 values were increased to 70 €/tCO2 and they were gradually increased to the 150 €/tCO2 of the EU Baseline 2020.

In the current proposal for the revision of the Effort Sharing Regulation (pg148)[8] it is stated that the "*carbon value achieves in 2050 levels between €360/tCO2 (in REG, where energy policy drivers play comparatively a larger role) and €430/tCO2 (MIX-CP).*", which clearly shows that the expectation is for higher carbon prices overall.

1.2.2 Renewable energy sources potentials

The assumptions which were included for the available RES potentials are the following:

a) Wind energy potential. Based on the input which was provided by EMS and MoME on the projects for wind plants which are at various stages of implementation (from feasibility to licensing) a total

[6] EU Reference scenario July 2020, https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

[7] Directive 2003/87/EC, https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf

[8] Regulation (EU) 2018/842, https://ec.europa.eu/info/sites/default/files/proposal-amendment-effort-sharing-regulation-with-annexes_en.pdf

capacity of 7GW can be reached. This was further increased to 11GW as the assumed wind potential by 2050 to allow for new sites and advances in technology.

b) Solar PV potential. Following discussions in the Working Group and input received on estimated rooftop potential an upper limit of close to 15GW of solar PVs by 2050 was included in the scenario runs, which was further relaxed in the very ambitious scenarios for 2050 reaching more than 20GW by 2050. A roof-top PVs level of 1.5GW is assumed to be in place by 2030, following the ambitions pursued by MoME.

c) Hydro power. Until 2050 it is considered to have a total potential of 3GW of large hydro plants (2354MW existing and 652MW possible new additions), 425MW of small hydro plants (107.6MWs existing in 2020) and 1.28GW of new pump storage hydro power plants on top of the existing 614MW (Bajna Basta) (this includes 680MW in Bistrica and 600MW in Djerdap). The capacity of the pump storage plant Djerdap 3 is considered to be able to reach up to 2.4GW which can be utilised in the ambitious RES scenarios.

The values described above are set as upper bounds (upper limits to the capacities of the different technologies) and the **actual penetration of each technology is determined by the model depending on the scenario formulation**.

2 RES TOOL INPUT DATA

The RES Tool consists of a market model, developed in the ANTARES software, of the electrical systems of the region shown in Figure 4. The market zone of Serbia which corresponds to the system modelled in SEMS is modelled as market zone RS01, while RS02 corresponds to the Autonomous Province of Kosovo and Metohija.

Figure 4: Modelled perimeter

The models of the market zones except RS01 are based on publicly available data of ENTSO-E for TYNDP 2020, NT (National Trends) scenario. Values for the Net Transfer Capacities of the Serbian system borders as provided by EMS have been used.

The model of market zone RS01 is based on the results of SEMS for the specific scenario which exhibited some of the highest levels of installed capacities for wind and PV installations in 2030. The reasoning behind this analysis is that if the power system operates adequately under these conditions, then it would also operate adequately with lower levels of installed capacities of RES.
Main inputs from SEMS which are used in the RES tool are the following, for **2030 and for 2040**:

- Installed capacities per technology/fuel for RES and conventional technologies.
- Annual electricity demand.
- Carbon price.
- Limitations in the operation of fossil fuel fired power plants, corresponding to limitations on the CO_2 emissions.

2.1 Modelling of the neighbouring power systems

For the market zones that will be modelled, ENTSO-E MAF 2020[9] and TYNDP2020[10] can be the main sources for model parameters, as well as data provided by EMS or other members of the Working Group. During the analysis of different scenarios for the Serbian system, the scenario which will be used for the neighboring systems will be fixed.
There are three scenarios in ENTSO-E TYNDP 2020 that can be used as reference for the neighbouring systems:
"National Trends" is the central bottom-up scenario in line with the NECPs in accordance with the governance of the energy union and climate action rules, as well as on further national policies and climate targets already stated by the EU member states. Following its fundamental principles, National Trends is compliant with the EU's 2030 Climate and Energy Framework (32 % renewables, 32.5 % energy efficiency) and EC 2050 Long-Term Strategy with an agreed climate target of 80–95 % CO_2 reduction compared to 1990 levels.
"Global Ambition" is a scenario compliant with the 1.5°C target of the Paris Agreement also considering the EU's climate targets for 2030. It looks at a future that is led by development in centralised generation. Economies of scale lead to significant cost reductions in emerging technologies such as offshore wind, but also imports of energy from competitive sources are considered as a viable option.
"Distributed Energy" is a scenario compliant with the 1.5°C target of the Paris Agreement also considering the EU's climate targets for 2030. It embraces a de-centralised approach to the energy transition. A key feature of the scenario is the role of the energy consumer (prosumer), who actively participates in the energy market and helps to drive the system's decarbonisation by investing in small-scale solutions and circular approaches.
In our analysis has been used the National Trends scenario as reference for the regional model. National Trends relies on data provided by the latest submissions of country specific NECPs for 2030 at the fixed date of the data. Where, in particular for 2040, NECPs do not provide sufficient information or necessary granularity, National Trends is based on TSOs' best knowledge in compliance with national long-term climate and energy strategies.
The available data from ENTSO-E, used in its MAF 2020 and TYNDP 2020, are described in more detail in the following sections.

2.2 Modelling of the Serbian power system

The generation fleet is dominated by lignite and hydro power plants. The gross electricity demand in Serbia in 2018 amounted to 34.2 TWh (excluding the Autonomous Province of Kosovo and Metohija). The

9 ENTSO-E, "Mid-term Adequacy Forecast 2020," 2020.
10 ENTSO-E, "Ten-Year Network Development Plan," 2020.

consumption of final customers amounted to 29.2 TWh while the remaining quantities were used for the operation of power plants and compensation of transmission and distribution network losses.
The interconnectivity index of the Serbian transmission system (expressed as the ratio between the sum of the maximum NTC values on the borders and the total installed generation capacity) is reported at 50%[11], i.e. much higher than the corresponding target of 10% for 2020 for EU member states. This high level of interconnectivity is expected to be utilized more efficiently as regional electricity market integration advances.

2.2.1 Generation units input data

For the Serbian system, additional virtual nodes were added in order to model the hydro power plants in detail (e.g. per river), since hydro is assumed lumped in each area. Data on the hydro power plants of the Serbian system are listed in the following table.

Table 7: Hydro generating units of the Serbian power system
(source: Data provided by EPS)

Generating Unit	River	Type	Installed Capacity [MW]
HPP Djerdap 1	Danube	RoR	1126.3
HPP Djerdap 2		RoR	270.0
PSHPP Bajina Basta	Drina	Pump Storage Plant	616.0
HPP Bajina Basta		RoR	420.0
HPP Zvornik		RoR	118.2
HPP Vrla 1	Vlasina	Reservoir Hydro	51.0
HPP Vrla 2		Reservoir Hydro	23.8
HPP Vrla 3		Reservoir Hydro	29.4
HPP Vrla 4		Reservoir Hydro	24.8
HPP Pirot		Reservoir Hydro	80.0
PAP Lisina		Pump Storage Plant	28.6
HPP Uvac	Lim	Reservoir Hydro	36.0
HPP Kokin Brod		Reservoir Hydro	22.5
HPP Bistrica		Reservoir Hydro	102.0
HPP Potpec		RoR	51.0
HPP Meduvrsje	Zapadna Morava	RoR	9.6
HPP Ovcar Banja		RoR	8.2

Also, for the Serbian system thermal units are modelled in detail, i.e. on a unit-by-unit. Data of thermal units in the Serbian system are listed in the following table.

Table 8: Thermal generating units of the Serbian power system

(source: Data provided by EPS)

11 Energy Community Secretariat, “Electricity Interconnection Targets in the Energy Community Contracting Parties”, Feb. 2021

Generating Unit	Fuel	Expected year of decommissioning or reserve status	Nominal Output Power [MW]
TPP Nikola Tesla A1	Lignite	2040	210
TPP Nikola Tesla A2	Lignite	2040	210
TPP Nikola Tesla A3	Lignite	after 2040	329
TPP Nikola Tesla A4	Lignite	after 2040	309
TPP Nikola Tesla A5	Lignite	after 2040	340
TPP Nikola Tesla A6	Lignite	after 2040	348
TPP Nikola Tesla B1	Lignite	after 2040	650
TPP Nikola Tesla B2	Lignite	after 2040	650
TPP Morava	Lignite	2023	125
TPP Kolubara A1	Lignite	2018	320
TPP Kolubara A2	Lignite	2018	320
TPP Kolubara A3	Lignite	2023	650
TPP Kolubara A5	Lignite	2023	110
TPP Kostolac A1	Lignite	2038	100
TPP Kostolac A2	Lignite	2038	210
TPP Kostolac B1	Lignite	after 2040	349
TPP Kostolac B2	Lignite	after 2040	349
TPP Kostolac B3	Lignite	after 2040	350
CHP Pancevo	Gas	after 2040	188

2.2.2 Wind, solar and non-dispatchable generation

Similarly, to load time series, RES time series from ENTSO-E PECD can be used as basis for the simulated Climate Years (CYs) or time series provided by the Working Group that correspond to the climate years to be simulated. From the capacity factor (CF) time series and the total installed capacities per technology as provided by SEMS results, the necessary time series in MW are calculated and inserted in RES tool.

For non-dispatchable generation (CHP, biomass, etc.), apart from the installed capacities that is provided from SEMS, CF hourly time-series are provided to the RES tool.

2.2.3 Hydro generation

In PECD the total hydro generation and inflows for Serbia are available for TYs 2025, for each CY and for the three categories, moreover, corresponding inflows provided by the Working Group are used.

The following characteristics have been provided per plant:

- Run-of-river hydro
- Reservoir hydro
- Open- Loop Pump-Storage hydro.

In terms of hydro plant characteristics, the model is fed by:

- Total installed capacity (based on the scenario analysis done in SEMS).
- Maximum generating capacity, (provided by EMS).
- Total net minimum stable generation [MW] (provided by EMS)
- Hourly generation of Run-of-River hydro (provided by EMS).

2.2.4 Thermal generating units

For each thermal generating unit, available data have been provided for the following parameters:

- Commissioning and Decommissioning dates (or if they are in-service or with reserve status in the target years to be analysed, e.g., 2030)
- Net maximum generating capacity [MW]
- Output power limitation, if any due to technical constraints [MW]
- Net minimum stable generation [MW]
- Average heat rate [GJ/MWh] or efficiency [%]
- Minimum up and minimum down time [h]
- Forced outage rate [%]
- Mean time to repair [number of days]
- Planned outage: annual rate [number of days], maintenance restriction periods
- ENTSO-E PEMMDB fuel and plant type
- Variable Operating & Maintenance Costs [€/MWh]
- Must-run obligations
- Any constraints, such as must-run/minimum generation

3 MACROECONOMIC ANALYSES TOOL INPUT

3.1 Serbian Input-Output table

To calibrate the model, a respective dataset that represent the Serbian economy for a reference year is provided, where the parameters of the model are calculated in order to replicate this dataset. When it comes to computable general equilibrium (CGE) models, the dataset used for this purpose is the Social Accounting Matrix (SAM) of the economy in question. SAM depicts the circular monetary flows that take place between the agents of the economy for a specific time period, usually for a year,[12] providing a static picture of the economy of interest for this year. In a SAM, every cell account for an expenditure for the agent of the corresponding column, and for the receipt of this expenditure, i.e., income, for the agent of the corresponding row. Thus, SAM, apart from providing quantitative data for the economy in question, also depicts its structure, such as the production and imports shares of the represented sectors. As a result, by replicating SAM, the model is adapted to the idiosyncrasy of the economy of the examined country, encompassing its specific features.

Table 9 presents an indicative example of a SAM that represents a hypothetical economy composed from four agents, as follows: (i) *Activities*, (ii) Factors of *production*, (iii) *Institutions* (e.g., households and government), and (iv) *Rest of the World* (ROW). Institutions own the factors of production and transfer them to Activities by earning the respective income, which in turn they use to buy domestic and imported final commodities. Activities use the factors of production along with raw commodities to produce final commodities, where a part of them is consumed domestically, a part is exported, and a part is used as raw input for producing other final commodities. It should be noted that a SAM represents an economy in balance, meaning that the total income of an agent equals its total expenditures, or in other words, supply equals demand.

Table 9: Example of a Social Accounting Matrix (SAM)

SAM	Commodities	Activities	Factors	Institutions	RoW	Total
Commodities		Intermediate consumption		Institutional consumption	Exports	Demand
Activities	Domestic production					Gross output
Factors		Factors domestic income			Factors' income from ROW	Factors' income
Institutions			Factors' income distribution to Institutions		Transfers to Institutions from ROW	Institutional income
RoW	Imports		Factors' income to ROW	Institutional transfers to ROW		Payments to ROW
Total	Supply	Cost of production activities	Expenditure on factors	Institutional expenditure	Income from ROW	

In our case, Macroeconomic analyses tool is fed by the SAM of Serbia with a reference year of 2019. Initially, the SAM of Serbia will be extracted from the Global Trade Analysis Project (GTAP) database version 10p1,

12 Mainar Causapé, A., Ferrari, E. and Mcdonald, S., 2018. Social Accounting Matrices: basic aspects and main steps for estimation, EUR 29297 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/010600

with a reference year of 2014. GTAP 10p1 Data Base will include Serbia for the first time as a separate country, based on the respective contribution made for the purposes of this project. It should be noted that in the previous versions of the GTAP Data Base Serbia was represented as a part of the "Rest of Europe" aggregate region. For each region reported in the GTAP Data Base, information about the values of production, intermediate and final consumption of commodities and services is provided in millions of U.S. dollars.[13]

The SAM reported by the GTAP 10p1 Data Base was prepared based on the data provided by the Statistical Office of the Republic of Serbia (SORS). In particular, the Input-Output (I-O) table for 2015 of the Serbian economy as supplied by SORS was used.[14] I-O tables, similar to SAMs, depict the circular monetary flows that occur inside an economy for a specific time frame. However, they do it in a more aggregate way than SAMs[15], not examining sub-categories of the agents represented, e.g., households. Thus, SAMs provide a more detailed and representative picture of the economy in question.

13 Aguiar, A., et al. The GTAP Data Base: Version 10. Journal of Global Economic Analysis, v. 4, n. 1, p. 1-27, June 2019. ISSN 2377-2999. doi:http://dx.doi.org/10.21642/JGEA.040101AF.

14 Available at: https://www.stat.gov.rs/en-us/oblasti/nacionalni-racuni/godisnji-nacionalni-racuni-ponuda-i-upotreba/.

15 La Marca, Massimiliano & Jiang, Xiao, 2017. From IO and Supply-and-Use to Social Accounting Matrix Analysis.

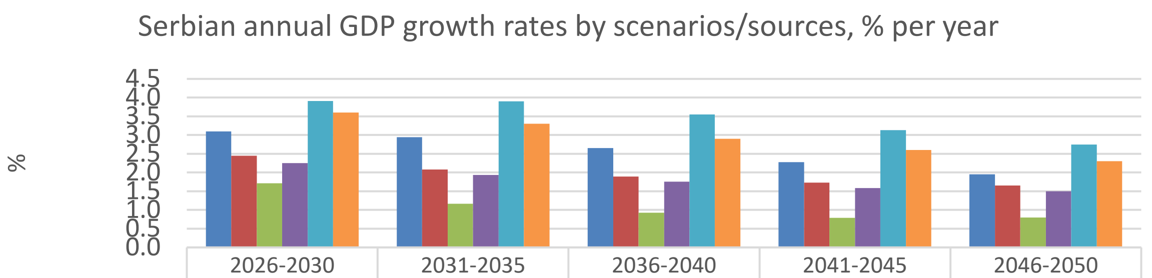
4 ANNEXES

4.1 GDP projections

The projected growth rate of real GDP can be seen in the following table:

Years/period	Annual growth rate, %
2021-2026	4.5
2026-2030	3.6
2031-2035	3.3
2036-2040	2.9
2041-2045	2.6
2046-2050	2.3

The overall rationale for this projection is that in the longer term the GDP growth rates will converge towards those of countries with higher GDP per capita. We have consulted the projections of GDP growth rates from the Shared Socioeconomic Pathways (SSP)[16], which are global long-term projections of GDP growth rates until 2100. The growth rates for Serbia after 2026 in the five SSP scenarios can be seen in the figure below[17] together with the projection used in SEMS. As can be seen the assumption we have used is that the projection path will be between SSP1 and SSP5 (the most optimistic scenarios). We have used the average between SSP1 and SSP5 in the period 2026-2030 and the period 2046-2050 and considered a linear path in between.



	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
SSP1	3.1	2.9	2.7	2.3	2.0
SSP2	2.4	2.1	1.9	1.7	1.7
SSP3	1.7	1.2	0.9	0.8	0.8
SSP4	2.3	1.9	1.8	1.6	1.5
SSP5	3.9	3.9	3.5	3.1	2.7
SEMS baseline	3.6	3.3	2.9	2.6	2.3

Based on the information which was shared, the EU funded project "EXTENSION OF THE EU ENERGY AND CLIMATE MODELLING CAPACITY TO INCLUDE THE EnC AND ITS NINE CPs'' is using the following growth rates for real GDP projections:

	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Average annual growth (%)	3.6	3.0	2.8	2.7	2.6

16 International Institute for Applied System Analisys, Shared Socioeconomic Pathways Database, December 2018, https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10
17 Dellink et al. (2017). Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change. Volume 42, January 2007, Pages 200-2014. https://doi.org/10.1016/j.gloenvcha.2015.06.004

4.2 GVA projections

The following tables present the evolution of the GVA in Euros 2015 which are used to project the useful services demand

									Growth Rates						
(mil Euro2015)	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2015-20**	**2020-25**	**2025-30**	**2030-35**	**2035-40**	**2040-45**	**2045-50**
GDP	35740	40676	50690	60866	71439	82596	94064	105515	2.62%	4.50%	3.73%	3.26%	2.94%	2.63%	2.32%
VA Agriculture	2400	2626	2856	3078	3213	3302	3343	3346	1.82%	1.69%	1.51%	0.86%	0.55%	0.25%	0.02%
VA Trade (1)	3977	4812	6326	7963	9735	11760	14220	17318	3.89%	5.62%	4.71%	4.10%	3.85%	3.87%	4.02%
VA Non-market services (2)	3733	4109	5012	5898	6834	7805	8730	9534	1.94%	4.05%	3.31%	2.99%	2.69%	2.26%	1.78%
VA Market services (3)	9580	10557	13474	16391	19418	22549	25616	28391	1.96%	5.00%	4.00%	3.45%	3.03%	2.58%	2.08%
VA Transport Sector	1320	1553	1972	2397	2845	3319	3804	4275	3.31%	4.90%	3.98%	3.48%	3.13%	2.77%	2.36%
VA Industry (This includes the following industrial sectors): (4)	5424	5901	7365	8837	10361	11995	13676	15353	1.70%	4.53%	3.71%	3.23%	2.97%	2.66%	2.34%
VA Iron and steel	27	49	62	73	85	97	108	119	12.82%	5.09%	3.34%	2.94%	2.64%	2.26%	1.91%
VA Non ferrous metals	24	31	36	39	41	44	45	47	5.87%	2.61%	1.66%	1.32%	1.08%	0.84%	0.64%
VA Chemicals	408	502	627	745	868	992	1098	1176	4.23%	4.52%	3.53%	3.09%	2.70%	2.05%	1.40%
VA Non metallic minerals	214	247	303	354	400	450	505	573	2.97%	4.17%	3.13%	2.50%	2.36%	2.35%	2.56%
VA Pulp, paper and printing	255	287	384	481	572	657	744	845	2.42%	6.00%	4.59%	3.52%	2.83%	2.52%	2.58%
VA Food, drink and tobacco	1375	1284	1589	1892	2204	2530	2856	3167	-1.35%	4.35%	3.55%	3.10%	2.80%	2.45%	2.09%
VA Textiles	410	425	425	424	425	423	416	405	0.72%	-0.01%	-0.06%	0.05%	-0.10%	-0.31%	-0.55%
VA Engineering	1409	1588	2083	2599	3161	3792	4471	5173	2.42%	5.58%	4.53%	3.99%	3.71%	3.35%	2.96%
VA Other industries	1304	1488	1831	2204	2573	2977	3408	3840	2.67%	4.24%	3.78%	3.14%	2.96%	2.74%	2.42%

Notes:

(1) This is used as a driver for the commercial building's activity

(2) This is used as a driver for the public sector buildings activity

(3) This is used as a driver for the private sector office buildings activity

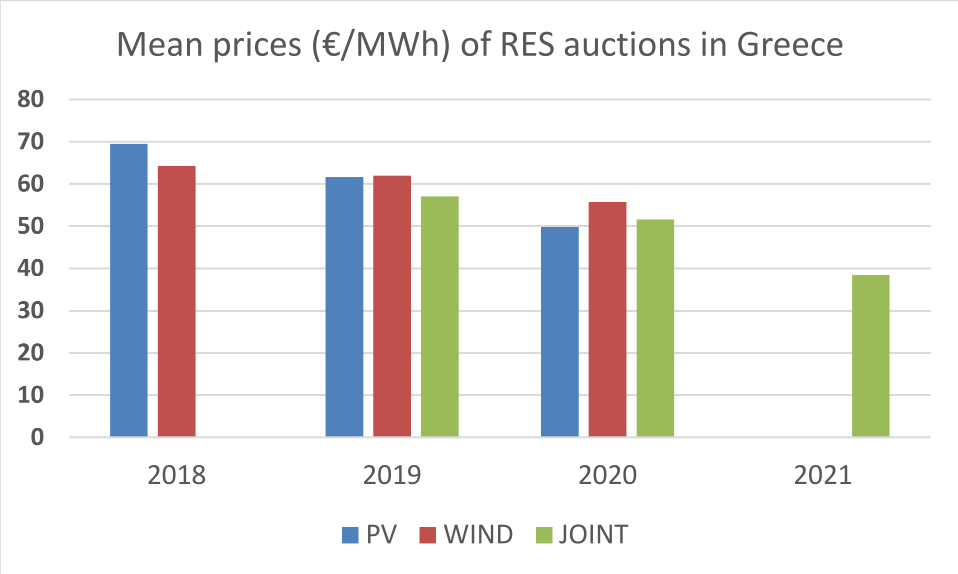
(4) This is not used in the projections it is just presented as a sum of the sectors below. The growth rates of each of these sectors are used in the demand projections.

Sectors:	**In the National accounts**
VA Trade	G Wholesale and retail trade; repair of motor vehicles and motorcycles 469 219 496 914 528 619 581 618 617 729
VA Non-market services	O Public administration and defence; compulsory social security, P Education, Q Human health and social work activities
VA Market services	I Accommodation and food service activities, J Information and communication, K Financial and insurance activities, L Real estate activities, M Professional, scientific and technical activities, N Administrative and support service activities, R Arts, entertainment and recreation, S Other service activities, E Water supply; sewerage, waste management and remediation activities, F Construction.
VA Transport Sector	H Transportation and storage.

Sectors reported above under Industry	NACE classifications included
Iron and steel	NACE Rev. 2 Groups 24.1, 24.2 and 24.3; and NACE Rev. 2 Classes 24.51 and 24.52 (transformation input in blast furnaces is included in the transformation sector)
Non-ferrous metals	NACE Rev. 2 Group 24.4; and NACE Rev. 2 Classes 24.53 and 24.54
Chemicals & petrochemicals	NACE Rev. 2 Divisions 20 and 21
Non-metallic minerals	NACE Rev. 2 Division 23
Cement and derived products	NACE Rev.2 Groups 23.5, 23.6
Ceramics, bricks, etc.	NACE Rev.2 Groups 23.3
Glass production	NACE Rev. 2 Groups 23.1
Other non-metallic minerals	NACE Rev.2 Groups 23.2, 23.4 ,23.7,23.9
Pulp, paper and printing	NACE Rev. 2 Divisions 17 and 18
Paper and pulp production	NACE Rev. 2 Divisions 17
Printing and publishing	NACE Rev. 2 Divisions 18
Food, drink and tobacco	NACE Rev. 2 Divisions 10, 11 and 12
Textiles	NACE Rev. 2 Divisions 13, 14 and 15
Engineering	NACE Rev. 2 Divisions 25, 26, 27 and 28, NACE Rev. 2 Divisions 29 and 30
Other industries	NACE Divisions 22, 31 and 32

4.3 Note on auction prices for wind and PV projects in the region.

The following graph and table shows the results of dedicated PV and Wind auctions in Greece during the last 4 years. Joint auctions refer to auctions with open participation from both PV and Wind projects and the most cost-efficient ones were selected.



Mean prices (€/MWh)			
	PV	WIND	JOINT
2018	69.48	64.24	
2019	61.58	62	57.03
2020	49.8	55.67	51.59
2021			38.5

(source: Regulatory Authority of Energy RAE aucitons[18])

For PVs considering a mean aimed Project IRR of 6.5% under a 40€/MWh award this translates to 500k€/MW. For Wind parks considering a mean aimed Project IRR of 6.5% under a 55€/MWh award this translates to 1000k€/MW considering a capacity factor of 25%. Higher CF are likely to be translated to higher Capex due to site requirements regarding accessibility, network extension etc. Generally, wind capex is varying and is estimated from a low 950k€/MW up to 1200k€/MW.
For PV auctions the projections for 2021 and onwards are for mean awarded prices less than 40€/MWh and for wind auctions around 50€/MWh.
The Regulatory Authority for Energy (RAE) the Greek Regulator of Energy, has launched a public consultation of the CONE (Cost of New Entry) in June 2021 in Greece on the basis of international benchmarking studies and by assessing the national auction results. The table below present the initial proposals for RAE presented for consultation with the stakeholders.

Technology Type	Capital Cost k€/MW	Annual fixed cost k€/MW
PV - Rooftop residential	550	13.8
PV - Commercial	400	10.0

[18] Regulatory Authority of Energy RAE aucitons (Decision in Greek), 2020 https://energypress.gr/sites/default/files/media/001_-_4i_apof._rae_-_diag._ioylioy_2020_-_1142_2020_-_oghiidx-trd_1.pdf

Wind-Onshore	1,000	25.0

The presented CAPEX values for the case of PVs have been heavily criticized by the market, with the main national PV association highlighting the following:
"*as far as concerns the residential PVs the 550 k€/MW is extremely low and is not reflecting market reality. The following benchmark costs for various residential systems were proposed: a)3 kW: 1250-1300 k€/MW b) 10 kW: 800-1000 k€/MW*
similarly for commercial PV the 400 k€/MW is rather low, and it reflects just the EPC cost (low end) and not the full cost. If everything is included, then a realistic benchmark cost is 500-550 k€/MW for large scale PV plants."
It should be also noted that **the PV auction in Albania in 2020** resulted to 24.9€/MWh for 70MW, however under a 50-50 capacity aid scheme allowing the rest of 70MW a direct market revenue. Nevertheless, it is evident that for PVs there is an overall convergence of prices under some utilization factors.

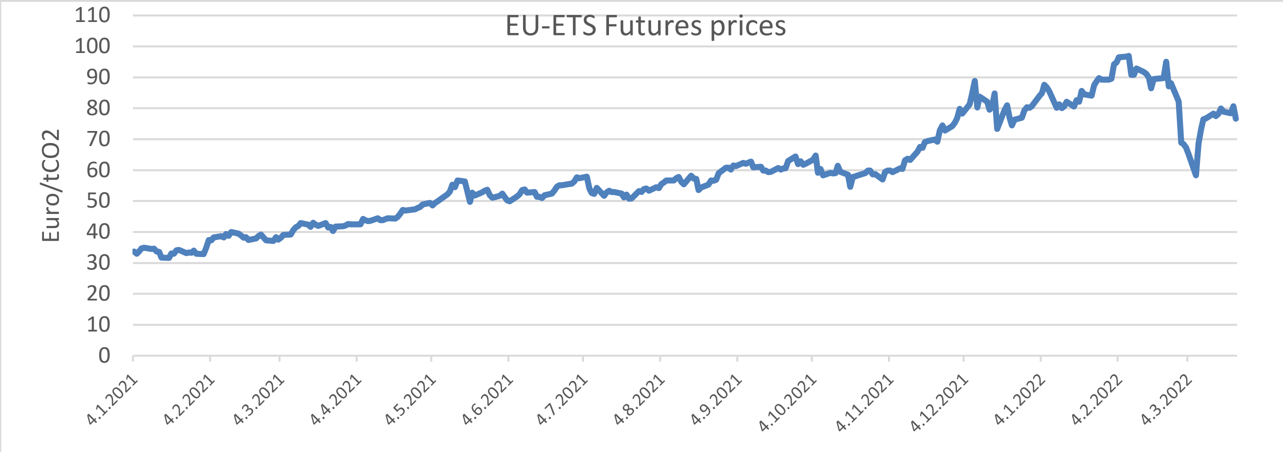
4.4 Carbon pricing options

The carbons prices options which were presented in **Table 6** are based on the following assumptions regarding the share of emissions which will have to participate in the auction procedure of the ETS. Therefore, the percentage of allocated free allowances would be 100% minus the % of auctions in the table below.

		Carbon Pricing Options in Serbia							
	Projected ETS price	**Option 1**		**Option 2**		**Option 3**		**Option 4**	
	Euro/tCO2	**Euro/tCO2**	**% of auctions**	**Euro/tCO2**	**% of auctions**	**Euro/tCO2**	**% of auctions**	**Euro/tCO2**	**% of auctions**
2025	60	15	25%	4	7%	4	7%	0	0%
2030	70	35	50%	20	29%	20	29%	20	29%
2035	80	60	75%	30	38%	25	31%	25	31%
2040	90	90	100%	45	50%	30	33%	45	50%
2045	115	115	100%	115	100%	40	35%	115	100%
2050	150	150	100%	150	100%	50	33%	150	100%

Furthermore, the current level of ETS prices, is consistently above 50Euro/ton since May 2021[19].

[19]Ember is the trademark of Sandbag Climate Campaign CIC https://ember-climate.org/data/carbon-price-viewer/



4.5 Building refurbishments

The building envelope refurbishments included in the scenarios definitions refer to the renovation of the building envelop using three alternative options i) replacement of windows, ii) replacement of windows plus 5cm walls and roof insulation, iii) replacement of windows plus 10cm walls and roof insulation. The corresponding costs and energy efficiency improvements were taken from the outputs of the TABULA and EPISCOPE[20] and ETRANZE[21] projects. The envelope refurbishment technologies reduce the demand for space heating by a percentage depending on which of the three levels of refurbishment described above is selected by SEMS.

Furthermore, SEMS includes a number of technologies to satisfy the heating, cooling, water heating, lighting, cooking, refrigerating, washing, and other appliances demands, with different efficiencies and costs. We do not impose any restrictions on the availability of these technologies, apart from the WEM scenario where we impose limited penetration rates of improved and advanced technologies. Therefore, the refurbishment rate imposed in each scenario, imposes a limit to building envelope improvements only.

[20] EPISCOPE project result for Serbia March 2016, project coordinator: Institut Wohnen und Umwelt, Darmstadt, Germany https://episcope.eu/monitoring/case-studies/rsserbia/

[21] ENTRANZE Project result, September 2014, project coordinator: Energy Economics Group from the Vienna University of Technology https://www.entranze.eu/