newTRENDs

D4.3

Assessment of energy demand-side models from the perspective of policy makers' needs at European level

Grant agreement	No. 893311		Acronym	newTRENDs
Full title	New Trends in Energy Demand Modeling			
Topic	LC-SC3-EE-14-2018-2019-2020			
Funding scheme	Horizon 2020, RIA – Research and Innovation Action			
Start date	September 2020		Duration	36 Months
Project website	https://newTRENDs2020.eu/			
Project coordinator	Fraunhofer ISI			
Deliverable	4.3			
Work package	4			
Date of Delivery	Contractual	31.12.2021	Actual	11.03.2022
Status	draft			
Nature	Report (R)		Dissemination level	Public
Lead beneficiary	Research and Innovation Centre Pro-Akademia (RIC)			
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Keywords	energy demand-side policies; policy needs; prosumers; digitalisation; circular economy; sharing economy			

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 893311.

Executive Summary

To achieve the Paris Agreement goals, two central strategies have to be implemented in all countries: i) enhancing energy efficiency (EE) and (ii) decarbonizing remaining energy supply and demand. Scenarios with different focus and assumptions have been developed to map this development until 2050. While these scenarios present a major step forward beyond previous modelling approaches by integrating societal trends, much more progress is necessary to enhance the empirical basis for such trends and their representation in models. In this context, the project newTRENDs is developing the analytical basis for a "2050 Energy Efficiency Vision" taking into account New Societal Trends: (i) digitalisation of the economy and of private lives; (ii) circular economy and low-carbon industry; (iii) shared economy, and (iv) prosumaging (combining production, consumption and storage of energy).

This report provides an assessment of energy demand-side models (FORECAST-Industry, FORECAST-Tertiary, INVERT, PRIMES-BuiMo, and PRIMES-TREMOVE) from the perspective of policy makers' needs at European level. The assessment is based on the analysis of models documentation as well as stakeholder engagement through semi-structured interviews with modelling groups developing the assessed models. In particular, the analysis evaluates in how far they are able to represent New Societal Trends and provide a quantitative assessment of the energy demand-side policies that affect those trends.

The report contributes to providing knowledge base for strengthening the modeling of relevant policies in demand-side models in the EU, to appropriately represent New Societal Trends.

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1. Introduction

1.1. About the newTRENDs project

The EU 2050 Long-term Strategy presents scenarios for a climate-neutral EU in 2050 that aim at full deployment of low-carbon technologies or assume increased climate awareness of EU citizens translating into lifestyle changes, consumer choices, and a more circular economy. While these scenarios integrate societal trends, further progress is necessary to enhance the empirical basis for such new societal trends and their representation in models. These trends have potentially a large (increasing or decreasing) impact on energy consumption and might lead to cross-sectoral demand shifts that go beyond extrapolation of presently observed trends (continuous trends) and may speed up when they are embraced by larger parts of the society (disruptive trends). Such trends include in particular: digitalisation of the economy and of private lives, circular economy and low-carbon industry, shared economy, and prosumaging, combining production, consumption and storage of energy, which are the main focus topics of the newTRENDs project. Hereinafter they will be referred to as New Societal Trends.

The newTRENDs approach relies on several well-established models (bottom-up energy demand and macro-models), which have all been used extensively in the European context for projections up to 2050 and beyond (EU-27 and individual Member States and countries) and which are run by experienced teams of modellers which have been cooperating frequently in the past. The newTRENDs project strengthens these models while working on New Societal Trends.

The project has the following detailed objectives:

- we aim at **identifying** and **quantifying** how such New Societal Trends affect energy demand (its structure and patterns, including cross-sectoral interdependencies).
- we investigate **how energy demand models are to be improved** to represent such New Societal Trends. We further aim at **representing in energy demand models policies** that can influence such trends in the light of the Energy Efficiency First (EE1) Principle brought forward in the EU policy framework.
- we aim for integrating into energy demand models **recent empirical findings** on the impacts of such New Societal Trends **as well as information from detailed data sources such as smart meter data** available from recent technical advances, in order to improve the empirical basis for such investigations. Special care will be given to **deal with uncertainties** that are inherent when assessing New Societal Trends.

This report is a part of *WP4 Policy needs and policy analysis for Influencing Energy Demand Arising from New Societal Trends*, which analyses policies that

can enhance the demand decreasing trends of New Societal Trends. It aims to strengthen the ability to model relevant EU-level policies in demand-side models.

In particular, WP4 provides:

- an assessment of energy demand-side policies and instruments at European level with major impacts on New Societal Trends (Task 4.1, linked with Deliverable D4.1) as well as of policies and instruments targeting large-scale behavioural changes (Task 4.2, Deliverable D4.2).
- an in-depth assessment of demand-side models in how far they are able to quantify energy demand-side policies impacting on New Societal Trends (Task 4.3, Deliverable D4.3).
- recommendations for better design of energy-demand modelling to appropriately represent such New Societal Trends (Task 4.4, Deliverable D4.4).

This deliverable summarises the third task of WP4, providing the assessment of demand-side models in how far they are able to quantify energy demand-side policies impacting on New Societal Trends.

1.2. Challenges for energy demand-side modelling from the EU policy making. Existing knowledge gaps.

Supporting the design, implementation and evaluation of public policies affecting the energy consumption is among the primary goals of the energy-demand side models. From the policy-making perspective, the expected outputs of the models are comprehensive analyses of interactions between energy-demand technologies, economy, environment, society, and specific policy instruments (Nikas et al. 2020).

In this context, the energy demand-side models addressed by this study, i.e., FORECAST-Industry, FORECAST-Tertiary, INVERT, PRIMES-BuiMo, and PRIMES-TREMOVE, allow for simulation of impacts resulting from implementation of both market and non-market policy measures. Even though the policy dimension is an inherent and important component of each model, the models have different approaches for modelling of policy instruments in terms of:

- **coverage of specific types of policy instruments:** for instance, some models allow for studying the impacts of soft measures, while some focus rather on regulations as well as economic and financial instruments.
- **level of aggregation and the way of implementation of specific types of policy instruments in the models:** for instance, some models allow for directly studying the impacts of EU grants, while some allow for

performing such analyses in an implicit manner (e.g., through energy efficiency value and renewables value[1]).

- **theoretical concepts driving the modelling:** for instance, some models are underpinned by the differentiation of technology diffusion rates, while others rely on utilities of alternative energy efficient technologies and other determine technology uptake endogenously.

All these differences result primarily from the specifics of sectors targeted by the different models, i.e., buildings, industry, transport, and tertiary sector. Even though the approaches for modelling of policy impacts significantly differ for each model, all of them are facing similar challenges from the policy perspective:

- **EU-level policy framework is changing due to New Societal Trends:** New societal trends, such as prosumaging, are forcing changes in the EU-level policy framework. On one hand, changes in the existing policies are implemented, such as more and more stringent targets for energy efficiency in various sectors. On the other hand, new regulatory instruments are anticipated, e.g., the Fit for 55 proposal for Renewable Energy Directive (RED) II recast has put forward a plan for an obligation for MSs to require the use of minimum levels of energy from Renewable Energy Sources (RES) in buildings in their building regulations and codes and, where applicable, in their support schemes. RED II recast also includes significant ambition for transport sector. Against this background, the extent to which energy demand-side models are following the changes in the evolving EU policy framework has not been yet clarified [knowledge gap 1].
- **Needs of EU-level policy makers with regard to energy-demand modelling are becoming more and more articulate in view of the New Societal Trends:** The EU-level policy makers are becoming more and more involved in the co-creation of energy-demand models (Kochanski et al. 2021). This is done through expert elicitation concerning, e.g.: (1) specific indicators of interest from the policy making perspective in the context of New Societal Trends; (2) identification of specific policy instruments affecting New Societal Trends that are important to be modelled according to policy makers. Against this background, the extent to which energy demand-side models are following up on these needs of policy makers has not been yet elucidated [knowledge gap 2].

1.3. Aim and scope of the study

In view of the above identified knowledge gaps, the overall aim of this study is to assess three energy demand-side models (PRIMES modules: PRIMES-BuiMo, PRIMES-TREMOVE, FORECAST modules (FORECAST-Industry and FORECAST-Tertiary), and INVERT) in how far they are able to represent New Societal Trends

[1] Energy efficiency value (in euros/toe of energy savings) acts as a virtual subsidy for achieved energy savings (or, equivalently, penalty on energy consumption). Renewables value (in euros/toe of fuel) acts as a virtual subsidy reducing prices of renewables.

and provide a quantitative assessment of the energy demand-side policies that affect those trends.

The analysis covers four focus topics of New Societal Trends, considered in newTRENDs as the most impactful:

- digitalisation of the economy and of private lives,
- circular economy and low-carbon industry,
- shared economy, and
- prosumaging (combining production, consumption and storage of energy).

The analysis focuses on three key elements of models' assessment:

- **current consideration of energy demand-side policies and policy instruments:** the objective of this element is to provide an overview of how EU-level policies and policy instruments[2] are considered in the analysed models.
- **consideration of energy demand-side policies addressing specific New Societal Trends covered by newTRENDs project:** the objective of this part is to assess to what extent the existing and emerging (potential) energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing New Societal Trends in the European Union are considered by each of the analysed models.
- **consideration of energy demand-side policy needs identified in newTRENDs:** the objective of this part is to assess the models' consideration for energy demand-side policy needs diagnosed within newTRENDs project (Deliverable D4.1), and to generate insights on what improvements or changes in the models could be introduced to better reflect the EU policy needs.

1.4. Methods

Our methods were desk research and elicitation of modelling developers through semi-structured interviews.

- **Desk research**

We analysed available data sources, especially the available specifications of the models, as well as relevant publications concerning the modelling design, in particular: Capros et al. 2012; Fotiou, de Vita, and Capros 2019; Siskos et al. 2018; Fleiter et al. 2018; Kranzl et al. 2013; Müller 2012.

- **Semi-structured interviews**

We performed semi-structured interviews with experts from the energy-demand modelling groups:

[2] Although the assessed models also cover national policies and measures.

1. PRIMES (2 interviews – one per each focus topic: prosumaging and shared economy).
2. FORECAST (2 interviews – one per each focus topic: circular economy, digitalisation).
3. INVERT (1 interview – on prosumaging).

Each modelling group was interviewed on one or more newTRENDs focus topics. Before each interview, the interviewees from the modelling groups received a briefing document, containing prior findings from D4.1 on the identified relevant policy instruments and policy needs. During the interview sessions, the following list of questions were discussed, grouped in two research topics:

A. Consideration of policy instruments relevant for New Societal Trends by the model

1. Which of the identified policy instruments are directly considered by the model? How are they considered?
2. Which of the identified policy instruments are indirectly considered? How are they considered? *E.g., a higher-level policy instrument category is considered in the model.*
3. Which of the identified policy instruments are not considered in the model, but they are potentially important for consideration in the model?
4. Which of the identified policy instruments are not considered in the assessed models and are not relevant for the model (e.g., due to the fact that the given policy instrument goes beyond the sectorial scope of the model)?

B. Consideration of EU policy needs relevant for New Societal Trends by the model

1. What policy needs, and indicators of interest from policy making perspective, are already considered in the model?
2. What policy needs, and indicators of interest from policy making perspective, are not yet considered in the model?
3. Would it be relevant/possible to consider these needs and indicators?

During each interview we asked the interviewees to express also their general opinions and thoughts, to further explore the studied research questions.

The following chapters (2, 3, 4) present the results of our analysis for two PRIMES modules (PRIMES-BuiMo and PRIMES-TREMOVE), two FORECAST modules (FORECAST-Industry and FORECAST-Tertiary), and INVERT, respectively. Chapter 5 provides a summary and synthesis of our findings.

2. PRIMES

2.1. Model overview

The PRIMES modelling suite is a family of linked models covering all aspects of the energy system and the demand and supply sectors (Capros et al. 2012). This section discusses the PRIMES-BuiMo and the PRIMES-TREMOVE models that are used to assess the policy needs for prosumaging and shared-economy, respectively.

PRIMES-BuiMo

PRIMES-BuiMo projects into the future energy demand in the buildings of the residential and services sectors. It focuses on the dynamic simulation of the renovation decisions and the depth of building renovation, the choice of technology types for covering the energy end-uses, including space heating, air cooling, cooking, water heating and different electric appliances (Fotiou et al. 2019).

PRIMES-BuiMo opts for a hybrid economic-engineering approach, covering the dynamics of stock evolution and placing great emphasis on modelling behaviours, as well as on policies influencing behaviours. Hence, the model represents idiosyncratic behaviours and (non-) market barriers, while also providing a high-resolution disaggregation of the building stock. Furthermore, it classifies the building stock in many different categories (termed “building classes”) based on house/building type, geographic location, age of construction, income class or services subsector. Thereby, the model projects into the future energy demand, using a dynamic simulation of the renovation of the buildings’ shell, together with the choice of technology and fuel types for the different uses of energy (Fotiou et al. 2019).

The model formulates the individual decision as a structural microeconomic optimisation problem of an agent, involving maximisation of consumer’s utility under budget, technical, economic, and policy related constraints (Fotiou et al. 2019). Parameters varying by agent represent the heterogeneous behaviours of consumers.

The PRIMES-BuiMo includes a comprehensive taxonomy of market and non-market barriers hampering energy efficiency investment, which are commonly neglected in pure engineering calculations, and result in what is sometimes considered as irrational behaviour of consumers, bounded in any case. Irrational behaviour, which challenges conventional microeconomic theory, is for some authors the reason for limited rates of energy-efficient renovation of buildings (Fotiou et al. 2019). The approach followed in PRIMES-BuiMo consistently integrates non-market barriers in the microeconomic modelling framework, which, combined with idiosyncratic preferences, can capture poor energy

efficiency choices and still represent rational behaviours. In other words, the seemingly irrational behaviour of consumers may be well explained through the concept of non-market barriers. For the PRIMES-BuiMo modelling, the modellers decided to represent a formulation founded on the micro-economic framework enriched with representations of (market and non-market) barriers and idiosyncratic behaviours.

Despite the high resolution of buildings' segmentation in PRIMES-BuiMo, the consumer behaviours within each class of households are still not homogeneous. Idiosyncratic behaviours persist within each class, and thus the modelling approach has to capture this heterogeneity as well (Fotiou et al. 2019). For this purpose, the model applies a discrete choice theory formulation within every consumer and building category.

The projections of PRIMES-BuiMo pertain to the building stock, the renovation rates, the stock of equipment and appliances, the fuel consumption, and CO_2 emissions and are performed on a country-by-country basis up to 2050 and 2070 in five-year time steps. The residential stock of buildings includes 270 house classes differentiated by their age (nine age bands for 1920-2015 and per five-year period for future vintages), the type of building (single- or multi-storey), the location (urban, semi-urban, rural) and the income class (five categories). The heterogeneity of each class is maintained by producing a distribution of decisions per class.

PRIMES-TREMOVE

PRIMES-TREMOVE is a large-scale economic-engineering model of passenger and freight transport. Its recent applications are found in literature (e.g., Siskos et al. (2018)). PRIMES-TREMOVE projects future transport activity, the allocation of mobility to various road and non-road transport modes, the choice of technology for the dynamic renewal of the transport fleet, the use of the fleet in various trip types, the consumption of energy, emissions, and costs. The dynamic projections cover the period until 2050 and 2070 by 5-year steps and for each European Member State. The base year of the model is 2015.

PRIMES-TREMOVE solves an equilibrium problem with equilibrium constraints and involves individual models for the demand of mobility and the supply by transport services and self-supply using private cars. The model solves a structural microeconomic optimisation problem for each decision-maker, with embedded technical constraints referring to transport engineering and behavioural parameters reflecting preferences, as well as to policy-related parameters that influence decisions. The decision-making problem runs dynamically in a sequential manner keeping track of all vintages of transport technologies.

Based on evolving technical and economic features of technologies and under the influence of policies, decision makers may purchase new transport means by making choices over a variety of candidate technologies and fuels, and may also consider a scrappage of old vintages. The demanders of mobility follow nested choices to allocate mobility and trip types to the transport modes,

determine their rate of use and select technologies for investment. The choice controlling functions follow the discrete choice theory to adequately depict the heterogeneity of behaviours and decision circumstances and thus overcome the limitations of the representative agent hypothesis. The choice functions use utility and cost functions as arguments, which embed several parameters used to reflect behavioural factors (uncertainty, perceived costs, risk perception), as well as penalty factors to reflect technical, infrastructural and resource limitations, and policy-reflecting parameters.

The model simulates the balancing of demand and supply of transport services and self-mobility, through the concept of the generalised cost of transport which includes congestion (time of use), externalities and other factors along with costs. The model solves a mixed complementarity equilibrium problem, using the generalised cost of transport as a dual variable associated with the demand-supply balance. In a way, the model varies the generalised cost, which in turn influences the demand and supply behavioural modelling until reaching a balance. The cost of transport also includes transport fares that the model calculates endogenously on a cost-plus basis, eventually including subsidies for certain public transport means. The mixed complementarity equilibrium also includes overall policy constraints, reflecting policy targets, and uses the associated dual variables to influence demand and supply. The targets may concern emissions, efficiency and renewable energy targets.

Households are modelled to choose new vehicle equipment from a set of fleet and fuel choices provided by car manufacturers. Vehicle purchasing prices, as set by the manufacturing industry, change dynamically following cost-efficiency improvement curves that draw from engineering studies. Car manufacturers price their portfolio of electric vehicles (EVs) depending on the evolution of battery costs. Households compare costs, convenience and congestion to make a decision which also depends on penalty factors in case the density and coverage of refuelling/recharging infrastructure are not adequate. The model also includes subjective factors as additional costs. In this manner, the model captures travelling inconvenience (range anxiety), technical risk perceptions (regarding maintenance and performance), imperfect information and the opportunity cost of funding capital costs to reflect the consumer conservatism towards choosing a new technology like an EV. The various cost elements constitute components of the generalised unit cost of transport services.

The model represents public policy based on fiscal instruments (e.g., subsidies, tax exemptions, etc.), tolling and congestion pricing, CO_2 or efficiency standards applying on vehicle manufacturing, overall policy targets and the extent and timeliness of infrastructure development. The model applies a penalty mechanism specifically by vehicle technology type, to discourage the production of vehicle varieties that do not comply with the standard, CO_2 or efficiency or both. The model captures the effects of the refuelling and recharging infrastructure by splitting the trip types into stylised geographic areas (i.e., metropolitan, other urban, highways, and other roads). In addition, the model includes public policy, e.g., campaigns aiming to increase the awareness of the

new technology and reduce the subjective surcharges and thus enable the emergence of the new technology in the markets.

2.2. Current consideration of energy demand-side policies in the model

PRIMES-BuiMo

PRIMES-BuiMo allows the possibility to include various policy measures of market and non-market nature. An overview of the existing policy and regulatory measures is provided in Table 1.

Table 1 Coverage of policies and measures in PRIMES-BuiMo

	Policy instrument category	Policy and measure
Regulation	Codes/ standards/ mandates	Building energy codes
		(Energy Performance of Buildings Directive)
		Minimum energy performance standards (MEP) for equipment and appliances (Eco-Design Framework Directive, EC/2009)
	Obligation schemes/ quotas/ mandatory targets	Energy Efficiency Directive
		Renewable Energy Directive
Economic and financial instruments	Direct investment	Energy taxation
		Subsidies/financing rebates
	Market- based instruments	Carbon pricing
		Energy efficiency value representing the market clearing price of white certificates or marginal value of an energy efficiency obligation Renewable value for the promotion of the uptake of RES in buildings
	Fiscal/ financial incentives	Access to funding
Soft instruments	Information campaigns	Perceived costs
		Awareness/learning
	Performance labels	Energy labelling
	Voluntary approaches	-

PRIMES-TREMOVE

Identifying the likely impacts of policies is a key application of PRIMES-TREMOVE, for which the model can provide a quantitative basis for the long-term projection and outlook for the transport system under a variety of contexts. An overview of the existing policy and regulatory measures in PRIMES-TREMOVE is provided in Table 2.

Table 2 Coverage of policies and measures in PRIMES-TREMOVE

Policy instrument category		Policy and measure
Regulation	Codes/ standards/ mandates	CO_2 emission standards for vehicles
		EURO standards
		Emission standards for non-road models
		Speed limits
		Fuel quality
		Transport safety
		Clean Power for Transport and refuelling/recharging Infrastructure
	Obligation schemes/quotas /mandatory targets	Renewable energy shares in transport
		GHG intensity target
		GHG Effort Sharing Regulation
	Other	Capacity and quality of transport systems
		Liberalization of rail services
		Common access rules to international haulage market
		Passenger rights
		Job quality & working conditions - Truck driver regulations
		Job quality & working conditions - Promotion of telecommuting (working from home)
		Ecolabelling
Economic and financial instruments	Fiscal/financial incentives	Public funding of transport (e.g., subsidies)
		Infrastructure charges (e.g. Eurovignette)
	Market-based instruments	Emissions Trading Scheme
	Taxes	Energy and CO_2 taxation/exemption from taxation
		Vehicle taxation

2.3. Assessment of model's consideration for energy demand-side policies addressing New Societal Trends

2.3.1. Prosumaging

This section assesses to what extent the existing (Table 3) and emerging/potential (Table 4) energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing prosumaging in the European Union are considered by PRIMES-BuiMo.

Table 3 Consideration of existing most important EU-level energy demand-side policies and instruments in the field of prosumaging by PRIMES-BuiMo

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[3]:
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Rights of renewables self-consumers (RED II, art. 21)	3
			- Energy required by nearly Zero Energy Buildings (nZEBs) should be covered to a very significant extent by RES, including energy produced on-site or nearby (Energy Performance of Buildings Directive - EPBD, art. 2)	2
		Product standards	- Numerous IEC standards, e.g., for PV systems, electric installations, and batteries	3
		Auditing	- Summary & assessment of the enabling framework for renewables self-consumption to be included in the MS' National Energy and Climate Plans and progress reports (RED II, art. 21 (6))	3
	Obligation schemes/ quotas/ mandatory targets	Mandatory targets	- At least 32% of RES in the EU gross final consumption of energy in 2030 (RED II art. 3 (1)) - Measures promoting the installation of small-scale RES on or in buildings eligible to be considered for the fulfilment of the energy savings obligation (EED, art. 7 & Annex V (1)(e))	1

[3] Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[3]:
		Energy market regulations	- MSs to put in place an enabling framework to promote and facilitate the development of renewables self-consumption (RED II, art. 21 (6)) - Final customers entitled to act as active customers (ED, art. 15)	3
Economic and financial instruments	Direct investment	Government procurement	- Public procurement on renewables self-consumption under Renovation Wave (renovation of at least 3 % of the total floor area of heated and/or cooled public buildings each year) (EED, art. 5)	2
		RD&D funding	- Horizon Europe, including Pillar II Global Challenges, Cluster 5: Climate, Energy and Mobility	3
		Grants and subsidies	- European Regional Development Fund, Cohesion Fund, Just Transition Fund	2[4]
		Loans/soft loans	- InvestEU programme	2[2]
	Market- based instruments	GHG emissions allowances trading scheme	- MSs to use revenues from auctioning of GHG emission allowances to develop renewable energies (ETS Directive, art. 10(3)(b))	2
		User charges	- Prohibited and permissible forms of charges and fees for renewables self-consumers (RED II, art. 21)	2[2]
Soft instr.	Information campaigns	Contact points in MSs	- MSs to establish contact points for renewables self-consumers and develop programmes to inform citizens on renewables self-consumption (RED II, art. 16 & 18)	2[5]

4 Indirectly considered through energy efficiency value and renewables value

5 Enabling conditions reducing perceived costs

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[3]:
	Performance labels	Comparison label	Smart Readiness Indicator (EPBD recast)	3
	Voluntary approaches	Unilateral Commitments (Private sector)	- Renewable Energy Communities (RED II, art. 2 (16)) - Citizen Energy Communities (ED, art. 2 (11))	3

Table 4 Consideration of emerging (potential) most important EU-level energy demand-side policies

Policy instrument category			Emerging EU policy instruments	Assessment of policy instrument consideration in the model[6]:	
Regulation	Codes/ standards/ mandates	Auditing	- Benchmarking of prosumaging across the EU (similar to benchmarking of Smart Metering rollouts)	3	
	Obligation schemes/ quotas/ mandatory targets	Mandatory targets	- Obligation for MSs to require the use of minimum levels of energy from RES in buildings in their building regulations and codes and, where applicable, in their support schemes (Fit for 55 proposal for RED II recast, art. 15a) - At least 40% of RES in the EU gross final consumption of energy in 2030 (Fit for 55 proposal for RED II recast) - Set targets for MSs on minimum share of prosumers in the population of final energy consumers (Petrick et al. 2019) - Stringent and quantified RES targets for building sector, e.g., 50% of RES share in buildings; ensuring that 40% of heating is provided by heat pumps in 2030 and 70% in 2050 (European Commission 2021)	1	2
		Carbon Emissions Reduction Target	- Obligation for MSs to link any support for prosumaging with emissions reduction and/or energy savings (Jahn and Rosenow 2019)	3	

6 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Emerging EU policy instruments	Assessment of policy instrument consideration in the model[6]:
Economic and financial instruments	Direct investment	Government procurement	- Include PV systems and batteries in Green Public Procurement scheme (Dunlop et al. 2018; EC 2020)	3
		Grants and subsidies	- Obligation for MSs to check that any grants/subsidies for prosumaging are offered to stakeholders meeting certain minimum energy efficiency standards (Jahn and Rosenow 2019)	3
		Loans/soft loans	- Require MSs to establish national loan schemes/guarantees for prosumagers (Scarpellini et al. 2021)	3
	Market-based instruments	GHG emissions allowances trading scheme	- Require MS to earmark certain part of revenues from GHG auctioning to specific prosumaging-related purposes (Kochanski et al. 2020)	3
			- Potential inclusion of the buildings sector into the EU ETS	1
	Fiscal/ financial incentives	Tariffs	- Introduce the right of consumers for time-differentiated network tariffs in all MSs (ENEFIRST 2021)	3
		Taxes – tax reliefs/exemptions	- Exemptions from VAT, e.g., for PVs / batteries (Kochański, Korczak, and Skoczkowski 2020)	3
		User charges	- Change in conditions for permissible forms of charges and fees for renewables self-consumers (CEER 2021)	3
Soft instruments	Information campaigns	Contact points in MSs	- Introduce obligatory quality assessment in information campaigns (e.g., consumers' satisfaction) (Rivas, Cuniberti, and Bertoldi 2016)	4
	Performance labels	Endorsement label	- Introduction of Eco-Design measures for PV panels and inverters (Polverini, Dodd, and Espinosa 2021) - Energy Labels for residential PV systems (Polverini et al. 2021)	3
	Voluntary approaches	Negotiated Agreements (Public-private)	- Establish an EU-level PPP to directly support prosumaging (e.g., through R&I)	3
		Public Voluntary Schemes	- Introduce an EU-level voluntary scheme on prosumaging for local authorities (e.g., within the Covenant of Mayors)	4

2.3.2. Shared Economy

This section assesses to what extent the energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing shared economy in the European Union are considered by PRIMES-TREMOVE (Table 5). Some of the policy instruments deserve an additional comment. In particular, it should be noted that Carbon Emission Reduction Target (Regulation (EU) 2018/842) is directly considered in the overall PRIMES model. Furthermore, public voluntary schemes (e.g., cycling infrastructure) is implicitly included in the model.

Table 5 Consideration of existing most important EU-level energy demand-side policies and instruments in the field of shared economy by PRIMES-TREMOVE

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[7]:
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure	1
		Product standards	- Regulation (EU) 2019/1781 of 1 October 2019 laying down eco-design requirements for electric motors and variable speed drives - Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles - Directive 1999/94/EC of the European Parliament and of the Council of 13 December 1999 relating to the availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars	1
		Sectoral standard	- Regulation (EC) No 1071/2009 of the European Parliament and of the Council of 21 October 2009 establishing common	2

7 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category		Existing EU policy instruments	Assessment of policy instrument consideration in the model[7]:
		rules concerning the conditions to be complied with to pursue the occupation of road transport operator	
Obligation schemes/ quotas/ mandatory targets	Mandatory targets	- Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles	1
	Carbon Emission Reduction Target	- Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement	1
Other regulation	Labour market regulations	- Directive 2002/15/EC of the European Parliament and of the Council of 11 March 2002 on the organisation of the working time of persons performing mobile road transport activities - Regulation (EC) No 561/2006 of the European Parliament and of the Council of 15 March 2006 on the harmonisation of certain social legislation relating to road transport	2
	Market access regulations	- Directive 2006/123/EC of the European Parliament and of the Council of 12 December 2006 on services in the internal market - Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce	2
	Energy market regulations	- Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU	1

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[7]:
Econ. & fin. instruments	Direct investment	Government procurement	- Regulation (EU) 2020/852 (Taxonomy) on the establishment of a framework to facilitate sustainable investment and the Commission Delegated Act establishing technical screening criteria	2
		RD&D funding	- Horizon2020/Horizon Europe, including the EIT Urban Mobility initiative	2
		Grants and subsidies	- EU structural and regional funds (ERDF, Cohesion Fund) - LIFE programme - Proposed Digital Europe Programme	3
		Loans/soft loans	- EIB lending	3
	Fiscal/ financial incentives	Taxes—tax relief/exemption	- (Planned revision of) Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity	1
	Market- based instruments	GHG emissions allowances trading	- Potential inclusion of the transport sector into the EU Emissions Trading Scheme.	1
Soft instr.	Voluntary approaches	Negotiated Agreements (Public-private sector)	- European Clean Bus deployment Initiative	2
		Public Voluntary Schemes	Green Public Procurement toolkit including general GPP guidelines and specific guidance on GPP in transport and in public space maintenance EU guidance on the development of cycling infrastructure - CLARS Platform providing information on LEZ, congestion charging schemes and urban traffic restrictions in EU	2
		Unilateral Commitments (Private sector)	- Providing insurance by platform operators	4

2.4. Assessment of model's consideration for the identified energy demand-side policy needs concerning New Societal Trends

2.4.1. Prosumaging

This section provides an assessment of PRIMES-BuiMo consideration for the identified energy demand-side policy needs concerning prosumaging (Table 6). With regard to the first indicator that has been identified as an indicator of interest for policy making (i.e., share of energy consumers in the residential sector that are renewables self-consumers per category of consumer), it should be noted that to some extent this need is already covered by PRIMES-BuiMo, since income classes and building types are already modelled. Furthermore, the share of energy poor and vulnerable consumers in the residential sector that are renewable self-consumers/part of an energy community could be modelled as an output for low-income class. One of the identified indicators of interest for policymakers (i.e., share of public authorities that are prosumagers) has been assessed as not relevant for PRIMES-BuiMo, since the foreseen model enhancements within newTRENDs pertain in a first instance only to the residential sector. With regard to the policy needs, the identified need for informing the policy making on the impacts of changes in introducing performance labels & GPP for PV systems on overall energy demand could be modelled through technology classes for PVs.

Table 6 Consideration of the identified EU-level policy needs in the field of prosumaging by PRIMES-BuiMo

Policy need identified	Assessment of need consideration in the model[8]:
Needs for modelling of specific indicators	
(1): Share of energy consumers in the residential sector that are renewables self-consumers per category of consumer: • social (energy poor and vulnerable; middle class; high class; tenants/owners); • economic (residential, service and industry sectors);	2

8 Legend:
1 – already directly considered;
2 – already indirectly considered;
3 – not considered in the model, but potentially important;
4 – not considered in the model, since it is not relevant for the modelling

Policy need identified	Assessment of need consideration in the model[8]:
• technical (single/multi-family buildings; urban/rural; prosumer/prosumager)	
(2) Share of energy consumers equipped with electricity storage facilities	3
(3) Share of household energy consumers/SMEs/local authorities that are a part of an energy community/collective self-consumption schemes	3
(4): Share of energy poor and vulnerable consumers in the residential sector that are renewable self-consumers/part of an energy community	3
(5): Share of energy consumers in the residential sector equipped with a gas boiler, heat pump and electrolyser	1
(6): Share of energy consumers equipped with smart meters	3
(7): Share of public authorities that are prosumagers.	4
Other needs expressed by policy makers with regard to energy-demand modelling	
(1) inform the policy making on the 'outputs' of prosumaging activity - the amounts of overall energy demand, as well as energy generated by self-consumers, including energy stored by them, energy self-consumed, and energy introduced to the national power grids;	3
(2) inform the policy making on the 'outputs' of prosumaging activity - the amounts of energy sold under time-of-use tariffs	3
(3) inform the policy making on the 'outputs' of prosumaging activity - · the amounts of energy generated by individual and collective renewables self-consumers;	3
(4) inform the policy making on the 'outputs' of prosumaging activity - impacts on grid infrastructure for a broad range of different input assumptions	3
(5) inform the policy making on the impacts of changes in conditions for introduction of permissible charges and fees for renewables self-consumers that are set in RED II, art. 21(3), e.g.: increasing the capacity threshold (30 kW) to incentivise community prosumaging in bigger RES installations	3
(6) inform the policy making on the impacts of changes in business models of prosumaging (e.g., see Dodd et al. 2020, Table 50)	3
(7) inform the policy making on the impacts of introducing an obligation scheme requiring certain share of building energy demand to be covered by RES, including energy produced on-site or nearby	2
(8) inform the policy making on the impacts of changes in various public support forms for prosumagers (e.g., net metering, subsidies) on overall energy demand	3

Policy need identified	Assessment of need consideration in the model[8]:
(9) inform the policy making on the impacts of changes in introducing performance labels & GPP for PV systems on overall energy demand	3

2.4.2. Shared Economy

This section provides an assessment of PRIMES-TREMOVE considering the identified energy demand-side policy needs for shared economy (Table 7). With regard to the needs for modelling of specific indicators, those of interest to the policy makers are already indirectly considered. However, the explicit representation of thses policy needs could be an improvement model. For example, by differentiating the occupancy rate of the cars which can be differentiated by type of trip, or modifying the average annual mileage of vehicles by trip type.

Table 7 Consideration of the identified EU-level policy needs in the field of shared economy by PRIMES-TREMOVE

Policy need identified	Assessment of need consideration in the model[9]:
Needs for modelling of specific indicators	
(1) Shared mobility energy use and its structure by type of energy source	2
(2) Share of vehicles covered by the sharing economy in the total fleet	2
(3) Share of transport activity covered by the sharing economy	2
Other needs expressed by policy makers with regard to energy-demand modelling	
(1) inform the policy making on the impacts of carsharing and carpooling policies on urban mobility, in particular the individual car ownership levels and net impacts on the energy demand	3
(2) inform the policy making on the impacts of carsharing and carpooling policies on energy demand and use, in particular whether they support faster electrification and to what extent other energy and climate policies may support electrification of this segment of market	3

9 Legend:
1 – already directly considered;
2 – already indirectly considered;
3 – not considered in the model, but potentially important;
4 – not considered in the model, since it is not relevant for the modelling

(3) inform the policy making on the policy conditions for sharing economy and public transportation development as a complementary and non-competing services	2

3. FORECAST

3.1. Model overview

The FORECAST modelling platform aims to develop annual long-term scenarios for future energy demand and GHG-emissions of individual European countries (EU27 + UK, CH, NO) and world regions (e.g. Taiwan, Brasil) until 2050. The model allows to address research questions related to energy demand including scenarios for the future demand of individual energy carriers like electricity or natural gas, calculating energy saving potentials and the impact on greenhouse gas (GHG) emissions as well as abatement cost curves, ex-ante policy impact assessments and long-term sustainable energy transition scenarios. Furthermore, the model integrates different policy options as described in the following sections.

The FORECAST platform comprises three individual modules, each representing one sector according to the Eurostat (or national) energy balances: industry, services/tertiary, and residential. The model is based on a bottom-up modelling approach considering the dynamics of technologies and socio-economic drivers. While all sector modules follow a similar bottom-up simulation methodology,

they also consider the particularities of each sector like technology structure, heterogeneity of actors and data availability.

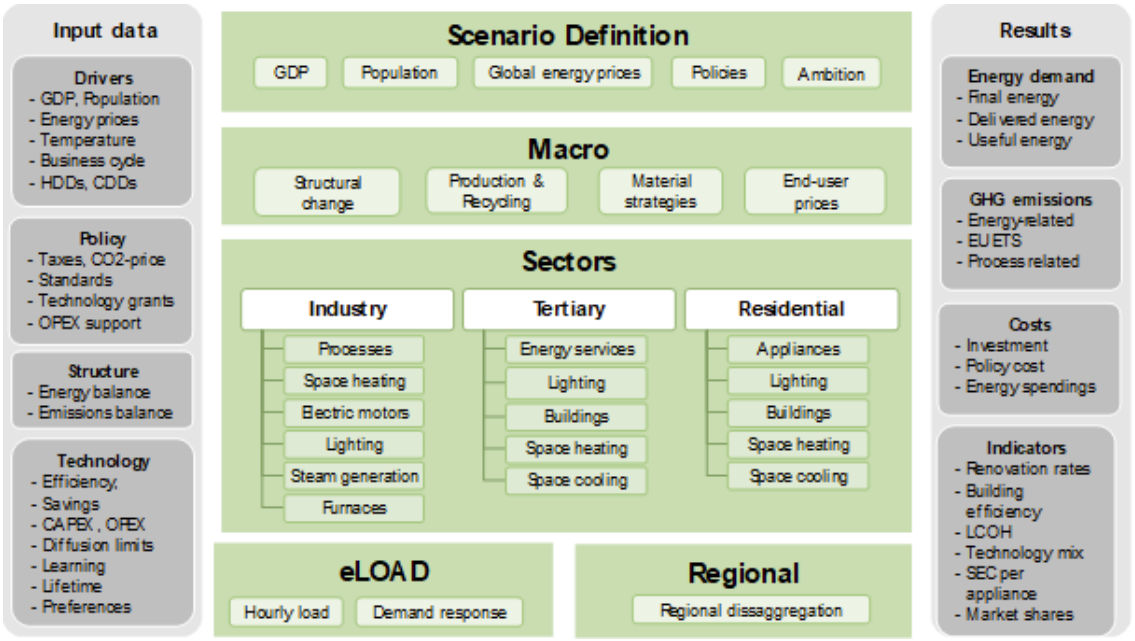

Figure 1 FORECAST model overview

Each sector requires sector specific activity data, like industrial production in the industry sector and the number of households in the residential sector. Furthermore, end-consumer energy prices play an important role in each sector as they are distinguished by energy carrier. The third group of input data, the technology characterisation also reflects data availability of the individual sectors as data availability is hetereogeneous between sectors (see Figure 2).

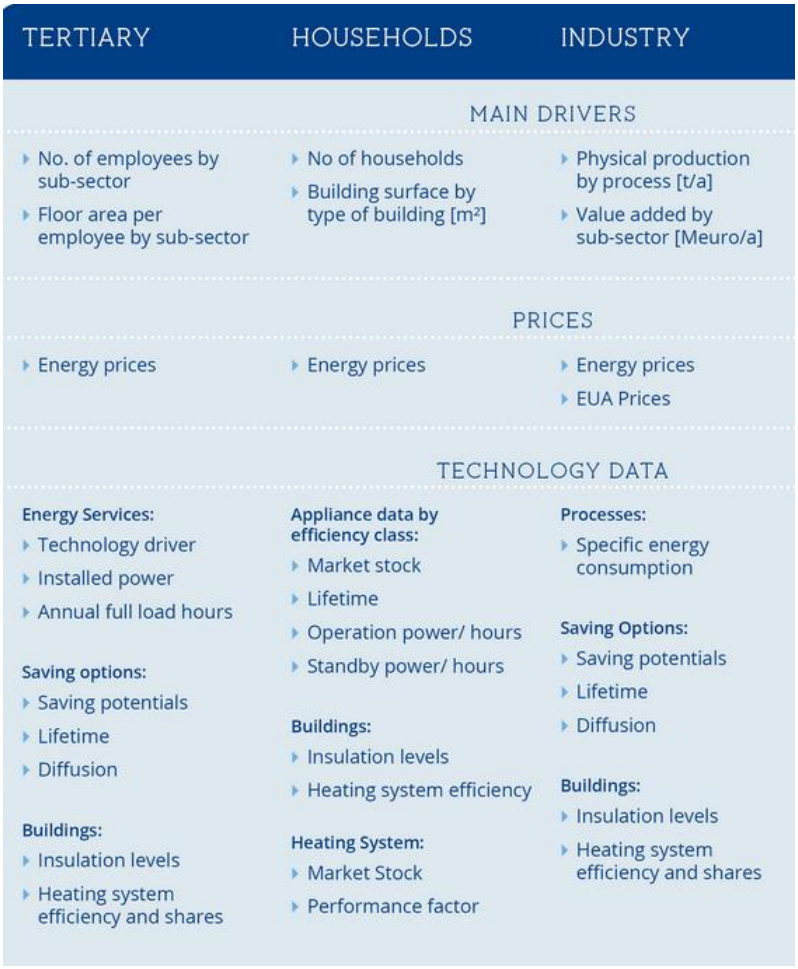

Figure 2 FORECAST input data

While in the industry and tertiary sector the model works with so-called energy-efficiency measures (EEMs), which represent all kinds of actions that reduce specific energy consumption, in the residential sector the stock of alternative appliances and the market share of different efficiency classes is explicitly modelled. In all cases, energy savings can be calculated and traced back to technological dynamics including cost considerations.

As a result of the bottom-up approach model results can be disaggregated with a very high resolution comprising sectors and sub-sectors, but also end-use technologies and energy carriers.

The bottom-up approach, which distinguishes individual technologies, allows modeling the diffusion of technologies as the result of individual investment decisions taken over time. For all types of investment decisions, the model follows a simulation approach rather than optimization in order to better capture the real-life behaviour of companies and households.

Whenever possible, the investment decision is modelled as a discrete choice process, where households or companies choose among alternative technologies to satisfy a certain energy service. It is implemented as a logit-approach considering the total cost of ownership (TCO) of an investment plus other intangible costs. This approach ensures that even if one technology choice is more cost-effective than the others, it will not gain a 100% market share. This effect reflects heterogeneity in the market, niche markets and non-rational behaviour of companies and households, which is a central capability to model policies. Still, the resulting technology development (and energy demand) is price sensitive.

The replacement of equipment/buildings/technologies is based on a vintage stock approach allowing to realistically model the replacement of the capital stock considering its age distribution. Some parts of the industrial and the tertiary sector are not using a vintage stock approach, due to the huge heterogeneity of technologies on the one hand and data scarcity on the other. Technology diffusion, however, is modelled based on a similar simulation algorithm taking heterogeneity and non-rational behaviour into account.

Overall, the FORECAST-model considers a broad range of mitigation options combined with a high degree of technological detail and allows insights into transition pathways and speed for the different sectors.

3.2. Current consideration of energy demand-side policies in the model

FORECAST-Industry allows the simulation of policy impacts. This includes price-based policies like subsidies or taxes, market-based instruments like the EU's Emissions Trading Scheme, but also standards like minimum energy performance standards for individual products. In a more aggregated form, policy instruments such as energy management or audits schemes are also considered by adjusting behaviour parameters. The need to simulate the impact of policies also requires detailed representation of investment decisions in the model, because these are the main anchor for policy intervention. They include investments in new steam generation technology, energy efficiency improvements in existing installations, new electric motors but also investments in radically new production plants. Investment decisions in energy efficiency are modelled according to the real-life behaviour of companies, which often deviates from cost-optimal decisions under perfect knowledge and faces manifold barriers (Fleiter et al. 2018). Instead, investment decisions are myopic (based on costs and prices in a specific year) and simplified decision rules are applied (like payback time threshold).

FORECAST-Tertiary module models the energy of tertiary sectors. The tertiary sector is divided in 8 sub-sectors, and each sub-sector is modelled separately. On the transportation sub-sector, only street-lighting and buildings (stations, lager, pump-stations, etc) are modelled in FORECAST, so traction energy is outside the scope of the model. FORECAST Tertiary has four submodules: a simulation of building dynamic, where the required floor area is determined, and thus the quantity of new buildings and of decommissioning of old buildings; the electric consumption of appliances and devices; an agent-based model for heat demand; and finally an aggregation model.

FORECAST-Residential covers multiple aspects of energy consumption in the residential sector, including the modules for appliance, building stock dynamics, space heating and hot water, and space cooling. In the newTRENDs project, the appliance module is used to consider the efficiency improvement and electricity consumption of the residential sector. In the appliance module, 22 end-uses (e.g., television) are further broken down into 39 technologies (e.g., LCD, plasma). These technologies are additionally split into 10-15 efficiency classes to yield a total of approximately 2000 technological alternatives. Two standards policies can be considered, including the energy labelling and eco-design.

3.3. Assessment of model's consideration for energy demand-side policies addressing New Societal Trends

3.3.1. Circular Economy

This section assesses to what extent the existing and emerging (potential) energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing circular economy and low-carbon industry in the European Union are considered by FORECAST. Since the module FORECAST-Industry is used for this evaluation, the following overview (Table 8, Table 9) refers exclusively to this. The existing policy instruments mentioned are to be understood as examples, since no dedicated consideration of individual instruments is implemented, but rather the consideration of instrument types (see section 3.2).

Several existing policy instruments are already directly included in the modelling. For instance, the Emission Trading Scheme (ETS) is considered via ETS CO_2 price in bottom-up modelling, while voluntary carbon emission reduction targets are considered via bottom-up simulation of industrial emission pathways.

Furthermore, several existing policy instruments are indirectly covered. Among others, recycling quotas are considered but can be further enhanced. Research, Development and Demonstration (RD&D) funding and loans are considered via technology diffusion for new carbon-neutral processes. Similarly, grants and subsidies are considered via technology diffusion for new carbon-neutral processes as well as subsidies for carbon-neutral energy carriers.

Several existing policy instruments concerning circular economy have been assessed as not relevant for modelling within FORECAST-Industry. For example, the EU action plan for the Circular Economy and several soft instruments, such as negotiated public-private agreements, were found relevant for scenario storyline, but they cannot be explicitly modelled. Furthermore, the energy market regulations were assessed as out of scope for the bottom-up energy demand modelling within FORECAST-Industry.

With regard to the emerging regulations, it was found that some potential new policy instruments (e.g., energy taxation directive) can be already modelled in FORECAST-Industry – e.g., via energy prices. Some other instruments, such as long-term renovation strategies under EPBD, could be potentially important for modelling of embodied carbon from construction materials. The emerging product and sectoral standards were found as potentially important for newTRENDs sector focus. Furthermore, it was found that shares of secondary material content in certain products are already considered in the assessed model, but this type of information can be further enhanced. Similar observation

was done regarding the review of the Industrial Emissions Directive, including the integration of circular economy practices in upcoming Best Available Techniques reference document: this policy instrument is already considered via technology diffusion, but further enhancements are possible. Some other instruments, such as Roadmap to a Resource Efficient Europe, were assessed as not relevant for modelling under FORECAST-Industry: they are relevant for scenario storyline but they are not explicitly modelled. Some other instruments, such as Carbon Border Adjustment Mechanism, were evaluated as out of scope due to the character of FORECAST-Industry energy demand modelling approach, which is bottom-up.

Table 8 Consideration of existing most important EU-level energy demand-side policies and instruments in the field of circular economy and low-carbon industry by FORECAST

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[10]:
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Energy performance of buildings directive - Eurocodes	3
		Product standards	- Eco-design Directive, Energy Labelling Regulation, Harmonised European Standards - Construction Products Regulation (CPR)	3
		Sectoral standards	- Waste Framework Directive	4
		Auditing	- The monitoring framework for the circular economy	3
	Obligation schemes/ quotas/ mandatory targets	Obligation schemes	- Waste Framework Directive (quotas for recycling rates for MS) - Directive on packaging and packaging waste (quotas for recycling rates of packaging materials for MS) - The Directive on the landfill of waste - Directive 2018/849	2
	Other regulation		- The EU action plan for the Circular Economy - The Raw Material Initiative - The Strategy for plastics - A hydrogen strategy for a climate-neutral Europe	4

10 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[10]:
		Energy market regulations	- The Internal energy market - The Energy Union - The Clean energy package	4
Econ. & fin. instruments	Direct investment	Government procurement	- Green public procurement	3
		RD&D funding	- Horizon Europe, in particular Pillar II Global Challenges and European Industrial Competitiveness, under Cluster 4: Digital, Industry and Space and Cluster 5: Climate, Energy and Mobility.	2
		Grants and subsidies	- European Regional Development Fund (ERDF) and Just Transition Fund (JTF)	2
		Loans/soft loans	- European Investment Bank	2
	Market- based instruments	GHG emissions allowances trading	- The EU Emissions Trading System	1
		White certificates	- White certificates scheme	4
	Performance labels	Endorsement label	- Energy Label, CE marking, WEEE label	4
Soft instruments	Voluntary approaches	Negotiated Agreements (Public-private sector)	- Bio-based Industries Joint Undertaking - Fuel Cells and Hydrogen Joint Undertaking - Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) - European Technology and Innovation Platforms	4
		Carbon emission reduction target	- Voluntary commitments to carbon emission reduction at a certain level	1
		Public Voluntary Schemes	- Green public procurement	3
		Unilateral Commitments (Private sector)	- The Ecolabel - The Circular Plastic Alliance	4

Table 9 Consideration of emerging (potential) most important EU-level energy demand-side policies

Policy instrument category			Emerging EU policy instruments	Assessment of policy instrument consideration in the model[11]:
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- EPBD: Long-term renovation strategies; addressing embodied carbon from construction materials -Strategy for a Sustainable Built Environment -Development of a digital building logbook	3
		Product standards	- Circular Electronics Initiative, common charger solution, and reward systems to return old devices - New regulations on batteries, waste oils, end-of-life vehicles - Expanding the Eco-design Directive to include embodied emissions and energy-intensive intermediates	3

11 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Emerging EU policy instruments	Assessment of policy instrument consideration in the model[11]:
		Sectoral standards	- Review of regulations on packaging (reduction of overpackaging) - Policy framework for bio-based, biodegradable or compostable plastics - EU Strategy for Textiles - EU-wide harmonised model for separate collection of waste and labelling to facilitate separate collection - Scoping the development of further end-of-waste and by-product criteria - Mainstreaming circular economy in free trade agreements, in other bilateral, regional and multilateral processes and agreements, and in EU external policy funding instruments	3
		Auditing	-Updating the Circular Economy Monitoring Framework to develop further indicators on resource use, incl. consumption and material footprints	3
	Obligation schemes/ quotas/ mandatory targets	Obligation schemes	-Mandatory shares of recycled plastic content in certain products -Waste reduction quotas for specific streams -REDII proposal sets obligation for industry to increase its energy consumption from RES by 1.1 pp. per year, and a target of 50% for renewable fuels of non-biological origin used as feedstock/energy carrier.	2
	Other regulation		-Roadmap to a Resource Efficient Europe sets milestones towards transforming the EU's economy into sustainable one by 2050.	4
Econ. & fin. instr.	Market-based instruments	GHG emissions allowances trading scheme	-Review of the Industrial Emissions Directive, including the integration of circular economy practices in upcoming BAT reference documents	2
		Tariffs	-Carbon Border Adjustment Mechanism	4
		Taxes	-Energy Taxation Directive	2
Soft ins.	Performance labels	Endorsement label	-Life-Cycle Assessment (LCA) certificate being obligatory for products -Harmonised information systems for the presence of substances of concern	3

3.3.1. Digitalisation

This section assesses to what extent the energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing digitalisation in the European Union are considered by FORECAST-Tertiary (Table 10).

The products standards, resulting from the eco-design requirements for servers and data storage products, are already directly implemented by design of FORECAST. However, some sectoral standards (e.g., EC Communication Digitising European Industry Reaping the full benefits of a Digital Single Market) may be too specific for the model. For instance, “Trade” is modelled as a single sector.

With regard to direct investment through RD&D funding, grants, and subsidies, concrete projects could be modelled indirectly, but FORECAST-Tertiary cannot predict how much (and in which sector/use) efficiency improvements by monetary input. Similarly, the EU Emissions Trading Scheme is also already indirectly modelled (via cost per energy unit).

When analysing the consideration of FORECAST-Tertiary for soft instruments in the field of digitalisation, such as negotiated public-private sector agreements (e.g., Big Data Value Public-Private Partnership), it should be pointed out that such instrument with long-term and broad (sectoral) impact could be considered. Data centres and ICT are already directly modelled in FORECAST-Tertiary.

Table 10 Consideration of existing most important EU-level energy demand-side policies and instruments in the field of digitalisation by FORECAST

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[12]:	
Regulation	Codes/ standards/ mandates	Product standards	- Regulation EU 2019/424 of 15 March 2019 laying down eco-design requirements for servers and data storage products	1	
		Sectoral standards	- EC Communication ICT Standardization Priorities for the Digital Single Market - EC Communication Digitising European Industry Reaping the full benefits of a Digital Single Market - Blockchain technology – gold standard of blockchain	2	4
	Obligation schemes/ mandatory targets	Europe Digital Targets	- EC Communication 2030 Digital Compass: the European way for the Digital Decade	2	
	Other regulation		- The 'Europe Fit for Digital Age' package	2	4
Econ. & fin. instr.	Direct invest-ment	Government procurement	- Green Public Procurement (e.g. computers, monitors, tablets and smartphones, data centres, office buildings, road lightning, transport)	1	
		RD&D funding	- Horizon Europe	2	4
		Grants and subsidies	- Digital Europe programme - ERDF and Cohesion Found	2	4

12 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[12]:		
Soft instruments		Loans/soft loans	- EIB lending	1		
	Fiscal/ financial incentives	Grants and subsidies	- Digital Europe programme - ERDF and Cohesion Found	1	2	3
		Loans/soft loans	- EIB lending	1	2	
	Market-based instr.	GHG emissions allowances trading	- EU Emissions Trading Scheme	2		
	Voluntary approa-ches	Negotiated Agreements (Public-private sector)	- Big Data Value Public-Private Partnership	2	3	4
		Public Voluntary Schemes	- European Innovation Partnership of Smart Cities and Communities - Code of Conduct of ICT - The European Blockchain Partnership - Code of Conduct for Energy Efficiency in Data Centres	2	3	4
		Unilateral Commitments (Private sector)	- Green and Digital Coalition	2		

3.4. Assessment of model's consideration for the identified energy demand-side policy needs concerning New Societal Trends

3.4.1. Circular Economy

This section provides an assessment of FORECAST-Industry consideration for the identified energy demand-side policy needs concerning circular economy (Table 11).

With regard to the first group of indicators that has been identified as indicators of interest for policy making (i.e., financial indicators), it should be noted that CAPEX and OPEX are part of the technology database of the model. Additionally, aggregated energy cost developments and selected investments are available as model results. With regard to the second indicator of interest (concerning energy mix), energy demand by sector and energy carrier is available as FORECAST-Industry result. With regard to the third indicator of interest (detailed results concerning energy demand for industry sectors), it should be stressed that more than 80 industrial processes are already considered in the model. Still, the consideration of the last group of indicators of interest from the policy making perspective (i.e. parameters describing the quality of the analysis performed, such as uncertainty levels), can be improved. Their current integration in FORECAST-Industry can be found in Fleiter et al. 2018.

Other presented needs of policy makers with regard to energy-demand modelling are not considered in the model at the moment. The carbon border adjustment mechanism has been found as a policy instrument that is not directly linked with circular economy, so it was assessed as not relevant for modelling improvements in FORECAST-Industry within newTRENDs. A similar observation was made with regard to the policy instruments directly influencing the fuel demand structure: the Hydrogen strategy for a climate-neutral Europe, the Clean energy package and the Energy Union. Even though these instruments will be included via scenario storyline, they were assessed as not relevant for the potential modelling improvements in FORECAST-Industry, since the focus of modelling improvements of FORECAST-Industry in newTRENDs concerns primarily the buildings sector.

Still, some policy needs were considered as potentially important for a better consideration in the model. Interactions between policy instruments will be considered thanks to establishing a linkage between Invert/EE-Lab and FORECAST-Industry for buildings. A simplified approach for assessment of the environmental impact of construction materials in entire life cycle could be also relevant and important to be addressed. Finally, the model consideration for extending the use phase of buildings by their repurposing (including modular buildings) could be also improved.

Table 11 Consideration of the identified EU-level policy needs in the field of circular economy by FORECAST

Policy need identified	Assessment of policy need consideration in the model[13]:
Needs for modelling of specific indicators	
(1) Financial indicators related to the policy instruments implementation – CAPEX, OPEX, optimal financial mix.	1
(2) Energy mix resulting from the implementation of policy instruments, in particular for gas, and blue and green hydrogen.	1
(3) More detailed results for industry sectors.	1
(4) Parameters describing the quality of the analysis performed with the use of an energy demand model: limitations, assumptions done, uncertainty levels.	3
Other needs expressed by policy makers with regard to energy-demand modelling	
(1) The "Fit for 55" package will bring many new or revised policy instruments. Since they will set the main direction of the EU climate and energy policy, it is important to know their impact. In particular, the carbon border adjustment mechanism, the revised renewable energy directive and the recast of the energy efficiency directive are of the biggest interest of stakeholders.	4
(2) Stakeholders also mentioned multiple times that knowing interactions between policy instruments, in a cross-sectoral dimension, is important to them.	3

13 Legend:
1 – already directly considered;
2 – already indirectly considered;
3 – not considered in the model, but potentially important;
4 – not considered in the model, since it is not relevant for the modelling.

Policy need identified	Assessment of policy need consideration in the model[13]:
(3) Policy instruments directly influencing the fuel demand structure: the Hydrogen strategy for a climate-neutral Europe, the Clean energy package and the Energy Union.	4
(4) Assessment of the environmental impact of construction materials in entire life cycle.	3
(5) Extending the use phase of a building by its repurposing (including modular buildings)	3

3.4.2. Digitalisation

This section provides an assessment of FORECAST-Tertiary consideration for the identified energy demand-side policy needs concerning digitalisation (Table 12). With regard to the first group of indicators that has been identified as indicators of interest for policy making (i.e., energy use by ICT equipment across different sectors), it should be noted that sectoral ICT and data-centres are directly a part of the FORECAST-Tertiary model. Still, some assumptions must be done for the types of equipment. The remaining two groups of indicators of interest were assessed as not relevant for this model The energy use and emissions related to ICT equipment production could be rather covered by FORECAST-Industry, in case of equipment produced in the EU. The Impact of teleworking on transport and households' energy demand was evaluated as an area out of FORECAST-Tertiary scope. Still, the other needs expressed by policy makers with regard to energy-demand modelling in the field of digitalisation (digitalisation targets, energy demand reporting by ICT devices) were assessed as not covered by the model, but potentially important.

Table 12 Consideration of the identified EU-level policy needs in the field of digitalisation by FORECAST-Tertiary

Policy need identified	Assessment of policy need consideration in the model[14]:
Needs for modelling of specific indicators	
(1) Energy use by ICT equipment across the sectors (incl. by type of equipment)	1
(2) Energy use and emissions related to ICT equipment production	4
(3) Impact of teleworking on transport and households' energy demand: by sector and net total	4
Other needs expressed by policy makers with regard to energy-demand modelling	
(1) Digitalisation targets and investment in new digital services	3
(2) Policies enabling energy demand reporting by ICT devices within smart grids	3

14 Legend:
1 – already directly considered;
2 – already indirectly considered;
3 – not considered in the model, but potentially important;
4 – not considered in the model, since it is not relevant for the modelling.

4. INVERT

4.1. Model overview

The **building stock model Invert/EE-Lab** is a bottom-up model to simulate energy related investment decisions in buildings focusing on space heating, hot water generation and space cooling. It is based on a highly disaggregated description of the building stocks in the different countries of the EU (+ Norway, Iceland, Switzerland, UK) including type of building, age, state of renovation, existing heating systems, user structure as well regional aspects such as availability of energy infrastructure, e.g., for district heating or natural gas, on a sub-country level and covers residential and tertiary buildings. It simulates investment decisions in the building shell and the heat supply and distribution systems via a combination of a discrete choice approach and technology diffusion theory. This makes it possible to study the influence of various side-conditions including policy measures on the decisions of the actors. The Invert model has been developed and applied in national and international projects in the EU for more than 10 years now, in many of them reflecting the entire EU building stocks (Invert/EE-Lab 2020).

Basic approach and methodology

Invert/EE-Lab is a dynamic bottom-up simulation tool that evaluates the effects of different framework conditions (in particular different settings of economic and regulatory incentives) on the total energy demand, energy carrier mix, CO_2 reductions and costs for space heating, cooling and hot water preparations in buildings. Furthermore, Invert/EE-Lab is designed to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviours, etc.) and their respective impact on future trends of energy demand and mix of renewable as well as conventional energy sources on a national and regional level. More information is available on www.invert.at or e.g. in (Kranzl et al. 2013) or (Müller 2012). The basic structure and concept are described in Figure 3.

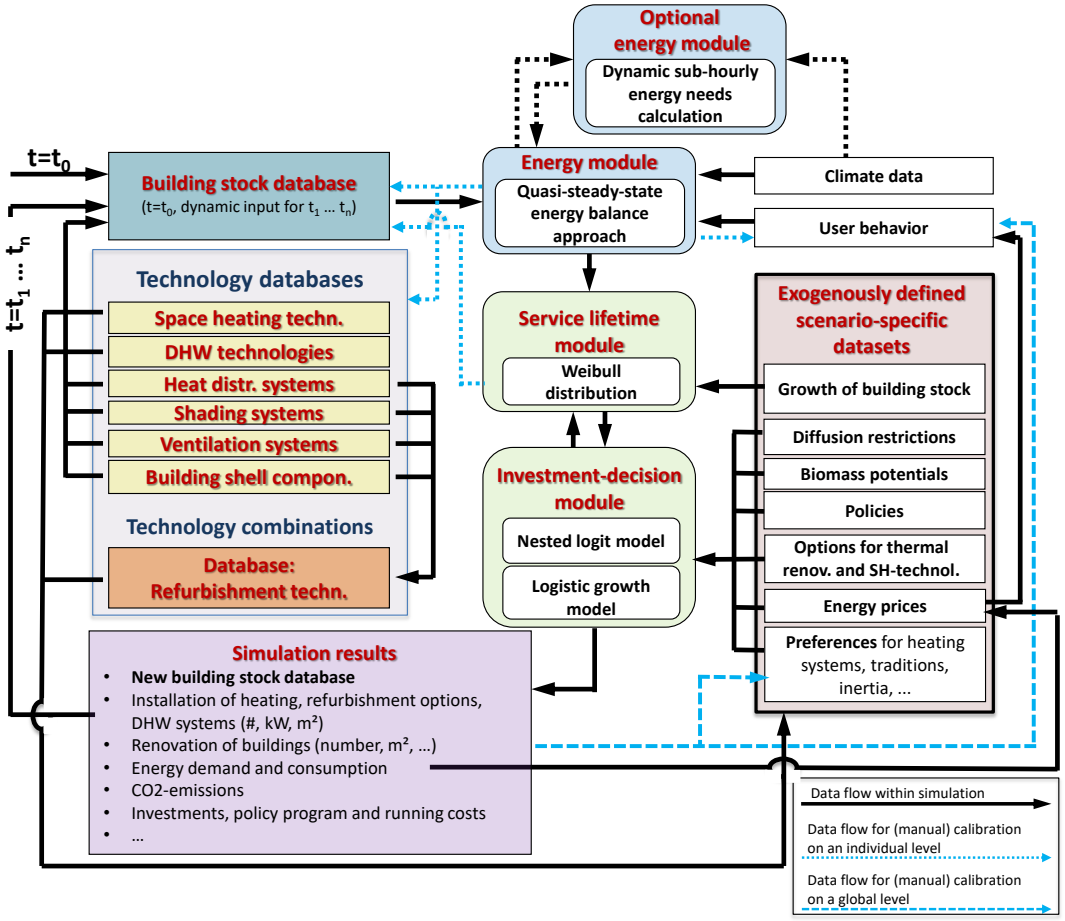

Figure 3 Overview structure of Simulation-Tool Invert/EE-Lab

The basic approach of the model is to describe the building stock, heating, cooling and hot water systems on highly disaggregated level, calculate related energy needs and delivered energy, determine reinvestment cycles and new investment of building components and technologies and simulate the decisions of various agents (i.e., owner types) in case that an investment decision is due for a specific building segment. The core of the tool is a myopic, multinomial logit approach, which optimizes objectives (minimize costs (considering investor-group specific capital recovery factor (CRF), adopted by user preferences regarding comfort, technology risk and environmental perception) of "agents" under imperfect information conditions and by that represents the decisions maker concerning building related decisions.

4.2. Current consideration of energy demand-side policies in the model

As efficiency technologies Invert/EE-Lab models the uptake of different levels of renovation measures (country specific) and the diffusion of efficient heating and hot water systems. The model derives the uptake of these energy efficient technologies by calculating and comparing the utility of each alternative against the other available options. The impact of energy demand-side policies is considered as they influence the utility of different alternatives.

The most important indicators, covered by the current model algorithm, which will have an impact on the utility of energy efficient technologies are cost-/price-based policies and mandatory/normative instruments.

The first set of instruments cover policies which affect the marginal costs of utilization. This covers the energy prices, CO_2 prices, or other energy carrier-specific taxes. The current model version is, however, not able to handle performance-based energy tax rates. This means that the model cannot handle demand specific energy costs for different energy efficiency classes. The second group of cost-/price-based parameters, which impact the utility of different alternatives, are policies which influence the investment needs of different alternatives. Here, the model can consider investment subsidies, subsidized annuities, loans with low interest rates. The model does not consider the available household budget of investors. Thus, the share of loans versus equity used to pay for investments is not within the scope of the model and must be defined exogenously the modellers.

The normative instruments that can be considered within the model are minimum energy performance standards (for both newly constructed buildings and existing buildings) as well as performance-related mandatory replacement/refurbishment policies.

The impact of “soft” policy measures such as labelling (energy performance certificates), awareness raising campaigns, etc. need to be implemented by adjusting the behaviour-related parameters of the modelled investors.

4.3. Assessment of model's consideration for energy demand-side policies addressing New Societal Trends

4.3.1. Prosumaging

This section assesses to what extent the existing (Table 13) and emerging/potential (Table 14) energy demand-side policies and instruments (regulations, economic and financial instruments, and soft instruments) addressing prosumaging in the European Union are considered by INVERT.

With regard to existing policy instruments in the field of prosumaging, several observations concerning the following instruments were made:

- Building/ grid codes and standards: The RES share required by nZEBs to qualify as such can be implemented directly.
- Product standards: Values for the parameters of PV and battery can be directly defined in the model, but not all the "product standards" are covered.
- Auditing: If this policy needs to be considered, the modeler needs to define the impact exogenously. The impact could be considered both as model outputs (e.g., the rate of self-consumption in PV systems) or as model inputs (e.g., the share of consumers being prosumers/ prosumagers).
- Mandatory targets: The model cannot set the parameters in such way, that the 32% RES target can be achieved, but the modeler needs to adjust the parameters.
- Loans/soft loans: Their interest rates can be implemented directly. The model, however, cannot endogenously assess the access to such programs.
- User charges for renewables self-consumers: The modeler needs to assess impact on consumer costs exogenously.

With regard to emerging policy instruments in the field of prosumaging, several observations concerning the following instruments were made:

- Obligation for MSs to require the use of minimum levels of energy from RES in buildings in their building regulations and codes: The minimum share of RES can be considered on an individual building level. Country or EU-wide specific targets (40% of RES in the EU) cannot be implemented directly. The minimum share of prosumers cannot be defined as an input parameter.
- Loans and subsidies: Their interest rates can be implemented directly. The model however cannot endogenously assess the access to such programs.

- Eco-Design measures for PV panels and inverters: Values for the parameters of PV and battery can be directly defined in the model. Parameters of inverters can be embedded.

Table 13 Consideration of existing most important EU-level energy demand-side policies and instruments in the field of prosumaging by INVERT

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[15]:
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Rights of renewables self-consumers (RED II, art. 21)	4
			- Energy required by nZEBs should be covered to a very significant extent by RES, including energy produced on-site or nearby (EPBD, art. 2)	1
		Product standards	- Numerous IEC standards, e.g., for PV systems, electric installations, and batteries	1
		Auditing	- Summary & assessment of the enabling framework for renewables self-consumption to be included in the MS' National Energy and Climate Plans and progress reports (RED II, art. 21 (6))	4
	Obligation schemes/ quotas/ mandatory targets	Mandatory targets	- At least 32% of RES in the EU gross final consumption of energy in 2030 (RED II art. 3 (1))	1

15 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category			Existing EU policy instruments	Assessment of policy instrument consideration in the model[15]:
			- Measures promoting the installation of small-scale RES on or in buildings eligible to be considered for the fulfilment of the energy savings obligation (EED, art. 7 & Annex V (1)(e))	2
	Energy market regulations		- MSs to put in place an enabling framework to promote and facilitate the development of renewables self-consumption (RED II, art. 21 (6)) - Final customers entitled to act as active customers (ED, art. 15)	2
Economic and financial instruments	Direct investment	Government procurement	- Public procurement on renewables self-consumption under Renovation Wave (renovation of at least 3 % of the total floor area of heated and/or cooled public buildings each year) (EED, art. 5)	4
		RD&D funding	- Horizon Europe, including Pillar II Global Challenges, Cluster 5: Climate, Energy and Mobility	4
		Grants and subsidies	- European Regional Development Fund, Cohesion Fund, Just Transition Fund	1
		Loans/soft loans	- InvestEU programme	2
	Market-based instruments	GHG emissions allowances trading scheme	- MSs to use revenues from auctioning of GHG emission allowances to develop renewable energies (ETS Directive, art. 10(3)(b))	3
		User charges	- Prohibited and permissible forms of charges and fees for renewables self-consumers (RED II, art. 21)	2
Soft instruments	Information campaigns	Contact points in MSs	- MSs to establish contact points for renewables self-consumers and develop programmes to inform citizens on renewables self-consumption (RED II, art. 16 & 18)	4
	Performance labels	Comparison label	- Smart Readiness Indicator (EPBD recast)	4
	Voluntary approaches	Unilateral Commitments (Private sector)	- Renewable Energy Communities (RED II, art. 2 (16)) - Citizen Energy Communities (ED, art. 2 (11))	3

Table 14 Consideration of emerging (potential) most important EU-level energy demand-side policies in the field of prosumaging by INVERT

Policy instrument category		Emerging (potential) EU policy instruments	Assessment of policy instrument consideration in the model[16]:	
Regulations	Codes/ standards/ mandates	Auditing	- Benchmarking of prosumaging across the EU (similar to benchmarking of Smart Metering rollouts)	4
	Obligation schemes/ quotas/ mandatory targets	Mandatory targets	- Obligation for MSs to require the use of minimum levels of energy from RES in buildings in their building regulations and codes (Fit for 55 proposal for RED II recast, art. 15a)	1
			- At least 40% of RES in the EU gross final consumption of energy in 2030 (Fit for 55 proposal for RED II recast)	1
			- Set targets for MSs on minimum share of prosumers in the population of final energy consumers (Petrick et al. 2019)	3
		Carbon Emissions Reduction Target	- Obligation for MSs to link any support for prosumaging with emissions reduction and/or energy savings (Jahn and Rosenow 2019)	4
Econ. & fin. instr.	Direct investment	Government procurement	- Include PV systems and batteries in Green Public Procurement scheme (European Commission 2020; Dunlop et al. 2018)	4

16 Legend:
1 – policy instrument directly considered;
2 – policy instrument indirectly considered;
3 – policy instrument not considered in the model, but potentially important;
4 – policy instrument not considered in the model, since it is not relevant for the modelling

Policy instrument category		Emerging (potential) EU policy instruments	Assessment of policy instrument consideration in the model[16]:	
		Grants and subsidies	- Obligation for MSs to check that any grants/subsidies for prosumaging are offered to stakeholders meeting certain minimum EE standards (Jahn and Rosenow 2019)	4
		Loans/soft loans	- Require MSs to establish national loan	2
	Market- based instruments	GHG emissions allowances trading scheme	- Require MS to earmark certain part of revenues from GHG auctioning to specific prosumaging-related purposes (Kochanski et al. 2020)	4
	Fiscal/ financial incentives	Tariffs	- Introduce the right of consumers for time-differentiated network tariffs in all MSs (ENEFIRST 2021)	1
		Taxes - tax reliefs/exemptions	- Exemptions from VAT, e.g., for PVs / batteries (Kochanski et al. 2020)	1
		User charges	- Change in conditions for permissible forms of charges and fees for renewables self-consumers (CEER 2021)	1
Soft instruments	Information campaigns	Contact points in MSs	- Introduce obligatory quality assessment in information campaigns (e.g., consumers‘ satisfaction) (Rivas, Cuniberti, and Bertoldi 2016)	4
	Performance labels	Endorsement label	- Introduction of (Polverini, Dodd, and Espinosa 2021) - Introduction of Energy Labels for residential PV systems (Polverini et al. 2021)	1
	Voluntary approaches	Negotiated Agreements (Public-private)	- Establish an EU-level PPP to directly support prosumaging (e.g., through R&I)	4
		Public Voluntary Schemes	- Introduce an EU-level voluntary scheme on prosumaging for local authorities (e.g., within the Covenant of Mayors)	4

4.5. Assessment of model's consideration for the identified energy demand-side policy needs concerning New Societal Trends

4.5.1. Prosumaging

Table 15 Consideration of the identified EU-level policy needs in the field of prosumaging by INVERT

Policy need identified	Assessment of policy need consideration in the model[17]:
Needs for modelling of specific indicators	
(1): Share of energy consumers in the residential sector that are renewables self-consumers per category of consumer: • social (energy poor and vulnerable; middle class; high class; tenants/owners); • economic (residential, service and industry sectors); • technical (single/multi-family buildings; urban/rural; prosumer/prosumager)	1
(2) Share of energy consumers equipped with electricity storage facilities	1
(3) Share of household energy consumers/SMEs/local authorities that are a part of an energy community/collective self-consumption schemes	3
(4): Share of energy poor and vulnerable consumers in the residential sector that are renewable self-consumers/part of an energy community	1
(5): Share of energy consumers in the residential sector equipped with a gas boiler, heat pump and electrolyser	1
(6): Share of energy consumers equipped with smart meters	1
(7): Share of public authorities that are prosumagers.	4
Other needs expressed by policy makers with regard to energy-demand modelling	
(1) inform the policy making on the 'outputs' of prosumaging activity - the amounts of overall energy demand, as well as energy generated by self-consumers, including energy stored by them, energy self-consumed, and energy introduced to the national power grids;	1
(2) inform the policy making on the 'outputs' of prosumaging activity - the amounts of energy sold under time-of-use tariffs	1

[17] Legend:
1 – already directly considered;
2 – already indirectly considered;
3 – not considered in the model, but potentially important;
4 – not considered in the model, since it is not relevant for the modelling

Policy need identified	Assessment of policy need consideration in the model[17]:
(3) inform the policy making on the 'outputs' of prosumaging activity - the amounts of energy generated by individual and collective renewables self-consumers;	1
(4) inform the policy making on the 'outputs' of prosumaging activity - impacts on grid infrastructure for a broad range of different input assumptions	1
(5) inform the policy making on the impacts of changes in conditions for introduction of permissible charges and fees for renewables self-consumers that are set in RED II, art. 21(3), e.g.: increasing the capacity threshold (30 kW) to incentivise community prosumaging in bigger RES installations	1
(6) inform the policy making on the impacts of changes in business models of prosumaging (e.g., see Dodd et al. 2020, Table 50)	1
(7) inform the policy making on the impacts of introducing an obligation scheme requiring certain share of building energy demand to be covered by RES, including energy produced on-site or nearby	3
(8) inform the policy making on the impacts of changes in various public support forms for prosumagers (e.g., net metering, subsidies) on overall energy demand	1
(9) inform the policy making on the impacts of changes in introducing performance labels & GPP for PV systems on overall energy demand	1

5. Summary and synthesis

5.1. Consideration of the EU-level energy demand-side policy instruments in the field of New Societal Trends in the assessed energy-demand models

The assessed models already consider a significant share of the identified EU-level policy instruments with major impacts on the analysed New Societal Trends – either directly or in an indirect way (Table 16). In most cases, these policies are modelled indirectly. For instance, with regard to prosumaging, information campaigns on renewables self-consumption are modelled as enabling conditions reducing perceived costs. With regard to shared economy, public voluntary schemes are modelled as specific infrastructural outputs of such initiatives, e.g., improvements in the cycling infrastructure. With regard to circular economy, RD&D funding for innovations in this area under Horizon Europe is modelled via technology diffusion for new carbon-neutral processes.

Table 16 Consideration of the identified EU-level policy instruments by the assessed energy-demand models

Incidence of the given score in the assessment of models / Trend and policy instrument category	Already considered in the models in a direct way (score 1)	Already considered in the models in an indirect way (score 2)	Not considered, but potentially important (score 3)	Not considered and not relevant for modelling (score 4)
TOTAL for all trends	**27**	**38**	**36**	**32**
Prosumaging	**13**	**13**	**21**	**16**
Regulations	7	4	7	4
Economic and financial instruments	5	8	9	5
Soft instruments	1	1	5	7
Shared economy	**7**	**7**	**2**	**1**
Regulations	5	3	2	0
Economic and financial instruments	2	2	0	0
Soft instruments	0	2	0	1
Circular economy	**2**	**7**	**10**	**9**
Regulations	0	2	7	4
Economic and financial instruments	1	5	1	2
Soft instruments	1	0	2	3
Digitalisation	**5**	**11**	**3**	**6**
Regulations	1	3	0	2

Incidence of the given score in the assessment of models / Trend and policy instrument category	Already considered in the models in a direct way (score 1)	Already considered in the models in an indirect way (score 2)	Not considered, but potentially important (score 3)	Not considered and not relevant for modelling (score 4)
Economic and financial instruments	4	5	1	2
Soft instruments	0	3	2	2

When comparing the consideration of different types of policy instruments in the models, the following conclusions can be drawn:

Prosumaging: Several regulations concerning this trend are already well reflected in the modelling, e.g., (1) PRIMES-BuiMo covers building energy codes and minimum energy performance standards for equipment and appliances; (2) INVERT covers the parameters of PV and batteries that can be directly defined depending on product standards. While many economic and financial instruments are already considered in the modelling, a more comprehensive coverage of this type of policy instruments is possible, e.g., with regard to the consideration of such instruments as: (1) RD&D funding for prosumaging-related innovations in PRIMES-BuiMo; (2) GHG emissions allowances trading in INVERT. Among the identified soft measures addressed to prosumaging, only information campaigns have been found to be already considered (indirectly in PRIMES-BuiMo), while majority of the other soft instruments identified have been evaluated as not relevant for the assessed models. Still, some soft instruments were assessed as potentially important to be better reflected in the models, especially with regard to voluntary approaches (Renewable Energy Communities and Citizen Energy Communities).

Shared economy: Several regulations concerning this trend are well reflected in the modelling, e.g., Regulation (EU) 2019/631 (CO_2 standards for cars and vans) is directly considered in PRIMES-TREMOVE. Economic and financial instruments are also considered, e.g., through infrastructure charges, such as Eurovignette. Still, two economic and financial instruments were evaluated as potentially important to be better reflected in modelling: grants and subsidies as well as loans/soft loans. With regard to the soft instruments analysed, two policy measures are already covered by the modelling, i.e., negotiated agreements (e.g., European Clean Bus) and public voluntary schemes (e.g., Green Public Procurement in transport and in public space maintenance).

Circular economy: Some regulations concerning this trend are already well reflected in the modelling, e.g., recycling rates under Waste Framework Directive are considered in an indirect way in FORECAST-Industry. However, several regulatory instruments were also found as potentially important to be better reflected in the modellling, e.g., Ecodesign Directive and the monitoring framework for the circular economy. Furthermore, majority of circular economy-relevant economic and financial instruments have been already well addressed, e.g., though consideration of subsidies for carbon-neutral energy carriers. Still,

Green Public Procurement was assessed as potentially important to be better reflected in the modelling. With regard to the soft instruments analysed, only one measure of this type is already covered by the modelling, i.e., voluntary carbon emission reduction targets. This policy instrument is included in the bottom-up simulations of industrial emission pathways. However, some soft instruments were assessed as possibly important to be better reflected in the modelling, especially with regard to voluntary approaches that are potentially emerging, i.e., obligatory LCA Certificates for industrial products.

Digitalisation: Regulations concerning this trend are already well reflected in the modelling, especially with regard to the ecodesign requirements for servers and data storage products. Similar observation was made with regard to economic and financial instruments. For instance, Green Public Procurement requirements for computers and other electronic devices are already directly covered by FORECAST-Tertiary. Still, grants and subsidies under Digital Europe programme as well as ERDF and Cohesion Found were found as potentially important to be better reflected in the modellling. While no soft EU-level public policy instrument concerning digitalisation was found as already directly included in the energy-demand modelling, several existing schemes (e.g., unilateral commitments of private sector under Green and Digiral Coalition) are already modelled.

The summary of identified EU-level policies in the field of New Societal Trends that were assessed as currently not considered by the analysed energy-demand models, but potentially important for modelling, is given in Table 17.

Table 17 Identified EU-level policies in the field of New Societal Trends that were assessed as currently not considered by the analysed energy-demand models, but potentially important for modelling

Policy instrument category			EU policy instruments	Model
PROSUMAGING				
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Rights of renewables self-consumers (RED II, art. 21)	PRIMES-BuiMo
		Product standards	- Numerous IEC standards, e.g., for PV systems, electric installations, and batteries	PRIMES-BuiMo
		Auditing	- Summary & assessment of the enabling framework for RES self-consumption to be included in the MS' NECP and progress reports (RED II, art. 21 (6)) - Benchmarking of prosumaging across the EU (similar to benchmarking of Smart Metering rollouts – potential new EU regulation)	PRIMES-BuiMo
	Obligation schemes/ quotas/ mandatory targets	Energy market regulations	- MSs to put in place an enabling framework to promote and facilitate the development of renewables self-consumption (RED II, art. 21 (6)) - Final customers entitled to act as active customers (ED, art. 15)	PRIMES-BuiMo
		Carbon Emissions Reduction Target	- Obligation for MSs to link any support for prosumaging with emissions reduction and/or energy savings (Jahn and Rosenow 2019) – potential new EU regulation	PRIMES-BuiMo
		Mandatory targets	- Set targets for MSs on minimum share of prosumers in the population of final energy consumers (Petrick et al. 2019) – potential new EU regulation	INVERT
Econ. & financial instr.	Direct investment	Government procurement	- Include PV systems and batteries in Green Public Procurement scheme (Dunlop et al. 2018; EC 2020) – potential new EU regulation	PRIMES-BuiMo
		Grants and subsidies	- Obligation for MSs to check that any grants/subsidies for prosumaging are offered to stakeholders meeting certain minimum energy efficiency standards (Jahn and Rosenow 2019) – potential new EU regulation	PRIMES-BuiMo

		Loans/soft loans	- Require MSs to establish national loan schemes/guarantees for prosumagers (Scarpellini et al. 2021) – potential new EU regulation	PRIMES-BuiMo
		RD&D funding	- Horizon Europe, including Pillar II Global Challenges (…), Cluster 5: Climate, Energy and Mobility	PRIMES-BuiMo
	Market- based instruments	GHG emissions allowances trading scheme	- MSs to use revenues from auctioning of GHG emission allowances to develop renewable energies (ETS Directive, art. 10(3)(b))	INVERT
			- Require MS to earmark certain part of revenues from GHG auctioning to specific prosumaging-related purposes (Kochanski et al. 2020) – potential new EU instrument	PRIMES-BuiMo
	Fiscal/ financial incentives	Tariffs	Introduce the right of consumers for time-differentiated network tariffs in all MSs (ENEFIRST 2021) – potential new EU instrument	PRIMES-BuiMo
		Taxes – tax reliefs/ exemptions	Exemptions from VAT, e.g., for PVs / batteries (Kochański, Korczak, and Skoczkowski 2020) – potential new EU instrument	PRIMES-BuiMo
		User charges	Change in conditions for permissible forms of charges and fees for renewables self-consumers (CEER 2021) – potential new EU instrument	PRIMES-BuiMo
Soft instruments	Performance labels	Comparison label	Smart Readiness Indicator (EPBD recast)	PRIMES-BuiMo
		Endorsement label	- Introduction of Eco-Design measures for PV panels and inverters (Polverini, Dodd, and Espinosa 2021) – potential new EU instrument - Introduction of Energy Labels for residential PV systems (Polverini et al. 2021) – potential new EU instrument	PRIMES-BuiMo
	Voluntary approaches	Negotiated Agreements (Public-private)	- Establish an EU-level PPP to directly support prosumaging (e.g., through R&I) – potential new EU instrument	PRIMES-BuiMo
		Unilateral Commit-ments (Private sector)	- Renewable Energy Communities (RED II, art. 2 (16)) - Citizen Energy Communities (ED, art. 2 (11))	PRIMES-BuiMo, INVERT
SHARED ECONOMY				

Econ. & fin. Instr.	Direct investment	Grants and subsidies	- EU structural and regional funds (ERDF, Cohesion Fund) - LIFE programme - Proposed Digital Europe Programme	PRIMES-TREMOVE
		Loans/soft loans	-EIB lending	PRIMES-TREMOVE
CIRCULAR ECONOMY				
Regulation	Codes/ standards/ mandates	Building/ grid codes and standards	- Eurocodes - EPBD: Long-term renovation strategies; addressing embodied carbon from construction materials (potential new instrument) - Strategy for a Sustainable Built Environment (potential new instrument) - Development of a digital building logbook (potential new instrument)	FORECAST-Industry
		Product standards	- Eco-design Directive, Energy Labelling Regulation, Harmonised European Standards - Construction Products Regulation (CPR) - Circular Electronics Initiative, common charger solution, and reward systems to return old devices (potential new standards) - New regulations on batteries (potential new standards) - New regulations of waste oils (potential new standards) - Expanding the Eco-design Directive to include embodied emissions and energy-intensive intermediates (potential new standards)	FORECAST-Industry
		Sectoral standards	- New regulations on end-of-life vehicles (potential new standards) - Review of regulations on packaging (reduction of overpackaging) (potential new standards) - Policy framework for bio-based plastics and biodegradable or compostable plastics (potential new standards) - EU Strategy for Textiles (potential new standards) - EU-wide harmonised model for separate collection of waste and labelling to facilitate separate collection (potential new standards) - Scoping the development of further EU-wide end-of-waste and by-product criteria (potential new standards)	FORECAST-Industry

			- Mainstreaming circular economy objectives in free trade agreements, in other bilateral, regional and multilateral processes and agreements, and in EU external policy funding instruments (potential new standards)	
		Auditing	- The monitoring framework for the circular economy	FORECAST-Industry
Econ. & fin. instr.	Direct investment	Government procurement	- Green public procurement	FORECAST-Industry
Soft instr.	Performance labels	Endorsement label	-LCA Certificate being obligatory for products (potential new instrument) -Harmonised information systems for the presence of substances of concern (potential new instrument)	FORECAST-Industry
DIGITALISATION				
Econ. & fin. Instr.	Fiscal/financial incentives	Grants and subsidies	- Digital Europe programme - ERDF and Cohesion Found	FORECAST-Tertiary
Soft instr.	Voluntary approaches	Negotiated Agreements (Public-private)	- Big Data Value Public-Private Partnership	FORECAST-Tertiary
		Public Voluntary Schemes	- European Innovation Partnership of Smart Cities and Communities - Code of Conduct of ICT - The European Blockchain Partnership - Code of Conduct for Energy Efficiency in Data Centres	FORECAST-Tertiary

5.2. Consideration of the EU-level energy demand-side policy needs in the field of New Societal Trends in the assessed energy-demand models

The assessed models already consider a significant share of the identified EU-level policy needs connected with the studied New Societal Trends – either directly or in an indrect way (Table 18). Unlike the policy instruments, in most cases the analysed policy needs are usually reflected in the models in a direct way. For instance, with regard to prosumaging, the indicator of interest for policy makers: share of energy consumers in the residential sector equipped with a gas boiler, heat pump and electrolyser, has been already directly included in PRIMES-BuiMo. With regard to circular economy, financial indicators related to the policy instruments implementation – CAPEX, OPEX – are a part of the technology database of the FORECAST-Industry model, with aggregated energy cost developments and selected investments available as model results.

Table 18 Consideration of the identified EU-level policy needs by the assessed energy-demand models

Incidence of the given score in the assessment of models / Trend and policy need category	Already considered in the models in a direct way (score 1)	Already considered in the models in an indirect way (score 2)	Not considered, but potentially important (score 3)	Not considered and not relevant for modelling (score 4)
TOTAL for all trends	**18**	**6**	**22**	**6**
Prosumaging	**14**	**2**	**14**	**2**
Indicators of interest for policy makers	6	1	5	2
Other policy needs identified	8	1	9	0
Shared economy	**0**	**4**	**2**	**0**
Indicators of interest for policy makers	0	1	2	0
Other policy needs identified	0	3	0	0
Circular economy	**3**	**0**	**4**	**2**
Indicators of interest for policy makers	0	0	3	2
Other policy needs identified	3	0	1	0
Digitalisation	**1**	**0**	**2**	**2**
Indicators of interest for policy makers	1	0	0	2
Other policy needs identified	0	0	2	0

When comparing the consideration of different types of policy needs in the models, the following conclusions can be drawn:

Prosumaging: Several indicators of interest for policy making in the field of prosumaging have been already directly covered by the assessed energy demand models, though the coverage differs between models. Among the identified policy needs in the field prosumaging only one need (indicator of interest: share of public authorities that are prosumagers) was assessed as not relevant for both PRIMES-BuiMo and INVERT (modelling improvements within newTRENDs in these models relate to the modelling of household choices). The assessment shows that one indicator of interest for policy makers is currently not covered by INVERT (share of household energy consumers/SMEs/local authorities that are a part of an energy community/collective self-consumption schemes), but it could be potentially important for the modelling. Furthermore, the following indicators of interest for policy makers are currently not covered by PRIMES-BuiMo, but they could be potentially important for the modelling, i.e.:

1. Share of energy consumers equipped with electricity storage facilities;
2. Share of household energy consumers/SMEs/local authorities that are a part of an energy community/collective self-consumption schemes;
3. Share of energy poor and vulnerable consumers in the residential sector that are renewable self-consumers/part of an energy community;
4. Share of energy consumers equipped with smart meters.

For INVERT, it was found that the need for informing the policy making on the impacts of introducing an obligation scheme requiring certain share of building energy demand to be covered by RES, is not covered by the model, but it potentially could be important for modelling.

Shared economy: PRIMES-TREMOVE already satisfies the identified 3 policy needs concerning indicators of interest in the field of shared economy, though in an indirect way. Among the identified policy needs in the field of shared economy, no policy need was found as not relevant for PRIMES-TREMOVE. On the contrary, the evaluation showed that the following two important policy needs are not yet covered, but they are potentially important for the modelling:

1. inform the policy making on the impacts of car sharing and car pooling policies on urban mobility, in particular the individual car ownership levels and net impacts on the energy demand;
2. inform the policy making on the impacts of car sharing and car pooling policies on energy demand and use, in particular whether they support faster electrification and to what extent other energy and climate policies may support electrification of this segment of the market.

Circular economy: FORECAST-Industry already directly satisfies the majority of the identified policy needs concerning indicators of interest in the field of circular economy. Still it was found that parameters describing the quality of the analysis performed with the use of the model (limitations, assumptions made,

uncertainty levels) can be improved. Furthermore, the following policy needs were found as important and will be considered in the model improvement:

1. Interactions between policy instruments, in a cross-sectoral dimension – they will be established as linkage between Invert/EE-Lab and FORECAST-Industry for buildings.
2. Assesment of the environmental impact of construction materials in entire life cycle – it will be improved for energy demand and GHG emissions.
3. Extending the use phase of a building by its repurposing (including modular buildings) – it will be established to a certain degree as part of the newTRENDs study as well.

Digitalisation: FORECAST-Tertiary already directly satisfies one of the identified policy needs concerning indicators of interest in the field of digitalisation, i.e., energy use by ICT equipment across the sectors (incl. by type of equipment). Still two other policy needs, i.e. digitalisation targets and investment in new digital services as well as policies enabling energy demand reporting by ICT devices, were found as important, but not yet addressed in the modelling.

References

Capros, Pantelis, Nikolaos Tasios, Alessia De Vita, Leonidas Mantzos, and Leonidas Paroussos. 2012. "Model-Based Analysis of Decarbonising the EU Economy in the Time Horizon to 2050." *Energy Strategy Reviews* 1 (2): 76–84. https://doi.org/10.1016/J.ESR.2012.06.003.

CEER. 2021. "Status Review of Renewable Support Schemes in Europe for 2018 and 2019. Renewables Work Stream of Electricity Working Group. Report Ref: C20-RES-69-04."

Dunlop, E.D., A. Gracia Amillo, E. Salis, T. Sample, and N. Taylor. 2018. "Standards for the Assessment of the Environmental Performance of Photovoltaic Modules, Power Conversion Equipment and Photovoltaic Systems." Luxembourg.

ENEFIRST. 2021. "Case 9: Using Time-Of-Use Tariffs To Engage Customers And Benefit The Power System." https://particulier.edf.fr/en/home/energy-and-services/electricity/tarif-bleu.html.

European Commission. 2020. "Remarks by Commissioner Sinkevič ius on the Green Deal - Sustainable Batteries for a Circular and Climate Neutral Economy." 2020. https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_20_2380.

———. 2021. *Proposal for a Directive of the European Parliament and of the Council Amending Directive (EU) 2018/2001*.

Fleiter, Tobias, Matthias Rehfeldt, Andrea Herbst, Rainer Elsland, Anna Lena Klingler, Pia Manz, and Stefan Eidelloth. 2018. "A Methodology for Bottom-up Modelling of Energy Transitions in the Industry Sector: The FORECAST Model." *Energy Strategy Reviews* 22 (November): 237–54. https://doi.org/10.1016/J.ESR.2018.09.005.

Fotiou, Theofano, Alessia de Vita, and Pantelis Capros. 2019. "Economic-Engineering Modelling of the Buildings Sector to Study the Transition towards Deep Decarbonisation in the EU." *Energies* 12 (14). https://doi.org/10.3390/EN12142745.

Jahn, Andreas, and Jan Rosenow. 2019. "Applying the Efficiency First Principle to Photovoltaic Self-Consumption." *Eceee Summer Study Proceedings* 2019-June: 55–60.

Kochanski, Maksymilian, Katarzyna Korczak, Piotr Chrzanowski, Aleksander Ś niegocki, and Izabela Zygmunt. 2021. "Diagnosis of Energy Demand-Side Policy Needs at European Level. (NewTRENDs - Deliverable No. D4.1)." https://newtrends2020.eu.

Kochań ski, Maksymilian, Katarzyna Korczak, and Tadeusz Skoczkowski. 2020. "Technology Innovation System Analysis of Electricity Smart Metering in the European Union." *Energies* 13 (4). https://doi.org/10.3390/en13040916.

Kranzl, Lukas, Marcus Hummel, Andreas Müller, and Jan Steinbach. 2013. "Renewable Heating: Perspectives and the Impact of Policy Instruments." *Energy Policy* 59 (August): 44–58. https://doi.org/10.1016/J.ENPOL.2013.03.050.

Müller, A. 2012. "Stochastic Building Simulation, Working Paper." Berkeley. http://www.marshallplan.at/images/papers_scholarship/2012/Mueller.pdf .

Nikas, Alexandros, Jenny Lieu, Alevgul Sorman, Ajay Gambhir, Ethemcan Turhan, Bianca Vienni Baptista, and Haris Doukas. 2020. "The Desirability of Transitions in Demand: Incorporating Behavioural and Societal Transformations into Energy Modelling." *Energy Research & Social Science* 70 (December): 101780. https://doi.org/10.1016/J.ERSS.2020.101780.

Polverini, Davide, Ana Gracia Amillo, Nigel Taylor, Tony Sample, Elena Salis, and Ewan D. Dunlop. 2021. "Building Criteria for Energy Labeling of Photovoltaic Modules and Small Systems." *Solar RRL*, 2100518. https://doi.org/10.1002/SOLR.202100518.

Polverini, Davide, Nicholas Dodd, and Nieves Espinosa. 2021. "Potential Regulatory Approaches on the Environmental Impacts of Photovoltaics: Expected Improvements and Impacts on Technological Innovation." *Progress in Photovoltaics: Research and Applications* 29 (1): 83–97. https://doi.org/10.1002/PIP.3344.

Rivas, Silvia, Barbara Cuniberti, and Paolo Bertoldi. 2016. "Effective Information Measures to Promote Energy Use Reduction in EU Member States Analysis of Information, Empowerment and Training Measures in Member States National Energy Efficiency Action Plans." https://doi.org/10.2790/360658.

Scarpellini, Sabina, José Ángel Gimeno, Pilar Portillo-Tarragona, and Eva Llera-Sastresa. 2021. "Financial Resources for the Investments in Renewable Self-Consumption in a Circular Economy Framework." *Sustainability 2021, Vol. 13, Page 6838* 13 (12): 6838. https://doi.org/10.3390/SU13126838.

Siskos, Pelopidas, Georgios Zazias, Apostolos Petropoulos, Stavroula Evangelopoulou, and Pantelis Capros. 2018. "Implications of Delaying Transport Decarbonisation in the EU: A Systems Analysis Using the PRIMES Model." *Energy Policy* 121 (October): 48–60. https://doi.org/10.1016/J.ENPOL.2018.06.016.

Citation and contact

Citation:

Kochanski, Maksymilian; Korczak, Katarzyna; Kobylka, Krzysztof; Chrzanowski, Piotr, Müller, Andreas; Yu, Songmin; Jakob, Martin; Herbst, Andrea; Lotz, Meta Thurid (2022): Assessment of energy demand-side models from the perspective of policy makers' needs at European level (newTRENDs - Deliverable No. D4.3). Available at: https://newTRENDs2020.eu.

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Date of release

03/2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 893311.