MIDAS includes the descriptions of models in use by the Commission in support to the policy cycle. MIDAS is developed and managed by the **Competence Centre on Modelling** of the European Commission.

Find out more at https://ec.europa.eu/knowledge4policy/modelling_en
Contact: EU-MIDAS@ec.europa.eu

Factsheet

SWD(2020) 346 final/2

IMPACT ASSESSMENT Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Regulation (EU) No 347/2013

Supporting model(s)

EEMM, EGMM, METIS

Impact assessment
SWD(2020) 346 final/2

Fact sheet on model contributions

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 28/04/2021

Dissemination: Public

Overview

Title

IMPACT ASSESSMENT Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Regulation (EU) No 347/2013

Document ID

SWD(2020) 346 final/2

Year of publication

2020

Led by

ENER

Model(s) used

EEMM, EGMM, METIS

EEMM

Full title
European Electricity Market Model

Run for this impact assessment by
REKK

Contributed to
Baseline and assessment of policy options

Helped to assess the following impacts

Impact area	*Impact category*	*Impact subcategory*
Economic impacts	Operating costs and conduct of business	Cost/availability of essential inputs (raw materials, machinery, labour, energy, ..)
Economic impacts	Operating costs and conduct of business	Investment cycle
Economic impacts	Operating costs and conduct of business	Affects on individual Member States
Economic impacts	Trade and investment flows	Investment flows & trade in services
Economic impacts	Competitiveness (sectoral) of business	Cost of doing business
Economic impacts	Competitiveness (sectoral) of business	Market share & advantages in international context
Economic impacts	Functioning of the internal market and competition	Free movement of goods, services, capital and workers
Economic impacts	Functioning of the internal market and competition	Competition
Economic impacts	Innovation and research	Promotion of academic or industrial research
Economic impacts	Public authorities	Budgetary consequences for public authorities
Economic impacts	Consumers and households	Consumer's ability to benefit from the internal market or to access goods and services from outside the EU
Economic impacts	Consumers and households	Prices, quality, availability or choice of consumer goods and services
Economic impacts	Consumers and households	Safety or sustainability of consumer goods and services
Economic impacts	Consumers and households	Impact on vulnerable consumers
Economic impacts	Specific regions or sectors	Significant effects on sectors
Economic impacts	Specific regions or sectors	Impact on regions
Economic impacts	Specific regions or sectors	Disproportionately affected region or sector
Economic impacts	Macroeconomic environment	Investments and functioning of markets
Environmental	Climate	Emission of greenhouse gases
Environmental	Climate	Economic incentives set up by market based mechanisms
Environmental	Climate	Ability to adapt to climate change
Environmental	Efficient use of resources (renewable & non-renewable)	Use of renewable resources
Environmental	Efficient use of resources (renewable & non-renewable)	Use of non-renewable resources
Environmental	International environmental impacts	Environment in third countries
Environmental	Transport and the use of energy	Fuel mix used in energy production

EGMM

Full title
European Gas Market Model

Run for this impact assessment by
REKK

Contributed to
Baseline and assessment of policy options

Impact area	*Impact category*	*Impact subcategory*
Economic impacts	Operating costs and conduct of business	Cost/availability of essential inputs (raw materials, machinery, labour, energy, ..)
Economic impacts	Operating costs and conduct of business	Affects on individual Member States
Economic impacts	Trade and investment flows	EU Exports & imports
Economic impacts	Trade and investment flows	Investment flows & trade in services
Economic impacts	Competitiveness (sectoral) of business	Cost of doing business
Economic impacts	Competitiveness (sectoral) of business	Market share & advantages in international context
Economic impacts	Functioning of the internal market and competition	Free movement of goods, services, capital and workers
Economic impacts	Functioning of the internal market and competition	Competition
Economic impacts	Innovation and research	Promotion of academic or industrial research
Economic impacts	Public authorities	Budgetary consequences for public authorities
Economic impacts	Consumers and households	Consumer's ability to benefit from the internal market or to access goods and services from outside the EU
Economic impacts	Consumers and households	Prices, quality, availability or choice of consumer goods and services
Economic impacts	Consumers and households	Safety or sustainability of consumer goods and services
Economic impacts	Consumers and households	Impact on vulnerable consumers
Economic impacts	Specific regions or sectors	Significant effects on sectors
Economic impacts	Specific regions or sectors	Disproportionately affected region or sector
Economic impacts	Macroeconomic environment	Investments and functioning of markets
Environmental	Climate	Emission of greenhouse gases
Environmental	Climate	Ability to adapt to climate change
Environmental	Efficient use of resources (renewable & non-renewable)	Use of non-renewable resources
Environmental	International environmental impacts	Environment in third countries
Environmental	Transport and the use of energy	Fuel mix used in energy production

METIS

Full title
Markets and Energy Technologies Integrated Software

Run for this impact assessment by
European Commission, JRC

Contributed to
Baseline and assessment of policy options

Helped to assess the following impacts

The key outcomes of the REKK model were cross-checked with the internal METIS model run by JRC.

EEMM

European Electricity Market Model

Fact sheet

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 28/04/2021

Dissemination: Public

Overview

Acronym EEMM
Full title European Electricity Market Model

Main purpose
EEMM is a dynamic, multi-market sectoral equilibrium model, simulating the European electricity wholesale markets to analyse the impact of policies on the European markets.

Summary
REKK's EEMM is a partial equilibrium microeconomic model. It assumes that the electricity market is fully liberalised and perfectly competitive. In the model, electricity generation as well as cross-border capacities are allocated on a market basis without gaming or withholding capacity: the cheapest available generation is used, and if imports are cheaper than producing electricity domestically, demand is satisfied from imports. Both production and trade are constrained by the available installed capacity and net transfer capacity (NTC) of cross-border transmission networks respectively. Due to these capacity constraints, prices across borders are not always equalised.

There are 41 countries (44 markets) modelled in EEMM: in these countries prices are derived from the demand-supply balance, while on outside markets we assume exogenous prices.

The EEMM model has an hourly time step, modelling 90 representative hours with respect to load, covering all four seasons and all daily variations in electricity demand. The selection of these hours ensures that both peak and base hours are represented, and that the impact of volatility in the generation of intermittent RES technologies on wholesale price levels are captured by the model.

There are three types of market participants in the model: producers, consumers, and traders. All of them behave in a price-taking manner: they take the prevailing market price as given and assume that their actions have a negligible effect on this price.

The model has been useful in assessing:

- Effects of different coal phase-out policies in Europe
- Cost-Benefit Analysis (CBA) of new infrastructure and cross-border cost allocation (CBCA)
- Electricity wholesale price forecast
- Effects of various fuel price assumptions (natural gas, coal) on the European electricity wholesale market
- Effects of the CO2 price on the European electricity wholesale market
- Effects of a new power plant/cross-border line on the European electricity market

Keywords

electricity , energy market modelling , infrastructure

Model category (thematic)

Energy

Model home page

No information provided

Ownership & license

Ownership

Sole ownership [3rd party]

Ownership details

REKK Kft

Licence type

Non-Free Software licence. The license has one or more of the following restrictions: it prohibits creation of derivative works; it prohibits commercial use; it obliges to share the licensed or derivative works on the same conditions.

Details

EEMM structure and approach

The European Electricity Market Model consists of the following building blocks:

Supply side:

As perfect competition is assumed when the supply curve is formed all units provide their production on a marginal cost basis. The final marginal production costs represents the sum of the CO_2 emission cost, energy tax (if any), fuel cost and variable OPEX.

For all given technologies (e.g. OCGT, CCGT, thermal) commissioning date defines the efficiency, the self-consumption and the variable OPEX cost for all units. Using the fuel prices as an input total fuel costs are calculated taking into account the above parameters. CO2 costs are based on the calculated emission level and the CO2 quota prices, and all these costs are then added to the total energy tax paid and the variable OPEX.

It is important to note that only short-term marginal costs are taken into account, the model does not analyse whether long-term operation is profitable or not. It is possible, that some units remain operational even if they provide electricity in a few hours per year. Power plant units are available until the end of their (pre-defined) lifetimes.

Demand side: When modelling the electricity system short-term market outcomes - representing only one hour - are simulated. However, typically yearly results are interesting, thus, reference hours are defined to be able to produce yearly outputs. In the EEMM 90 reference hours are used: there are six types of hours representing yearly differences, another 4 that represent daily seasonality and the 24 types of hours created this way are further separated to gain 90 representing hours. This latter separation is carried out in a way to gain as homogenous groups as possible, so the demand of all 8760 hours within one year could be represented very well with the given 90 reference hours.

Demand is calculated for each reference hour as the arithmetic mean of the demand of the hours it represents in 2018, and then adjusted according to the level of yearly demand assumed for the modelled year. Yearly demand forecasts are based on EU's PRIMES modelling for each country.

When modelling a whole year, the model runs 90 times, and outputs are saved for all reference hours separately. From these outputs yearly results are calculated taking into account the weight of all reference hours (based on how many hours they represent). This way yearly baseload prices, import-export positions and production of each unit are generated as outputs.

Cross-border trade

Power flow is ensured by 104 interconnectors between the countries, where each country is treated as a single node, thus no domestic power system constraint is taken into account. NTC values are used to indicate trading possibilities, seasonal differences are included in the modelling based on historical data from ENTSO-E Transparency Platform. Future investments are assumed based on data from ENTSO-E's latest Ten-Year Network Development Plan (TYNDP).

Equilibrium

The model calculates the simultaneous equilibrium allocation in all markets with the following properties:

- Producers maximize their short-term profits given the prevailing market prices.
- Total domestic consumption is given by the aggregate electricity demand function in each country.
- Electricity transactions (export and import) occur between neighbouring countries until market prices are equalized or transmission capacity is exhausted.
- Energy produced and imported is in balance with energy consumed and exported.

Given our assumptions about demand and supply, market equilibrium always exists and is unique in the model.

Electricity product prices

The calculated market equilibrium is a static one: it only describes situations with the same demand, supply, and transmission characteristics. However, these market features are constantly in motion. As a result, short run equilibrium prices are changing as well.

To simulate the price development of more complex electricity products, such as those for base load or a peak load delivery, we perform several model runs with typical market parameters and take the weighted average of the resulting short term (hourly) prices.

Input and parametrization

Data for the modelling scenarios is derived from publicly available sources.

- NTC capacity data based on ENTSO database, including the ENTSO-E latest TYNDP projects effect on NTCs
- Supply side database are based on national regulators, system operators, and individual power company and plant websites. These information are cross-checked with aggregated database (ENTSO-E, Eurostat)
- Natural gas price forecast is based on EGMM (European Gas Market Modelling) modelling results
- Other fuel prices (coal and oil) and CO2 price forecast are based on international organizations (IMF, IEA, European Commission, etc.)

- Demand based on ENTSO-E fact database, forecasted consumptions are based on PRIMES projections

Main output

Outputs of modelling are the wholesale electricity wholesale market prices per country per reference hours and from this information also the yearly base and peak load prices can be determined. Electricity trades between countries and production and CO2 emission of all producers are also calculated. Based on those outputs the model also calculates welfare on country and stakeholder level (consumer, producer, traders).

Spatial - temporal extent

The output has the following spatial-temporal resolution and extent:

Parameter	Description
Spatial Extent / Country Coverage	Countries from Northern Europe, Southern Europe, Western Europe; all countries from Central and Eastern Europe. EU Member states 27 (except Cyprus, Malta) and UK.
(Spatial) resolution	National (NUTS1)
Temporal extent	Very short-term (less than 1 year), Short-term (period of 5 years or less), Medium-term (5 to 15 years), Long-term (more than 15 years)
Temporal resolution	Hours, Years

Quality & transparency

Quality

Question	Answer	Details
Models are by definition affected by uncertainties (in input data, input parameters, scenario definitions, etc.). Have the model uncertainties been quantified? Are uncertainties accounted for in your simulations?	yes	Sensitivity runs performed. These are dependent on the context and not the model itself
Sensitivity analysis helps identifying the uncertain inputs mostly responsible for the uncertainty in the model responses. Has the model undergone sensitivity analysis?	yes	Sensitivity runs performed. These are dependent on the context and not the model itself
Has the model undergone external peer review by a panel of experts, or have results been published in peer-reviewed journals?	yes	See András Mezősi, László Szabó (2016).
Has model validation been done? Have model predictions been confronted with observed data (ex-post)?	yes	Ex post wholesale prices and electricity mix

References related to external peer-review and publication in scientific journals:

- András Mezősi, László Szabó (2016): Model based evaluation of electricity network investments in Central Eastern Europe, Energy Strategy Reviews. Volumes 13–14, November 2016, Pages 53-66, https://doi.org/10.1016/j.esr.2016.08.001

Transparency

Question	Answer	Details
Is the model underlying database (i.e. the database the model runs are based on) publicly available?	no	Proprietary data collection based on public sources
Can model outputs be made publicly available?	yes	At request
Is the model transparently documented (including underlying data, assumptions and equations, architecture, results) and are these documents available to the general public?	yes	Documentation included in annexes of respective studies and REKK website (except equations)
Is the model source code publicly accessible or open for inspection?	no	

References related to documentation:

- No references provided in MIDAS

The model's policy relevance and intended role in the policy cycle

The model is designed to contribute to the following policy areas

- Energy

The model is designed to contribute to the following phases of the policy cycle

- Formulation
- Implementation
- Evaluation

The model's potential

The EEMM is a partial equilibrium microeconomic model. It assumes fully liberalised and perfectly competitive electricity markets. The model was used to evaluate the infrastructure developments triggered by the implementation of the TEN-E Regulation by measuring benefits (e.g. socio-economic welfare derived from the higher trading opportunities allowed by the new infrastructure). The main purpose of the modelling carried out for this study was to monetise the realised and potential benefits (in term of socio-economic welfare change) of the projects of common interest (PCIs). In addition, based on modelling outcomes, several indicators were calculated in order to illustrate the effect of the TEN-E Regulation on market integration, competition, CO_2 emission reduction and RES integration.

Previous use of the model in ex-ante impact assessments of the European Commission

Use of the model in ex-ante impact assessments since July 2017.

In the Year	EEMM contributed to the Impact assessment called	Led by	By providing input to the	The model was run by	Details of the contribution
2020	IMPACT ASSESSMENT Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Regulation (EU) No 347/2013	DG ENER	Baseline and assessment of policy options	REKK	The model helped to assess the following impacts: • Cost/availability of essential inputs (raw materials, machinery, labour, energy, ..) • Investment cycle • Affects on individual Member States • Investment flows & trade in services • Cost of doing business • Market share & advantages in international context • Free movement of goods, services, capital and workers • Competition • Promotion of academic or industrial research • Budgetary consequences for public authorities • Consumer's ability to benefit from the internal market or to access goods and services from outside the EU • Prices, quality, availability or choice of consumer goods and services • Safety or sustainability of consumer goods and services • Impact on vulnerable consumers • Significant effects on sectors • Impact on regions • Disproportionately affected region or sector • Investments and functioning of markets • Emission of greenhouse gases • Economic incentives set up by market based mechanisms • Ability to adapt to climate change • Use of renewable resources • Use of non-renewable resources • Environment in third countries • Fuel mix used in energy production

Bibliographic references

- Mezősi, András ; Felsmann, Balázs ; Kerekes, Lajos ; Szabó, László: Coexistence of nuclear and renewables in the V4 electricity system: Friends or enemies?; ENERGY POLICY 140 Paper: 111449 , 11 p. (2020), DOI: 10.1016/j.enpol.2020.111449
- Szabó, László ; Kelemen, Ágnes ; Mezősi, András ; Pató, Zsuzsanna ; Kácsor, Enikő ; Resch, Gustav ; Liebmann, Lukas: South East Europe electricity roadmap – modelling energy transition in the electricity sectors; CLIMATE POLICY 19 : 4 pp. 495-510. , 1 p. (2019), DOI: 10.1080/14693062.2018.1532390
- Support to the evaluation of Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure (2021) DOI: 10.2833/154438
- Assessment for the identification of candidate PECI and PMI projects Final Report. (2020) https://www.energy-community.org/dam/jcr:95014585-69b6-417f-b38e-ecd578a25e37/REKK_PECI2020_062020.pdf

EGMM

European Gas Market Model

Fact sheet

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 28/04/2021

Dissemination: Public

Overview

Acronym EGMM
Full title European Gas Market Model

Main purpose
EGMM is a dynamic, multi-market sectoral equilibrium model, simulating the intricate workings of the European natural gas markets, to analyse the impact of policies on the European markets.

Summary
REKK's European Gas Market Model has been developed to simulate the operation of an international wholesale natural gas market in Europe or a broader region. The model covers the EU28, Switzerland, the EnC Contracting Parties, Turkey and Armenia. The demand and supply side of the gas market, pipeline, LNG and storage infrastructure is included on a country level. Large external markets, such as Russia, Norway, Libya, Algeria and LNG exporters are represented by exogenously assumed market prices, long-term supply contracts and physical connections to Europe.

Given the input data, the model calculates a dynamic competitive market equilibrium for the modelled countries, and returns the market clearing prices, along with the production, consumption and trading quantities, storage utilization decisions and long-term contract deliveries, as well as physical flows on the infrastructure.

Model calculations refer to 12 consecutive months. Dynamic connections between months are introduced by the operation of gas storages and TOP constraints (minimum and maximum deliveries are calculated over the entire 12-month period, enabling contractual "make-up").

The European Gas Market Model consists of the following building blocks: (1) local demand; (2) local supply; (3) gas storages; (4) external markets and supply sources; (5) cross-border pipeline connections; (6) LNG infrastructure (7) long-term take-or-pay (TOP) contracts; and (8) spot trading.

The model has been useful in assessing:

- Effects of major global developments on the European gas markets (e.g. LNG supply)
- Cost-Benefit Analysis (CBA) of new infrastructure and cross-border cost allocation (CBCA)
- Identifying main risks affecting the realisation of infrastructure projects
- Security of supply modelling
- Effects of various tariff regimes on the European gas market
- Effects of major infrastructure projects and long-term contract delivery point changes on the European gas market

Keywords

natural gas , energy market modelling , infrastructure

Model category (thematic)

Energy

Model home page

No information provided

Ownership & license

Ownership

Sole ownership [3rd party]

Ownership details

REKK Kft

Licence type

Non-Free Software licence. The license has one or more of the following restrictions: it prohibits creation of derivative works; it prohibits commercial use; it obliges to share the licensed or derivative works on the same conditions.

Details

EGMM structure and approach

The European Gas Market Model consists of the following building blocks:

1. **Local demand** is represented by demand functions. Demand functions are downward sloping, meaning that higher prices decrease the amount of gas that consumers want to use in a given period. For simplicity, we use a linear functional form, the consequence of which is that every time the market price increases by 0.1 €/MWh, local monthly consumption is reduced by equal quantities (as opposed to equal percentages, for example). The linearity and price responsiveness of local demand ensures that market clearing prices will always exist in the model. Regardless of how little supply there is in a local market, there will be a high enough price so that the quantity demanded will fall back to the level of quantity supplied, achieving market equilibrium.

2. **Local supply** shows the relationship between the local market price and the amount of gas that local producers are willing to pump into the system at that price. In the model, each supply unit (company, field, or even well) has either a constant, or a linearly increasing marginal cost of production (measured in €/MWh). Supply units operate between minimum and maximum production constraints in each month, and an overall yearly maximum capacity.

3. **Gas storages** are capable of storing natural gas from one period to another, arbitraging away large market price differences across periods. Their effect on the system's supply-demand balance can be positive or negative, depending on whether gas is withdrawn from, or injected into, the storage. Each local market can contain any number of storage units (companies or fields). Storage units have a constant marginal cost of injection and (separately) of withdrawal. In each month, there are upper limits on total injections and total withdrawals. There is no specific working gas fee, but the model contains a real interest rate for discounting the periods, which automatically ensures that foregone interest costs on working gas inventories are considered. There are three additional constraints on storage operation: (1) working gas capacity; (2) starting inventory level; and (3) year-end inventory level. Injections and withdrawals must be such during the year that working gas capacity is never exceeded, intra-year inventory levels never drop below zero, and year-end inventory levels are met.

4. **External markets and supply sources** are set exogenously (i.e. as input data) for each month, and they are assumed not to be influenced by any supply-demand development in the local markets. In case of LNG the price is derived from the Japanese spot gas price, taking into account the cost of transportation to any possible LNG import terminal. As a consequence, the price levels set for outside markets are important determinants of their trading volumes with Europe.

5. **Cross-border pipelines** allow the transportation of natural gas from one market to the other. Connections between geographically non-neighbouring countries are also possible, which allows the possibility of dedicated transit. Cross-border linkages are directional, but physical reverse

flow can easily be allowed for by adding a parallel connection that "points" into the other direction. Each linkage has a minimum and a maximum monthly transmission capacity, as well as a proportional transmission fee. Virtual reverse flow ("backhaul") on unidirectional pipelines or LNG routes can also be allowed, or forbidden, separately for each connection and each month. The rationale for virtual reverse flow is the possibility to trade "against" the delivery of long-term take-or-pay contracts, by exploiting the fact that reducing a pre-arranged gas flow in the physical direction is the same commercial transaction as selling gas in the reverse direction. Additional upper constraints can be placed on the sum of physical flows (or spot trading activity) of selected connections. This option is used, for example, to limit imports through LNG terminals, without specifying the source of the LNG shipment.

6. **LNG infrastructure** in the model consist of LNG liquefaction plants of exporting countries, LNG regasification plants of importing countries and the transport routes connecting them. LNG terminals capacity is aggregated for each country, which differs from the pipeline setup, where capacity constraints are set for all individual pipeline. LNG capacity constraints are set as a limit for the set of "virtual pipelines" pointing from all exporting countries to a given importing country, and as a limit on the set of pipelines pointing from all importing countries to a given exporting country.

7. **Long-term take-or-pay (TOP) contracts** are agreements between an outside supply source and a local market concerning the delivery of natural gas into the latter. Each contract has monthly and yearly minimum and maximum quantities, a delivery price, and a monthly proportional TOP-violation penalty. Maximum quantities (monthly or yearly) cannot be breached, and neither can the yearly minimum quantity. Deliveries can be reduced below the monthly minimum, in which case the monthly proportional TOP-violation penalty must be paid for the gas that was not delivered. Any number of TOP-contracts can be in force between any two source and destination markets. Monthly TOP-limits, prices, and penalties can be changed from one month to the next. Contract prices can be given exogenously, indexed to internal market prices, or set to a combination of the two options. The delivery routes (the set of pipelines from source to destination) must be specified as input data for each contract. It is possible to divide the delivered quantities among several parallel routes in pre-determined proportions, and routes can also be changed from one month to the next.

8. **Spot trading** serves to arbitrage price differences across markets that are connected with a pipeline or an LNG route. Typically, if the price on the source-side of the connection exceeds the price on the destination-side by more than the proportional transmission fee, then spot trading will occur towards the high-priced market. Spot trading continues until either (1) the price difference drops to the level of the transmission fee, or (2) the physical capacity of the connection is reached. Physical flows on pipelines and LNG routes equal the sum of long-term deliveries and spot trading. When virtual reverse flow is allowed, spot trading can become "negative" (backhaul), meaning that transactions go against the predominant contractual flow. Of course, backhaul can never exceed the contractual flow of the connection.

Equilibrium

The European Gas Market Model algorithm reads the input data and searches for the simultaneous supply-demand equilibrium (including storage stock changes and net imports) of all local markets in all months, respecting all the constraints detailed above.

In short, the equilibrium state (the "result") of the model can be described by a simple no-arbitrage condition across space and time. However, it is instructive to spell out this condition in terms of the behaviour of market participants: consumers, producers and traders. Infrastructure operators (TSO, storage and LNG operator) observe gas flows and their welfare is not factored in the equilibrium.

Welfare

Welfare calculations are done ex post. The maximized value of the objective function is adjusted to properly account for actual welfare in the market. The operating profit of transmission and storage system operators is added using estimates for their marginal costs, and the expenditure on import contracts is increased by the take-or-pay fixed cost element.

Welfare components are assigned to regional and outside markets based on location. For consumer and local producer surplus, long-term contract profit, storage operating income and congestion rent, the assignment is straightforward. Pipeline operating income is shared in the ratio of entry and exit fees and pipeline congestion rent is shared equally by the neighbouring markets. LNG-related welfare components are assigned to the market hosting the terminal.

Input and parametrization

Data for the modelling scenarios is derived from publicly available sources: infrastructure capacity data on transmission, LNG and storage from Gas Infrastructure Europe, demand and production data from Eurostat and for future forecast from Primes or IEA. For publicly not available data on long term contract prices the foreign trade statistics formed the basis of estimates.

1. Summary of modelling input parameters and data sources

Category	Data Unit	Source
Consumption	Annual Quantity (TWh/year) Monthly distribution (% of annual quantity)	PRIMES or Eurostat, supplemented by Energy Community or Eurostat data if applicable
Production	Minimum and maximum production (GWh/day)	PRIMES or Eurostat, supplemented by Energy Community or Eurostat data if applicable
Pipeline infrastructures	Daily maximum flow (GWh/day)	GIE, ENTSO-G, Energy Community data
Storage infrastructures	Injection (GWh/day), withdrawal (GWh/day), working gas capacity (TWh)	GSE
LNG infrastructures	Regasification capacity (GWh/day)	GLE, GIIGNL
LTC contracts	Yearly minimum maximum quantity, Seasonal minimum and maximum quantity	Gazprom, National Regulators Annual reports, Eurostat, Platts, Cedigaz

Storage, LNG regasification and transmission tariffs	€/MWh	TSO, SSO, LSO webpages

Main output

Outputs of modelling are the wholesale gas market prices per country and the natural gas flows. Based on those outputs the model also calculated welfare on country and stakeholder level (consumer, producer, traders, infrastructure operators).

Spatial - temporal extent

The output has the following spatial-temporal resolution and extent:

Parameter	Description
Spatial Extent / Country Coverage	All countries of Europe (Northern Europe, Southern Europe, Western Europe, Central and Eastern Europe). EU Member states 27 and UK.
(Spatial) resolution	World-regions (supranational), National (NUTS1)
Temporal extent	Very short-term (less than 1 year), Short-term (period of 5 years or less), Medium-term (5 to 15 years), Long-term (more than 15 years)
Temporal resolution	Months

Quality & transparency

Quality

Question	Answer	Details
Models are by definition affected by uncertainties (in input data, input parameters, scenario definitions, etc.). Have the model uncertainties been quantified? Are uncertainties accounted for in your simulations?	yes	Sensitivity runs performed. These are dependent on the context and not the model itself
Sensitivity analysis helps identifying the uncertain inputs mostly responsible for the uncertainty in the model responses. Has the model undergone sensitivity analysis?	yes	Sensitivity runs performed. These are dependent on the context and not the model itself
Has the model undergone external peer review by a panel of experts, or have results been published in peer-reviewed journals?	yes	See András Kiss, Adrienn Selei, Borbála Takácsné Tóth (2016)
Has model validation been done? Have model predictions been confronted with observed data (ex-post)?	yes	Ex post Eurostat, ENTSOG flows

References related to external peer-review and publication in scientific journals:

- András Kiss, Adrienn Selei, Borbála Takácsné Tóth (2016): A Top-Down Approach to Evaluating Cross-Border Natural Gas Infrastructure Projects in Europe. The Energy Journal Vol 37. https://doi.org/10.5547/01956574.37.SI3.akis

Transparency

Question	Answer	Details
Is the model underlying database (i.e. the database the model runs are based on) publicly available?	no	Proprietary data collection based on public sources
Can model outputs be made publicly available?	yes	At request
Is the model transparently documented (including underlying data, assumptions and equations, architecture, results) and are these documents available to the general public?	yes	Documentation included in annexes of respective studies and REKK website
Is the model source code publicly accessible or open for inspection?	no	

References related to documentation:

- No references provided in MIDAS

The model's policy relevance and intended role in the policy cycle

The model is designed to contribute to the following policy areas

- Energy

The model is designed to contribute to the following phases of the policy cycle

- Formulation
- Implementation
- Evaluation

The model's potential

The EGMM is a competitive, dynamic, multi-market equilibrium model that simulated the operation of the wholesale natural gas market across the whole of Europe. The model was used to evaluate the infrastructure developments triggered by the implementation of the TEN-E Regulation by measuring benefits (e.g. socio-economic welfare derived from the higher trading opportunities allowed by the new infrastructure). The main purpose of the modelling carried out for this study was to monetise the realised and potential benefits (in term of socio-economic welfare change) of the projects of common interest (PCIs). In addition, based on modelling outcomes, several indicators were calculated in order to illustrate the effect of the TEN-E Regulation on market integration, competition, CO2 emissions and RES integration.

Previous use of the model in ex-ante impact assessments of the European Commission

Use of the model in ex-ante impact assessments since July 2017.

In the Year	EGMM contributed to the Impact assessment called	Led by	By providing input to the	The model was run by	Details of the contribution
2020	IMPACT ASSESSMENT Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Regulation (EU) No 347/2013	DG ENER	Baseline and assessment of policy options	REKK	The model helped to assess the following impacts: • Cost/availability of essential inputs (raw materials, machinery, labour, energy, ..) • Affects on individual Member States • EU Exports & imports • Investment flows & trade in services • Cost of doing business • Market share & advantages in international context • Free movement of goods, services, capital and workers • Competition • Promotion of academic or industrial research • Budgetary consequences for public authorities • Consumer's ability to benefit from the internal market or to access goods and services from outside the EU • Prices, quality, availability or choice of consumer goods and services • Safety or sustainability of consumer goods and services • Impact on vulnerable consumers • Significant effects on sectors • Disproportionately affected region or sector • Investments and functioning of markets • Emission of greenhouse gases • Ability to adapt to climate change • Use of non-renewable resources • Environment in third countries • Fuel mix used in energy production

Bibliographic references

- Study on Quo vadis gas market regulatory framework. (2018) doi:10.2833/595884
- Follow-up study to the LNG and storage strategy. (2017) doi:10.2833/147760
- Study on gas market upgrading and modernisation (2020) DOI: 10.2833/968978
- Support to the evaluation of Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure (2021) DOI: 10.2833/154438

METIS

Markets and Energy Technologies Integrated Software

Fact sheet

Source: Commission modelling inventory and knowledge management system (MIDAS)

Date of Report Generation: 28/04/2021

Dissemination: Public

Overview

Acronym METIS
Full title Markets and Energy Technologies Integrated Software

Main purpose

Energy system model designed to simulate the operation of electricity, gas and heat markets and to assess impacts of policy initiatives on the European energy system and markets.

Summary

METIS is an energy model covering with high granularity the European energy system with a focus on electricity, gas and heat. The original model has been developed by the company Artelys. It is currently improved with respect to the representation of energy networks and renewable energy potentials with the aim of modelling and integrated European energy system. The model covers all EU Member States at the regional (NUTS2) level and can by run for medium term projection in an hourly resolution.

The METIS power system captures the European power system, representing power production, consumption and transmission assets. The gas system embeds gas-specific assets and performs simulations for the security of the gas supply or supply source dependence analysis. The intra-day module of METIS allows assessing the impact of the re-adaptation of the generation dispatch up-to real-time, while the balancing module allows simulating the real-time dispatch of the reserve units to face imbalance. Both system- and market-wide results can be computed also stochastically, to account for unpredictable events in the energy supply. The model incorporates four bidding strategies as a post treatment of power system simulations: marginal, strategic, oligopoly and fixed-operating costs.

The model can be used for the policy formulation. METIS is able to simulate the entire European energy system and markets operation for electricity, gas and heat energy carriers under a stochastic uncertainty, capturing for example weather variations and other stochastic events.

Keywords

Energy , energy system analysis , energy market analysis

Model category (thematic)

Energy

Model home page

https://ec.europa.eu/energy/en/data-analysis/energy-modelling/metis

Ownership & license

Ownership

Multiple ownership [Original code owned by European Union]

Ownership details

No information provided

Licence type

Non-Free Software licence. The license has one or more of the following restrictions: it prohibits creation of derivative works; it prohibits commercial use; it obliges to share the licensed or derivative works on the same conditions.

Details

METIS structure and approach

The METIS model consists of three main modules: *power system*, *gas system* and *power market*. Each of the three modules interact with each other mutually, as the output of one module is fed into other modules as input. Alternatively, the three modules can be run independently, when analysing electricity, gas and heat energy separately.

The *Power System module* of METIS has been designed to analyse multiple power systems issues, following a welfare-maximisation principle. It is also being used to analyse the European power systems' dynamics, by providing production plans, electricity flows, production costs, systemic marginal costs, scarcity periods and loss of load, or other standard indicators detailed further in the document. The Power System module contains a library of assets for production, consumption and transmissions that can be attached to each node of the network.

The Power System module contains the following assets: thermal non-renewable energy assets, hydro assets, other renewable energy assets, other storage assets, power consumption, power transmission, fuel contracts, CO2 emissions, reserve requirements, loss of load, and surplus of energy at each node.

The *Gas System module* has been designed to address multiple gas systems issues, following a welfare-maximisation principle, as in the Power System module. It allows the analysis of the European gas systems' dynamics, by providing production plans, gas flows, loss of load, etc.

The Gas System module contains the following assets: the gas consumption as described by the national demand of natural gas, the gas production as captures by the indigenous production of natural gas, the gas storage as described by storage facilities for gas, the liquefied natural gas (LNG) terminal as captured by gasification terminals that are receiving and transforming LNG into natural gas, LNG imports as described by imports of LNG sent to LNG terminals, LNG exports as captured by the liquefaction train liquefying natural gas and exporting, gas imports as captured by imports of natural gas from non-modelled countries through pipelines, gas exports as described by exports of natural gas to non-modelled countries through pipelines, pipelines as captured by gas transmissions between modelled zones, and CO2 emissions as described by CO2 emissions due to the consumption of natural gas associated with a CO2 price.

The *Power Market module* replicates the market participants' decision process. For a given period (typically, hours or days), the generation plan (including both energy generation and balancing reserve supply) is first optimised based on day-ahead demand and renewable energy generation forecasts. Market coupling is modelled via net transfer capacity (NTC) constraints for interconnectors. Then, the generation plan is updated during the day, taking into account updated forecasts and asset technical constraints. Finally, imbalances are drawn to simulate balancing energy procurement. Imbalances are the result of events that could not have been predicted before the gate closure.

The METIS model files, technical documentation and user's instructions can be found on the model's website:

https://ec.europa.eu/energy/data-analysis/energy-modelling/metis_en

Input and parametrization

METIS requires as inputs the following types of data (up to hourly granularity):

- Capacity and technical characteristics of infrastructure
- Capital and technology costs
- Fuel prices
- CO2 emission factors and prices
- Weather data (actual data and forecasts)
- Wind, solar and hydro profiles
- Demand profiles and level of demand

The main sources of data are derived from publically available sources, in particular Eurostat, ENTSO-E and ENTSO-G.

Data for renewable energy potentials and time series are currently updatedA significant part of the input is context dependent, i.e. on the scenario against which METIS is calibrated (e.g. relevant PRIMES scenarios as in the case of the Market Design studies).

In general METIS is very flexible in using very different sources of data and not being restricted to specific databases or sources.

Main output

The model provides the dispatch of energy assets at hourly (or otherwise specified) time resolution.

Spatial - temporal extent

The output has the following spatial-temporal resolution and extent:

Parameter	Description
Spatial Extent / Country Coverage	The model can be used at EU country or regional level,as specified by analysts.
(Spatial) resolution	MS level or finer granularity if specified.
Temporal extent	One year unless specified differently.
Temporal resolution	Hourly.

Quality & transparency

Quality

Question	Answer	Details
Models are by definition affected by uncertainties (in input data, input parameters, scenario definitions, etc.). Have the model uncertainties been quantified? Are uncertainties accounted for in your simulations?	yes	METIS allows stochastic simulations.
Sensitivity analysis helps identifying the uncertain inputs mostly responsible for the uncertainty in the model responses. Has the model undergone sensitivity analysis?	yes	Sensitivities runs are included in several METIS studies. These are highly dependent on the context rather than the model.
Has the model undergone external peer review by a panel of experts, or have results been published in peer-reviewed journals?	yes	Review by expert panel, led by JRC in 2019.
Has model validation been done? Have model predictions been confronted with observed data (ex-post)?	not_applicable	Most of the analysis performed with METIS addresses future time periods.

References related to external peer-review and publication in scientific journals:

- No references provided in MIDAS

Transparency

Question	Answer	Details
Is the model underlying database (i.e. the database the model runs are based on) publicly available?	yes	Based on Eurostat, ENTSO-E, ENTSO-G
Can model outputs be made publicly available?	yes	At request or by re-running publically available scenario files.
Is the model transparently documented (including underlying data, assumptions and equations, architecture, results) and are these documents available to the general public?	yes	Fully documented. All documentation can be found on the METIS website: https://ec.europa.eu/energy/data-analysis/energy-modelling/metis_en
Is the model source code publicly accessible or open for inspection?	yes	Model scripts are available for download from DG ENER's website.

References related to documentation:

- No references provided in MIDAS

The model’s policy relevance and intended role in the policy cycle

The model is designed to contribute to the following policy areas

- Energy

The model is designed to contribute to the following phases of the policy cycle

- Formulation

The model’s potential

The model can be used for the policy formulation. METIS is able to simulate the entire European energy system and markets operation for electricity, gas and heat energy carriers under a stochastic uncertainty, capturing for example weather variations and other stochastic events (short to medium term).

Previous use of the model in ex-ante impact assessments of the European Commission

Use of the model in ex-ante impact assessments since July 2017.

In the Year	METIS contributed to the Impact assessment called	Led by	By providing input to the	The model was run by	Details of the contribution
2020	IMPACT ASSESSMENT Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on guidelines for trans-European energy infrastructure and repealing Regulation (EU) No 347/2013	ENER	Baseline and assessment of policy options	*European Commission, JRC*	The key outcomes of the REKK model were cross-checked with the internal METIS model run by JRC.
2017	Impact assessment accompanying the document Commission Regulation (EU) No .../... on: establishing a Guideline on Electricity Balancing SWD/2017/0383 final	ENER	Baseline and assessment of policy options	*Artelys*	Used to assess the activation of balancing energy

Bibliographic references

- *Wholesale market prices, revenues and risks for producers with high shares of variable RES in the power system. - MJ-04-19-401-EN-N*
- *Cost-efficient district heating development. - MJ-04-19-410-EN-N*
- *The role and potential of Power-to-X in 2050 : METIS Studies : Study S8. - MJ-01-19-431-EN-N*
- *Effect of electromobility on the power system and the integration of RES : study S13. - MJ-02-19-296-EN-N*
- *Effect of high shares of renewables on power systems : study S11. - MJ-03-19-327-EN-N*
- *Simulating electricity market bidding and price caps in the European power markets : S18 report. - MJ-01-19-439-EN-N*
- *Weather-driven revenue uncertainty for power producers and ways to mitigate it : study S16. - MJ-03-19-328-EN-N*
- *Assessing market design options in 2030 : study S12. - MJ-02-19-302-EN-N*
- *The role and need of flexibility in 2030 focus on energy storage : study S07. - MJ-01-19-440-EN-N*
- *Assessing TYNDP 2014 PCI list in power : study S02. - MJ-02-19-303-EN-N*
- *Impact of PCIs on gas security of supply in Europe : study S05. - MJ-02-19-305-EN-N*
- *Generation and system adequacy analysis : study S04. - MJ-03-19-329-EN-N*
- *Optimal flexibility portfolios for a high-RES 2050 scenario : METIS Studies : study S1. - MJ-01-19-415-EN-N*
- *Decentralised heat pumps : system benefits under different technical configurations : METIS Studies, study S6. - MJ-02-19-295-EN-N*