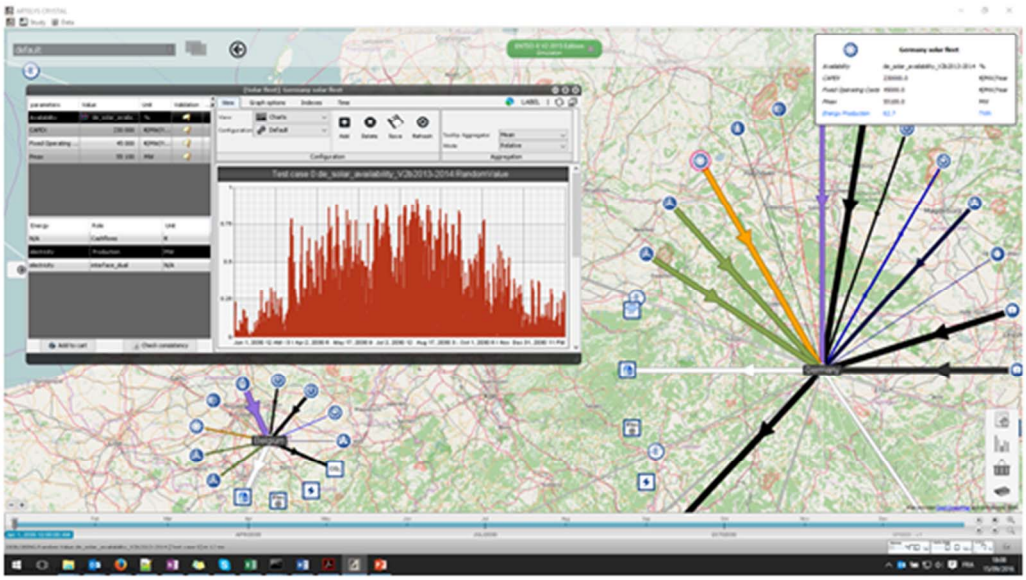
METIS

METIS is a research project[1] of DG ENER for the development of an energy simulator software with the aim to further support ENER's evidence based policy making. It is developed by a consortium (Artelys, IAEW (RWTH Aachen University), ConGas, Frontier Economics) as part of Horizons 2020 and is closely followed by DG ENER.

Contrary to other simulators, *METIS will be owned and operated by DG ENER*, with the support of JRC. The intention is to have an in-house tool that can quickly provide insights and robust answers to complex economic and energy related questions, focusing more on the short term operation of the energy system and markets. *METIS was used, along with PRIMES, in the impact assessment of the Market Design Initiative.*



Snapshot from user interface screen

METIS is an energy model covering with high granularity (geographical, time) the whole European energy system for electricity, gas and heat. In its final version it should be able to simulate both

[1] http://ec.europa.eu/dgs/energy/tenders/doc/2014/2014s_152_272370_specifications.pdf

system and markets operation for these energy carriers, on an hourly level for a whole year and under uncertainty (capturing weather variations and other stochastic events).

METIS works *complementary* to long-term energy system models (like PRIMES and POTEnCIA), as it focuses on simulating in detail a specific year. It will be fully transparent concerning the modelling techniques applied within, with the final goal of being able to offer the relevant source code and non-commercial data inputs. On top all technical documentation and studies produced will be available.

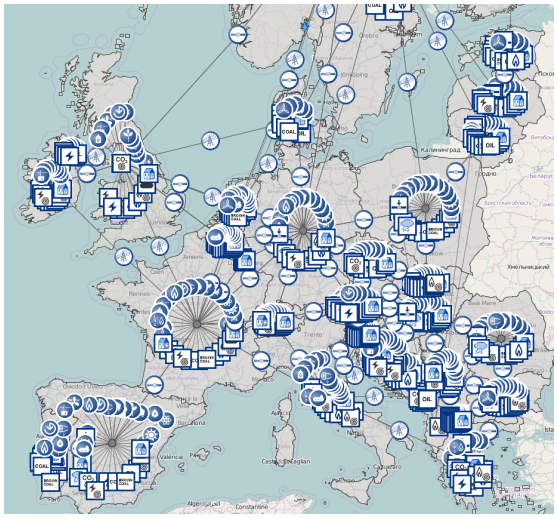
Although intended to be a detailed output-tool, significant weight is also placed on its user friendliness and fast operability. The end goal of METIS is that it can be used not only by expert modellers, but also (trained) policy makers and analysts.

With the first version of METIS having been delivered in January 2015 and second version in November 2016, new versions are expected to be delivered gradually over the next two years, including additional modelling capabilities related to gas markets, heat and demand side modelling.

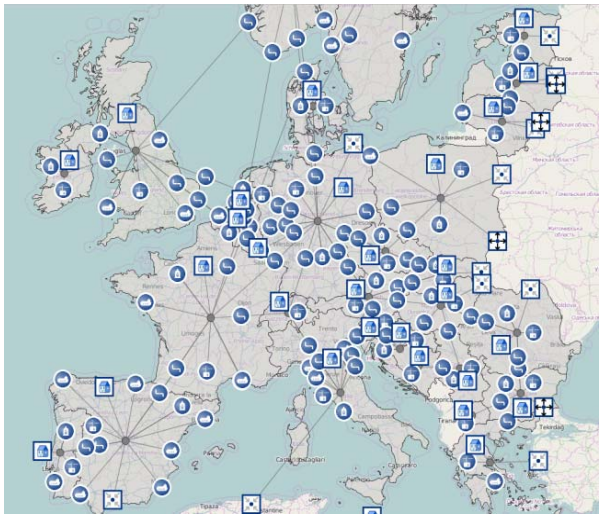
Parallel to the software development, the Consortium will be producing studies using METIS. These are intended as technical studies of a length around 50 pages, fully exploiting the available capabilities of the METIS software. The scope of the studies is threefold:

(a) Investigate topics that are deemed important for DG ENER, providing quantitative results associated with the impact of the examined policies or aspects of the energy system;
(b) Present the capability and appropriateness of the software to address the policy questions of interest for DG ENER;
(c) Provide ready templates for DG ENER in order to perform similar studies in the future.

For transparency reasons, all deliverables related to METIS, including all technical specifications documents and studies, are intended to be published on the website of DG ENER[2].



METIS: Power Model



METIS: Gas Model

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

Annex - Q&A on METIS

30.11.2016

1. *How would one classify METIS as a model?*

METIS is a multi-model simulation software covering the electricity, gas and heat sectors. It has a modular structure that makes it easy to extend the software through the addition of new modules or the adjustment of existing ones. The model runs are performed by a powerful numerical component dedicated to large energy system optimization[3]. All components and modules are managed by a platform[4] providing a common framework and set of interoperable libraries.

2. *Which policy questions can METIS answer and which it cannot?*

Upon final delivery, METIS will be able to answer a large number of questions and perform highly detailed analyses of the electricity, gas and heat sectors. A number of topics will be possible to be tackled with METIS for the whole EU and/or specific regions/MS (list below is indicative):

- The impacts of mass Renewable Energy Sources integration to the energy system operation and markets functioning (for one or all sectors);
- Modelling of electricity and gas markets under different market designs;
- Modelling of electricity and gas flows between zones;
- Cost-benefit analysis of infrastructure projects, as well as impacts on security of supply;
- Generation adequacy analysis;
- Studying the potential synergies between the various energy carriers (electricity, gas, heat);
- What is the cost / savings of a specific measure for a given year?
- Impact of new energy usages (e.g. electrical vehicles, demand response) on the network reinforcement and generation costs.

On the other hand METIS is not designed to answer (at least at this stage) the following questions (list below is indicative):

- Any type of projection for the energy system;
- Optimal investment planning (capacity expansion) for the EU generation or transmission infrastructure[5];
- Impacts of measures on network tariffs and retail markets;
- Short-term system security problems for the electricity and gas system (requiring a precise estimation of the state of the network and potential stability issues);
- Flow-based market coupling and measures on the redesign of bidding areas.

3. *What is the scope of the studies performed by METIS?*

The scope of the METIS studies is threefold:

(a) Investigate topics that are deemed important for DG ENER, providing quantitative results associated with the impact of the examined policies or aspects of the energy system;

[3] *Crystal Optimization Engine*, intellectual property of Artelys.
[4] *Artelys Crystal Platform,* intellectual property of Artelys.
[5] The planned version of METIS will include some capacity expansion capability, able to optimize the capacity of certain transmission and generation assets. Future versions of METIS may have additional capabilities.

(b) Present the capability and appropriateness of the software to address the policy questions of interest to DG ENER;

(c) Provide ready templates for DG ENER in order to perform similar studies in the future.

The studies may be used by DG ENER as deemed appropriate. They are not necessarily linked with any other on-going initiative or other process run by DG ENER. Their results are intended mainly for information purposes.

4. *What is the validation / verification process foreseen for METIS? Will third parties have the possibility to access data or the software?*

The development of METIS has been based on the commercial Artelys Crystal software platform owned by Artelys, already used by several TSOs, regulators and utilities. Therefore no validation is considered to be necessary to verify the software.

Still, as METIS foresees considerable extensions to the existing software leading to a final product with very strong capabilities, there is an effort to provide as much information as possible to the public and especially the Member States, as results of the METIS studies may be used for supporting energy policy proposals of the European Commission. Therefore, every effort will be made so that most relevant deliverables of METIS, as well supporting material, is made public.

At the same time, DG ENER plans to gradually allow third parties (notably state administration bodies) to directly replicate the METIS simulations. This is made possible by the agreement of DG ENER with Artelys for the provision of a limited time of use license (6 months) for the components of METIS which constitute its ownership (see footnotes 3 and 4 above). The license of use will be limited to review the specific pre-agreed results, replicate simulation results and define alternatives based on the scenario provided. The associated support and maintenance services by Artelys will be provided at the expense of the third party.

5. *Is there any link between the METIS studies on the electricity and gas PCI lists and the PCI evaluation post 2015?*

Currently no such links exists nor are they planned.

Concerning the first study on the electricity PCI list, its general aim is to assess the usefulness of METIS analyzing the power network PCIs (from the ENTSO-E's TYNDP 2014 project list) in terms of security of supply, sustainability, economy and market integration. This will follow the ENTSO-E methodology. The studied contexts are the ones of 2030 ENTSO-E Visions - V1 (“slow progress”) and V3 (“green transition”) - in terms of demand and power generation capacities. The scope of the study is to perform a quantitative assessment of the benefits of an electricity interconnection project that is comprised of all assets from the PCI list. The study compares the flows of electricity with and without the existence of these projects. Further it will provide an assessment of their benefits, including those of market integration, security of supply, competition and sustainability.

The second study, on the gas PCIs, is not a Cost-Benefit Analysis. The objective of the study is to assess the impact of PCIs on gas security of supply in Europe through METIS models. The benefits are only assessed concerning the contribution of PCIs on security of supply, which is measured with two main indicators: disrupted demand and supply source dependence. The European natural gas network is represented at its state in 2015 with additional financed projects, then including additional projects from the first list of PCIs and finally including the remaining projects from the second list of PCIs. The optimal supply and dispatch of gas throughout Europe is simulated based on these specifications and under different stress cases (standard and cold temperatures, source disruptions including a very strong case with no Russian import over a whole year). Finally, results are

analyzed to highlight indicators relevant to security of supply issues. It should also be noted that again the lists of PCIs are added to the model as a whole. Therefore the study does not assess the efficiency of PCIs individually, but the impact of whole lists of PCIs on gas security of supply.

6. *How could METIS be used for the development of an EU Reference Scenario and/or for the preparation of EU guidance/template for national energy and climate plans including regional cooperation?*

METIS has not been used in the context of the EU Reference Scenario 2016 exercise, nor does a specific plan exist for including it as part of the Reference Scenario exercise in the future, without though excluding this.

The primary intended use of METIS for the time being is the performance of targeted specific analyses, especially related to questions requiring high geographical and/or time granularity, such as the specific studies planned for 2016.

In the future a soft-link with a long term model, such as PRIMES or POTEnCIA, is possible for performing future studies.

7. *How could METIS modelling and planning tool be used for assessing policies related to electricity markets, e.g. in the context of the preparation of legislative and non-legislative measures for the Electricity Market Design?*

METIS is an ideal tool to be used for modelling policies related to electricity markets and as such it was used to support the Impact Assessment of the Market Design Initiative for the electricity sector.

METIS software can already model in significant detail the functioning of the electricity market as well as the power system operation for the whole of Europe. METIS simulates the successive clearing of the short-term markets, including day-ahead, reserve procurement and intra-day markets, using fundamental data on the power systems (installed capacities, fuel costs) and market design rules such as priority dispatch, banning of resources or parameters related to the granularity of markets. A more detailed description of the power module of METIS is provided below.

In its simulations, the effect of weather forecasts plays an important role on the outcomes of the power markets, affecting the producer's revenues, market prices, net positions and flows. An hourly time resolution is used in the simulations, which are generally run over a year. Several realizations in terms of demand and RES profiles can be simulated, in order to estimate the distribution of producer's revenues.

8. *Please provide more technical details on the modelling capabilities of METIS, particularly the modelling of transmission and distribution networks, as well as assessing the impact of variable RES generation.*

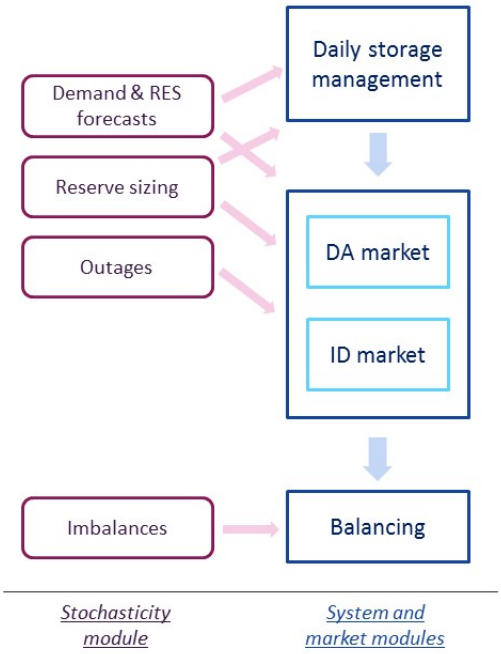
All technical details on the methodologies followed in METIS are planned to be published on the dedicated METIS webpage. Below a summary of the technical characteristics of the power market module of METIS are described.

Main characteristics of the power market module

METIS market module replicates the participants' decision process. For each day of the studied year, the generation plan (including both energy generation and balancing reserve supply) is first optimized based on day-ahead demand and RES generation forecasts. Market coupling is modeled via NTC constraints for interconnectors. Then, the generation plan is updated during the day, taking

into account updated forecasts and technical constraints of assets. Finally, imbalances are drawn in order to simulate balancing energy procurement.

Figure 1: Simulations follow day-ahead to real-time market decision process



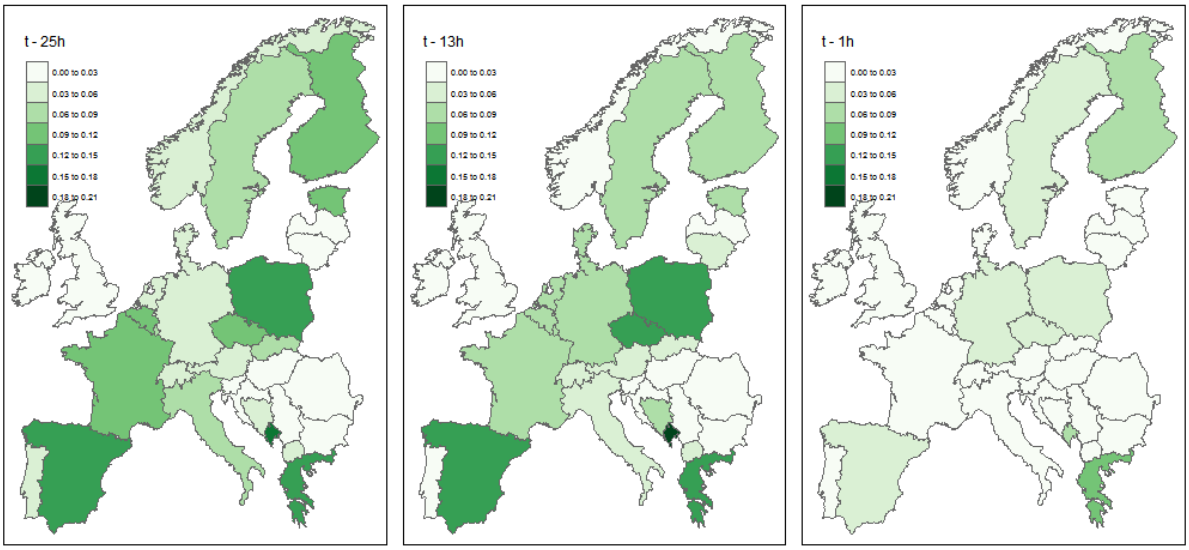
1. Perform a system module run to decide on storage level at the end of each day
   a. Including reserve requirements
2. Then, day-ahead (DA) and intra-day (ID) generation plans are decided jointly :
   a. With forecasts of increased accuracy
   b. Taking into account unit flexibility constraints (coal, lignite and CCGT have to be turned on/off up to 6 hours ahead)
   c. Possibly allowing for exchanges between zones and reallocation
3. The balancing resources are inherited from the DA procured reserve (+ available resources)
   a. Imbalances are generated based on outages, demand & RES fluctuations / forecast errors
   b. Possibly allowing for imbalance netting and regional cooperation (regional optimal balancing dispatch)

Source: METIS

Imbalances – Imbalances are the result of events that could not have been predicted before gate closure. METIS includes a stochasticity module which simulates power plant outages, demand and RES-E generation forecast errors from day-ahead to 1-hour ahead. This module uses a detailed database of historical weather forecast errors (for 10 years at hourly and sub-national granularity), provided by ECMWF[6], to capture the correlation between MS forecast errors and consequently to assess the possible benefits of Imbalance Netting. The stochasticity module also includes the possibility to generate random errors picked from various probability distributions either set by the user or based on historical data.

Figure 2: Example of wind power forecast errors for a given hour of ten years of data.

[6] European Centre for Medium-Range Weather Forecasts



Source: METIS

Reserve product definition – METIS simulates FCR, aFRR and mFRR reserves. The product characteristics for each reserve (activation time, separation between upward and downward offers, lists of assets able to participate etc.) are inputs to the model.

Reserve dimensioning – The amount of reserves (FCR, aFRR, mFRR) that have to be secured by TSOs can be either defined by METIS users or be computed by the METIS stochastic module. The stochastic module can assess required levels of reserves that can ensure enough balancing resources are available under given probability. Hence, METIS stochasticity module can take into account the statistical cancellation of imbalances between MS and the potential benefits of regional cooperation for reserve dimensioning.

Balancing reserve procurement – Different market design setups can also be compared by the geographical area in which TSOs may procure the balancing reserves they require. METIS has been designed so as to be able to constrain the list of power plants being able to participate to the procurement of reserves according to their location. The different setups can be translated in different geographical areas in which reserves have to be procured (national or regional level). Moreover, METIS users can choose whether demand response and renewable energies are allowed to provide balancing services.

Balancing energy procurement – The procurement of balancing energy is optimized following the same principles as previously described. In particular, METIS can be configured to ban given types of assets, to select balancing energy products at national level, to exchange balancing energy products between MS if price differential is higher than the cost to use the interconnection,, or to optimize balancing merit order at a regional level.

Transmission Network Modelling[7] – METIS model is an NTC model. Its default granularity for transmission modelling is at country level. The user though will be able to specify more detailed constraints at NUTS2 level. The NTC model has been implemented based on the current state-of-the-art for pan-European long-term studies such as the recent Pentalateral Generation Adequacy Study. However, as METIS is a highly modular software. In the future additional linear network models such as flow-based or DC load-flow could be added.

[7] Work on the distribution network modelling has only recently begun.

9. *Does METIS include behavioural assumptions on how the market actors / assets / consumers operate?*

METIS captures the behaviour of consumers / demand via assumed load profiles (hourly, weekly, annual), determined exogenously. It can also model demand response and take into account short-term flexibility of specific usages (EV charging, domestic hot water, power to gas…). Long-term behaviour of demand could be examined as a future extension of METIS.

For market actors, specific bidding behaviours can be assumed for the various market participants. All are defined by the analyst (not optimized endogenously).

10. *Please list the data sources providing input to METIS*

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
- CO_2 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 DG ENER's EMOS database, ENTSO-E and ENTSO-G databases as well as Eurostat. Weather data are provided by ECMWF.

A significant part of the input is context dependent, i.e. on the scenario where METIS is calibrated (e.g. the relevant PRIMES scenario 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.