Modeler Poll for EMF 23 Study on International Natural Gas Markets

EMF WP 23.2

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(edited comments from participating modelers)

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Argonne National Laboratory

Model Name: AMIGA

Model Proprietor(s): Donald A. Hanson

Organization: Argonne and DePaul University

Do you report wellhead (field) prices or a similar concept by supply region? Yes.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region? Yes.

Can you report end-use prices and demand by sector? Which ones?

Residential, commercial, light manufacturing, heavy industrial sectors, oil refinery complexes, power generation.

For which supply regions can you report price and quantity estimates?

Russia & former Soviet Republics, Middle East, USA, Canada, South America & Mexico, North Sea, Asia and Australia, Africa.

For which demand regions can you report price and quantity estimates?

We have been working with Fatih Birol and Laura Cozzi at IEA. We use IEA regions, of which there are 22.

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.? Yes

Are there other variables that we should try to compare?

What years do you report? We can select any years to report.

If you have a brief overview of your model approach, please provide to EMF staff.

Regarding gas trade, instead of a formal network model or LP, we use Lagrange multipliers where appropriate to introduce shadow prices on constraints, and for comparing a list of discrete choices, we call a "quiksort" by the criteria, and choose the least cost option.

We have an elaborate process model for the oil refinery sector we did jointly with DOE/NETL. Refineries are large gas users and this is likely to increase.

DIW Berlin (German Institute for Economic Research)

Model Name: GASMOD (regional model for Europe)

Model Proprietor(s): DIW Berlin - GASMOD group

Organization: DIW Berlin

Do you report wellhead (field) prices or a similar concept by supply region?

not yet (for the time being we use long run marginal costs by field / supply region)

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?

yes: wholesale delivery prices

Can you report end-use prices and demand by sector? Which ones?

no: one price per country (industry-household-power confounded)

For which supply regions can you report price and quantity estimates?

Algeria, Libya, Egypt, Iraq, Iran, Middle East (incl. Oman, Qatar, UAE),

Former Soviet Union, Norway, Netherlands, UK,

Nigeria, Trinidad & Tobago, Venezuela

For which demand regions can you report price and quantity estimates?

UK, Netherlands, Spain/Portugal, France, Italy/Switzerland,

Belgium/Luxemburg, Germany, Denmark, Sweden/Finland,

Austria, Poland, Czech/Slovak Rep./Hungary, Baltic,

Balkan (incl. former Yugoslavia, Albania), Romania/Bulgaria, Greece, Turkey

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

not yet, but in the process of being introduced. then: price, % of consumption, trade

Are there other variables that we should try to compare?

What years do you report?

static for the time being. planned to be from 2005 to 2030 in 5-year-steps

If you have a brief overview of your model approach, please provide to EMF staff.

EWI - Institute of Energy Economics at the University of Cologne

Model Name: EUGAS – European Gas Supply Model

Model Proprietor(s): David Bothe, Andreas Seeliger

Organization: EWI - Institute of Energy Economics at the University of Cologne

Do you report wellhead (field) prices or a similar concept by supply region?

Yes. Prices based on long-range marginal costs for all production regions relevant for the European market (Europe, CIS, Middle East, Caribbean).

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?

No.

Can you report end-use prices and demand by sector? Which ones?

Yes. For Western European Electricity Sectors.

For which supply regions can you report price and quantity estimates?

Quantities and long-range marginal cost based border prices for all production regions relevant for the European market (Europe, CIS, Middle East, Caribbean).

For which demand regions can you report price and quantity estimates?

Detailed analysis for about 30 countries: EU-25-Members, Romania, Bulgaria, Former Yugoslavia, Turkey and Ukraine.

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

Yes. Detailed gas flows and marginal transport costs, investment needed for liquefaction and regasification plants, share of LNG on total trade.

What years do you report?

2005 to 2030 in 5-year-periods.

ICF Consulting and US Environmental Protection Agency

Model Name: The Climate Change Risk Assessment Framework (CCRAF)

Model Proprietor(s): William Pepper

Organization: ICF Consulting and US Environmental Protection Agency

Do you report wellhead (field) prices or a similar concept by supply region? Yes.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region? Yes.

Can you report end-use prices and demand by sector? Which ones?

The model projects total secondary energy use and its share by fuel type. The inertia in the energy systems is captured through an auto-regressive formulation where energy use in year t is strongly correlated with energy use in the previous year. The income trends are captured with components that address growth in GDP per capita in two different income ranges. The energy price trends are captured through own price and crude oil price elasticities.

For which supply regions can you report price and quantity estimates?

United States, Europe, Former Soviet Union, Japan, Australia and New Zealand, Canada, China, Brazil, Mexico, India, Rest of Latin America, South and East Asia, Central Asia, Africa, Middle East.

For which demand regions can you report price and quantity estimates?

United States, Europe, Former Soviet Union, Japan, Australia and New Zealand, Canada, China, Brazil, Mexico, India, Rest of Latin America, South and East Asia, Central Asia, Africa, Middle East.

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

Are there other variables that we should try to compare?

What years do you report? Annually, through 2100.

If you have a brief overview of your model approach, please provide to EMF staff.

Draft document has been submitted to Energy Modeling Forum.

International Institute for Applied Systems Analysis (IIASA)

Note: The information in square brackets refers to future plans.

Model Name: GASCOM (Gas Market Competition)

Model Proprietor(s): Leo Schrattenholzer and Yaroslav Minullin

Organization: IIASA

Do you report wellhead (field) prices or a similar concept by supply region? Yes.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region? No.

Can you report end-use prices and demand by sector? Which ones? Yes; power sector, industry in Northeast Asia (NEA).

For which supply regions can you report price and quantity estimates? Former Soviet Union (FSU) [, Egypt, Middle East]

For which demand regions can you report price and quantity estimates? NEA, Turkey [, Western Europe, Central and Eastern Europe]

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.? Yes to price and % of gas used.

Are there other variables that we should try to compare? A-priori estimated demand (in contrast to strategically optimized supplies); cumulative (optimized) supply; optimized timing of pipeline projects.

What years do you report? 2005–2050.

If you have a brief overview of your model approach, please provide to EMF staff.
We include an overview of GASCOM as a separate attachment.

The IIASA model of competition in the natural-gas market (GASCOM)

A predecessor version of the IIASA model of competition in the natural-gas market (GASCOM) was developed jointly with the Energy Systems Institute of Russian Academy of Sciences (Irkutsk), where the model input data (world and world-regional data on energy production and transportation) were compiled. At present, further model development takes place at IIASA. GASCOM was the model presented by IIASA-ECS at the meeting in Washington (EMF23), where it was still unnamed.

1. Summary of the model

1.1 Subject

GASCOM is a gaming model describing competition within one natural-gas market (incorporating multiple interconnected markets is in planning), which may emerge in a region (typically a country) that has important characteristics of a perfect market.

The players (agents) are investors who consider options of investments into gas pipeline project(s). Each agent has the following control parameters: supply – the volume of natural gas delivered to the market at any "fast time" of operation and start of construction time – a moment in "slow time" on the timescale when an agent would start making investments into a pipeline.

The natural-gas price at any time is determined by gas demand and its price elasticity, the price of LNG (exogenous parameters) and the supply quantities of all the agents (endogenous).

The time frame for simulations is 2005 to 2060.

1.2 Purpose

The objective of the model can be formulated as follows: to determine, for all agents, the "slow times" when each of them should start the construction and operation so that one or both (depending on user's choice) optimality criteria, namely maximization of net present value (NPV) and minimization of the time passed from the beginning of operation to payback, hold for all agents simultaneously.

GASCOM is designed to give answers to the following questions:

- When to start the construction of a gas pipeline and when to enter the market considering that the behavior of the competitors is not fixed in advance (a set of admissible opponents strategies, which can be defined basing on assumption of a game with full information is used to build an agent's strategy)?
- Which volume of gas to deliver to the market at each point in time in order to maximize agent's profit, considering the admissible strategies of other participants and the market condition?
- What price dynamics will evolve on the market?
- What will be the NPV of a project at the end of its lifetime, considering that an agent had started operation at the "optimal" time?
- Which will be the role LNG?

1.2 Audience

The model is aiming at decision makers and energy markets analysts for whom it provides an assessment of the market and potential competitors from an economic perspective.

2. Input parameters

A complete list of exogenous model inputs is listed in the following Table 1.

Table 1

Variable	Units	Description
Gas Market		
$d_0(t)$	bcm	Demand for natural gas at time t.
$p_0(t)$	USD/1000cm	Equilibrium price for natural gas at time t
$p_{LNG}(t)$	USD/1000cm	LNG price (incl. transportation to terminal) at time t

$e_p(t)$*	-	Gas demand price elasticity at time t
λ	-	Annual discount rate
Agents		
i	-	Index of player, i=1, 2,…,N.
C_i	bln USD	Construction cost of the pipeline project i.
Δt_i	years	Pipeline construction time of project i.
M_i	bcm/year	Capacity of the pipeline i.
c_i^{fix}	USD/1000cm/year	Fixed operation and maintenance cost of pipeline i.
c_i^{var}	USD/1000cm	Variable costs for the extraction and transportation of gas for pipeline i.

* Gas demand price elasticity is dynamic and identified as the weighted average between the elasticity of electricity production and that of the industry.

3. Output parameters

We distinguish between model runs in "optimal" (in terms of chosen optimality criterion, see note [1]) mode or in "fixed time" mode. The original purpose of the model is to be run in the "optimal" mode, the "fixed time" mode being used when a concrete situation (known or targeted times of entering the market) is to be examined.

The main model output parameters are[1]

t_i^0 – *optimal₂* starting time for construction
ti – *optimal₂* commercialization time
$y_i(t)$ – *optimal₁* volume of supply for agent i, where $t=[t_i^0,t_{end}]$ and $t_{end}= t_i^0+\Delta t_i+\text{lifetime}_i$
p(t) – price for natural gas at time t
NPVi – *optimal₂* Net Present Value of the project i
t_i^{ROI} – *optimal₂* payback time for project i

[1] Note: "*optimal₁*" refers to a maximization of instantaneous profit, "*optimal₂*" to maximization of NPV or minimization of time passed from the beginning of construction to payback.

Other outputs

LNG(t) – volume of LNG supplied at time t

$c_i(y_i,t)$ – total costs for delivering gas by agent i (volume-dependant)

4. Algorithm

The model is composed of two interrelated levels. For convenience of notation and without loss of generality, it will be assumed that LNG plays a role of price restriction, that there is one market only and that the optimality criterion for Level 2 is the maximization of NPV.

Level 1. Instantaneous supply game (dynamic).

By controlling the volume of supply y_i, agents can maximize their profit (determined in accordance with conventional profit definition) at any moment of "fast" time t in response to all admissible strategies of other agents, forming thereby a vector Y* of (strong) Nash-equilibrium solutions:

$$t - \textit{fixed}$$
$$Y^* = \{y_1^*, y_2^*, \ldots, y_N^*\}$$
$$y_i^* = y_i : \pi_i(y_i, \sum_{j \neq i} y_j^*) \xrightarrow[y_i \in U]{} \max,$$

where

y_i – supply of agent i

π_i – profit of agent i

$\sum_{j \neq i} y_i$ – total *optimal* supply of competitors

U – domain defined by restrictions

Level 2. Game of timing (static).

On the basis of total profit, integrated from the start of operation to the end of lifetime or payback, each agent can estimate possible strategies in response to the strategies of other agents for all admissible "slow" times, representing the start of construction, and to find the best strategies, forming thereby a vector of (weak) Nash-equilibrium solutions[2]:

$$T_K^{0*} = \{t_{K,1}^{0*}, t_{K,2}^{0*}, \ldots, t_{K,N}^{0*}\}$$

$$t_{K,i}^{0*} = t_i^0 : NPV_i[t_i^0, (t_{j\neq i}^{0*}) \in \mathbb{R}^{N-1}] \xrightarrow[t_i^0]{} \max,$$

where

t_i^0 – start of construction time

$(t_{j\neq i}^{0*}) \in \mathbb{R}^{N-1}$ – *optimal* start of construction times of competitors

[2] Note that it is possible that more than one (up to *K*) Nash-equilibrium solutions exist.

Rice University

Model Name: Rice World Gas Trade Model

Model Proprietor(s): Peter Hartley and Ken Medlock

Organization: Rice University developed using Altos software

Do you report wellhead (field) prices or a similar concept by supply region?

Yes.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?

Yes.

Can you report end-use prices and demand by sector? Which ones?

Distribution costs are not layered in, and demand is not at the moment sector-specific.

For which supply regions can you report price and quantity estimates?

Virtually all of them. This is simply too numerous to list.

For which demand regions can you report price and quantity estimates?

Same as above.

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

See below.

Are there other variables that we should try to compare?

What years do you report?

If you have a brief overview of your model approach, please provide to EMF staff.

There is a paper describing the model at www.rice.edu/energy. We have run cases looking at options for Russian Gas, Gas-OPEC, higher demand and more rapid adoption of an alternative technology. We are currently updating the model and investigating different ways of handling some issues (associated vs. nonassociated production, e.g.). We intend to integrate at least some of these aspects for the final EMF study.

Statistics Norway

Model Name: FRISBEE

Model Proprietor(s): Statistics Norway

Organization: Statistics Norway

Do you report wellhead (field) prices or a similar concept by supply region? YES

Do you report citygate (wholesale delivery) prices or a similar concept by demand region? YES

Can you report end-use prices and demand by sector? Which ones?
Households/services, industry, electricity generation

For which supply regions can you report price and quantity estimates?
OPEC core (Saudi-Arabia, Iran, Iraq, Kuwait, UAE, Qatar), OPEC rest (Nigeria, Algeria, Libya), Venezuela, Indonesia, Africa, Russia East, Russia West, Europe West, Europe East, USA, Canada, Latin America, China, Caspian region, OECD Pacific, Rest Asia

For which demand regions can you report price and quantity estimates?
OPEC core (Saudi-Arabia, Iran, Iraq, Kuwait, UAE, Qatar, Venezuela), OPEC rest (Nigeria, Algeria, Libya, Indonesia), Africa, Russia (incl. Ukraine, Belarus), Europe West, Europe East, USA, Canada, Latin America, China, Caspian region, OECD Pacific, Rest Asia

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?
Trade, liquefaction costs, shipping costs, regasification costs

Are there other variables that we should try to compare?
Reserves, investments

What years do you report?
2000-2030

If you have a brief overview of your model approach, please provide to EMF staff.

US Energy Information Administration

Scenarios

The scenarios described in the "Preliminary EMF 23 Scenario Design" paper provide a good range of options for addressing international gas markets and trade issues. The following comments indicate which of the scenarios could be addressed by EIA's domestic energy modelling system, the National Energy Modeling System (NEMS), and by EIA's international energy modelling system, the System for the Analysis of Global Energy Markets (SAGE). Because portions of the SAGE model that could address some of the scenarios are still under development, SAGE would have to be used with the understanding that the version used would not be a fully developed and tested model.

The following comments address the individual suggested scenarios and the capabilities of EIA's models relative to addressing them.

1) **Russian geopolitics** – this is not modeled in NEMS or in SAGE, but splitting Russia out from the "Former Soviet Union" region is one of the planned enhancements for SAGE. If we are able to move the timing up for this from our current target date of January 2006, SAGE could address this scenario.

2) **LNG costs** -- In general, this scenario will not be a problem in NEMS. There are some details to be worked through. EIA triggers LNG terminal construction when domestic market prices exceed cost estimates. Our cost estimates include a risk premium, as well as a factor that represents a tightening market over time (not necessarily increasing "costs"). Unless we hear otherwise, the plan would be to only apply the reduction to actual costs. The reduction could be taken as a simple percentage of total costs, or separate reduction factors could be made to the various segments of the LNG chain (production, liquefaction, transportation, and regasification).

   SAGE does not at this time include LNG costs as a model parameter.

3) **Liquefaction constraints / Gas OPEC**

In theory we could restrict liquefaction capacity in NEMS, but this could easily just result in an infeasibility in our model. The preferred approach is to simply restrict regasification capacity. While our main focus is on the U.S. market, we make assumptions about LNG imports into Mexico and Canada. Presumably we should restrict imports here as well.

Regarding option 3.1, it would seem appropriate to restrict regasification capacity to the same year that liquefaction capacity is restricted in the other models. However, I would suggest restricting capacity to current levels plus capacity for projects where construction has already started. Presumably the group could agree on a list for both regasification and liquefaction. The more specific the restriction, the better.

SAGE does not separate LNG from pipeline gas, so is not applicable here.

Regarding option 3.2, we could work with a constraint on how rapidly regasification capacity can grow. However, we would have to work out the details about how we impose the restrictions, what regions, timing, implications for regasification size, etc. (Currently some of our facilities can come on in rather large increments.) If other groups can handle a more explicit description of the restriction (i.e., year facilities of specific sizes come online in specific locations), this may be preferable so that we all are consistent.

SAGE could possibly represent the effects of a cartel by applying various trade restrictions.

4) **Higher Natural Gas Demand Growth**

This should be reasonably straightforward in both SAGE and NEMS.

5) **EMF23 Reference Case**

EIA will probably select a reference case from the *Annual Energy Outlook 2005*, which is closest to the world oil price path selected for the study. If EIA were to instead select a reference case from the *International Energy Outlook 2005*, we have a comparison table that could be used to compare potential world oil price paths with those of other forecasters, particularly the IEA. The *IEO2005* will not be released until July, 2005, but the *IEO2005* reference case price path is very close to the *AEO2005* October Futures price case.

WOP $2003 per barrel

	2005	2010	2015	2020	2025
AEO2005 October Futures	43.63	30.99	32.33	33.67	35.00
GII	35.36	27.06	27.02	28.20	29.39
IEA Reference Scenario	25.09	23.32	25.44	27.56	29.15
IEA High Oil Price Case	37.10	37.10	37.10	37.10	37.10
Altos	29.94	21.92	22.67	23.93	24.60
PEL	27.00	25.00	27.00	27.00	29.00
PIRA	39.90	34.75	39.15	N/A	N/A
Deutsche Bank AG	37.20	24.45	24.43	24.43	24.44
EEA	39.76	26.58	25.55	24.93	N/A
SEER	33.69	26.13	28.40	28.25	29.00
EVA	41.92	28.99	28.39	30.97	34.77

Global Insight, Inc. (GII), Global Petroleum Outlook Winter 2004/2005, Lexington, MA, January 2005, refiners acquisition imported.
PIRA: PIRA Energy Group, "Retainer Client Seminar," October 2004, NY, NY, Table II-4 (WTI at Cushing).
IEA Reference Scenario and High Oil Price Case - World Energy Outlook 2004, (Paris, France, October 2004), IEA crude oil import price.
Deutsche Bank AG - "Comparison Templates (Sieminski)," e-mail from Adam Sieminski of March 21, 2005. US imported RAC
PEL - Petroleum Economics Limited, "World Long Term Oil & Energy Outlook," (London, UK, March 2004), p. 53 (Brent Equivalent)
EEA - Energy and Environmental Analysis, Inc. EEA's October 2004 Base Case; EEA Compass Service. (U.S. Refiners Avg Acquisition Cost)
SEER - Strategic Energy & Economic Research, Inc. Natural Gas Scenarios 2004 (Winchester, MA, October 2004) (WTI at Cushing)
EVA - Energy Ventures Analysis, Inc. FUELCAST: Long Term Outlook August 2004, (OPEC Basket)
Altos - Altos Partners, World Oil Model, as of October 27, 2004

Although we have not done an analysis of the differences in GDP growth rates between the IEA and the EIA assumptions, the general consensus is that the IEA estimates are more conservative than the EIA estimates.

Outputs

EIA can provide output results for all the items listed for the NEMS model used to produce the *Annual Energy Outlook*. The SAGE model, used to produce the *International Energy Outlook*, reports only production and consumption by region, no import, export, LNG, or price forecasts.

Appendix: Model Reporting Poll

You can provide any table templates if it would be easier than answering specific questions.

Model Name: National Energy Modeling System

Model Proprietor(s): Office of Integrated Analysis and Forecasting

Organization: Energy Information Administration

Do you report wellhead (field) prices or a similar concept by supply region?

NEMS reports wellhead prices for 6 onshore and 2 offshore domestic regions.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?

NEMS generally reports delivered prices by sector, although we can provide citygate prices by census division, if desired.

Can you report end-use prices and demand by sector? Which ones?

NEMS reports end-use consumption and prices for residential, commercial, industrial, electric generators, and CNG vehicles.

For which supply regions can you report price and quantity estimates?

NEMS can report supply quantities and prices for 6 onshore and 2 offshore domestic regions. We might be able to provide some information on Canada and Mexico.

[For the world modelers, is this supply of LNG or total supply of natural gas?]

For which demand regions can you report price and quantity estimates?

U.S. Census Divisions

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

Not really.

Are there other variables that we should try to compare?

Imports/exports by country/region, broken out by LNG versus pipeline gas, if possible. It was on your other list, but not here. A base region would have to be identified for the reporting of imports/exports.

What years do you report? Annually through 2025.

If you have a brief overview of your model approach, please provide to EMF staff.

The NEMS estimates the cost of bringing LNG to the U.S. from various probable sources. When the cost plus a risk premium exceeds the current regional market price in the model, the construction of an LNG terminal is triggered. The slate of potential terminals, with their various sizes, is set exogenously. There are some restrictions on the speed at which new terminals can be added. The use of constructed terminals is limited by an exogenously specified maximum utilization rate. Import volumes can theoretically be lower than the maximum if prices were to come in lower than costs in the future, but this does not typically occur.

The rest of the domestic gas market (gas flows and prices) is modelled for 12 domestic regions using a heuristic algorithm, which balances supply and demand, moving from current levels progressively towards the lower cost solution. Demand is represented at the Census region level for the following sectors: residential, commercial, industrial, electric generator, and CNG vehicles. Supply is represented for 6 onshore and 2 offshore regions with a detailed oil and gas supply model. There is a limited representation of Canada in the model, including a potential LNG terminal(s) in the east. Trade with Mexico is largely exogenously specified, with a simple triggering mechanism used to provide progressive levels of LNG to the U.S. through Baja.

Model Name: System for the Analysis of Global Energy Markets (SAGE)

Model Proprietor(s): Office of Integrated Analysis and Forecasting

Organization: Energy Information Administration

Do you report wellhead (field) prices or a similar concept by supply region?
SAGE does not report wellhead prices.

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?
SAGE does not report prices.

Can you report end-use prices and demand by sector? Which ones?
SAGE reports end-use consumption for residential, commercial, industrial, electric power, and transportation sectors, but does not report any prices.

For which supply regions can you report price and quantity estimates?
SAGE reports supply quantities and prices for 15 international regions, but does not report prices.

[For the world modelers, is this supply of LNG or total supply of natural gas?]
SAGE reports total supply of natural gas, and does not split out LNG.

For which demand regions can you report price and quantity estimates?
SAGE reports consumption by 17 international regions.

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?
No.

Are there other variables that we should try to compare?
Imports/exports by country/region, broken out by LNG versus pipeline gas, if possible. It was on your other list, but not here.

What years do you report? 2002 and five year increments from 2010 through 2025.

If you have a brief overview of your model approach, please provide to EMF staff.
SAGE, EIA's new international energy modeling tool, is an integrated set of regional models that provide a technology-rich basis for estimating regional energy consumption. For each region, reference case estimates of 42 end-use energy service demands (e.g., car, commercial truck, and heavy truck road travel; residential lighting; steam heat requirements in the paper industry) are developed on the basis of economic and demographic projections. Projections of energy consumption to meet the energy demands are estimated on the basis of each region's existing energy use patterns, the existing stock of energy-using equipment, and the characteristics of available new technologies, as well as new sources of primary energy supply.

Period-by-period market simulations aim to provide each region's energy services at minimum cost by simultaneously making end-use equipment and primary energy supply decisions. For example, in SAGE, if there is an increase in residential lighting energy service, either existing generation equipment must be used more intensively or new equipment must be installed. The choice of generation equipment (type and fuel) incorporates analysis of both the characteristics of alternative generation technologies and the economics of primary energy supply.

All projections are computed in 5-year intervals through the year 2025. SAGE provides projections for 15 regions or countries, including the North American countries of the United States, Canada, and Mexico; Western Europe; Japan; Australia/New Zealand; Eastern Europe; the former Soviet Union (FSU); China; India; South Korea; other developing Asia; the Middle East; Africa; and Central and South America.

US Environmental Protection Agency-ICF Consulting

Model Name: North American Natural Gas Analysis System (NANGAS)

Model Proprietor(s): ICF Consulting in support of EPA

Organization: ICF Consulting

Do you report wellhead (field) prices or a similar concept by supply region?

Yes, for North America, except Mexico

Do you report citygate (wholesale delivery) prices or a similar concept by demand region?

Yes

Can you report end-use prices and demand by sector? Which ones?

Yes. Power, residential, commercial, and industrial

For which supply regions can you report price and quantity estimates?

Pacific Offshore
Pacific Onshore
San Juan
Rockies Foreland
Williston
Permian
Mid-Continent
Arkla-East Texas
Texas Gulf Coast
Gulf of Mexico-West
GOMW UltraDeepwater
Gulf of Mexico-Cntr
GOMC UltraDeepwater
Norphlet
Gulf of Mexico-East
So-Louisiana
MAFLA Onshore
Mid-West
Appalachia
North Alaska
Lower-48
Total U.S.
Canadian Regions
Alberta
British Columbia
MacKenzie Delta
Sable Island
Total Canada (WCSB+MD+SI)

For which demand regions can you report price and quantity estimates?

1	Central New England
2	South New England
3	Maine
4	Upstate New York
5	New York City
6	Rest of Mid Atlantic
7	South Carolina
8	Rest of South Atlantic
9	Florida
10	East South Central
11	East North Central
12	West South Central
13	West North Central
14	Mountain South
15	Mountain North
16	California
17	PNW I-5
18	PNW East
19	Alberta-Demand
20	BC-Demand
21	Saskatchewan
22	Manitoba
23	Ontario
24	Quebec
25	Maritime Provinces
26	Mexico-Demand
	United States
	Canada
	Total

Do you report any special LNG variables, e.g., price, % of gas used, trade, etc.?

LNG import regas terminals are inputs to the model. LNG enters the market through each terminal when prices in the terminal region reach a threshold and remain there. We also adjust the price of LNG over time to reflect world markets – LNG is tied to the price of crude after 2015. (This algorithm was developed from ICF's long term Climate Change Risk Assessment Framework (CCRAF), which has a long-term world energy component.) When terminals begin operations, they operate at 50% capacity first year and 85% capacity thereafter.

Are there other variables that we should try to compare?

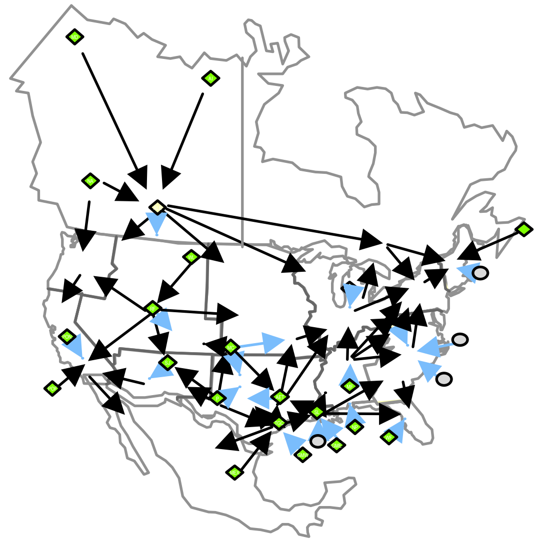
Carbon prices.

What years do you report?

2005 to 2025.

If you have a brief overview of your model approach, please provide to EMF staff.

The North American Natural Gas Analysis System (NANGAS®) is an integrated dynamic linear programming model of the North American gas market. It incorporates the most thorough representation of gas supply of any model used today. Demand is represented both regionally and by sector. (New England is one region and includes residential, commercial, industrial, and electric demand.) Pipeline transmission integrates supply with demand over a 200-segment transmission network that includes storage and LNG. NANGAS® is designed to perform comprehensive assessments of the entire North American gas market: prices, supply, demand, and flow patterns. It provides forecasts of gas prices, consumption, and supply in regional detail.



NANGAS® employs many of the same inputs that IPM® uses. These are principally electricity demand growth and oil prices. Further NANGAS® develops regional oil product pricing along with gas prices. Some of the key features of NANGAS® include the following

<u>Reservoir level analysis</u> uniquely evaluates exploration, development and production at the level of 17,000 individual reservoirs. NANGAS® develops wellhead prices for 23 distinct gas supply regions) such as Sable Island, the Western Canadian Sedimentary Basin, and Gulf Coast (multiple sub-regions), which are the major supply regions for New England.

<u>Regional Demand</u> is modeled on a sectoral and seasonal basis, in 26 North American regions.

<u>End use demand</u> is modeled for residential, commercial, industrial and electric sectors for each demand region. Demand is represented seasonally; storage is represented as a demand during off-peak seasons and as supply during winter seasons. Fuel switching between oil and gas is an element of industrial and electric demand.

<u>Electric generation</u> is modeled regionally with plant dispatching based upon operating cost. Competing power generation technologies are evaluated on a full-cost basis to determine lowest cost capacity additions. ICF iterates between IPM and NANGAS®. NANGAS uses a reduced form of ICF's Integrated Planning Model to model the electric sector.

<u>Pipeline Transportation</u> is modeled by 200 transportation links between supply and demand regions, balancing seasonal, sectoral, and regional demand and prices, including pipeline tariffs and capacity allocation. Pipeline expansions are modeled either as specified user input to the model or, alternatively, the user can let the model expand capacity whenever the market justifies expansion.

NANGAS® is used to develop integrated gas price forecasts along with IPM® and that include a common set of assumptions. NANGAS® reports gas flows, demand response, new pipeline expansions, LNG imports, and frontiers gas imports. It is highly useful in identifying key developments in gas market dynamics over a long planning horizon.