EMF 23 Scenario Design
(Second Round - Revised)

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Preliminary EMF 23 Scenario Design

This revised document expands upon the first-round scenarios and provides further guidelines on reporting output variables for the EMF 23 study, "World Natural Gas Markets and Trade." The left side of Table 1 shows the seven first-round scenarios, marking those cases to be deleted in the second round with italicized and underlined red type. The right side lists all nine of the second-round cases including those included in the first round. Table 2 summarizes the key input assumptions for each case. **Major changes include a new Russian monopoly case as well as a new baseline oil price and economic growth assumptions for the reference and other cases.**

Input for the preparation of scenarios

1 Constrained Russian exports

The objective of this scenario is to analyze a situation where Russia does not expand its natural gas exports as planned. Reasons for this might be unexpectedly high production costs, lack of investment in pipeline and LNG-infrastructure, or a political decision to restrain exports. Table 3 confirms the dominant position of Russia in terms of both proven reserves and production of world natural gas. Both the global and the regional natural gas models, except those focused on North America, should be able to include such an exogenous restriction of Russian natural gas exports.

Modelers are asked to implement these conditions by restricting Russian natural gas exports both to Europe and Asia to their current 2005 levels plus any volumes flowing from projects already under construction. Russian exports are defined as volumes produced within Russia but exported to other countries through a variety of transportation routes. Gas trades from Caspian states should not be restricted if they are feasible.

The working group agreed to eliminate the first-round, "constrained Russian imports" case that limited the share of European imports of natural gas from Russia to no more than 50%.

2 Liquefaction constraints

It is sometimes argued that natural gas prices could be significantly impacted by i) a shortage of liquefaction and perhaps tanker capacity in the exporting region; or ii) a "Gas OPEC", i.e. a cartel of major natural gas exporters. Since these two cases are very different from each other, the first round included two separate scenarios. However, few models could adequately capture the cartel case, which requires the cartel producers to withhold production until their net export earnings started to decline. The working group also decided that a useful first step for understanding any cartel possibilities would be to understand how constrained supplies in the potential cartel regions would affect prices.

Modelers are asked to simulate "liquefaction constraints" by restricting the export capacity of LNG in each region exogenously to their current 2005 levels plus any additional volumes from plants currently under construction.

Regional European and North American models should apply the same restrictions on the export capacity of LNG for any regions that provide gas to the demand countries represented in the model. For example, North American models would not allow any additional LNG imports beyond these constraints.

The working group decided to eliminate the lower LNG costs scenario based upon the results reported at the last meeting. Most models revealed that market prices were much more responsive to limitations on LNG capacity than to changes in LNG delivery costs.

3 Constrained Persian Gulf Exports

Natural gas production from the Persian Gulf represents the other major source besides Russia for potential cartel behavior in this market. Table 3 again confirms the important role of both regions, once it is recognized that U.S. natural gas production is used exclusively within that country. Modelers are asked to represent these conditions by restricting all natural gas exports from the Persian Gulf to their 2005 levels plus any additional volumes from plants currently under construction. Persian Gulf exports refer to natural gas produced in Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and United Arab Emirates.

4 Constrained Russian and Persian Gulf Exports

If exports from both Russia and the Persian Gulf did not expand, natural gas markets around the globe would essentially retain their autarkic and balkanized nature. Although these conditions may seem to be extreme energy futures, this case would allow the group to comment on the relative impacts of more natural gas trade. Modelers are asked to represent these conditions by restricting all natural gas exports from both Russia and the Persian Gulf to their 2005 levels plus any additional volumes from plants currently under construction.

5 Higher Natural Gas Demand Growth

An important issue is the extent to which natural gas resources will remain remote and relatively inexpensive compared to other energy sources. This scenario will provide an opportunity to evaluate how much natural gas prices in different regions will respond to higher natural gas demand conditions. It is based upon a high economic growth case where each region's economy grows by 0.5% per year faster than the reference case.

Modelers who can simulate directly the effects of higher economic growth should operate their model with this assumption. Other modelers who would like some guidance on how much to shift natural gas demand functions should allow total natural gas consumption in each region to grow by 0.27% per year more than in their reference case. Assume that this shift in natural gas demand is due to faster economic growth in each of the regions.

This estimated shift is broadly consistent with the EIA model for the US energy system after making a few adjustments. Their projections show *total energy* growing by 0.27% per year faster when real GDP grows by 0.5% per year more. U.S. natural gas consumption in the EIA model, however, grows at 0.15% (rather than 0.27%) per year faster in the high-growth case than in the reference scenario, because U.S. wellhead prices are rising by 0.34% per year more in this case.

Regional European and North American models should apply the same demand assumptions to the gas-consuming regions represented in their frameworks.

6 Lower Chinese Gas Demand Growth

Chinese officials expect that their rapidly growing economy will shift strongly towards natural gas over the next several decades. Some companies and governments are asking what would happen to natural gas markets in other countries if some of the expected demand growth within China did not materialize as rapidly as expected. Modelers are asked to implement this scenario by reducing the *annual rate* of natural gas demand growth within China in the reference case by 0.5% per year.

7 Modeler's Choice (or "Strut-Your-Stuff")

Each modeling framework was developed to address certain issues or may be particularly well suited to illustrate certain insights. This case is strictly optional, but it allows each modelling team to specify its own alternative case, which when compared with the reference case, will stimulate discussion at our next meeting. The basic requirement is that each team should clearly outline the key assumptions in developing this case.

8 Russian Monopoly

As Russia strives to increase its international prominence, the country may decide to restrict gas supplies to increase her profits from exporting natural gas. Modelers who can simulate this behavior are asked to represent a scenario that shows the possibility for such a strategy. You do not need to calculate the optimal monopoly price if your model cannot determine such a price. The choice of imperfect competition conditions (Nash-Cournot or Stackelberg) is left to each modeler. The scenario simply asks that the scenario implements less competitive behaviour than what was used in the reference case, if that is possible. Modelers do not need to consider this case if they represented Russia with monopolistic strategies in the reference case. If you simulate this case, please also submit results for ***percent change in profits*** from the reference case.

9 EMF 23 Reference Case

The new EMF 23 scenarios for both the reference and alternative cases will be based upon the recent *International Energy Outlook 2006* reference case (not the previous 2005 case used in the last round) released recently by the U.S. Energy Information Administration. The EIA scenarios were chosen primarily because that projection it is readily available without cost to all modeling teams. Key projections can be accessed at:

http://www.eia.doe.gov/oiaf/ieo/ieorefcase.html

Table A3 provides real GDP by world region. Table A5 provides natural gas consumption by world region.

In addition, the worksheet, http://www.stanford.edu/group/EMF/research/doc/IEO2006.xls, contains the IEO 2006 natural gas supply projections by world region and the AEO 2006 fuel prices for the United States. The IEO 2006 does not provide detailed regional information on natural gas prices but it has adopted similar world oil price paths as the AEO 2006. Hopefully, modelers will find the US prices in the AEO useful

The standard EMF rule is that modelers should project variables that they normally consider as endogenous and use EMF assumptions for variables that are generally exogenous. Thus, a modeler would use the natural gas inputs if the model starts with exogenous natural gas demand curves, but would use economic growth inputs if the model develops demand estimates from a more fully developed energy demand module. This general rule should be applied to other parts of the model as well.

Modelers who use assumptions other than the EIA inputs are requested to supply these estimates in a separate spreadsheet and to explain the sources for these estimates.

Output Variables

Although much of the comparison will focus upon a few key importing and exporting regions, it would be helpful to have summary results for major regional groups as well. If you need to

aggregate from smaller to larger regions, please use volume-weighted prices. Modelers are asked to report the following variables:

United States

- Total Production
- Lower-48 Production
- Total Consumption
- Total Imports
- Total LNG Imports
- LNG Pacific Imports
- LNG Atlantic Imports
- Average Wellhead Price (Please indicate if Henry Hub price)
- Average Industrial Price (Please indicate if average citygate price)

Western Europe (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom)

- Total Production
- Total Consumption
- Total Imports
- Total LNG Imports
- LNG Persian Gulf Imports
- LNG Atlantic Imports
- Average Wellhead Price (Please indicate if other wellhead price)
- Average Industrial Price (Please indicate if average citygate price)

Russia (excluding other former USSR states)

- Total Production
- Total Consumption
- Total Exports

Western Exports (e.g., to Europe)

Eastern Exports (e.g., to Asia)

LNG Exports

Average Wellhead Price

Average Industrial Price

Persian Gulf (Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates)

Total Production

Total Consumption

Total Exports

Western Exports (e.g., to Europe & USA)

Eastern Exports (e.g., to Asia)

LNG Exports

Average Wellhead Price

Average Industrial Price

Consumption, Imports and Average Industrial (or Wholesale) Price for these countries:

Germany

Italy

United Kingdom

Japan

China

India

South Korea

Consumption and Imports for these regions:

North America (United States, Canada, and Mexico)

Mature Market Asia (Japan, Australia, and New Zealand)

Total Transitional Economies (Eastern Europe and Former Soviet Union)

Total Emerging Asia (excludes Japan, Australia, and New Zealand)

Middle East

Africa
Central & South America
Total World
Australia

If there are any questions about which countries are included in the various groups, please consult the categories used and defined by the U.S. Energy Information Administration at: http://www.eia.doe.gov/oiaf/ieo/appj.html

In order to standardize natural gas quantities and prices across regions, the EMF staff proposes the following adjustments for converting cubic feet (the measure used by the EIA):

cubic feet	Btu	megajoule	cubic meter
1	1031	1.08	0.0283

Thus, a model using the IEA's trillion cubic meters will have its estimate divided by 0.0283 to convert it into trillion cubic feet (a multiple of about 35.3). Similarly, prices expressed as 2003$ per thousand cubic meters will be multiplied by 0.0283 to derive 2003$ per thousand cubic feet.

Modelers are asked to report results in one of these four units or multiples thereof, e.g., trillion cubic feet. Please be explicit in the worksheet about which units you are using. The EMF staff has tried to simplify the process of reporting different units by including some conversion factors within the attached worksheet. (Modelers who report units that are not in cubic feet may want to review these conversion factors to see that you agree with them.)

For each variable, modelers will be asked to report historical values for the year 2001. Projections should be reported in five-year increments beginning in 2005 for as many years as possible (but ending with 2050). If possible, please do not change the variable name and region in the worksheet. If the variable is fundamentally different, it is preferable that you insert a comment or column with your explanation.

The worksheet will allow the EMF working group to report results in several interesting ways:

1. Any model's projection can be reported in terms of cubic feet, Btu, megajoules or cubic meters;
2. Any model's projection can be reported relative to its 2001 level;
3. Any model's projection in any scenario can be reported as a percent deviation from its projection in the reference or any other scenario.

We expect that the impacts of the alternative cases will be compared with their reference values, as in approach #3 above.

Please report each scenario's results on a separate worksheet of the enclosed workbook, EMFOutput_Name.xls. Replace "Name" in the workbook's title with your preferred short name for your results in our comparison charts. Generally, the reader will understand your organization ("EIA") better than the model name ("NEMS") for most models, unless there are multiple models from your group in this study. Please electronically submit the results back to the EMF office by October 31 (yes, Halloween). This date will allow some opportunity to compare and discuss results informally by telephone before we hold the next meeting in January. Please address all questions to Hill Huntington (hillh@stanford.edu; 650-723-1050).

Table 1. First and Second-Round EMF 23 Scenarios

Existing	**Proposed**
Constrained Russian Exports	Constrained Russian Exports
Constrained Russian Imports	Liquefaction Constraints
LNG Delivery Costs	Constrained Middle Eastern Exports
Liquefaction Constraints	Constrained Middle Eastern & Russian Exports
Gas Cartel	Higher World Demand Growth
Higher Demand Growth	Lower Chinese Demand Growth
EMF 23 Reference	EMF 23 Reference **(Revised)**
	Modeler's Choice: "Strut-Your-Stuff" (SYS)
	Russian Monopoly

Table 2. EMF 23 Scenario Design

	Key Assumptions	2005	2010	2015	2020	2025	2030-50
Constrained Russian Exports	Russian export levels for natural gas and LNG	2005 levels + volumes under construction					
Liquefaction Constraints	LNG Liquefaction capacity in all regions	2005 levels + volumes under construction					
Constrained Middle Eastern Exports	Middle Eastern export levels for natural gas and LNG	2005 levels + volumes under construction					
Constrained Russian and Middle Eastern Exports	Russian and Middle Eastern export levels for natural gas and LNG	2005 levels + volumes under construction					
Higher World Demand Growth	Add to GDP rate (p.a.)	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
	Add to gas demand rate (p.a.)	0.27%	0.27%	0.27%	0.27%	0.27%	0.27%
Lower Chinese Demand Growth	Reduce gas demand growth rate (p.a.) by	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
Modeler's Choice (SYS)	Reveals an important insight from your model	Adjust inputs but report these changes					
Russian Monopoly Case	Simulate less competitive behavior by Russia	If perfect competition was assumed in other cases, replace with imperfect competition strategy (modeler's choice of strategy); if imperfect competition was assumed in other cases, replace with a more stringent set of imperfect competition assumptions (if possible).					
EMF 23 Reference (Based on EIA *International Energy Outlook 2006* reference case.	World Oil Price	$56	$47	$48	$51	$54	$57 +1.0% p.a.
	World Economic Growth	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
	World Gas Demand Growth	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%

Table 3. Major Natural Gas Producing Countries, 2003

Natural Gas: Reserves	2003 Share of total	2003 Cumulative Share	R/P ratio	**Natural Gas: Production ****	2003 Share of total
Russian Federation	26.7%	26.7%	81.2	Russian Federation	22.1%
Iran	15.2%	41.9%	*	Iran	3.0%
Qatar	14.7%	56.6%	*	Qatar	1.2%
Saudi Arabia	3.8%	60.4%	*	Saudi Arabia	2.3%
United Arab Emirates	3.4%	63.8%	*	United Arab Emirates	1.7%
USA	3.0%	66.8%	9.5	USA	21.0%
Nigeria	2.8%	69.6%	*	Nigeria	0.7%
Algeria	2.6%	72.2%	54.6	Algeria	3.2%
Venezuela	2.4%	74.6%	*	Venezuela	1.1%
Iraq	1.8%	76.4%	*	Iraq	
Turkmenistan	1.6%	78.0%	52.6	Turkmenistan	2.1%
Indonesia	1.5%	79.5%	35.2	Indonesia	2.8%
Australia	1.4%	80.9%	76.9	Australia	1.3%
Norway	1.4%	82.3%	33.5	Norway	2.8%
Malaysia	1.4%	83.7%	45.0	Malaysia	2.0%
Kazakhstan	1.1%	84.8%	*	Kazakhstan	0.5%
Uzbekistan	1.1%	85.8%	34.5	Uzbekistan	2.0%

Source: BP, Statistical Review of World Energy 2004.

* Over 100 years

** Excluding gas flared or recycled