Extended Abstact - R. Egging, F. Holz, Timing of Investments in an Uncertain World.

The World Gas Model (WGM) is a multi-period mixed complementarity model for the global natural gas market, allowing for endogenous capacity expansions in the liquefied natural gas, pipeline and storage sectors. The model contains over 80 countries and regions and covers 98% of world wide gas production and - seasonally and over the years varying – consumption for three demand sectors; as well as a detailed representation of border-crossing natural gas pipelines and contractual and spot trades in liquefied natural gas. The model has been jointly developed by DIW Berlin and the University of Maryland. Various journal and conference papers have been written using the WGM.

The WGM as presented and used in earlier work is a deterministic model. All input parameters are certain and model agents can optimize their decisions for a specific known future. Since uncertainty is a major issue in markets – think of demand, market prices and resource bases - we have recently expanded our research to facilitate stochastic modeling with the World Gas Model. The stochastic modeling approach is a scenario approach, and in early periods in the model the economic agents in the model face different possible futures (i.e. *scenarios*). Optimal decisions will now have to hedge for the different possible futures with more or less favorable market circumstances. To give an example of this scenario approach, consider the following scenario tree, in Figure 1 This scenario tree contains 31 nodes. One node, 01, to represent the first year 2005. In years 2010 through 2020 there are two scenario nodes. Each year after 2020 is represented by four different scenario nodes.

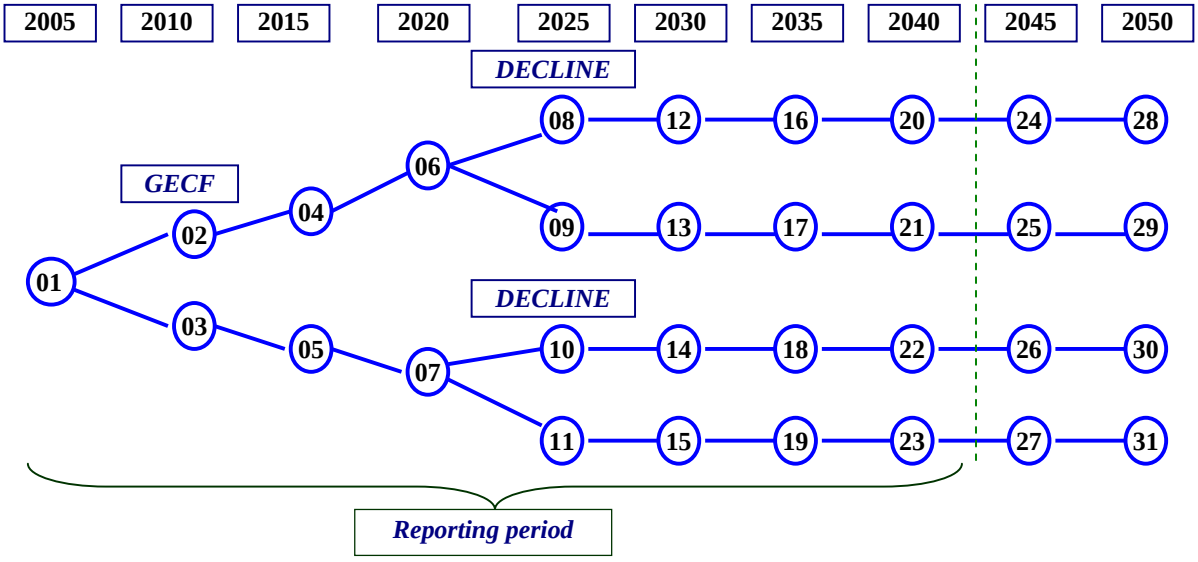

Figure 1 Scenario tree for case STOCH

Each scenario node has its own set of input parameters. Input parameters can differ in aspects such as market power assumptions, consumption levels and production capacities. The scenario (in Figure 1) ending in node 28 could be a scenario where in 2010 the members of the Gas Exporting Countries Forum (*GECF)* would start to collaborate like a cartel; and in 2025 a harsh decline in production levels of some western countries would occur. The scenario (in Figure 1) ending in node 31 would be a *business-as-usual* scenario where all baseline assumptions would play out over the time horizon.

Besides specific input parameters each scenario node also has its own set of decision variables. So for example the investment level in a pipeline in the year 2035 depends on the scenario, and may assume different levels among nodes 16, 17, 18 and 19. All market agents maximize their *expected* profits, having perfect information about all possible scenarios, however not knowing which one will play out. Decisions, notably investment levels, will be optimal 'on average' among the different scenarios of which the relevant scenario node is a part. E.g., in early periods, before 2025, the optimal decisions hedge against the outcomes of different futures. The decisions taken in 2005 have consequences for all future periods, to the contrary a decisions taken in scenario node 08 in year 2025 will only have consequences for its succeeding nodes in a single scenario, nodes: 12, 16, 20, 24 and 28.

Since investments in capacity expansions need some time to earn a return, investment decision outcomes in the last model periods tend to be distorted. We deal with that issue by including scenario nodes for the last two periods in every scenario, but not reporting any outcomes for them. (This is indicated by)

In this paper we address uncertainty of input parameters and its impact on model results. We have developed a stochastic version of the WGM. We will present and discuss results of this stochastic version of the multi-period World Gas Model, with a focus on the impact on infrastructure investments, production and consumption levels; trade flows by pipeline and LNG; and market prices. We will contrast stochastic results with the results from deterministic runs, in which each scenario is optimized separately.

A main result of the stochastic case is that especially the timing of investments is affected by the hedging behavior of market players deciding on capacity expansions facing an uncertain future.