

# ***NORTH AMERICAN NATURAL GAS MARKET AND INFRASTRUCTURE UNDER DIFFERENT LNG EXPORT SCENARIOS***

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## **Overview**

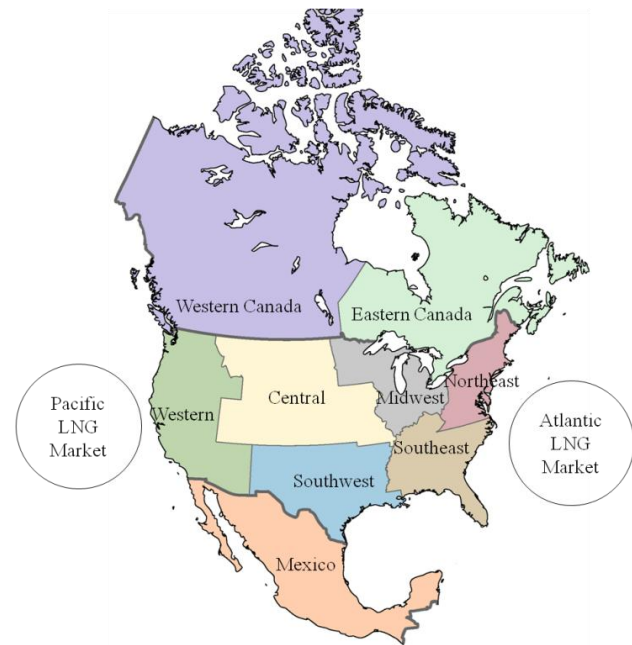
In this study, we construct an equilibrium model of the North American natural gas market formulated as a mixed complementarity problem. Our model includes nine regions (six for the United States, two for Canada, and one for Mexico), Atlantic and Pacific liquefied natural gas (LNG) markets (Figure 1), and six types of strategic market players which are all profit maximizers. We then conduct a series of scenario analyses to investigate the effects of increased LNG demand, particularly from the Asia-Pacific region and restrictions on new LNG export infrastructure development on west coasts of Canada and the United States.

## **Methods**

We model the natural gas market as a mixed complementarity problem by explicitly writing the optimization problem associated with every market player: producers, traders, storage operators, liquefiers, pipeline network operator, and LNG tanker network operator. All these players are modeled as profit maximizers required to satisfy their technical constraints and meet the demand in spot and LNG markets. Interactions among the players are modeled with market clearing constraints whose dual variables represent the prices in the various markets. The roles of the players are as follows:

- *Suppliers*: Extract natural gas from the ground and sell to the trader in their region
- *Traders*: Buy natural gas from their local producer or traders in adjacent nodes (regions), sell gas to the liquefiers, storage operators, and spot market in their node, as well as other traders in adjacent regions
- *Storage Operators*: Buy gas from their local trader in the low demand season and sell it to the spot market in the high demand season
- *Liquefiers (LNG Export Terminals)*: Buy gas from their local trader, liquefy it and sell to LNG markets
- *Pipeline Network Operator*: Operates the pipeline system, collects regulatory and congestion fees from traders for gas transmission
- *Tanker Network Operator*: Operates LNG tanker system, collects regulatory and congestion fees from liquefiers for LNG transport

Since all optimization problems are convex, they can be solved to optimality using their Karush-Kuhn-Tucker (KKT) conditions. These KKT conditions, together with market clearing conditions, form a mixed complementarity problem. We use linear demand curves to represent spot and LNG market demands in different regions. The model is calibrated with publicly available data from various sources including the U.S. Energy Information Administration (EIA).



**Figure 1: Model Regions**

## Results

We have analyzed four scenarios which are reference (REF), a scenario where no LNG export facility is allowed on the west coast of the United States and Canada (NWC), a high overall LNG demand scenario (HLN) and a high LNG demand scenario with west coast restrictions (NWH). In reference scenario we observe that when there is no geographical restrictions on LNG export terminal investments, Western Canada will take the lead in capturing the growing Pacific LNG demand potential in 2050. However when NWC is employed, we see that most of the Pacific LNG demand starts to be satisfied by Southwest region of the United States and Pacific coast of Mexico also captures some of the Pacific LNG demand as well as shown in Figure 2. We observe a similar pattern under HLN and NWH scenarios as well where increased LNG demand causes more greater LNG export and production capacity investments in the Southwest region.

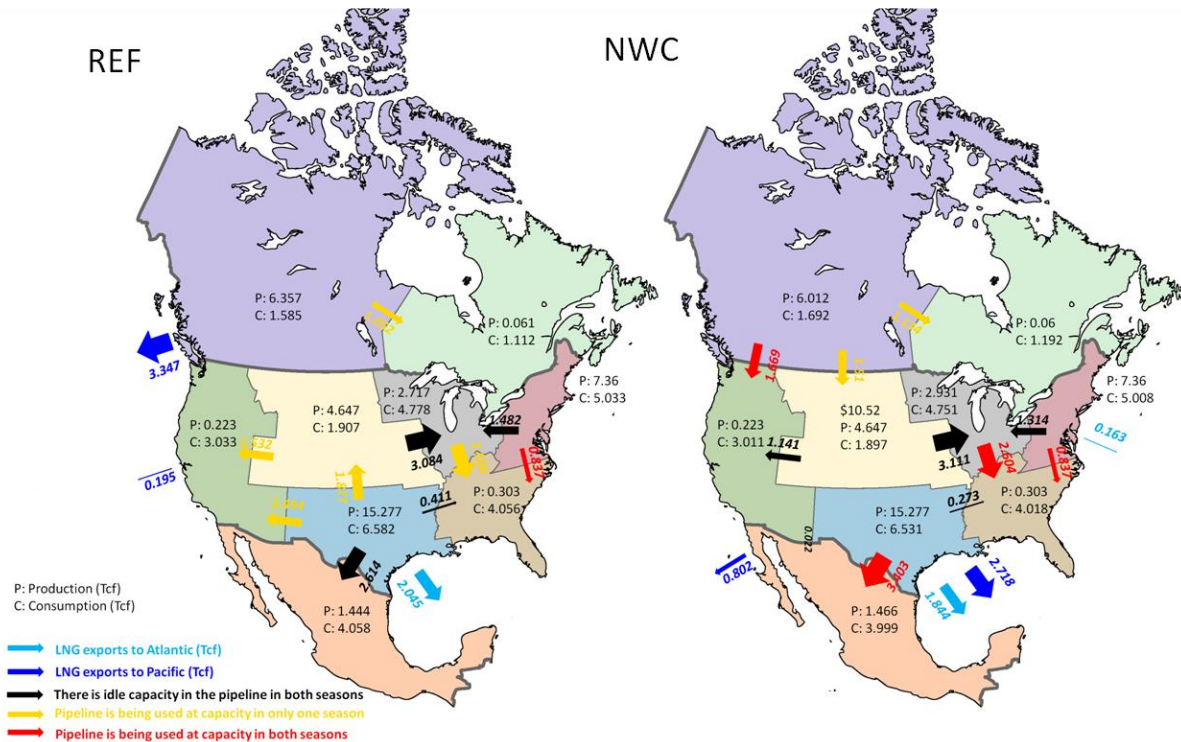


Figure 2: Comparison of REF and NWC scenario results for 2050

## Conclusions

We observe that restricting LNG export terminal construction on the west coast of Canada and the United States causes significant infrastructure changes, particularly along the Gulf Coast and on the Pacific coast of Mexico. Our results also indicate that under location restrictions, gas flows among the regions change considerably. We see that the total volume of LNG provided remains unchanged even when location restrictions are in place, demonstrating the strength of rising Asia-Pacific demand.

## References

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