REAL-TIME OPTIMIZATION OF A COMPLEX INDUSTRIAL GAS NETWORK

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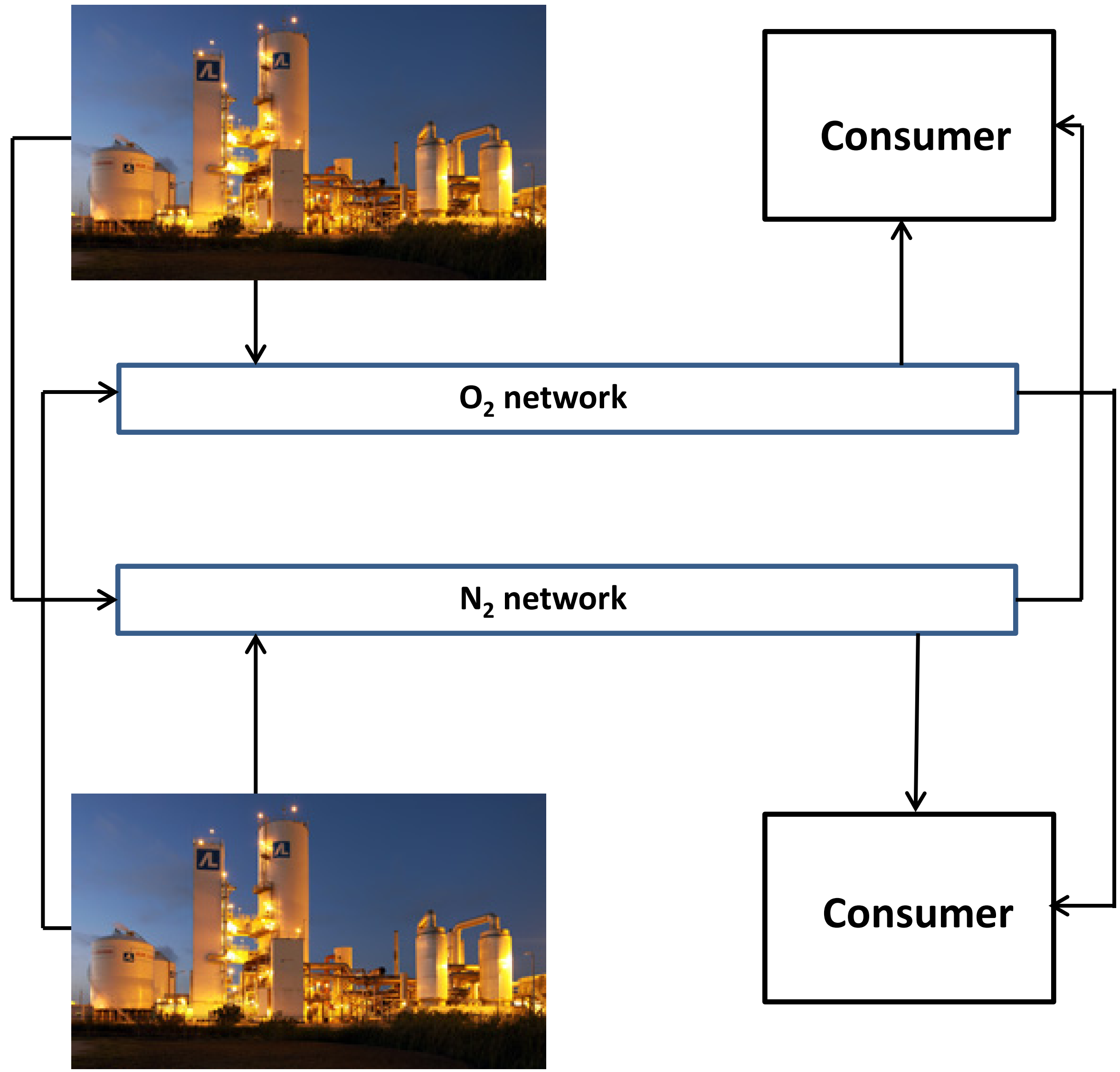
GAS PIPELINE NETWORKS

Pre-existing network of gas pipelines connecting air separation units and consumers



SCOPE OF CURRENT WORK

- **Consider operation of a network of 4 plants, 3 pipelines, and external sources**
- **Optimize operations under changing demands and fluctuating electricity prices**
- **Ensure small solution times for application as a real time optimizing tool**
  - **Select and tune solvers**
  - **Reformulate the model to be friendlier to solvers**
  - **Simplify the model if necessary to account for important interactions while maintaining reasonable complexity**

RESULTS WITH DIFFERENT SOLVERS

SOLVER	LOWER BOUND	UPPER BOUND
Antigone	6996	6996
AlphaECP	-	6075
LINDOGlobal	6169	6964
Scip	5086	-
Couenne	6105	6217
Sbb	unbounded	
DICOPT	rminlp unbounded	
BARON 12.7	infeasible	
BARON 13.1	5692	-

MOTIVATION

- **Numerical characteristics of the model proving a challenge to all solvers**

- **Difficult to use the results from a numerically unstable model in the RTO application**

- **It is necessary to develop global optimization facilities to deal with problems with many local solutions**

ASSUMPTIONS OF THE MODEL

- **Consider operation for a single time period**
  - **Implemented on a real time basis**

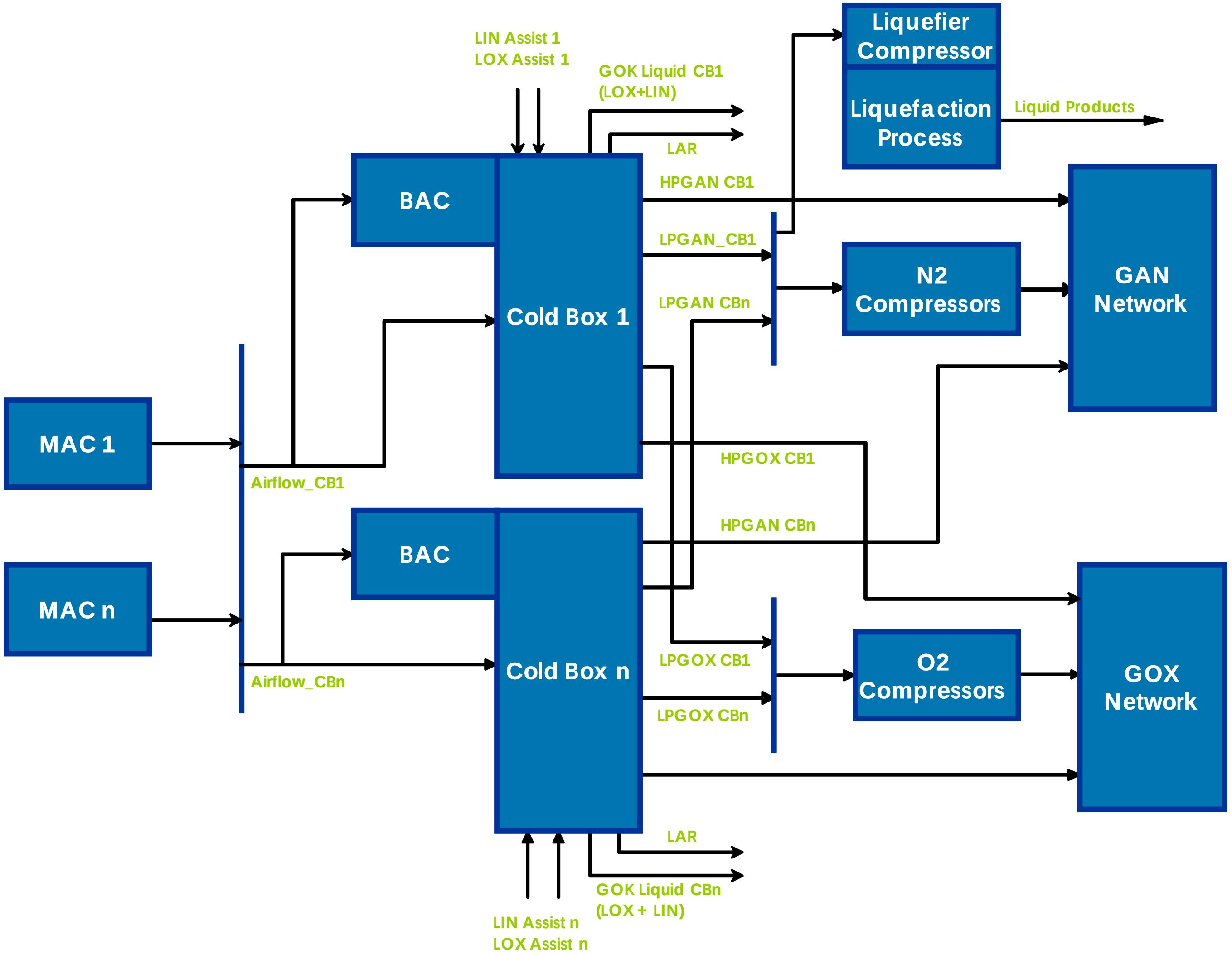
- **All demands are necessarily satisfied**

- **Demands and electricity prices revealed at start of the period**

- **No plant dynamics are considered, and pipeline dynamics will be added later**

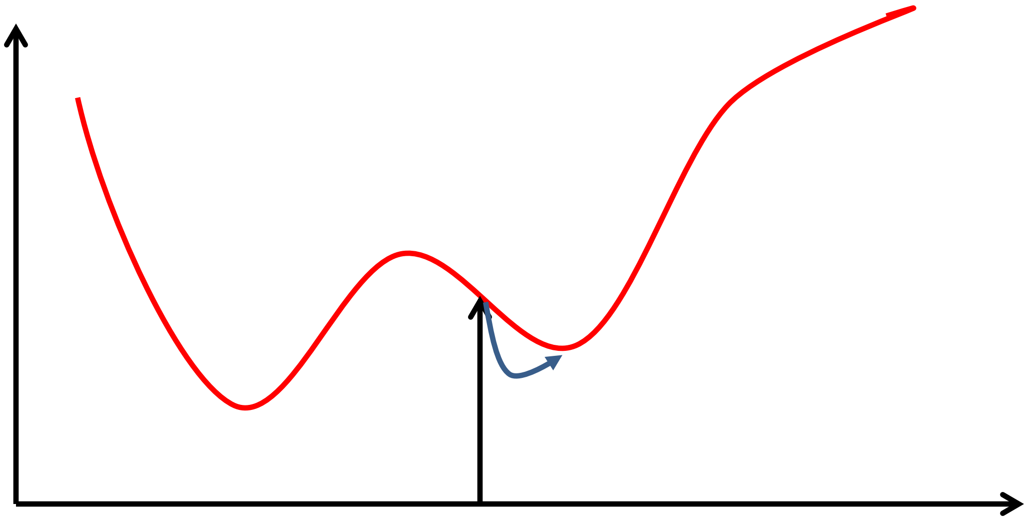
Previous experience at Air Liquide shows presence of multiple local minima. Global optimization techniques essential

GENERIC PLANT DIAGRAM



NETWORK MODEL: NONCONVEX

- **Model for a single column with 40 trays had size 320 differential equations, 1200 algebraic equations (Huang et al., 2013)**
- **Regression-based models developed at Air Liquide**
- **Nonconvex models necessary to capture system dynamics**



NETWORK MODEL: COMBINATORIAL

- **Logic conditions**
  - **Conjunctions: Certain equipment must be used in concert**
  - **Disjunctions: Certain equipment cannot be used together**
  - **Reformulations with binary variables lead to challenging combinatorial characteristics in the model**

- **Problem Size**
  - **~150 binaries, ~600 continuous variables, ~800 equations**

CONCLUSIONS

- **Novelty of the work**
  - **Systematic treatment of infeasibilities narrows attention to a source of inconsistency in an infeasible model**
  - **Model reduction and dynamic scaling strategy to deal with numerical issues**

- **Impact for industrial applications**
  - **Systematic treatment of numerically challenging formulations that are ubiquitous in regression models for industrial applications**