National CCUS Assessment Framework and Blue-H_2 Production

Robert Symonds and Robin Hughes
CanmetENERGY, Natural Resources Canada (NRCan)

NRCan Labs

- Oil sands & heavy oil

CanmetENERGY-Devon (CE-D)

- Buildings & Communities
- Clean Fossil Fuels
- Industrial Processes
- Renewables (wind, marine, solar thermal, bioenergy)
- Transportation

CanmetENERGY-Ottawa (CE-O)

- Buildings
- Industrial process integration
- Smart grids
- Solar PV
- RETScreen International

CanmetENERGY-Varennes (CE-V

<u>The other Canmets:</u>

CanmetMATERIALS (Hamilton)
CanmetMINING (Ottawa)

Industrial Decarbonization Research Team

- **Dynamic Carbon Capture for Iron and Steel Production**
  - This project is focused on identifying and developing decarbonization solutions for the hard-to-abate GHG emissions from traditional and future integrated steel mills, and DRI-EAF facilities.
- **Bringing Pressurized Chemical Looping (PCL) to Market for Small/Medium Industrial Decarbonization**
  - This project aims to adapt the pressurized chemical looping (PCL) process to provide a decarbonization solution for small & medium (<100 MW_{th}) industrial heat applications via application-specific TEA and pilot plant testing.
- **Electric Fluidized Beds**
  - This project is focused on advancing electrification technologies for industrial decarbonization in high-impact applications. Fluidized beds are often chosen for effective heat and mass transfer. The project consists of six main activities, each to be applied to various industrial applications of electric fluidized beds (e.g., upgrading of Ontario’s graphite for use in batteries).

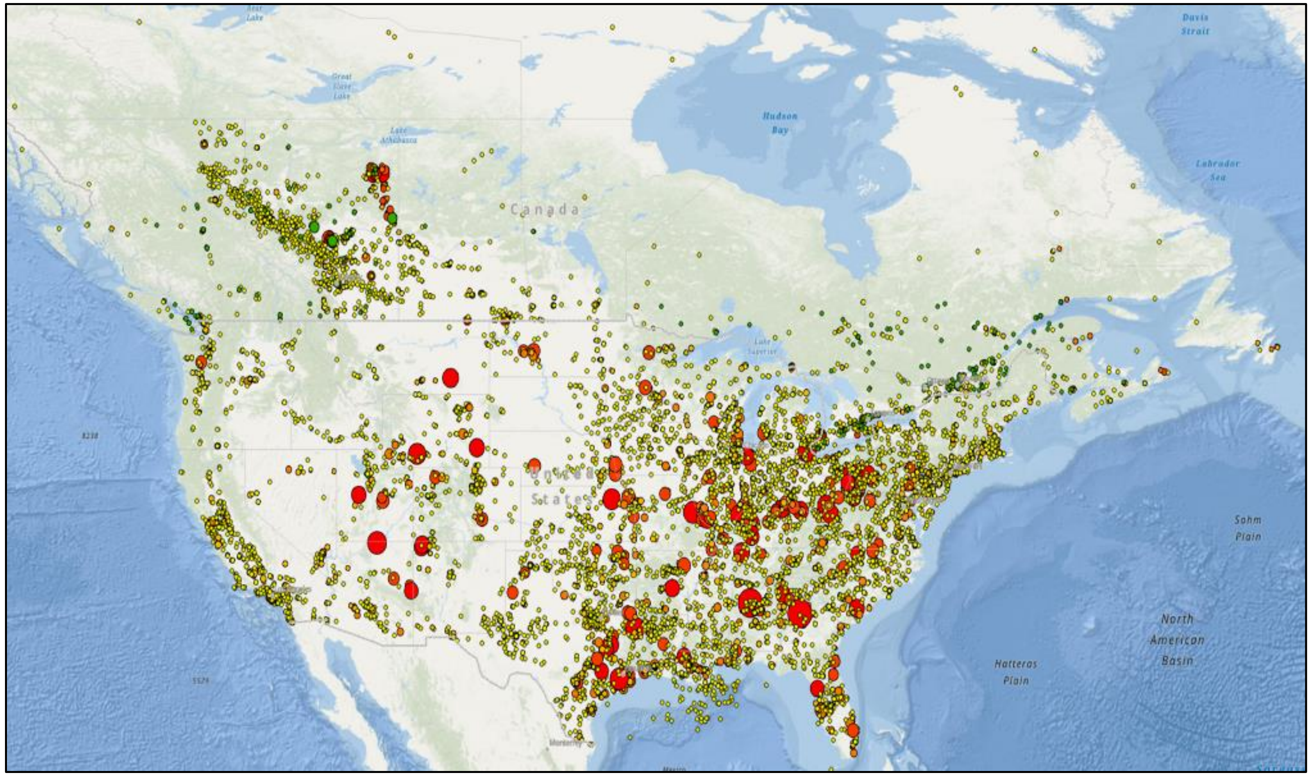
Industrial Decarbonization Research Team

- **National CCUS Assessment Framework (NCAF)**
  - This project aims to develop rigorous datasets, network models, and tools that translate process, techno-economic, and life cycle/environment data for carbon management into a clear, consistent, and accessible format for supporting technical guidelines, policy/market decision making, infrastructure investment, and industry technology adoption.
  - It considers the diversity of emitting processes, location, CCUS technology approach and TRL, storage site location and capacity, current and future energy/emissions/economy conditions, in a single decision support platform
- **Modeling, TEA, and LCA of CCUS-H_2 Production, Purification, and Transportation (Blue-H_2)**
  - This project is focused on determining the lowest cost and lowest environmental impact pathways for blue-H_2 production, purification, and transportation. The project uses process simulation, techno-economic assessment (TEA), and life cycle assessment (LCA) methods, in combination with machine learning algorithms, to achieve this objective.

How do we achieve net-zero CO_2 emissions?

- The management of carbon dioxide emissions through **CCUS and CDR**, in combination with other strategies, **is critical** in meeting net-zero emissions targets

- Given the **complexity** of the entire CO_2 value chain, from emitting sites to storage locations, and the **diversity** of situations across Canada, decision-makers must have access to **unbiased scientific analysis of carbon management pathways**

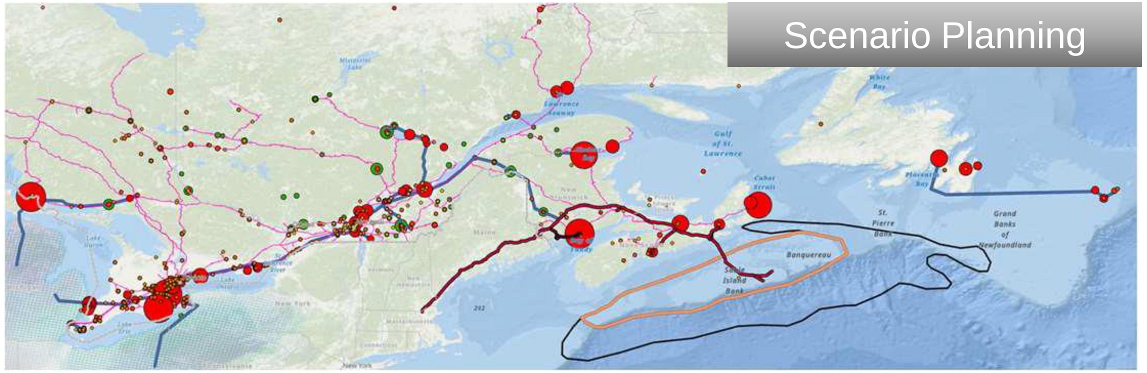


All major CO_2 emitters in Canada (2020) and USA (2013)
Coloured and sized by emission rate and source (largest emitter 22 Mt CO_2/year)
Green circles are biogenic CO_2 emissions

NRCan Technical Support for Planning CCUS in Canada

- Researchers at NRCan are developing CCUS and CDR planning tools to **solve and coordinate the CCUS part of the puzzle**
- CO_2 capture from fossil, process, and biogenic sources
- Fuel switching from natural gas to H_2 with CO_2 capture
- CO_2 and H_2 storage prospectivity
  - Geological reservoirs
  - Mineralization (e.g., tailings)
- CO_2 transportation
- CCUS and H_2 hubs and clusters
- Extensive external collaboration with industry, governments, and universities

Major CO_2 emitters in Canada by emission type and rate



Scenario Planning

National CCUS Assessment Framework and Blue-H_2

Key Research Questions

- What is the **best approach for CCUS and carbon dioxide removal (CDR) in Canada,** given varied
  - Industrial processes;
  - CO_2 source and sink/utilization locations; and
  - Existing rights-of-way, topography, population density, areas of concern, obstacles, long-term capacity, costs, and environmental impacts?

- What is the **impact of attaining CO_2 capture targets on costs and the overall CCUS value chain (including CDR and low-emission H_2 utilization),** given uncertainty related to
  - Varying site availability over time due to shifting markets;
  - Emissions profile variations due to industrial process changes; and
  - Reservoir capacity, injectivity, and cost estimations due to geological heterogeneity?

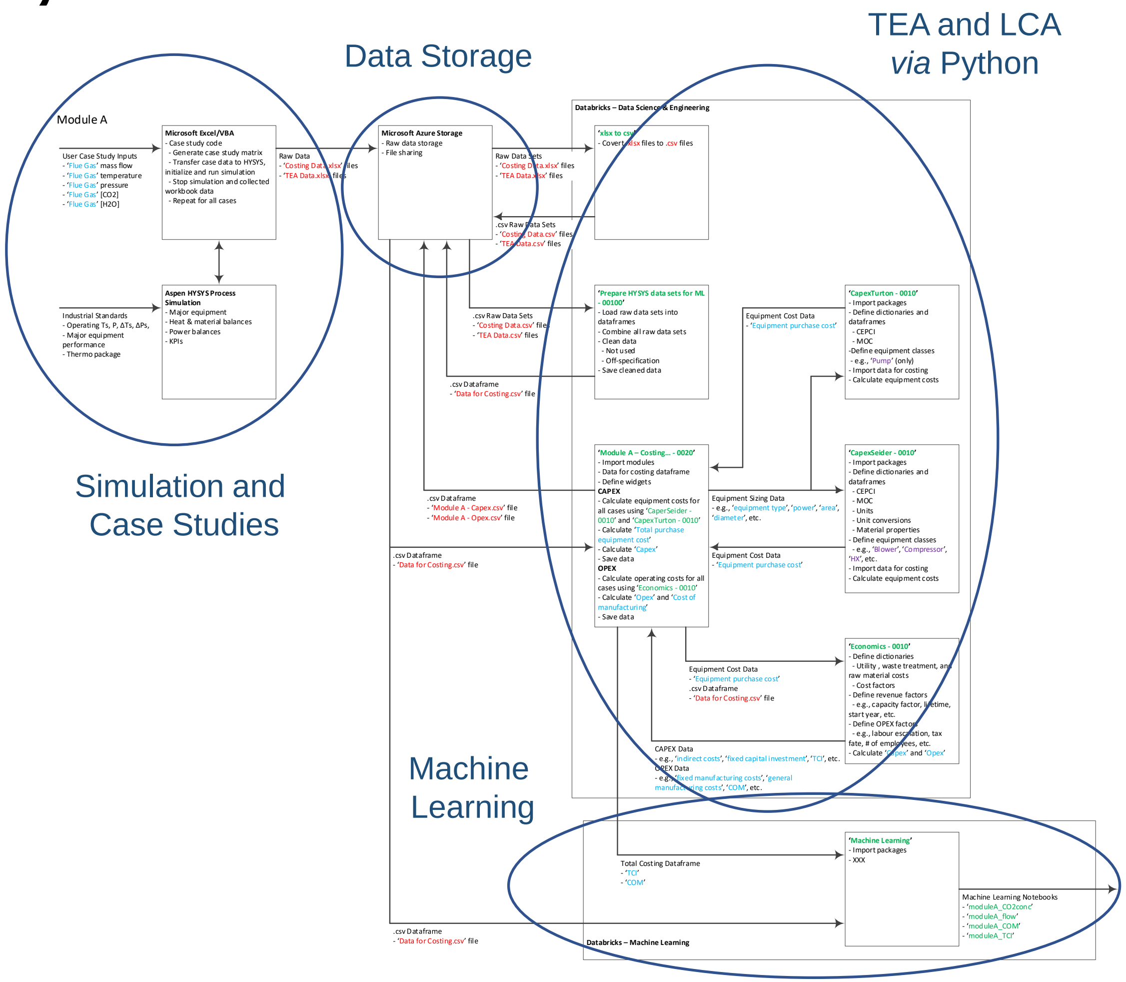
- How do **CO_2 pricing and other policy/regulatory constraints**, such as pipelining, drilling, and storing CO_2 at the regional and provincial/territorial level, **affect CO_2 capture targets, costs, and the overall CCUS value chains** in the different Canadian provinces and territories?

National CCUS Assessment Framework and Blue-H_2
Collaborators and Expertise

- Collaborators
  - CE-O & CE-V, provincial & federal government departments, technology developers, industry, and universities
  - Research scientists, engineers, technologists, mathematicians, and analysts
- Expertise
  - Process development and modeling (TEA and LCA)
  - Bench- and pilot-scale technology development
  - Transport network modeling and optimization
  - CO_2 and blue-H_2 storage
  - Stakeholder engagement

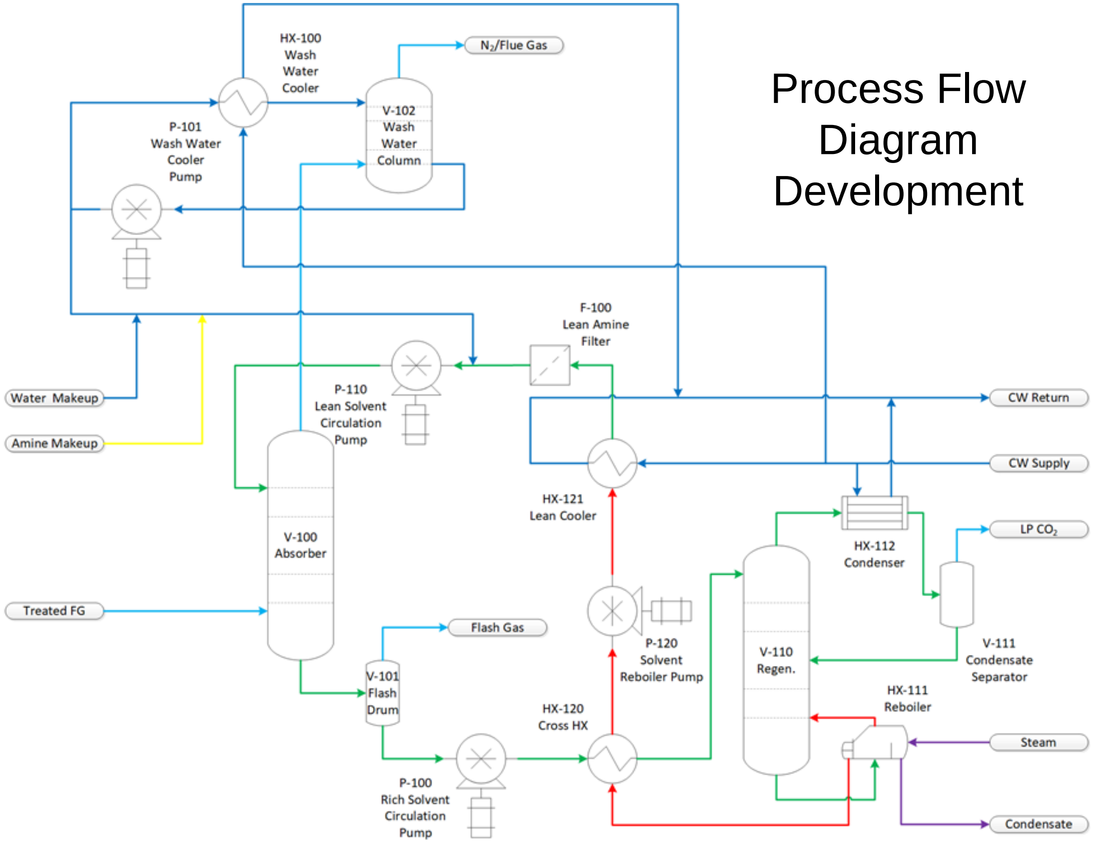
Process Simulation, TEA, and LCA

- Sector-specific and regional bottoms-up performance and costs for **carbon capture, CDR, and blue-H_2 technologies**:
    - Absorption, adsorption, membranes cryogenic, oxy-fuel, and chemical looping
    - Direct air capture (DAC) and enhanced mineralization
    - SMR, gasification, ATR, PCL-SMR, and NG pyrolysis
- Extensive parametric studies with tens of thousands of cases used to create **machine learning models** that are applied to estimate **costs and environmental burdens**:
    - ‘Stack by stack’ at an **existing or prospective facility** using real temperatures, pressures, flows, and compositions
    - Using localized resource (e.g., electricity, water) and **cost parameters**
    - Accurate enough to **differentiate between technology types** (e.g., amine vs. membrane vs. adsorption vs. other advanced techs)
    - Employing **process modularization** (e.g., flue / syngas treatment, CO_2 removal, H_2 purification, and CO_2/H_2 compression) for consistency and robustness
    - Cost and performance being **validated using industry-specific cases** *via* cost recovery contracts and task share agreements (TSAs)
    - Battery limits data sent to **openLCA code for automated LCA**

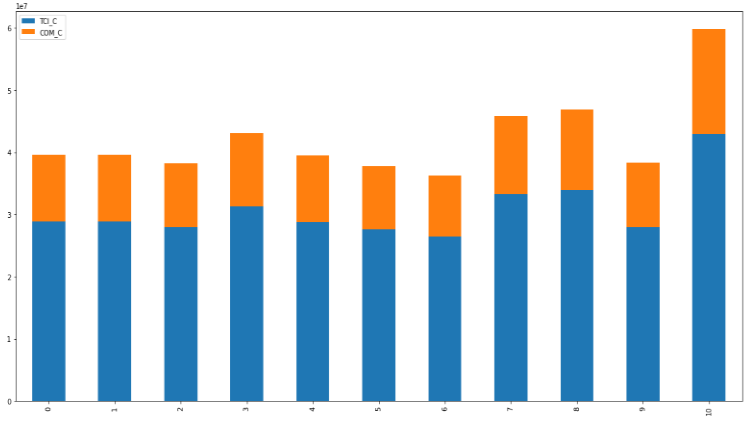


Generalized workflow – Machine Learning approach

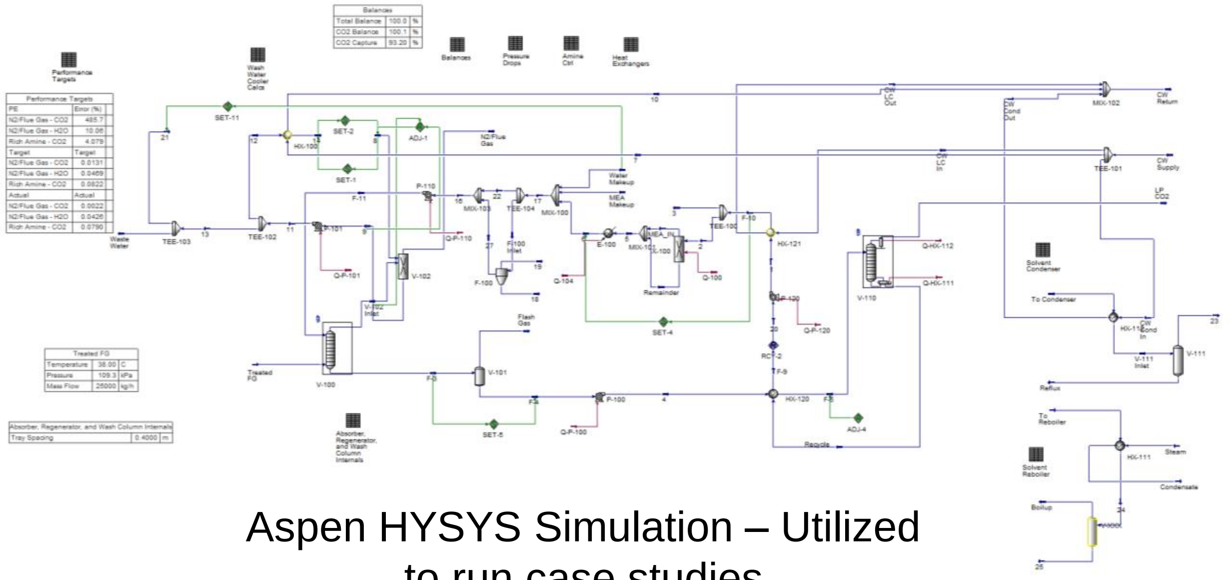
Process Simulation, TEA, and LCA



Process Flow Diagram Development



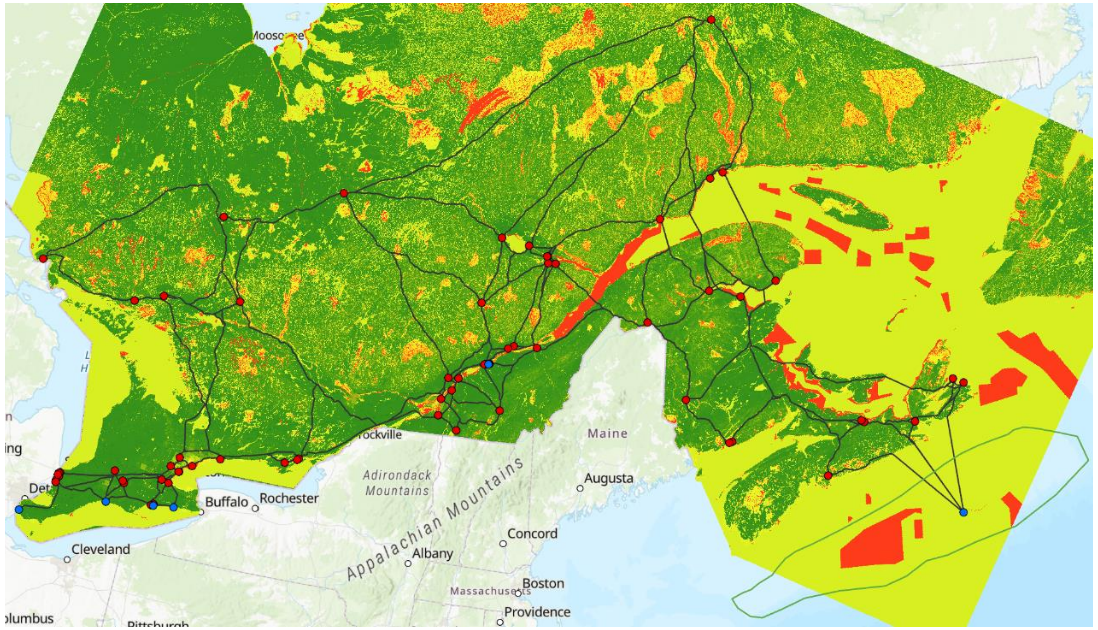
Machine Learning model – CAPEX and OPEX



Aspen HYSYS Simulation – Utilized to run case studies

Modeling and Optimization

- Using outputs from TEAs to determine the **total cost of capture/removal, transportation, and storage** across Canada
  - Regional, provincial, and national
  - Utilizing ArcGIS software with **in-house code development**
  - Example **– High-throughput CO_2 pipelines** connect the provinces' major emitters to **favourable CO_2 storage locations** in southwest Ontario and very large CO_2 storage reservoirs in NS and NL
  - Medium facilities are connected to pipelines *via* **ship & rail**
- Considering **multiple CO_2/H_2 transport phases**
  - Supercritical, compressed, liquefied, and ammonia (H_2 only)
  - Multi-modal transport linked with scenario-based **supply and demand models**
- Including **all potential pathways**, such as the use of bio-materials, mining tailings, construction materials, and agricultural products

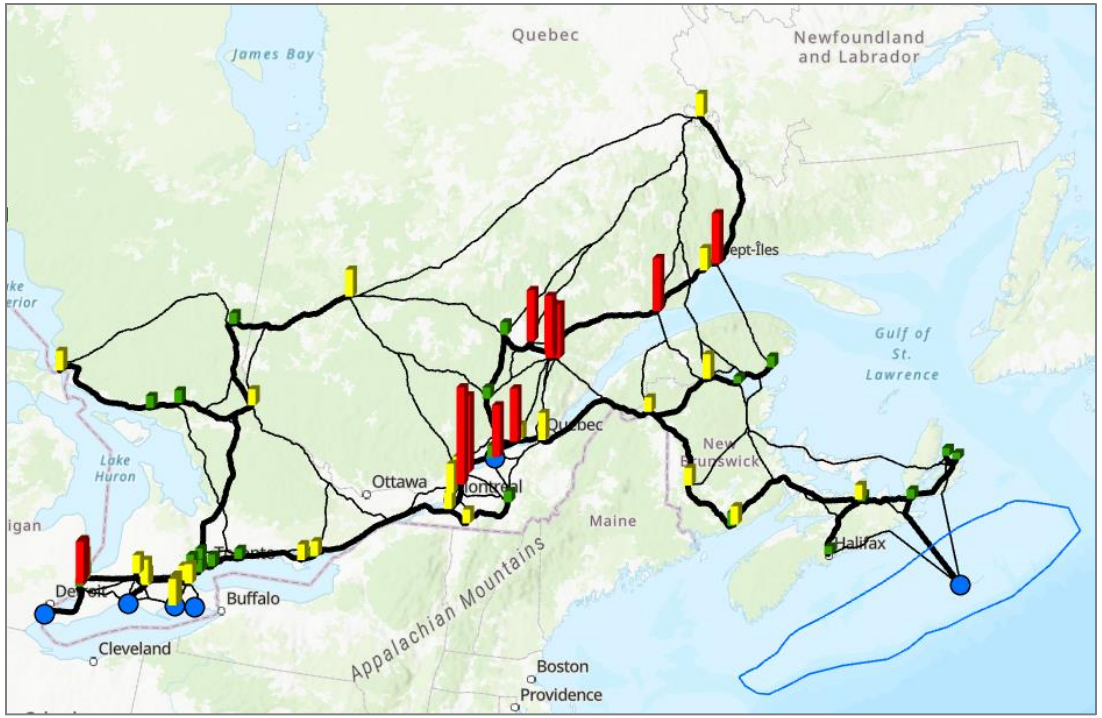


Candidate pipeline network following **lowest-cost paths**

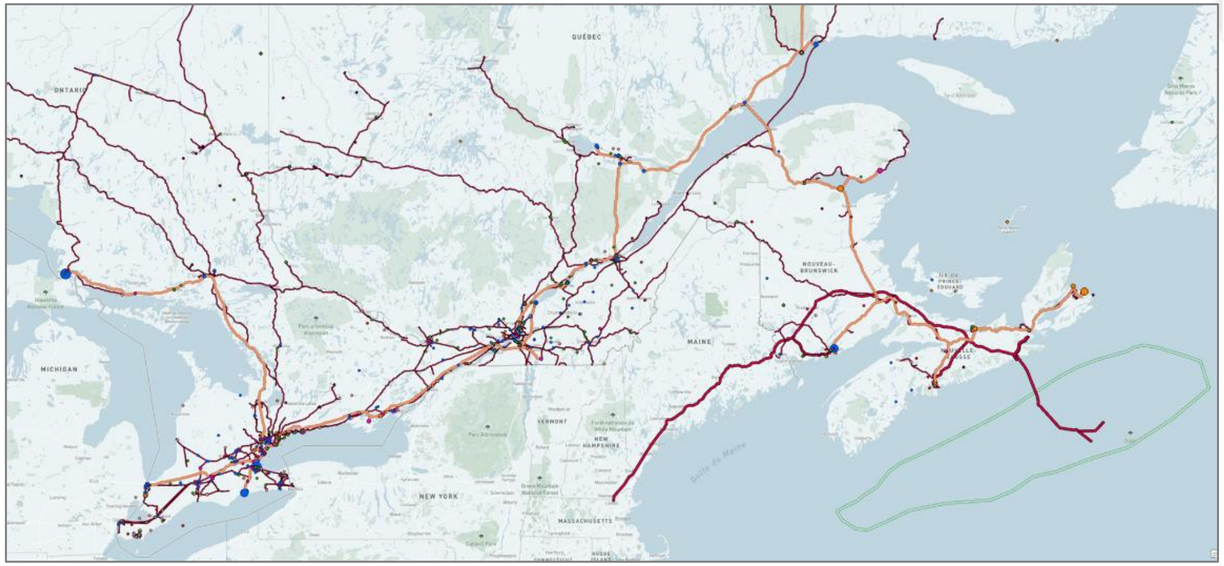
Resolution: grid region in squares of 200m x 200m

Parameters considered: population, rivers, lakes and ocean, protected areas, First Nations territories, slope of land, power line and railway rights-of-way, border with United States

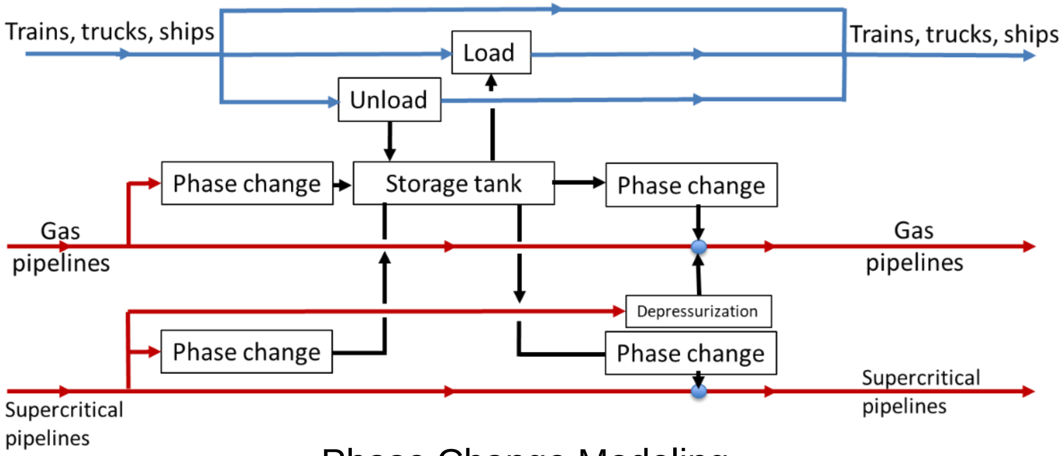
Network Modeling and Optimization



Optimized Transport Network with Cost of CO_2 Capture



Multi-modal Optimization – Source to Sink



Phase Change Modeling

Industrial Collaborations

- Working with major companies in all sectors:
  - Iron & steel, cement, oil & gas, pulp & paper, power generation, metallurgy/smelting, gas and solids transport, etc.

- This gives the team access to key insights:
  - Differences in wants and need across all sectors
  - Public perception within given jurisdictions
  - Regulatory gaps (e.g., transportation and storage, accounting)
  - Facility details (e.g., major equipment, emissions, access to utilities) and cost factors
  - Actual costs for construction and operation – Benchmarks that show this is possible and moving forward

Next Steps to Support CCUS in Ontario

- Finalizing a case study for all major emitters in Eastern Canada (>300 ktCO_2/year)
  - Cost of capture for each facility, considering process specifics and multiple capture rates (high TRL absorption-based CO_2 capture)
  - Costs for optimized transportation routes linking all emitters to CO_2 storage
  - Initial costs for well development and injection
- Working with Ontario and Ontario's industries to develop and fine-tune scenarios/costs and sector-specific solutions
  - Infrastructure needs
  - Storage locations, capacities, and policies/regulations
  - Indigenous perspectives and opportunities
- Interprovincial options evaluation
- Seminar series on CCUS technologies
- Technical support in policy development and proposal evaluation (full CCUS value chain)
- Technical support in Regional Energy Table discussions with Federal Government

Thank you!

CONTACT

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and
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