Reconciling the short and long term in applied policy modeling in Canada: Two case studies

Accommodating the short term and long term in modelling
ETSAP
London, UCL, April 29 2016

Dr. Chris Bataille, cbataill@gmail.com,
Currently
Associate Researcher, IDDRI/SciencesPo &
Adjunct Professor, Simon Fraser University
Presentation overview

- Me in one slide
- Our two modelling approaches: bottom-up and top-down hybrids
- Case 1: Uptake of CCS in the Alberta oil sands under high and low policy uncertainty (effectively foresight and myopia on carbon pricing) using a bottom-up simulation model
- Case 2: *Using policy as your foresight.* Use of a long run “downward attractor” to guide short run policy in a myopic modelling and policy environment; the Canadian chapter of the DDPP
- General comments and questions I have
- Your questions?
Me in one slide

• Associate researcher with IDDRI in Paris, lead editor of the DDPP Climate Policy Special Issue, WholeSEM fellow
• Adjunct Professor at Simon Fraser University in Vancouver
• PhD (SFU) in energy & climate change policy modelling 2005
  – Clients: National Roundtable of the Environment and the Economy; Canadian federal ministries of energy & environment; BC, AB, SK, ON, NFL, & NWT governments; provincial regulators; energy utilities; NGOs; OECD
Our modelling approaches

• CIMS simulation model: firm and household behaviourally realistic technology stock turnover (hybrid from the bottom-up)
  – Heterogenous decision agents, technology competitions include a mix of financial and non-financial components, investment decision and financial flow discount rates separated
  – 5 year business cycle myopia is standard but foresight is available for carbon pricing

• RGEEM regionally disaggregated dynamic recursive CGE (hybrid from the top-down)
  – Lots of sectoral and end-use disaggregation, key technologies added, tech parameters set using CIMS
  – Sequence of static models with year by year myopia

• Both models focussed on policy response and have fully integrated coverage of energy but at different levels of detail
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• General comments and questions I have
• Your questions?
Scenarios

• Why Alberta? Huge GHG storage potential + fossil industry
  – Autarky (Canada reduces alone) w/ foresight (policy certainty)
  – Autarky with myopia (policy uncertainty)
  – International trading in permits (we all reduce together) with foresight
  – International trading in permits with myopia (!!)

• Difference between scenarios is proxied by the carbon price $/tonne CO2e (assumed 0.9:1 USD, not currently the case)

<table>
<thead>
<tr>
<th></th>
<th>2016-2020</th>
<th>2021-2025</th>
<th>2026-2030</th>
<th>2031-2035</th>
<th>2036-2040</th>
<th>2041-2045</th>
<th>2046-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abatement autarky</td>
<td>85</td>
<td>227</td>
<td>312</td>
<td>368</td>
<td>425</td>
<td>425</td>
<td>425</td>
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<tr>
<td>International emissions trading</td>
<td>28</td>
<td>57</td>
<td>85</td>
<td>113</td>
<td>142</td>
<td>170</td>
<td>198</td>
</tr>
</tbody>
</table>
CO$_2$ sequestered in Alberta, by scenario

[Bar chart showing CO$_2$ sequestration by scenario and year (2020, 2030, 2050).]

- **A: Autarky & Confident**
- **B: Autarky & Uncertain**
- **C: Trading & Confident**
- **D: Trading & Uncertain**
Alberta’s energy-related GHG emissions in each scenario

- Business as usual
- Int. emissions trading with policy confidence
- Int. emissions trading with policy uncertainty
- Abatement autarky with uncertainty
- Abatement autarky with confidence
# Cumulative Alberta abatement

<table>
<thead>
<tr>
<th></th>
<th>Annual</th>
<th></th>
<th></th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2050</td>
<td></td>
</tr>
<tr>
<td>A: Autarky &amp; Confident</td>
<td>70</td>
<td>151</td>
<td>236</td>
<td>5,519</td>
</tr>
<tr>
<td>B: Autarky &amp; Uncertain</td>
<td>19</td>
<td>106</td>
<td>229</td>
<td>4,288</td>
</tr>
<tr>
<td>C: Trading &amp; Confident</td>
<td>23</td>
<td>64</td>
<td>153</td>
<td>2,833</td>
</tr>
<tr>
<td>D: Trading &amp; Uncertain</td>
<td>7</td>
<td>27</td>
<td>116</td>
<td>1,605</td>
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The Deep Decarbonization Pathways Project

- **Network:** Researchers from 16 countries, covering 74% of global energy system GHGs.

- **Goals:** 1) Maintain domestically defined development priorities while 2) limiting global temperatures to +2°C, proxied by 1.7 t/cap in 2050.

- **Means:** To aid & encourage domestic teams of all capabilities to form deep decarbonization pathways (DDPs). The purpose of DDPs is to stimulate stakeholder & decision-maker debates to create the necessary political consensus to form robust, resilient and dynamic policy post Paris.
Key methodological elements of the DDPP

• “Downward attractor” based on long run targets (~1.7 tonnes per capita global average)
• Technological guidance: GHG intensity targets for electricity generation, passenger vehicles, availability of CCS, etc.
• Explicit map of technical and economic transition, filled out in a common dashboard
• Some limitations:
  – Global consistency in trade in energy and GHG intense materials (see Pye *et al* 2016 and Denis-Ryan *et al* 2016)
A little law and regional thermodynamics

The fundamental challenge of CP in Canada:

- While the federal government is responsible for international treaty making ...
- Canada’s constitution assigns control of natural resources to the provinces, unless they cross borders or there is a national interest the federal government wishes to press
- The regional cost curves are wildly different
- The implementation costs of an equimarginal policy are concentrated in Alberta, Saskatchewan and to a lesser extent Ontario and the Atlantic provinces, i.e. thermally powered regions with heavy industry
What we have now: A “policy laboratory”

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<tr>
<th>Sector</th>
<th>Federal Policies</th>
<th>Provincial Policies</th>
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</thead>
<tbody>
<tr>
<td>Multi-Sector</td>
<td></td>
<td>British Columbia Carbon Tax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alberta (current) Specified Gas Emitters Regulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alberta (announced) C-tax+ OBA C&amp;T+ methane regs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Québec WCI – upstream C&amp;T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ontario (announced) upstream C&amp;T</td>
</tr>
<tr>
<td>Buildings</td>
<td>Strengthened efficiency standards</td>
<td>Various building and appliance codes</td>
</tr>
<tr>
<td>Transport</td>
<td>Passenger Emissions Regulations</td>
<td>Generally equal to or less stringent than federal policies</td>
</tr>
<tr>
<td></td>
<td>Heavy Duty Vehicle Emission Standards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Renewable Fuels Content Regulation</td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>Missing</td>
<td>See multi-sector above</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>-45% methane regs just announced</td>
<td>Alberta 100 Mt oil sands cap, plus see above</td>
</tr>
<tr>
<td>Electricity</td>
<td>New coal ban, sets standard at NGCCGT</td>
<td>British Columbia Clean Energy Act</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alberta (announced) 30% wind goal, coal phase out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Various CCS projects in Alberta and Saskatchewan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ontario Coal Phase-Out and Feed-In-Tariff</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NB &amp; NS Renewable Portfolio Standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nova Scotia Cap on Electricity Sector Emissions</td>
</tr>
<tr>
<td>Landfill gas</td>
<td></td>
<td>Varying levels of regulation by province</td>
</tr>
</tbody>
</table>
The DDPP in context for Canada*

* No agriculture or LULUCF
The policy principles we used for long run guidance in a myopic world

- **Performance orientated regulations** and information for less price-sensitive sectors (buildings and transport).
- **Carbon pricing** for price-sensitive sectors, and to incentivize technology innovation.
- **Policies that support:**
  - **innovation**, pushing the technology frontier forward, R&D, prototyping and commercialization support
  - **infrastructure change**, (e.g. municipal land use, transit finance,).
- **Institutions to monitor sectoral progress towards decarbonization**, and to adjust policy if necessary (e.g. the CCC).
The DDPP policy package

• Best-in-class mandatory energy and GHG intensity regulations requiring the use of zero- or near-zero emission technologies in the buildings and transport sectors (\& potentially electricity):
  – Net-zero-energy residential buildings after 2025, and commercial buildings after 2035.
  – All new personal vehicles to run on decarbonized energy by the early 2030s, and heavy freight vehicles by 2040.

• **Hybrid carbon-pricing, for heavy industry & the rest of the economy**:
  – Some form of cap and trade for heavy industry, designed for competitiveness concerns and linkage to other systems. We used an intensity based standard w/ OBA falling to -90%.
  – A carbon price rising to CDN $50 by 2020 and then reaching CDN $350 through $10 annual increments to 2050. We used BC’s 50/50 formula. The charge would be flexible to technological progress.

• **Methane and land-use policies.**
Results: Decarbonization Pathways

- Forecast energy GHGs 666 Mt
- Deepending Trends
- Decarbonized electricity
- Energy efficiency everywhere
- Reduce, cap & flared non-energy GHGs
- Structural economy change
- Zero emitting transport fuels
- Decarbonize industrial processes
- GHGs 78 Mt in 2050

Remaining GHGs

Pushing into NexGen

Co2e Mt

2015 2020 2025 2030 2035 2040 2045 2050
Oil production is sensitive to oil price, not carbon policy

- HIDDPP Oil price evolving to ~$114/barrel
- NEB Low Ref - Oil price evolving to ~$80/barrel
- MIDDPP - Oil price evolving to ~$80/barrel
- LODDPP - Oil price evolving to ~$40/barrel
Key questions/points for discussion

• What foresight do firm and household decision making agents really use? Myopic, discounted, average?

• Our research indicates something between myopic and highly discounted (2-5 year paybacks – or less). Firms vary, with utilities using the lowest rates, and smaller firms higher rates (capital conservation, management limitations, etc.)

• What are the key considerations for:
  – Short run operations? Actor heterogeneity, variable vs. fixed costs, stock in place will keep running
  – Long run investment? “, capital conservation, maintenance of option value, policy
Plug

• A special issue of *Climate Policy* on the DDPP will appear online soon.
  – A focus on methodologies
    • Synthesis article on the DDPP method
    • Necessary developments in models and processes (Steve and me)
    • Dynamic policy adjustment
  – Global consistency doing national modelling
    • The value of multiples scales: Global fossil fuel energy trade
    • Accounting for GHG intense materials
  – National circumstances
    • Energy security
    • Decarbonization and development needs
Thank you for your time

Chris Bataille
cbataill@gmail.com

Questions/Comments?
How we modified CIMS and RGEEM

- Algorithm: Efficiency, decarbonization of energy carriers, energy carrier switching & direct emissions control
- CIMS (Behaviourally realistic tech sim and stock turnover)
  - CCS for all big process heat
  - Advanced oil sands techs
  - Reduced battery and solar costs, grid flexibility costing
  - Grid level solid oxide fuel cells with 99% CCS
- RGEEM (Recursive dynamic putty-clay CGE)
  - Alternative production functions to allow “jumps” between capital and energy mixes & to CCS (a la Paltsev & SueWing)
  - Expanded elasticities at key technological junctures (K for E, between E_i).
## Incremental investment required: Canada

<table>
<thead>
<tr>
<th></th>
<th>2000-13 annual inv. CANSIM 31-0002</th>
<th>Capital investment</th>
<th>Energy</th>
<th>Labour</th>
<th>Net</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual incremental investment, 2015-50, $2005 billion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential Homes/Buildings</td>
<td>-0.4</td>
<td>1.6</td>
<td>0.0</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Commercial Buildings</td>
<td>0.6</td>
<td>0.6</td>
<td>0.0</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Personal Transport</td>
<td>-3.6</td>
<td>-0.7</td>
<td>-0.8</td>
<td>-5.1</td>
<td></td>
</tr>
<tr>
<td>Transport &amp; warehousing/(just rail and trucks)</td>
<td>14.2/(3.2)</td>
<td>-0.9</td>
<td>1.1</td>
<td>-2.2</td>
<td>-2.0</td>
</tr>
<tr>
<td>Electricity Generation</td>
<td>13.0</td>
<td><strong>11.2 (+86%)</strong></td>
<td>0.3</td>
<td>0.8</td>
<td>12.3</td>
</tr>
<tr>
<td>Oil, NG &amp; pipelines</td>
<td>41.8</td>
<td><strong>2.4 (+6%)</strong></td>
<td>1.1</td>
<td>0.0</td>
<td>3.5</td>
</tr>
<tr>
<td>All other heavy industry – (elec, O&amp;G)</td>
<td>35.2</td>
<td>0.5 (+1.4%)</td>
<td>1.2</td>
<td>1.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Household expenditure required</td>
<td>-4.0</td>
<td>0.9</td>
<td>-0.8</td>
<td>-3.8</td>
<td></td>
</tr>
<tr>
<td>Private sector investment required</td>
<td>172</td>
<td><strong>13.9 (+8%)</strong></td>
<td>4.1</td>
<td>-0.2</td>
<td>17.8</td>
</tr>
</tbody>
</table>
GDP

- Overall growth is 1.97%/yr vs. 2.27/yr 2015-2050
Results by technology pathway: Canada

- Biofuels & hydrogen in transport: 130 Mt CO₂e
- Expanded electrification*: 171 Mt CO₂e
- Decarb of elec w/ renewables*: 45 Mt CO₂e
- Decarb of elec with CCS or nuclear*: 92 Mt CO₂e
- Ind process heat w/ CCS or elec techs: 164 Mt CO₂e
- Energy efficiency: 108 Mt CO₂e
- Methane controls: 42 Mt CO₂e
- Output adjustment: 31 Mt CO₂e
- Others: 18 Mt CO₂e

Emission Reductions (Mt CO₂e)
Method: CIMS

- Simulates evolution of energy-using capital stock from 2000 to 2050 under reference and policy scenarios
- Regions: BC, AB, SK, MB, ON, PQ, ATL
- Advantages
  - Highly technologically detailed
  - Behaviourally realistic
  - Balances supply and demand for energy
  - Allows mix of tech regulations and pricing
- Limitations
  - Focus on energy consuming and producing sectors
  - Partial equilibrium
Method: GEEM

- Dynamic recursive general equilibrium
- Based on 2002 IO tables, labour force and productivity grown out so provincial GDP forecasts match NRCan CEO 2011 and NEB 2011 for oil and gas
- Regions: BC, AB, SK, MB, ON, PQ, ATL, US
- Flexible regional and sectoral aggregation structure
- Key technologies non-extant in the 2002 IO tables added through competitive alternative Leontieff production functions (e.g. CCS)
CIMS, a hybrid energy economy model

• Combines characteristics of top-down economic and bottom-up technology models
• Covers 7 regions & 18 sectors, all energy use, GHGs & CACs
• Simulates the evolution of the energy-using capital stock to 2050 under business as usual and policy:
  ➢ Explicit view of transitional and transformative technologies, explicit capital stock turnover to capture fuel and emissions profile and costs
  ➢ Behaviourally realistic investment and consumption policy responses, not cost-minimizing
  ➢ Balances supply and demand for energy intense goods and services, including trade
Basic CIMS Structure

I. Microeconomic dynamics
II. Energy S&D Equilibrium
III. Goods and Services S&D Equilibrium

CIMS Macro-Economy Module
Option 1# Own price elasticities
Option 2# GEEM Dynamic recursive CGE

Product Prices
Product Demands

Energy Demand Models

Energy Supply Models

Demand
Prices
Energy Demand

- Natural Gas Demand
- Coal Demand
- Crude Oil Demand

Energy Supply

- Natural Gas Supply Model
- Coal Supply Model
- Crude Oil Supply Model

Models

- Residential Model
- Commercial Model
- Industrial Models
- Transport Models

Regions

- Region X
- Region Y
- Region Z

Chemical Production
- Industrial Minerals
- Iron and Steel
- Metal Smelting
- Mining
- Other
- Manufacturing
- Pulp and Paper

Cogeneration of electricity =

Energy prices
## Transport model

### Transportation Demand

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost</th>
<th>Fuel Type</th>
<th>Fuel Consumption</th>
<th>Direct CO2 Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>$25,511</td>
<td>85/15 Eth/Gas</td>
<td>0.0034 GJ/km</td>
<td>0.049 kg/km</td>
</tr>
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<tr>
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### Diagram

- **Passenger Vehicle (vkt)**
  - Car
    - Old Car
    - Recent Car
    - New Car
  - Truck
    - Old Truck
    - New Truck
- **Public Transit**
  - Public Transit Bus
  - Rapid Transit
- **US**
  - US Light/Medium Diesel
  - US Heavy Diesel
- **Domestic Heavy Diesel**
Basic General Equilibrium Structure
Why CIMS?

- Many current energy policy issues have the dual requirement of physical and economic realism
  - Energy efficiency, climate change, and CAC emissions policy analysis require detailed engineering knowledge of the capital stock in use under both the business as usual and policy futures
  - Also, stronger policies have the potential to engender direct demand and wider macroeconomic effects

- CIMS was designed to incorporate three key policy analysis capabilities in one package:
  - Technological explicitness (vintage model) to capture the fuel and emissions profile
  - Behavioural realistic technology choice
  - Supply and demand equilibrium feedbacks
Transport model

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</table>
Technology Vintage Model

1. Retire old stock (age-dependant)
2. Assess demand (exogenous forecast plus macroeconomic adjustments)
3. Assess the gap between supply and demand
4. Retrofit existing stock (behaviour algorithm)
5. Purchase new stock (behaviour algorithm)
New Stock Purchase and Retrofit Algorithm

• Technologies compete on the basis of life cycle cost
• Focus is on realistic representation of the real world
• Algorithm is simulation, not optimization - limited foresight about future technologies, policies, and prices
• Algorithm is probabilistic - not “winner-take-all”
New Stock Purchase and Retrofit

Three key parameters:

- **Discount rate** \( (r) \) - *time preference, option value, risk premium*

- **Intangible cost** \( (i) \) - *costs and benefits additional to simple financial costs*

- **Market heterogeneity** \( (v) \) - *different consumers and businesses have different preferences, etc.*

\[
MS_j = \frac{CC_j \cdot CRF_j + OC_j + EC_j + i_j}{\sum (CC_k \cdot CRF_k + OC_k + EC_k + i_k)}^v
\]

\[
CRF_j = \frac{r}{1 - (1 + r)^{-n_j}}
\]
Basic CIMS Structure

I. Microeconomic
   - Energy Demand Models
II. Partial Equilibrium
   - Demands
   - Prices
III. Macroeconomic
   - Product Prices
   - Product Demands

CIMS Macro-Economy Module

Energy Demand Models
Energy Supply Models
Estimation of Microeconomic Parameters

• In the past we used expert judgement and literature estimates to set parameter values.
• For several years we have been moving to a model where we use stated and revealed choice surveys to calculate the parameters for key technology competitions, such that they reflect real choices so that policy simulations provide realistic and accurate results.
Technology and Preference Dynamics

- “Learning by doing” – A declining capital cost function that simulates changes in technology cost over time. Parameters estimated from literature.
- “The neighbourhood effect” – A declining intangible cost function that simulates preference change over time. Estimated from our own empirical studies.
II. Partial Equilibrium (Energy Supply and Demand)
Energy supply & demand equilibrium

• All volumes driven by domestic demand plus net exports
• Pricing driven by changes in the average or marginal cost of production
• Full endogenous pricing for electricity and RPP
• Supply curve pricing available for NG, coal and crude oil.
• Electricity, NG and crude oil trade adjusted by Armington elasticities
Energy supply/demand equilibrium

Province X
- Transport Model
- Commercial Model
- Residential Model
- Industrial Models

Province Y

Province Z

NG Supply Models
- NG Supply Models
- Coal Supply Models
- Crude Oil Supply Models

Energy supply/demand equilibrium

Changed Energy Prices
III. Goods and services supply and demand equilibrium in CIMS
Goods and Services Supply and Demand Equilibrium

- Most intermediate good substitution included in the sub-models
- Traded goods (Industry) - Armington substitution elasticities used to provide a blended own price response for domestic and foreign demand
- Non-traded goods (Residential, Commercial / Institutional and Freight Transportation) – Driven by changes in value-added in the traded sector using an econometrically estimated relationship
- Personal Transportation – Driven by personal kilometres travelled (pkt) elasticities
Basic General Equilibrium Structure

Households

Firms

Factors

Goods

Exports

Imports

Armington

Welfare

Government

Goods

Import Tax

Sales Tax

Foreign Exchange

Transfers

Goods

Exports

Firms

Goods

Factors

Households

Production Tax

Direct Tax

Leisure

Basic General Equilibrium Structure
The use of CIMS & RGEEM for 40-90% GHG reduction analysis
The fundamental challenge of CP in Canada:

• While the federal government is responsible for international treaty making ...

• Canada’s constitution assigns control of natural resources to the provinces, unless they cross borders or there is a national interest the federal government wishes to press

• The regional cost curves are wildly different

• The implementation costs of an equimarginal policy are concentrated in Alberta, Saskatchewan and to a lesser extent Ontario and the Atlantic provinces, i.e. thermally powered regions with heavy industry
Sector Cost Curves

GHG Price ($/tonne) vs GHG Reductions (Mt) for various sectors:
- Residential
- Commercial
- Transportation
- Industry
- Electricity

Kyoto CA GHG Price is indicated by a horizontal line at approximately $150 per tonne of GHG.
“Other” consists of Pet. Refining, Chemical Prod., Mining, Smelting, Iron and Steel and Industrial Minerals
The upshot: The “policy laboratory”

<table>
<thead>
<tr>
<th>Sector</th>
<th>Federal Policies</th>
<th>Provincial Policies</th>
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<tbody>
<tr>
<td>Multi-Sector</td>
<td></td>
<td>British Columbia Carbon Tax</td>
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<td></td>
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<td>Alberta (current) Specified Gas Emitters Regulation</td>
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<td>Alberta (announced) C-tax+ OBA C&amp;T+ methane regs</td>
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<td>Québec WCI – upstream C&amp;T</td>
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<td>Ontario (announced ) upstream C&amp;T</td>
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<tr>
<td>Buildings</td>
<td>Strengthened efficiency standards</td>
<td>Various building and appliance codes</td>
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<tr>
<td>Transport</td>
<td>Passenger Emissions Regulations</td>
<td>Generally equal to or less stringent than federal policies</td>
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<td>Heavy Duty Vehicle Emission Standards</td>
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<td>Renewable Fuels Content Regulation</td>
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<tr>
<td>Industry</td>
<td><strong>Missing</strong></td>
<td>See multi-sector above</td>
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<tr>
<td>Oil and Gas</td>
<td>-45% methane regs just announced</td>
<td>Alberta 100 Mt oil sands cap</td>
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<td>Electricity</td>
<td>New coal ban, sets standard at NGCCGT</td>
<td>British Columbia Clean Energy Act</td>
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<td>Alberta (announced) 30% wind goal, coal phase out</td>
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<td>Various CCS projects in Alberta and Saskatchewan</td>
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<td>Ontario Coal Phase-Out and Feed-In-Tariff</td>
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<td>NB &amp; NS Renewable Portfolio Standards</td>
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<td>Nova Scotia Cap on Electricity Sector Emissions</td>
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<td>Landfill gas</td>
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<td>Varying levels of regulation by province</td>
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