Canada's Energy Transition and the Role of Computational Consequence Mapping: An Analysis Using the AMuN Decision Intelligence Framework

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Abstract—Canada faces a multi-dimensional energy crisis characterized by fragmented provincial grid infrastructure, severe energy poverty in remote and Indigenous communities, rapidly escalating data centre electricity and water demand, a contested interprovincial energy corridor, and the compounding pressures of decarbonization commitments and workforce transition. These are not independent problems. They are interconnected through second and third-order causal chains that conventional energy policy analysis tools struggle to make visible. This paper presents an analysis of Canada's energy crisis across five dimensions and argues that computational consequence mapping, as implemented in PTH Meridian's AMuN platform, represents a critical missing layer of decision-support infrastructure for energy policy. AMuN's architecture, its five live scenarios, its human-AI assessment structure, and its ethical design constraints are described in detail. The cross-platform integration of energy analysis with PTH Meridian's security, health, and AI ethics frameworks is examined, demonstrating that energy infrastructure is simultaneously a cybersecurity problem, a public health determinant, and a human rights and reconciliation challenge. The paper concludes that transparent, open-source consequence mapping is a prerequisite for democratic legitimacy in energy transition decision-making.

Index Terms—energy transition, consequence mapping, Canadian energy policy, grid fragmentation, Indigenous energy sovereignty, data centre energy demand, interprovincial energy corridor, decision science, computational policy analysis, energy poverty, AMuN, open-source, energy security, workforce transition.

I. Introduction

Canada is simultaneously one of the world's largest energy producers and the site of some of the developed world's most acute energy crises. The country generates approximately 1,700 TWh of electricity annually [1]. Its hydroelectric capacity alone would rank among the largest in the world if considered independently. And yet: more than 200 remote First Nations communities pay rates three to five times the national average for diesel-generated electricity [12][13]. Provincial grids are almost entirely disconnected from one another, preventing the sharing of clean hydro surplus with fossil-dependent provinces [1]. Alberta's grid remains among the most carbon-intensive in the country while facing the fastest-growing data centre electricity demand in Canada [10]. And the national commitment to net-zero by 2050 [18] implies a workforce transition of a scale and speed that existing policy infrastructure has not adequately planned for.

These challenges share a common feature: their consequences extend far beyond the energy sector. Diesel dependency is a health crisis. Grid fragmentation is a sovereignty failure. Data centre water demand in a water-stressed province is an agricultural conflict. The workforce transition is the lived experience of the AI ethics challenge. None of these consequences are fully visible in energy policy models currently driving decisions about them.

This paper argues that computational consequence mapping — the systematic tracing of first, second, and third-order consequences across interconnected systems — is the missing analytical layer in Canadian energy governance. PTH Meridian's AMuN platform is designed to provide this layer: not to prescribe outcomes, but to make the consequences of decisions visible to the public, decision-makers, and affected communities.

II. Canada's Energy Landscape

A. Grid Fragmentation

Canada's electricity system is not a national grid. It is thirteen provincial and territorial grids operating substantially independently under provincial constitutional jurisdiction. Interprovincial electricity trade accounts for only approximately 10% of total generation [1]. Fig. 1 illustrates the consequence: Quebec and Manitoba generate over 95% of electricity from hydropower with substantial surplus, while Alberta generates approximately 58% from natural gas and 9% from coal. The opportunity cost of grid disconnection — clean electricity that could flow west rather than burning natural gas — is measured in megatonnes of avoidable annual emissions [1][2].

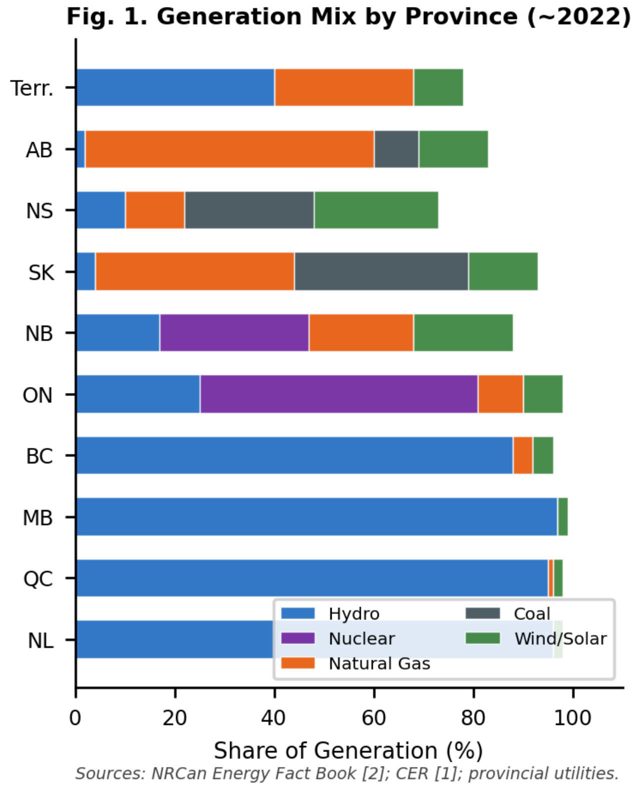


Fig. 1. Generation Mix by Province (~2022)

Sources: NRCan Energy Fact Book [2]; CER [1]; provincial utilities.

Fig. 1. Generation mix by province (~2022). Hydro-dominant provinces (QC, MB, BC, NL) contrast sharply with fossil-dependent grids (AB, SK), illustrating the opportunity cost of interprovincial disconnection. Sources: NRCan [2]; CER [1].

B. Decarbonization Commitments

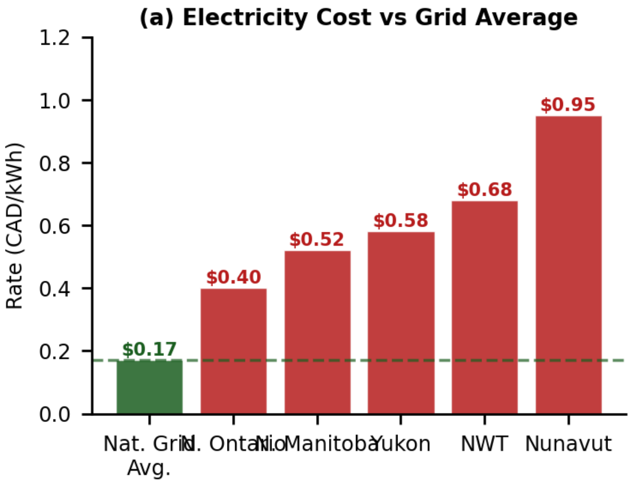
Canada's 2030 Emissions Reduction Plan [18] commits to a 40–45% reduction below 2005 levels by 2030 and net-zero by 2050, with electricity sector net-zero targeted by 2035. The IEA Canada Energy Policy Review [4] notes that while per-capita clean electricity generation is among the highest globally, total per-capita emissions are among the highest in the OECD, driven by oil sands, transport, and building heating. The IPCC Sixth Assessment Report [19] establishes that limiting warming to 1.5°C requires rapid phase-out of unabated fossil electricity by the mid-2030s — an existential economic challenge for Alberta and Saskatchewan that consequence mapping must take seriously.

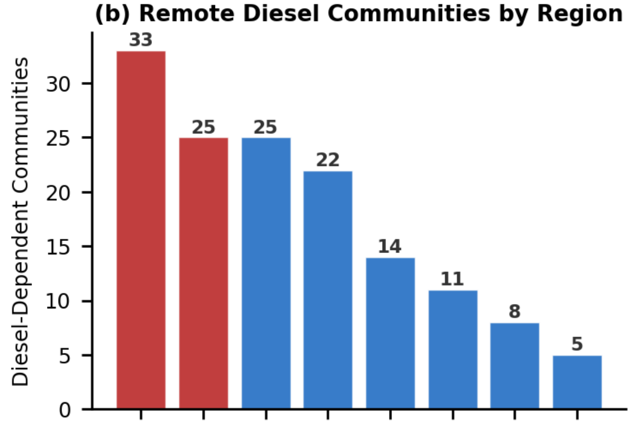
III. Indigenous Energy Sovereignty

Of Canada's energy challenges, the most acute in human terms is the situation of remote First Nations, Métis, and Inuit communities dependent on diesel generators. Natural Resources Canada estimates over 200 such communities across the country [12], concentrated in Northern Ontario, Manitoba, Quebec, and the territories. Characteristics are consistent: electricity rates three to five times the national average, volatile fuel costs that reduce resources for health and education, significant GHG emissions, air quality impacts, and complete energy insecurity during supply disruptions [13][14].

Fig. 2 illustrates the cost disparity and community distribution. In Nunavut, rates in some communities approach $1.00/kWh — approximately six times the Ontario grid average even after territorial subsidy programs [13]. The federal Off-Diesel Initiative [12] targets elimination of diesel dependency by 2030 but faces substantial technical and governance challenges in geographically remote settings.

Fig. 2. Remote Community Energy Poverty


(a) Electricity Cost vs Grid Average


(b) Remote Diesel Communities by Region

Sources: NRCan Off-Diesel Initiative [12];
Indigenous Services Canada [13]; Pembina Institute [14].

Fig. 2. (a) Retail electricity rates in remote communities vs national average. (b) Diesel-dependent communities by region. Sources: NRCan [12]; Indigenous Services Canada [13]; Pembina Institute [14].

The energy sovereignty dimension extends beyond cost. The FNIGC [15] documents that First Nations communities consistently identify energy self-determination as integral to broader self-determination goals. AMuN Scenario 3 — "Indigenous Remote Energy Sovereignty" — maps the consequence chains of both continued diesel dependency and accelerated microgrid transition, framed within Canada's reconciliation obligations under UNDRIP [20].

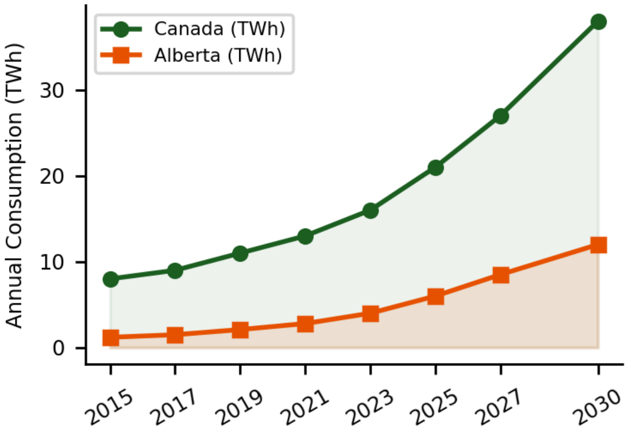
IV. Data Centres, Energy, and Water

A. Demand Growth

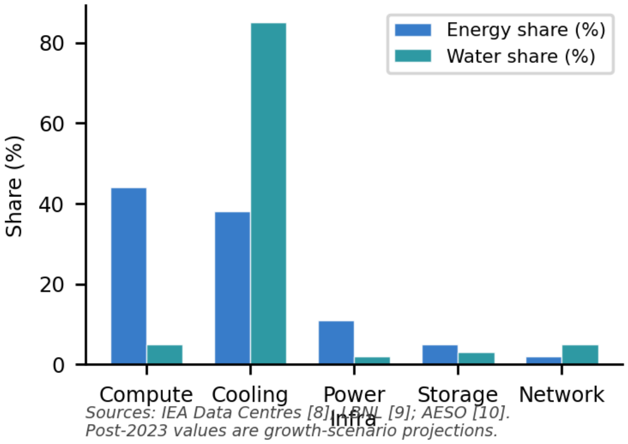
Data centres are the fastest-growing electricity consumers in Canada. The IEA projects global data centre consumption exceeding 620 TWh annually by 2030 [8]. In Canada, consumption of approximately 16 TWh in 2023 is projected to reach 38 TWh by 2030 under high-growth scenarios [8][10]. Alberta has actively positioned itself as a preferred jurisdiction, with multiple large-scale interconnection applications pending at AESO [10]. Fig. 3 illustrates demand growth trajectories and the disproportionate share of cooling systems in water consumption.

Fig. 3. Data Centre Energy and Water Demand

(a) Data Centre Electricity Growth



(b) Resource Use by Component



Sources: IEA Data Centres [8]; LBNL [9]; AESO [10].
Post-2023 values are growth-scenario projections.

Fig. 3. (a) Data centre electricity demand: Canada and Alberta projections to 2030. (b) Energy and water consumption share by component, showing cooling's dominant water footprint. Sources: IEA [8]; LBNL [9]; AESO [10].

B. The Water Dimension

Cooling systems for large-scale data centres consume two to five litres of water per kilowatt-hour processed [8]. A 500 MW hyperscale cluster at 80% capacity factor consumes approximately 3.5–7 billion litres annually. In Alberta, where the North Saskatchewan River basin faces documented water stress from agricultural, municipal, and industrial demands [22], this represents a non-trivial compounding stress. DeepMind's demonstration that AI-driven cooling optimization reduces energy use by ~40% [11] does not proportionally reduce water use, as evaporative cooling efficiency is governed by different system parameters. The multi-variable tradeoffs of energy, water, carbon, land use, and community impact require exactly the consequence analysis AMuN provides.

C. AMuN Scenario 1 — Alberta Data Centres

AMuN Scenario 1 maps the consequence chains of large-scale data centre development in Alberta, tracing effects across grid stress, rate impacts, water table, agricultural conflict, workforce transition, ICS cybersecurity exposure, and carbon trajectory. Fig. 4 illustrates the consequence tree architecture, demonstrating how a single policy decision propagates through interconnected systems to produce third-order consequences including energy cost poverty, Indigenous water rights legal challenges, and net-zero target delay.


AMuN: Alberta Data Centre — Consequence Tree
(Scenario 1 · Likelihood shown as ranges, not point estimates)

Sources: AESO [10]; CER [1]; NRCan [2]. AMuN ranges are qualitative judgments (e.g., 45–65%), never specific percentages. Human and AI assessments shown separately in the live AMuN tool.

Fig. 4. AMuN consequence tree for Alberta data centre scenario (Scenario 1). Likelihood shown as ranges only — never point estimates. Human and AI assessments presented separately in the live AMuN tool. Sources: AESO [10]; CER [1]; NRCan [2].

V. The Interprovincial Energy Corridor

AMuN Scenario 2 addresses the most consequential infrastructure decision facing Canada in the energy transition: a national east-west electricity transmission corridor connecting Quebec and Labrador's hydro surplus with fossil-dependent grids in Ontario, Saskatchewan, and Alberta. The barriers are not primarily technical. HVDC transmission technology for the distances involved is commercially mature [4]. The barriers are constitutional, political, and economic: provincial reluctance to depend on externally controlled electricity; revenue guarantee disputes; and UNDRIP [20] consultation requirements for Indigenous communities along proposed routes.

The IEA Canada Energy Policy Review [4] identifies interprovincial grid integration as the single highest-leverage infrastructure investment for Canadian decarbonization. Clean Energy Canada [6] estimates a fully integrated national grid could reduce electricity system costs by $5–10 billion annually by 2035 through avoided fossil generation and optimized renewable dispatch. AMuN maps both opportunity and risk consequences of corridor construction, including equity dimensions of route selection, revenue distribution, and provincial energy sovereignty implications.

VI. The Energy-Health Nexus

The relationship between energy access and health outcomes is well-established and is a primary design consideration for PTH Meridian's Bioinformatics Division. Diesel combustion produces PM2.5, NO■, and volatile organic compounds associated with respiratory disease, cardiovascular disease, and adverse birth outcomes [16][17]. The WHO estimates household and community air pollution causes approximately 3.2 million annual deaths globally [17], with Indigenous communities in high-income countries representing a documented high-exposure subpopulation.

Energy poverty itself is a health determinant. Cold housing is linked to respiratory illness and cardiovascular mortality. Energy price volatility creates food insecurity when community budgets are redirected to energy costs. The GBD study [25] identifies energy poverty as a modifiable risk factor for a broad range of preventable disease outcomes.

HqA, PTH Meridian's disease causation engine, includes environmental energy exposure as a causal inference data layer, allowing energy policy decisions to be modeled for their downstream health consequences. This cross-platform integration between the Energy Division and Bioinformatics Division is a deliberate architectural choice.

VII. Energy Infrastructure and Cybersecurity

Canada's energy infrastructure relies on ICS/SCADA systems classified by NIST SP 800-82 [23] as among the most security-critical in national infrastructure. Dragos's annual ICS/OT review [24] consistently identifies the energy sector as the primary target of state-sponsored and criminal threat actors targeting operational technology. Data centre expansion in Alberta creates a specific compounding risk: each new hyperscale facility is itself critical infrastructure dependent on grid reliability, while simultaneously expanding the AESO grid's attack surface at interconnection points.

PTH Meridian's AKR cryptographic infrastructure — implementing post-quantum key encapsulation (ML-KEM, FIPS 203), digital signatures (ML-DSA, FIPS 204), and zero-knowledge proof-based identity verification — is directly applicable to the authentication and secure channel requirements of next-generation grid management. The "harvest now, decrypt later" quantum threat is particularly acute for energy infrastructure data whose operational sensitivity may extend decades into the quantum transition horizon.

VIII. AMuN: Consequence Mapping Framework

A. Design Philosophy

AMuN is a consequence mapping platform, not a prediction engine. It does not forecast what will happen. It maps what could happen — surfacing consequence chains of policy decisions across interconnected systems, presenting human and AI likelihood range assessments, and making those assessments visible to any member of the public, not only technical experts or policy insiders. The theoretical foundation draws on scenario planning methodology [26][27] and structural causal modeling [28].

B. Human-AI Dual Assessment

AMuN explicitly separates human expert and AI-generated likelihood assessments for each consequence node. This dual-assessment structure prevents over-reliance on AI estimates where human domain knowledge is superior, allows identification of systematic divergences between human and AI judgment, and maintains the principle that consequential decisions remain under human authority rather than algorithmic determination.

C. The Range-Only Constraint

All AMuN likelihood estimates are expressed as ranges only (e.g., 45–65%), never as specific point probabilities. Policy consequence chains in complex socio-technical systems are not amenable to actuarial precision. A specific probability creates false confidence and invites misuse of the analysis as a decision mandate rather than a decision support tool. This constraint is hardwired in three locations across the AMuN interface — an architectural requirement, not a preference.

D. Five Live Scenarios

AMuN currently presents five live scenarios spanning Canadian and global contexts. Three directly address energy: Scenario 1 (Alberta Data Centres, Energy and Water), Scenario 2 (Canada Interprovincial Energy Corridor), and Scenario 3 (Indigenous Remote Energy Sovereignty). Scenario 4 (Global Data Centre Sustainability) extends the data centre analysis to a global frame. Scenario 5 (Antimicrobial Resistance) connects the energy-health nexus to AMR surveillance, noting that energy access is a prerequisite for the cold-chain integrity required for antibiotic and vaccine distribution in remote communities.

IX. Workforce Transition and Human Ethics

Alberta's oil sands sector employs approximately 150,000 workers directly [2]. The IEA's Net Zero roadmap [7] is explicit that a credible decarbonization pathway requires no new oil and gas field development beyond committed projects as of 2021. The gap between this trajectory and Alberta's workforce reality is a defining Canadian political tension.

PTH Meridian's AI Ethics framework — published as "Work Together to Keep Everyone Working" — applies directly here. The energy workforce transition is precisely the technology-driven labor displacement the framework addresses: gains accruing broadly (global emissions reductions) while costs concentrate locally (Alberta communities whose economic identity is bound to fossil fuel extraction). AMuN's consequence mapping quantifies the workforce displacement timelines, retraining requirements, and income continuity gaps associated with specific decarbonization scenarios — making these consequences visible in the policy discussion rather than treating them as externalities.

X. Cross-Platform Integration

The energy crisis is simultaneously: a cybersecurity problem (grid ICS vulnerability, post-quantum cryptographic readiness); a public health problem (diesel combustion, energy poverty, AMR cold-chain dependency); an AI ethics problem (workforce transition, data centre carbon footprint, algorithmic transparency); and a decision science problem (consequence mapping of interconnected choices across sectors and decades). PTH Meridian's platform addresses all four layers: Security Division (AKR), Bioinformatics Division (HqA/MNTU), AI Ethics (Human by Design), and Decision Science (AMuN). Each division extends the others. The platform is the integration.

XI. Ethical Framework

AMuN's consequence maps are analytical tools for public transparency, not financial, legal, or policy advice. This disclaimer is hardwired in three interface locations and all associated documentation. All scenario data is sourced from publicly available primary sources: Statistics Canada, NRCan, CER, WHO, IEA, and Hydro-Québec. All sources are cited within the interface. The methodology is published openly. AMuN does not advocate for specific energy policy outcomes — it maps consequences on all branches of the decision tree, enabling deliberation between competing perspectives by making their consequence chains mutually visible.

XII. Conclusion

Canada's energy crisis is five interlocking problems: grid fragmentation, Indigenous energy poverty, data centre resource demand, interprovincial corridor politics, and workforce transition. Each propagates consequences into public health, cybersecurity, reconciliation, and the ethics of technological change. AMuN provides an open-source, publicly accessible, transparency-first consequence mapping layer designed to fill this analytical gap. Its range-only constraint, dual human-AI assessment structure, and policy-neutral framing reflect a design philosophy grounded in epistemic honesty and democratic accountability. All AMuN scenarios are published at pth-meridian.io/decisions.

Glossary of Terms

AESO

Alberta Electric System Operator: manages Alberta's interconnected electricity system [10].

AMuN

Applied Mindshift Universal Navigator: PTH Meridian's consequence mapping platform. Publishes likelihood ranges (not point estimates) and separates human from AI assessments.

CER

Canada Energy Regulator: federal body regulating interprovincial pipelines, power lines, and energy trade [1].

Consequence Mapping

A decision analysis technique tracing first, second, and third-order effects of policy decisions across interconnected systems, derived from scenario planning [26] and causal modeling [28].

Diesel Dependency

Condition of remote communities lacking grid connection that rely on diesel generators, characterized by high costs, emissions, and energy insecurity [12][13].

HVDC

High-Voltage Direct Current: commercially mature transmission technology for long-distance electricity transport [4].

ICS/SCADA

Industrial Control Systems and Supervisory Control and Data Acquisition: operational technology managing energy infrastructure [23].

Interprovincial Energy Corridor

Proposed east-west electricity transmission network connecting provincial grids to enable trade of hydro surplus with fossil-dependent provinces [1][4].

Microgrid

Localized energy system combining renewables, storage, and backup generation, applicable to remote community energy sovereignty [14].

NRCan

Natural Resources Canada: federal department responsible for energy statistics and the Energy Fact Book [2].

UNDRIP

United Nations Declaration on the Rights of Indigenous Peoples: international framework establishing Indigenous rights to self-determination, including control over lands, territories, and resources [20].

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