# FIDER: A DEREGULATION TOOLKIT FOR SMALL-MARKET ELECTRICITY SYSTEMS: NOVA SCOTIA AS A CASE STUDY

By

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# Table of Contents

# LIST OF TABLES

# LIST OF FIGURES

# ABSTRACT

This thesis presents a practical framework, termed the FIDER Toolkit, for guiding the deregulation of electricity markets in small jurisdictions, using Nova Scotia as a case study. Drawing on global best practices from Ireland, New Zealand, and Singapore, the toolkit identifies five core components essential for successful market reform: Demand-Side Management (DSM), Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. Each component is supported by measurable indicators and actionable strategies. The research applies the toolkit to Nova Scotia's electricity market, highlighting its structural limitations under a regulated monopoly and evaluating pathways to a competitive, transparent, and resilient energy system through the establishment of an Independent System Operator (ISO). The findings offer tailored recommendations to support Nova Scotia's transition and provide a scalable model for similar small-market jurisdictions undergoing energy reform.

# LIST OF ABBREVIATIONS AND SYMBOLS USED

| | |
|---|---|
| CPP | Critical Peak Pricing |
| CRU | Commission for Regulation of Utilities |
| DSM | Demand Side Management |
| EA | Electricity Authority |
| ECNZ | Electricity Corporation of New Zealand |
| EMA | Energy Market Authority |
| ESB | Electricity Supply Board |
| EV | Electric Vehicles |
| FIDER | Framework for ISO Development and Energy Reforms |
| HHI | Herfindahl-Hirschman Index |
| IPP | Independent Power Producers |
| ISEM | Integrated Single Electricity Market |
| ISO | Independent System Operator |
| MBIE | Ministry of Business, Innovation & Employment |
| NEMS | National Electricity Market of Singapore |
| NERC | North American Electric Reliability Corporation |
| NSIESO | Nova Scotia Independent Energy System Operator |
| NSP | Nova Scotia Power |
| PSO | Power System Operator |
| RTO | Regional Transmission Operator |
| RTP | Real-Time Pricing |
| SEMO | Single Electricity Market Operator |
| SO | System Operator |
| SPA | Singapore Power Authority |
| TOD | Time of Day |
| TOU | Time of Use |

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# 1 INTRODUCTION

In recent decades, several jurisdictions worldwide, both large and small, have transitioned to Independent System Operator (ISOs) to facilitate the operation of competitive electricity markets and ensure open access to transmission networks. The shift to ISOs is part of broader energy market reforms aimed at increasing transparency, improving efficiency, and integrating renewable energy (Hogan, 1998). However, smaller jurisdictions often face unique challenges such as limited market liquidity, high operational costs, and difficulty in achieving economies of scale (Oxford Energy, 2019). These challenges must be addressed when designing an ISO for a region like Nova Scotia.

Nova Scotia's electricity market is predominantly regulated and centralized, with limited competition and a single, dominant utility Nova Scotia Power. This design has led to challenges such as high consumer electricity prices, limited integration of renewable energy sources, and a lack of transparency (NSP, 2024; CETF, 2024). The province now aims to transition toward a more open, competitive market structure that enables diverse energy producers to contribute, particularly in renewable energy. This transition involves establishing the Nova Scotia Independent Energy System Operator (NSIESO), facilitating grid independence and open access for Independent Power Producers (IPP). The approach will focus on developing regulatory frameworks, enhancing market liquidity, and fostering system flexibility. This strategic shift not only seeks to improve market efficiency and reduce energy costs but also aligns with Nova Scotia's commitment to a sustainable, resilient energy future (NSP, 2024e).

A notable development in Nova Scotia is Bill 404, which proposes the creation of an ISO for the province (NS Legislature, 2024). This legislative effort is based on the recommendations of the Clean Energy Solutions Task Force, a key body responsible for identifying the structural reforms needed to transition Nova Scotia's energy sector (CETF, 2024). The Task Force highlighted the necessity of establishing an IESO to tackle issues such as limited competition, high electricity prices, and the dominance of a single player, Nova Scotia Power. Their recommendations, reflected in Bill 404, provide a structured framework to ensure transparency, foster competition, and address the province's unique energy challenges, including the integration of renewable energy sources.

The NSIESO is crucial for addressing key issues in the province's electricity market. The current system, operated by Nova Scotia Power, creates conflicts between NSPI's corporate interests and the public's need for transparent, unbiased decisions (CETF, 2024). An independent NSIESO would ensure impartial management of the grid, fostering competition by allowing more IPPs to participate in energy generation (CETF, 2024). It would also enhance system flexibility, enabling quicker adjustments to integrate renewable energy sources and respond to future energy demands without requiring government intervention.

Across the globe, ISOs and Regional Transmission Operator (RTOs) have become essential in managing and optimizing electricity markets. ISOs are independent entities that operate within specific jurisdictions, handling everything from grid reliability to market operations, while ensuring fair, non-discriminatory access to transmission networks for multiple energy producers (FERC, 2024). This structure is crucial in preventing monopolistic practices by the transmission owner and allows for a more competitive energy market. RTOs, typically larger in scale, manage grid operations across multiple jurisdictions, balancing energy supply and demand over large, interconnected grids that span states, provinces, or countries (FERC, 2024). This cross-regional coordination is particularly valuable in regions with diverse energy sources and demand patterns, as it allows for a more resilient and efficient electricity system. Both ISOs and RTOs represent a significant departure from traditional, centralized control, offering a framework that supports competitive markets, renewable energy integration, and grid reliability on a larger scale (CMU, 2009).

The importance of ISOs and RTOs in modern energy systems cannot be overstated, given their contributions to both market and grid performance (IRC, 2024) . ISOs and RTOs create an open environment where IPPs and utilities compete on equal footing, fostering innovation and a diverse energy mix that can drive down costs and improve reliability (Mesa Solution, 2023). They are particularly beneficial for regions aiming to integrate renewable energy, as they provide the operational flexibility needed to accommodate intermittent energy sources like wind and solar. RTOs, for instance, can leverage their cross-regional capabilities to balance renewable energy flows across multiple jurisdictions, allowing for a more stable grid and minimizing the risk of blackouts or energy shortages (Best Practise Energy, 2020). Both models reduce dependency on government intervention for grid adjustments, giving energy markets the tools to respond dynamically to fluctuations in demand and supply. This adaptability is especially vital as energy systems undergo the ongoing transition to cleaner, more sustainable sources.

To support this transition, the thesis introduces FIDER, Framework for ISO Development and Energy Reforms, a structured approach tailored for small jurisdictions. FIDER is built around five key pillars: Demand-Side Management, Market Access and Liquidity, Renewable Integration, Energy Security and Diversification, and ISO Governance and Independence. Each component reflects critical lessons from international case studies and addresses the specific limitations and opportunities within Nova Scotia's electricity system. The toolkit not only outlines foundational requirements but also provides actionable strategies to ensure a successful transition to a transparent, competitive, and resilient electricity market.

This thesis provides a structured roadmap aimed at guiding Nova Scotia's transition to an IESO-led electricity market. The toolkit developed in this research can be applied to any smaller jurisdiction intending to establish a deregulated electricity market. The toolkit will lay out the foundational requirements necessary for establishing an effective IESO, covering critical elements such as legal and regulatory frameworks, governance structures, and technical design principles. The central objective of this roadmap is to facilitate Nova Scotia's movement toward a more transparent, competitive, and resilient electricity market, which balances consumer protection with the need for sustainable energy solutions.

The first chapter of the thesis will involve an analysis of best practices from relatively smaller jurisdictions worldwide that have successfully transitioned to an ISO. This section will draw on case studies from smaller markets, including Ireland, New Zealand, and Singapore, which have each navigated unique regulatory, operational, and technical challenges in creating ISOs or similar independent entities. By closely examining these case studies, this part of the thesis will identify the governance and regulatory structures that allowed these regions to establish ISOs that promote market efficiency, energy security, and renewable energy integration. For example, the case of Ireland's Single Electricity Market, where two jurisdictions coordinate under a single regulatory framework, will provide insights into fostering market liquidity and resilience despite the challenges of scale (SEMO, 2024a). These case studies will highlight transferable strategies and principles, particularly those that ensure non-discriminatory access and operational transparency, which will form the backbone of the proposed toolkit for Nova Scotia.

An essential aspect of the research is a detailed examination of potential challenges and pitfalls that Nova Scotia may encounter in establishing its own IESO. Learning from New Brunswick's experience, where an attempted ISO was ultimately reintegrated under NB Power, this section will consider critical factors that led to this reversal, such as market size limitations, financial pressures, and low competition. This analysis will assess whether these issues might arise in Nova Scotia and, if so, how they might be mitigated. Furthermore, the thesis will investigate the financial sustainability and technical viability of an independent operator in a smaller market like Nova Scotia, where maintaining an ISO without significant market liquidity presents inherent risks. Identifying these risks will enable the thesis to outline specific lessons learned, shaping a toolkit that incorporates strategies for avoiding the conditions that led to New Brunswick's challenges, ultimately providing Nova Scotia with a foundation for a more sustainable model.

The thesis will then propose practical steps and targeted recommendations to guide Nova Scotia's transition toward an IESO. The toolkit will provide a clear roadmap for establishing regulatory and operational independence for the IESO, including legal safeguards to ensure independence from political and corporate influences. Governance structures will be outlined to prevent conflicts of interest and establish transparent market rules that facilitate entry for diverse energy producers, from traditional utilities to renewable energy suppliers. The technical aspects of the toolkit will include suggestions for creating real-time pricing mechanisms and integrating demand-response systems, which will allow Nova Scotia's electricity market to adapt to shifts in supply and demand more dynamically. This section will also address the need for renewable integration strategies, such as grid modernization measures and investment in energy storage technologies, that can support Nova Scotia's environmental goals while maintaining grid reliability.

The thesis introduces FIDER, a Framework for ISO Development and Energy Reforms. FIDER is a structured model designed specifically for small jurisdictions around the world seeking to transition to competitive, ISO-led electricity markets. Each component reflects key lessons from global case studies and addresses the common challenges faced by smaller markets, such as limited competition, market concentration, and renewable integration. After establishing this framework, the thesis applies FIDER to Nova Scotia as a detailed case study. This application illustrates how the toolkit can guide the province's transition by offering tailored, actionable steps to implement an ISO. Through this dual focus, global relevance and local application, the research provides a comprehensive roadmap to support small jurisdictions in building transparent, efficient, and resilient electricity markets. By drawing on international best practices, addressing unique local challenges, and defining clear indicators of success, the research will provide Nova Scotia with a comprehensive strategy to transform its electricity market. This roadmap will not only focus on the transition but also prioritize the long-term sustainability, competitiveness, and consumer benefits of the energy sector in Nova Scotia. Through this approach, the thesis aspires to create a framework that Nova Scotia, and similar jurisdictions, can rely on to foster a transparent, efficient, and resilient energy system.

The following chapters provide a comprehensive, step-by-step guide to achieving Nova Scotia's energy reform goals. The next chapter presents a global perspective of Ireland, Singapore and New Zealand electricity market design, analyzing each country's energy mix, regulatory structure, and the specific factors influencing the design of their ISOs and RTOs. This context highlights diverse approaches and key lessons from other jurisdictions. This is followed by a discussion of the methodology, which identifies recurring patterns and best practices from these case studies and serves as the foundational principles of the toolkit. Tailored specifically to Nova Scotia, the toolkit integrates successful strategies to support establishing an independent energy system. A case study is presented which focuses on the province's current regulatory and market structure, detailing how the toolkit can directly address its unique challenges, including limited competition, market concentration, and renewable integration. Finally, the thesis concludes with a synthesis of the findings and provides clear, actionable recommendations to guide Nova Scotia’s transition. Together, these chapters lay out a structured, evidence-based roadmap, positioning Nova Scotia to establish an efficient, resilient, and transparent electricity market through the effective implementation of an ISO.

# 2 BACKGROUND

Deregulated electricity markets have transformed energy systems worldwide, shifting from monopolistic structures to competitive environments that promote efficiency, transparency, and renewable integration (CEEPR, 2022). In a deregulated market, independent entities operate in various segments, like generation, transmission, and distribution, rather than being managed by a single monopoly/utility. ISOs or similar market structures are central to this shift, as they balance the grid, ensure fair competition, and coordinate energy flows across the system. For smaller markets, however, this transition brings specific challenges. Issues such as limited market liquidity, operational cost, and managing economies of scale make it complex for small jurisdictions to adopt competitive market models seamlessly. This chapter will analyze the electricity markets in three smaller systems Ireland, New Zealand, and Singapore. Each of them faced and addressed unique challenges in implementing deregulated structures.

## 2.1 Ireland's Electricity Market

Ireland's electricity system has undergone significant transformation over the past few decades. Historically, the sector was highly regulated, with the Electricity Supply Board (ESB) being the sole entity responsible for the generation, transmission, and distribution of electricity (ESB, 2024). This system was centralized, and ESB played a key role in managing the entire electricity supply chain. However, following the deregulation reforms initiated in the late 1990s and early 2000s, Ireland's electricity market evolved towards greater competition and liberalization, aimed at fostering a more integrated and competitive electricity market. The result of these reforms led to the creation of the Integrated Single Electricity Market (ISEM), which governs electricity trading not only in the Republic of Ireland but also in Northern Ireland, allowing for cross-border electricity trading and more efficient market operation (CRU, 2024).

The energy mix in Ireland is diverse, with a substantial shift towards renewable sources in recent years. Ireland's electricity market has made significant strides in adopting renewable energy contributing 38.9% of the total electricity generation (SEAI, 2024). Despite the growth of renewables, natural gas still plays a dominant role in electricity generation, accounting for about 50% of the energy mix. Gas-fired power plants offer a flexible and reliable source of power, especially when renewable generation, particularly wind power, is insufficient to meet demand. This reliance on gas makes Ireland susceptible to global gas price fluctuations, adding to the cost of energy. In response, Ireland aims to achieve 80% renewable electricity by 2030, with plans to expand both onshore and offshore wind energy as well as solar power. (Climate Council, 2024)

**Table 1: Final consumption of electricity by sector compared with previous years (SEAI, 2023)**

| Sector | Quantity (TWh) | | | | Share (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2012 | 2018 | 2021 | 2022 | 2012 | 2018 | 2021 | 2022 |
| Services | 9.9 | 12.6 | 13.6 | 14.8 | 40.1% | 45.2% | 45.4% | 48.4% |
| Residential | 8.1 | 8.1 | 8.8 | 8.2 | 32.7% | 29.3% | 29.4% | 26.9% |
| Industry | 6.1 | 6.4 | 6.8 | 6.8 | 24.7% | 23.2% | 22.8% | 22.3% |
| Agriculture | 0.5 | 0.5 | 0.5 | 0.5 | 2.2% | 2.0% | 1.8% | 1.7% |
| Transport | 0.05 | 0.07 | 0.1 | 0.2 | 0.2% | 0.2% | 0.5% | 0.7% |
| Total | 24.8 | 27.8 | 30.0 | 30.7 | 100% | 100% | 100% | 100% |

The table provides an overview of Ireland's electricity consumption by sector from 2012 to 2022, showing both the total quantity in terawatt-hours (TWh) and the percentage share of each sector. Over this period, Ireland's total electricity consumption rose from 24.8 TWh in 2012 to 30.7 TWh in 2022, reflecting a growing electricity demand.

The services sector emerged as the largest consumer, with its usage increasing from 9.9 TWh (40.1%) in 2012 to 14.89 TWh (48.4%) in 2022. This indicates a significant expansion in the sector's electricity usage, driven likely by Ireland's shift towards a more service-oriented economy. In contrast, the residential sector, while showing a small increase in absolute consumption from 8.1 TWh to 8.2 TWh, experienced a decline in its share of total consumption, dropping from 32.7% in 2012 to 26.9% in 2022. This suggests that the growth in residential electricity demand has not kept pace with the overall increase in national consumption.

The industrial sector showed modest growth, with its consumption rising from 6.1 TWh in 2012 to 6.8 TWh in 2022. However, its share of total electricity usage decreased from 24.7% to 22.3%, indicating that other sectors, particularly services, have driven most of the growth in demand. The agriculture sector maintained stable electricity consumption, fluctuating slightly around 0.5-0.5 TWh, but its relative share declined from 2.2% to 1.7%, highlighting its lower contribution to overall growth.

Lastly, the transport sector showed a marked increase in electricity consumption, growing from 0.05 TWh in 2012 to 0.21 TWh in 2022. Its share of total consumption also rose from 0.2% to 0.7%, likely reflecting efforts towards electrification in the transport industry. Overall, the data points to significant growth in the services sector and an emerging increase in transport electrification, while residential, industrial, and agricultural sectors have seen slower relative growth.

A variety of entities play crucial roles in managing Ireland’s electricity market, ensuring that it operates efficiently, reliably, and sustainably. EirGrid, as the Transmission System

Operator (TSO), is responsible for managing the high-voltage transmission network, balancing supply and demand in real-time, and ensuring the stability of the grid. EirGrid's role has become even more critical as Ireland integrates a higher percentage of renewable energy, which can be intermittent and variable. This integration requires careful management of both generation and consumption to avoid grid instability (EIR Grid, 2024). The Commission for Regulation of Utilities (CRU) oversees the regulatory framework for the electricity sector, ensuring that market participants operate fairly and that consumers are protected. The CRU's responsibilities also extend to promoting market efficiency and ensuring the security of supply, as well as overseeing the transition towards renewable energy sources (CRU, 2024).

Electricity suppliers such as SSE Airtricity, Bord Gáis Energy, and Electric Ireland purchase electricity from the wholesale market and sell it to consumers, handling customer billing, service, and energy efficiency programs (SSE Airtricity, 2024; Bord Gais Energy, 2024; Electric Ireland, 2024). The role of suppliers has evolved as deregulation has allowed for greater market choice for consumers, and many suppliers now offer energy efficiency programs designed to reduce overall consumption, especially during peak periods. Distribution of electricity to end-users is managed by ESB Networks, which is responsible for the low-voltage network that delivers electricity to homes and businesses. As part of this role, ESB Networks ensures the maintenance of infrastructure and connects new customers to the grid (ESB Networks, 2024).

Consumers are also increasingly adopting solar installations, with growing government incentives to promote distributed generation. However, the high price of electricity continues to be a concern, especially during peak periods. In terms of energy security, Ireland remains moderately secure, though it imports a significant portion of its natural gas. The reliance on wind energy and the ongoing development of offshore wind farms will play a critical role in reducing this dependence. Ireland's future energy plans are heavily focused on reducing emissions, with the country committed to a 75% reduction in electricity-related emissions by 2030, aligning with the broader EU climate goals (SEAI, 2024).

Additionally, demand response entities are becoming increasingly important in Ireland's electricity market. These organizations work with both residential and industrial consumers to encourage changes in their electricity usage patterns, often by providing incentives for consumers to reduce or shift their energy consumption during periods of peak demand. These programs help stabilize the grid and reduce the need for additional generation capacity (EIR Grid, 2024).

Overall, the integration of renewable energy, coupled with increased competition and deregulation, has transformed Ireland's electricity sector into a more dynamic, flexible, and sustainable system. The roles of the various entities, including EirGrid, the CRU, ESB Networks, and electricity suppliers, are interconnected and essential in managing a secure and efficient electricity supply. These entities work together to balance the growing demand for electricity with the need for clean energy, helping Ireland meet its climate goals and ensuring that the electricity system operates smoothly and reliably.

## 2.2 New Zealand’s Electricity Market

New Zealand’s electricity market has undergone significant transformation, evolving from a government-controlled system to a liberalized market model, with a strong focus on renewable energy integration. Historically, the electricity sector in New Zealand was centralized, with the government directly managing generation, transmission, and distribution through state-owned entities. During the early 20th century, the country relied primarily on hydroelectric power, which continues to dominate the energy mix today due to New Zealand's abundant water resources (EA, 2024b).

In 1987, the government established the Electricity Corporation of New Zealand (ECNZ) to operate the national electricity system commercially, separating generation from direct government control (ECNZ, 2024). The Electricity Act of 1992 further transformed the sector, allowing private competition in generation and distribution, leading to the establishment of separate generation companies and local network operators. In 1999, ECNZ was split into three main generation companies: Meridian Energy, Genesis Energy, and Mercury Power (formerly known as Mighty River Power), to foster competition in electricity generation (Meridian, 2024; Genesis Energy, 2024; Mercury, 2024).

New Zealand’s market reforms ended up in the establishment of the Electricity Authority (EA) in 2010, an independent regulatory body tasked with overseeing the electricity market to promote competition, reliability, and efficiency (EA, 2024b). The EA introduced market mechanisms, enabling wholesale electricity trading, and allowed consumers to choose among multiple retailers for their electricity needs. Transpower, as the system operator, manages the transmission network, coordinating electricity flow from generators to distribution networks and balancing supply with demand to ensure system stability (Transpower, 2024).

New Zealand’s electricity market stands out due to its heavy reliance on renewable energy, with over 85% of its electricity generated from hydropower and geothermal sources (MBIE, 2024). Hydropower contributes 60% and geothermal 18% to the energy mix. The country aims for 100% renewable electricity by 2030, with growing efforts to incorporate more solar and wind energy into the mix (MBIE, 2024).

**Table 2: Final consumption of electricity by sector compared with previous years (MBIE, 2024)**

| Sector | Quantity (TWh) | | | | | Share (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 | 2019 | 2020 | 2021 | 2022 | 2023 |
| Industrial | 14.8 | 14.0 | 13.7 | 13.5 | 12.9 | 37.3% | 36.1% | 35.2% | 35.2% | 33.5% |
| Residential | 12.6 | 12.8 | 13.2 | 13 | 13.2 | 31.8% | 33.1% | 33.9% | 33.7% | 34.3% |
| Commercial | 9.5 | 9.1 | 9.2 | 9.3 | 9.5 | 24.1% | 23.5% | 23.8% | 24.2% | 24.7% |
| Agriculture, Forestry, and Fishing | 2.5 | 2.6 | 2.6 | 2.4 | 2.5 | 6.4% | 6.9% | 6.6% | 6.3% | 6.6% |
| Transport | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2% | 0.2% | 0.3% | 0.4% | 0.7% |
| Total | 39.7 | 38.8 | 39.0 | 38.5 | 38.5 | 100% | 100% | 100% | 100% | 100% |

In the last five years, New Zealand's energy consumption trends have shown notable shifts across sectors, reflecting changes in societal priorities, economic conditions, and technological adoption. Between 2019 and 2023, residential energy demand consistently increased, peaking at 13,237 GWh in 2023. This rise aligns with greater energy efficiency in households, an uptick in electrification for heating, and increased time spent at home during pandemic-related restrictions.

The transport sector exhibited the most dramatic increase in energy consumption, growing from 108 GWh in 2019 to a substantial 275 GWh in 2023. This surge is likely influenced by the expanding adoption of Electric Vehicles (EVs) and investments in electrified public transportation infrastructure, part of New Zealand's broader decarbonization efforts.

Industrial energy usage, while traditionally dominant, saw a decline over this period, dropping from 14,827 GWh in 2019 to 12,903 GWh in 2023. This reduction may reflect efficiency gains, a shift towards renewable energy processes, and economic changes affecting industrial activity. Commercial energy consumption remained relatively stable, fluctuating slightly but averaging around 9,500 GWh annually.

The management and regulation of New Zealand's electricity system involve several key entities. The Ministry of Business, Innovation & Employment (MBIE) is responsible for overarching energy policy, ensuring that the government's energy objectives align with broader goals like sustainability, security, and affordability (MBIE, 2024). The Electricity Authority, an independent regulator, ensures that the electricity market operates efficiently, with the goal of providing reliable electricity at the lowest sustainable cost for consumers (EA, 2024b). It also monitors electricity market performance, ensuring that it remains competitive and free from manipulation. Transpower plays a critical role as the system operator, managing the transmission network and ensuring that electricity generated at power stations is delivered to homes, businesses, and industries across New Zealand (Transpower, 2024). It also balances supply and demand across the grid, ensuring that the system remains stable. On the generation side, state-owned enterprises such as Meridian Energy and Genesis Energy are key players, responsible for producing a significant portion of New Zealand's electricity, largely from renewable sources

Retailers, such as Contact Energy, then purchase electricity from the wholesale market and sell it to end consumers, offering various pricing plans and services (Contact Energy, 2024). This liberalized market structure is designed to encourage competition and improve efficiency, but it also requires careful coordination and regulation to ensure that all participants adhere to the rules, especially as new market dynamics, such as the growth of EVs, reshape demand patterns.

A key challenge for New Zealand has been the integration of renewable energy, particularly hydro and wind, into its grid while ensuring reliability. The country faces challenges related to variability in hydropower output during dry years, which can strain the system. To mitigate these risks, New Zealand is investing in solar and wind energy, though the penetration of these sources remains relatively low. The government is encouraging distributed generation and residential solar installations and is working to improve energy storage technologies to enhance grid resilience (PV Tech, 2024). New Zealand's solution was to develop robust market mechanisms that provide real-time pricing and demand response capabilities, enabling efficient balancing of supply and demand even in a small market (EA, 2022; Philpott, Read, Batstone, & Miller, 2019). The country's experience shows how a well-designed regulatory framework, combined with advanced market mechanisms, can allow a small jurisdiction to manage grid operations independently.

## 2.3 Singapore's Electricity Market

Singapore's electricity sector has undergone significant transformation since its early days. Initially, the country's electricity market was a vertically integrated monopoly, with the Singapore Power Authority (SPA) responsible for generation, transmission, and distribution (SP, 2024). However, in the late 1990s, Singapore began restructuring its electricity market to introduce competition and improve efficiency, inspired by global trends towards liberalization in the energy sector. This shift was formalized with the establishment of the Energy Market Authority (EMA) in 2001, which led to the creation of a more competitive and market-driven electricity framework (EMA, 2024).

Singapore's electricity market is unique in that it combines a competitive wholesale market with centralized grid management in a highly dense urban area (HEPG, 2009). One of Singapore's main challenges when transitioning to deregulated electricity was managing the transition from a vertically integrated monopoly to a competitive market. The process required significant regulatory oversight to ensure fair competition while maintaining system reliability. Singapore also faced challenges with market liquidity due to its small size, necessitating the import of natural gas. Integrating renewables and balancing the energy mix while ensuring energy security posed further difficulties, especially with limited land and infrastructure for large-scale renewable deployment (Eco-Business, 2011).

Singapore's electricity market is highly dependent on natural gas; in 2022, Singapore imported 145.3 Mtoe of energy products, 2.8% lower than the preceding year. This was primarily due to lower imports of Petroleum Products, especially in the form of Fuel Oil (13.4% decrease). The major share of Singapore's energy imports continued to be in the form of Petroleum Products (58.1 %). Natural Gas imported 10.5 Mtoe in 2022, with the bulk comprising Piped Natural Gas (6.4 Mtoe). The amount of Natural Gas imports decreased by 0.8% in 2022. While the amount of Pipeline Natural Gas imported decreased by 13.0%, the amount of Liquefied Natural Gas increased by 27.0%.

Energy products exports fell by 4.1%, from 75.8 Mtoe in 2021 to 72.7 Mtoe in 2022. This decrease was mainly due to lower Petroleum Products exports (71.7 Mtoe) in 2022. (EMA, 2024). This reliance on imported gas, primarily from Malaysia and Indonesia, offers a relatively cleaner form of fossil fuel but exposes the country to supply risks and geopolitical tensions (CNA, 2023). Despite limited land for renewable energy projects, Singapore is investing in solar power, aiming for 2 GW of solar capacity by 2030, though solar currently makes up only about 1-2% of the energy mix. To diversify further, Singapore is exploring regional electricity imports from neighboring countries, and hydrogen technologies are being developed for future energy needs.

**Table 3: Final consumption of electricity by sector compared with previous years (EMA, 2024e)**

| Sector | Quantity (TWh) | | | | | Share (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2023 | 2019 | 2020 | 2021 | 2022 | 2023 |
| Industrial | 21,464 | 20,979 | 22,293 | 22,694 | 22,103 | 41.4% | 41.3% | 41.6% | 41.3% | 40% |
| Commerce & Services | 19,319 | 18,518 | 19,837 | 21,187 | 22,093 | 37.3% | 36.4% | 37.1% | 38.6% | 40% |
| Transport | 3,019 | 2,809 | 2,845 | 2,900 | 3,030 | 5.8% | 5.5% | 5.3% | 5.2% | 5% |
| Households | 7,681 | 8,245 | 8,278 | 7,911 | 8,003 | 14.8% | 16.2% | 15.4% | 14.4% | 14% |
| Others | 247 | 229 | 231 | 193 | 158 | 0.4% | 0.4% | 0.4% | 0.3% | 0.3% |
| Total | 51,730 | 50,780 | 53,483 | 54,885 | 55,387 | 100% | 100% | 100% | 100% | 100% |

Singapore's electricity consumption profile reflects a diverse set of sectors, each contributing to the overall demand. The industrial sector is the largest consumer, accounting for around 40% of the total electricity consumption in 2023, a share that has remained relatively stable over the past few years. In 2023, it consumed 22.1 TWh, slightly lower than in previous years. This sector includes manufacturing and heavy industries, which are central to Singapore's economy.

The commerce and services sector follows closely, also consuming 40% of the total electricity, with a consumption of 22.1 TWh in 2023. The transport-related sector, while smaller, saw a slight increase in its share, consuming 3 TWh in 2023, or 5% of the total. This sector's consumption has remained relatively stable, with some increase in energy usage linked to EV adoption and transport electrification initiatives. Households accounted for 14% of total electricity consumption in 2023, with 8 TWh, reflecting the energy demands of residential areas. Household consumption fluctuated over the years, with a slight increase in 2020, possibly due to the pandemic-driven changes in work-from-home arrangements.

Lastly, the "Others" category, which includes smaller sectors, accounted for 0.3% of total electricity consumption, amounting to 158 GWh in 2023. This share has decreased over time, reflecting the consolidation and shift of energy usage into other sectors.

Several entities are involved in the management of Singapore’s electricity market. The Energy Market Authority (EMA) is the regulatory body overseeing the energy sector, ensuring reliable and competitive electricity supply (EMA, 2024). SP Group operates the transmission and distribution infrastructure, playing a key role in maintaining the reliability of the electricity grid (SP, 2024). The Singapore Electricity Market is a competitive wholesale market managed by the Singapore Energy Market Company (SEMC), which coordinates electricity generators, retailers, and consumers (EMC, 2024). Private sector players such as Senoko Energy, Tuas Power, and Sembcorp Power are involved in electricity generation and retail, contributing to the market's competitiveness (Senoko Energy, 2024; TUAS Power, 2024; Sembcorp Power, 2024). Through these reforms, Singapore’s electricity market has evolved into a modern, efficient system that balances sustainability, reliability, and competition.

## 2.4 Summary

This chapter explores the transformation of electricity markets in Ireland, New Zealand, and Singapore from regulated, monopolistic systems to competitive, deregulated environments. It highlights the unique challenges faced by each country and the strategies they employed to ensure efficient market operation, renewable energy integration, and system reliability. In Ireland, deregulation shifted the electricity market from the control of the ESB to the Integrated Single Electricity Market (ISEM), fostering cross-border electricity trading with Northern Ireland. Despite a growing share of renewables, natural gas still dominates Ireland’s energy mix, with plans to achieve 80% renewable electricity by 2030. Entities such as EirGrid and the CRU play key roles in grid management and market regulation.

New Zealand's electricity market underwent significant liberalization starting in the late 1980s, transitioning from government control to a competitive market overseen by the Electricity Authority. The country's energy mix is dominated by renewables, with hydropower and geothermal energy accounting for over 85% of electricity generation. New Zealand aims for 100% renewable electricity by 2030, relying on robust market mechanisms like real-time pricing and demand response to maintain grid stability. Transpower manages the transmission network, ensuring the balance of supply and demand across the grid.

Singapore's journey toward deregulation involved transforming its vertically integrated monopoly into a competitive market regulated by the Energy Market Authority (EMA). The city-state's reliance on imported natural gas presents challenges for energy security, but efforts are underway to diversify through solar energy development and regional electricity imports. Despite limited land for large-scale renewables, Singapore is targeting 2 GW of solar capacity by 2030. The Energy Market Company oversees the wholesale market, ensuring efficient operation in Singapore's dense urban environment.

The selection of components, Demand-Side Management, Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance is based on their critical importance in understanding and addressing the challenges faced by deregulated electricity markets and Independent System Operators. These dimensions were chosen through a detailed review of established research and policy frameworks. For instance, insights from FERC Orders 888/889 emphasize the importance of transparent governance structures and fair market access for ISOs to ensure efficiency and stakeholder trust, which directly supports the inclusion of Market Access and Liquidity and ISO Governance as key dimensions (FERC, 2024a). Similarly, the MIT Center for Energy and Environmental Policy Research identifies market liquidity and renewable energy integration as essential to maintaining system reliability and competitiveness in deregulated markets (CEEPR, 2022). The IMF and IEA highlights the criticality of Energy Security and Diversification in reducing dependency on single energy sources and ensuring system resilience (IMF, 2024; IEA, 2024). These foundational studies highlight how these five dimensions address the universal challenges faced by ISOs during transitions to deregulated energy systems.

These dimensions are sufficient for this study because they collectively sum up the technical, economic, and governance challenges of energy market transitions. The interconnected nature of these dimensions ensures that addressing them provides a comprehensive understanding of market dynamics. For example, effective governance (ISO Governance) is essential to support renewable energy integration and ensure energy security. Similarly, DSM plays a critical role in optimizing market operations and supporting liquidity by shifting demand patterns. By focusing on these five dimensions, the study targets the critical levers of system performance that are consistently prioritized in global energy market reforms. Furthermore, their selection reflects a balance between breadth and depth, allowing for focused, actionable insights without overextending the scope.

While other dimensions, such as environmental or socioeconomic impacts, could also be considered, they were excluded because they either overlap indirectly with the chosen dimensions or are context-specific and less relevant to the operational priorities of ISOs. The chosen dimensions are universal in their application across jurisdictions, as evidenced by their recurring prominence in regulatory frameworks and research. This focus ensures that the study is both manageable and meaningful, concentrating on the essential components required to analyze and improve the performance of deregulated electricity markets.

Overall, the chapter concludes that deregulation has introduced competition, improved efficiency, and accelerated renewable integration across these markets. However, challenges remain, including managing market liquidity, ensuring energy security, and overcoming infrastructure constraints. The experiences of these countries emphasize the importance of tailored regulatory frameworks, strategic investments, and coordinated market mechanisms in achieving successful electricity market reforms.

# 3 METHODOLOGY: THE FIDER TOOLKIT

This study employs a comparative analysis of the electricity markets in Ireland, New Zealand, and Singapore to understand the critical factors that contributed to their successful transitions from regulated to deregulated markets. The primary focus is to explore how these countries developed ISOs or similar market mechanisms that enabled competitive market environments, ensured reliable grid operations, and integrated significant shares of renewable energy.

Insights from these case studies are synthesized to develop a structured framework called FIDER (Framework for ISO Development and Energy Reforms). FIDER is designed as a practical toolkit to assist small jurisdictions in planning and implementing electricity market reforms, particularly those transitioning to ISO-led structures. Rather than offering a one-size-fits-all solution, FIDER provides a flexible, adaptable roadmap grounded in global best practices, tailored for markets with limited scale, low competition, or institutional capacity constraints.

FIDER captures the institutional, regulatory, and technical strategies observed in leading examples of market reform and repackages them into an accessible framework that can guide other jurisdictions through similar transitions. The methodology first develops this toolkit through cross-case pattern recognition and analysis, and then in the next chapter, it applies directly to Nova Scotia’s electricity sector to assess its relevance and potential impact.

## 3.1 Selection of Components

This study identifies five key components critical for understanding and addressing the challenges of deregulated electricity markets. These components are Demand-Side Management (DSM), Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. The selection of these components is rooted in their universal relevance to electricity market reforms and their proven significance in successful transitions from regulated to deregulated markets. Below, each component is defined, and its selection is justified, followed by a discussion of how Ireland, New Zealand, and Singapore support or utilize these elements in their electricity market frameworks.

The selection of components, Demand-Side Management, Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance is based on their critical importance in understanding and addressing the challenges faced by deregulated electricity markets and Independent System Operators. These dimensions were chosen through a detailed review of established research and policy frameworks. For instance, insights from FERC Orders 888/889 emphasize the importance of transparent governance structures and fair market access for ISOs to ensure efficiency and stakeholder trust, which directly supports the inclusion of Market Access and Liquidity and ISO Governance as key dimensions (FERC, 2024a). Similarly, the MIT Center for Energy and Environmental Policy Research identifies market liquidity and renewable energy integration as essential to maintaining system reliability and competitiveness in deregulated markets (CEEPR, 2022). The IMF and IEA highlights the criticality of Energy Security and Diversification in reducing dependency on single energy sources and ensuring system resilience (IMF, 2024; IEA, 2024). These foundational studies highlight how these five dimensions address the universal challenges faced by ISOs during transitions to deregulated energy systems.

These components are key dimensions for understanding the functions and challenges of ISOs in deregulated electricity markets. DSM allows consumers to adjust energy use in response to price signals or reliability needs, reducing peak demand and enhancing grid flexibility, with the IEA highlighting its role in cost reduction and resilience, and FERC Order 745 ensuring demand response is compensated like generation. Market Access and Liquidity are essential for efficient pricing and competition; FERC Orders 888/889 addressed opaque transmission access and preferential treatment, which had previously limited market efficiency and stakeholder trust, and ISOs now enforce transparent rules and monitor liquidity. Renewable Energy Integration introduces variability and requires storage and responsive demand, with MIT CEEPR emphasizing market reforms to allow flexible resources to participate competitively, a task managed operationally by ISOs. Energy Security and Diversification mitigate dependency on single fuels or suppliers, as stressed by IMF and IEA reports, and ISOs coordinate diverse generation mixes and contingency planning to maintain system resilience. Strong ISO Governance ensures transparency, accountability, and fair decision-making, while ISO Independence allows impartial operation free from market or political influence. Together, these components reflect both historical and potential failures, such as limited transparency, insufficient demand participation, and vulnerability to supply shocks, while highlighting how ISOs implement measures to address them, making these dimensions critical for analyzing ISO performance and the effectiveness of deregulated markets.

These dimensions are sufficient for this study because they collectively sum up the technical, economic, and governance challenges of energy market transitions. The interconnected nature of these dimensions ensures that addressing them provides a comprehensive understanding of market dynamics. For example, effective governance (ISO Governance) is essential to support renewable energy integration and ensure energy security. Similarly, DSM plays a critical role in optimizing market operations and supporting liquidity by shifting demand patterns. By focusing on these five dimensions, the study targets the critical levers of system performance that are consistently prioritized in global energy market reforms. Furthermore, their selection reflects a balance between breadth and depth, allowing for focused, actionable insights without overextending the scope.

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### 3.1.1 Demand-Side Management (DSM)

DSM refers to strategies aimed at optimizing electricity consumption by reducing peak demand, enhancing efficiency, and encouraging consumer participation (Enel, 2025). It is essential for balancing supply and demand, minimizing grid strain, and reducing operational costs (DNV, 2024). In the context of this study, DSM is particularly relevant at the industrial and large customer level, as these consumers have a greater capacity to influence overall grid stability through demand adjustments. DSM was chosen because it directly influences market stability and consumer engagement, both critical in deregulated environments

To illustrate the practical applications and effectiveness of DSM, the experiences of Ireland, Singapore, and New Zealand offer valuable insights into how these strategies have been successfully implemented in diverse energy markets:

- Ireland: EirGrid's real-time pricing signals and demand-response programs incentivize industrial consumers to adjust usage during peak periods, demonstrating how DSM can reduce costs and improve grid reliability.
- Singapore: The Energy Market Authority (EMA) employs time-of-use pricing and demand-response programs primarily targeting commercial and industrial consumers, shifting consumption patterns, enhancing system efficiency.
- New Zealand: Real-time pricing mechanisms encourage consumers to adjust usage dynamically, improving market participation and operational efficiency. While residential customers may also participate through aggregation, the most significant impact comes from large energy users.

### 3.1.2 Market Access and Liquidity

Ensuring open and fair access to electricity markets fosters competition, drives innovation, and reduces prices. Liquidity, defined as the ease of buying and selling electricity without significant price changes (Ofgem, 2025), is critical for a competitive market. Practical examples demonstrate how this is achieved through transparent rules, regulatory frameworks, and grid modernization:

- Ireland: Transparent market rules established by SEMO and the creation of day-ahead and balancing markets facilitate efficient trading, enhancing liquidity.
- Singapore: EMA's regulatory framework guarantees non-discriminatory market access, enabling diverse participants to compete fairly.
- New Zealand: The Electricity Industry Participation Code ensures open access, supported by grid modernization to integrate new participants and enhance liquidity.

### 3.1.3 Renewable Energy Integration

Integrating renewable energy sources is vital for sustainability and cost-effectiveness, it comes with challenges, including the often-overlooked costs of battery storage (Mckinsey & Company, 2025). This component addresses the technical and market challenges of managing variable renewable generation. Practical implementations demonstrate how different regions have tackled this complexity:

- Ireland: EirGrid's DS3 program incorporates advanced forecasting tools and ancillary services to manage wind energy variability.
- Singapore: Innovative projects like floating solar farms and energy storage systems maximize solar PV integration.
- New Zealand: The reliance on hydroelectricity, complemented by investments in wind and geothermal, illustrates diverse strategies for renewable integration.

### 3.1.4 Energy Security and Diversification

A diversified energy mix ensures system resilience, reduces dependency on single energy sources, and mitigates supply risks (NREL, 2025). Energy security encompasses both availability and affordability. Key examples highlight how this is effectively implemented:

- Ireland: The East-West Interconnector and gas-fired power plants complement wind generation, stabilizing the energy supply.
- Singapore: Regional partnerships, such as the LTMS-PIP, and exploration of alternative fuels reduce reliance on imported natural gas.
- New Zealand: Capacity mechanisms and a balanced mix of hydro, wind, and geothermal energy ensure reliability, even during droughts.

### 3.1.5 ISO Governance and Independence

Strong governance ensures impartial grid management, market transparency, and stakeholder trust. ISOs play a pivotal role in separating grid operations from market participants (Science Direct, 2013). Effective governance frameworks illustrate how these principles are implemented to maintain fairness and efficiency:

- Ireland: EirGrid and SEMO operate independently under CRU oversight, fostering transparency and preventing anti-competitive practices.
- Singapore: EMA and PSO's distinct roles in regulation and grid management ensure unbiased market operations.
- New Zealand: The Electricity Authority and Transpower's independent operations maintain market fairness and efficiency.

### 3.1.6 Interdependencies and Scope

These components are interconnected, creating a holistic framework for electricity market reform. For instance, effective ISO governance supports renewable integration and market access, while DSM complements energy security by optimizing consumption patterns. The focus on these five components ensures a balance between breadth and depth, providing actionable insights without diluting the study's scope.

Other dimensions, such as environmental and socioeconomic impacts, were considered but excluded due to their indirect overlap with the selected components or their context-specific nature. The chosen components represent universal priorities that address both technical and governance challenges in electricity market transitions.

In the subsequent sections, each component will be analyzed in detail, demonstrating how Ireland, Singapore, and New Zealand have successfully leveraged these elements to navigate the complexities of deregulated electricity markets. This analysis will highlight best practices and provide a foundation for actionable recommendations tailored to jurisdictions pursuing similar reforms.

The New Brunswick System Operator (NBSO) was established in 2004, as an independent not-for-profit statutory corporation under New Brunswick's Electricity Act (NB Power, 2025). Its primary responsibilities included ensuring the adequacy and reliability of the province's integrated electricity system and facilitating the development and operation of the NB Electricity Market. This involved managing the NBSO controlled grid and administering the Open Access Transmission Tariff and the New Brunswick Electricity Market Rules.

Despite these objectives, several critical issues emerged that hindered the NBSO's effectiveness including the dominance of NB Power that retained control over most of the generation, transmission, and distribution assets, leaving limited opportunities for IPPs to participate. This dominance impeded the development of a competitive market, rendering the NBSO's role in facilitating open access and competition largely ineffective.

In response to these challenges, the New Brunswick government enacted a new Electricity Act, which came into effect in 2013 (Canlii, 2013). This legislation led to the amalgamation of the NBSO with the NB Power Group of Companies, creating a vertically integrated utility. The new structure aimed to streamline operations and address the inefficiencies arising from the previous market structure. Under the restructured framework, NB Power assumed responsibility for system operation functions, while the New Brunswick Energy and Utilities Board took over the adoption, monitoring, and enforcement of North American reliability standards.

## 3.2 The FIDER Toolkit for Electricity Market Deregulation

The previously described five components that have been distilled into a generalized toolkit (FIDER) intended to guide any small jurisdiction seeking to transition from a regulated to a deregulated electricity market. These elements are essential for creating a competitive, transparent, and resilient market that ensures affordability, reliability, and sustainability.

### 3.2.1 Demand-Side Management

Engaging consumers as active participants in electricity markets is critical for maintaining grid stability and cost efficiency. Implementing real-time pricing, time-of-use tariffs, and demand-response programs allows consumers to adjust their electricity usage based on price signals. While these measures often help reduce peak demand, their benefits extend beyond just managing peak periods. They also contribute to overall grid efficiency by smoothing demand fluctuations and minimizing the need for expensive backup generation.

However, the reduction in peak demand depends on consumer participation, the availability of enabling infrastructure, and the adoption of advanced technologies. Smart meters play a crucial role in DSM by providing real-time consumption data, enabling automated responses to price signals, and allowing consumers to make informed decisions about their electricity usage. Without smart meters, consumers lack the timely and precise information needed to shift demand effectively. Similarly, financial incentives, such as dynamic pricing structures and demand-response payments, encourage participation by offsetting costs and providing tangible benefits for consumers who adjust their usage. To maximize these benefits, jurisdictions should prioritize the widespread deployment of smart meters and the development of well-structured incentive programs that align consumer behavior with grid stability needs. By combining technology with financial motivation, DSM programs can achieve greater participation, enhance cost savings, and improve overall system efficiency.

A key aspect of Ireland’s deregulation was the implementation of demand-side management programs. EirGrid introduced real-time pricing signals to incentivize industrial consumers to reduce electricity usage during peak periods (EIR Grid, 2024a). These programs provided financial incentives for large energy users to shift consumption to off-peak hours, reducing the need for costly peaking plants (Diskin & Fallon, 2012). This approach alleviated grid stress and minimized operational costs, benefiting both consumers and market operators. EirGrid's demand side framework provided the regulatory basis for these initiatives, ensuring consumers could participate actively in grid balancing (Morgan, Mullany, & Walsh, 2004).

DSM plays a significant role in enhancing market stability and consumer confidence (Lupo & Kiprakis, 2016). In deregulated markets, exposure to real-time price signals allows participants to make informed consumption decisions, reducing price volatility and improving market efficiency (Abate, Riccardi, & Ruiz, 2021). Without mechanisms like DSM, some consumers especially industrial users could face higher and more unpredictable costs, potentially leading to reduced support for the deregulated market structure. By implementing a structured DSM framework, Ireland was able to balance market flexibility with consumer protection, ensuring that deregulation remained both competitive and widely accepted.

Demand-side management has been a critical focus of Singapore's electricity market. EMA implemented demand-response programs that incentivize large commercial and industrial consumers to reduce electricity usage during peak periods (EMA, 2024a). These programs are supported by time-of-use (TOU) pricing, which offers lower rates during off-peak hours, encouraging consumers to shift their usage patterns. EMA's Demand-Side Management Framework outlines how commercial and industrial consumers can participate in these programs, reducing peak demand and operational costs (Open electricity market, 2024). This approach has helped stabilize the grid and lower electricity costs for consumers while improving system efficiency.

A cornerstone of New Zealand's market reform was the implementation of demand-side management through Real-Time Pricing (RTP) mechanisms (EA, 2024). Unlike traditional fixed tariffs, RTP allows prices to reflect actual supply-demand conditions, changing throughout the day based on generation costs and system demand. Consumers, particularly large industrial and commercial users, have access to real-time price signals that enable them to adjust usage accordingly (EA, 2024a).

This mechanism encourages consumers to reduce consumption during high-price periods and shift demand to times when electricity is cheaper. The Electricity Authority implemented RTP in the wholesale electricity market, enabling the publication of final spot prices at the end of each half-hour trading period. This has enhanced price certainty, allowing participants to make more informed decisions about electricity consumption and generation. This benefited in improved market participation through the introduction of dispatch notification products, which provide a low-cost path for small-scale providers of distributed energy resources, such as aggregated residential solar and battery systems, to bid into the market

In Ireland, the Integrated Single Electricity Market (I-SEM) employs a real-time imbalance pricing mechanism to balance supply and demand. When the System Operator (SO) identifies an imbalance between forecasted and actual demand, it issues balancing instructions to generators and consumers (V & Downey, 2018). The real-time imbalance price is determined by collating all balancing instructions issued by the SO for a particular imbalance pricing period, which is 5 minutes in I-SEM. This price reflects the cost of balancing the system and is used to settle the financial positions of market participants.

Similarly, Singapore's National Electricity Market of Singapore (NEMS) utilizes a nodal pricing mechanism to efficiently dispatch generation resources and balance the grid (EMC, 2023). Each node in the electricity network has a specific price, determined by the demand and supply characteristics at that location. The Market Clearing Engine co-optimizes energy, reserve, and regulation services to determine the optimal dispatch of generation resources. Nodal prices are determined according to the demand and supply characteristics of each of the injection nodes.

RTP is also expected to enhance operational efficiency by enabling greater demand flexibility and unlocking innovation across the electricity system, supporting New Zealand’s transition to a net-zero carbon future. By facilitating these changes, RTP is helping to create a more efficient and responsive electricity market, potentially reducing grid strain, lowering operational costs, and integrating renewable energy sources more effectively (EA, 2024f).

## Actionable Strategies with Measurable Indicators

1. Peak Demand Reduction:

**Recommendation:** Implement DSM programs to reduce peak electricity demand during high-load periods.

**Rationale:** Reducing peak demand lowers the need for additional, often less efficient, peaking power plants, leading to overall system cost reductions. This strategy also helps avoid the highest-cost units of electricity generation, which are typically brought online only during peak demand periods.

**Indicators**: Success can be assessed by the cost reduction in meeting peak power requirements, specifically by measuring the savings during the highest-cost hours of each year. This will reflect the financial efficiency of DSM programs in reducing the need for expensive peak power generation.

2. Consumer Participation Rates:

**Recommendation**: Encourage consumer enrollment in DSM programs, such as real-time pricing (RTP), time-of-use (TOU), and demand-response initiatives.

**Rationale:** Encouraging consumer participation in DSM programs like RTP, TOU, and demand-response helps manage peak demand, reduce the cost to serve, and increase demand flexibility. This leads to improved grid efficiency, cost savings, and better system reliability.

**Indicators**: Success can be measured by the change in MW from eligible load participation. This focuses on the impact of DSM programs in reducing peak demand and improving grid efficiency. By tracking load reduction, we can assess how much energy is shifted or reduced during peak times, directly affecting operational costs and grid stability. Monitoring MW changes over time helps evaluate the long-term effectiveness of DSM strategies in optimizing grid performance.

3. Adoption of Smart Metering Technology:

**Recommendation**: Accelerate the rollout of smart meters to enable real-time monitoring and participation in DSM programs.

**Rationale:** Smart meters enable real-time monitoring, accurate billing, and delivery of price signals, which are crucial for effective participation in DSM programs. They provide detailed consumption data, helping both consumers and utilities manage demand efficiently and improve grid performance.

**Indicators**: The proportion of consumers equipped with smart meters can be measured by tracking the percentage of households or businesses that have adopted smart metering technology. Additionally, the frequency and accuracy of data reporting can be evaluated by monitoring how often data is transmitted and checking the consistency and precision of the data provided by smart meters over time.

### 3.2.2 Market Access and Liquidity

Open and transparent access to the electricity market is vital for fostering competition and driving down prices. Regulatory frameworks should guarantee non-discriminatory market entry for IPPs and smaller renewable energy generators. In this context, market liquidity refers to the ease with which electricity can be bought and sold within the market without causing significant price fluctuations (Ofgem, 2024). Clear rules for market participation and transparent pricing mechanisms encourage a diverse set of participants, enhancing competition and ensuring that electricity prices are driven by market dynamics rather than monopolistic control.

Ireland's market design also prioritized open access to enhance liquidity. SEMO established transparent market rules that enabled IPPs to compete fairly with legacy generators (SEMO, 2024). The creation of a day-ahead market and a real-time balancing market allowed participants to trade electricity efficiently, fostering a competitive environment (EIR Grid, 2016). The Market Rules and Governance Framework ensured compliance and fairness, contributing to a well-functioning market where competition succeeded, and consumers benefited from lower prices.

Market access and liquidity were enhanced through a transparent wholesale electricity market where independent generators could participate. EMA's regulatory framework ensures that all participants have equal access to the market, fostering competition and driving down prices. NEMS market rules provide clear guidelines for entry, pricing, and trading, ensuring a level playing field for all market participants (EMC, 2024a). By allowing multiple players to compete fairly, Singapore has increased market liquidity, reduced monopolistic control, and provided consumers with more competitive pricing (EMA, 2009).

Equal competition was ensured for independent power producers (IPPs) and smaller renewable generators, enhancing market access and liquidity alongside established market players. The Electricity Industry Participation Code (EIPC), regulated by the EA, provides clear rules for market entry, ensuring non-discriminatory access to the wholesale market (EA, 2010). Transpower's grid modernization efforts facilitated the integration of new market participants by enhancing grid capacity and efficiency (Transpower, 2021). This open market framework encouraged greater competition, driving down electricity prices and improving market liquidity. The EA's focus on ensuring competitive neutrality has been instrumental in maintaining a fair and dynamic market environment where consumers benefit from a wider range of suppliers and more competitive pricing.

## Actionable Strategies with Measurable Indicators

1. Establishing Day-Ahead and Real-Time Markets:

**Recommendation**: Create platforms for day-ahead and real-time electricity trading to improve efficiency and price transparency.

**Rationale:** These improve efficiency by providing better price signals and enabling participants to respond to supply and demand. These markets promote competition, allow IPPs to compete fairly, and enhance liquidity, reducing price volatility and benefiting consumers with lower electricity costs.

**Indicators**: Success can be measured by tracking market participation rates, which is determined by the share of electricity generation contributed by IPPs compared to the total generation. Market liquidity can be evaluated by monitoring the volume of electricity traded, tracking the frequency and size of trades to assess how easily electricity can be bought or sold without significant price fluctuations.

2. Monitoring Market Concentration using the Herfindahl-Hirschman Index (HHI):

The Herfindahl-Hirschman Index (HHI) calculates market concentration by summing the squared market shares of all firms, typically expressed as a number between 0 and 10,000, where a lower HHI indicates less dominance by a few players and a healthier, more competitive market. To express it as a fraction, the value can be divided by 10,000, with a lower value signaling greater competition.

**Recommendation**: Regularly monitor the HHI to ensure reduced market dominance and assess whether a steady state of market concentration is reached. While a stable level of competition may eventually emerge, ongoing monitoring is necessary, as market dynamics, technological changes, and regulatory shifts could cause fluctuations in the HHI over time.

**Rationale:** Regularly tracking the HHI is essential to gauge market competition. A lower HHI reflects a competitive landscape with no dominant players, fostering fair pricing and better outcomes for consumers.

**Indicator**: Track changes in HHI over time, aiming for a competitive market with lower concentration levels.

3. Facilitating Grid Modernization and Access:

**Recommendation:** Invest in cost-effective grid infrastructure to accommodate new participants, including renewable generators and smaller IPPs while ensuring that the network costs remain the minimum for customers.

**Rationale:** Enhanced infrastructure reduces congestion, increases capacity, and boosts competition, with new connections and improved grid performance serving as clear progress indicators.

**Indicators:** Evaluate progress by tracking grid capacity additions through annual infrastructure development reports, monitoring the number of new renewable generators and smaller IPPs integrated via grid connection agreements, and analyzing reductions in congestion frequency and severity using real-time grid performance metrics. Success is reflected in consistent capacity growth, an increasing number of participants, and noticeable decreases in grid congestion events, and minimal cost increases for customers.

### 3.2.3 Renewable Energy Integration Strategy

As renewable energy costs have declined over the past two decades and are not subject to fuel price volatility, electricity markets that effectively integrate these low-cost resources are likely to be the most economical. Jurisdictions should invest in advanced forecasting tools to predict variable renewable output, such as wind and solar, and develop ancillary services markets to maintain grid stability. Flexible generation and demand-side resources, including hydro and battery storage, are essential for managing variability. Additionally, modernizing the grid with smart technologies will enable higher renewable penetration while ensuring reliability and power quality.

Integrating renewable energy sources effectively is essential for creating a sustainable and cost-effective electricity market. Jurisdictions should invest in forecasting tools that can predict variable renewable output, such as wind or solar, and establish ancillary services markets to support grid stability. Flexible generation and demand resources, such as hydro or battery storage, are critical for balancing renewable variability. Grid modernization, including the development of smart grid technologies, ensures that the grid can accommodate high levels of renewable penetration while maintaining reliability and power quality.

The modular nature of renewable energy technologies, such as solar and wind, reduces entry barriers in the energy sector. Unlike traditional thermal plants, which require substantial capital and long-term commitments, renewable projects are more flexible and scalable. This allows smaller-scale installations and opens up opportunities for a broader range of investors, including individuals and small businesses. As a result, the energy market becomes more decentralized, fostering competition and accelerating the shift to a sustainable energy system. The flexibility and scalability of renewables make energy production more accessible and help enhance energy security.

A significant achievement in Ireland's deregulation was the seamless integration of renewable energy, particularly wind. EirGrid's Delivering a Secure, Sustainable Electricity System (DS3) program played a pivotal role in managing the variability of wind energy (EIR Grid, 2024d). Investments in advanced forecasting tools enabled grid operators to predict wind generation fluctuations accurately, while the ancillary services market provided critical support for frequency regulation and reserve capacity. These efforts reduced reliance on imported fossil fuels, stabilizing prices and contributing to sustainability (RGI, 2024). The DS3 program report highlights how effective planning and infrastructure investment ensured a reliable and cost-effective integration of renewables.

Renewable energy integration, though limited by geographic constraints, has been a priority for Singapore. EMA has focused on maximizing solar photovoltaic (PV) integration through innovative solutions such as floating solar farms and energy storage systems (EMA, 2024d). Pilot projects on energy storage have demonstrated the feasibility of storing excess solar energy for use during peak demand (EMA, 2024c). PSO's real-time monitoring of solar PV output ensures that the grid remains stable, despite the variability of solar energy. These initiatives have reduced Singapore's reliance on imported natural gas and supported the transition to a cleaner energy mix.

New Zealand has focused on integrating renewable energy, particularly hydro resources, into its electricity market. Hydro generation, managed by Transpower, plays an important role in grid stability, offering flexible reserves that can adjust to fluctuations in wind and geothermal energy production. However, New Zealand's reliance on hydro has faced challenges, particularly during droughts, which can affect the availability of hydroelectric power (The Conversation, 2024). In response, investments in wind farms and other renewable sources have been made to diversify the energy mix and reduce the impact of hydro variability (DLA Piper, 2024). According to the Transpower Grid Reliability Report, the integration of variable renewables, with hydro serving as a balancing resource, has allowed New Zealand to achieve high levels of renewable penetration while striving to maintain grid stability (Transpower, 2023).. While challenges such as droughts remain, efforts to increase renewable generation aim to reduce reliance on fossil fuels, improve long-term price stability, and support environmental sustainability.

## Actionable Strategies with Measurable Indicators

1. Invest in Advanced Forecasting Tools:

**Recommendation:** Develop and deploy advanced forecasting tools to predict the variable output of renewable energy sources like wind and solar. Accurate forecasting helps optimize supply-demand balancing, supports the lowest-cost energy portfolio, and reduces dependence on costly peaking plants, thereby contributing to price stability.

**Rationale:** Lower the costs by optimizing renewable use and reducing reliance on backup power. These tools also improve system flexibility by coordinating with flexible generation and storage. Additionally, they increase renewable integration by minimizing curtailment and maximizing resource use.

**Indicator:** Measure success by evaluating improvements in forecast accuracy through comparisons of predicted versus actual renewable energy output, tracking reductions in reserve capacity requirements using grid operation data, and monitoring the frequency and volume of renewable curtailment events in grid performance reports. Success is indicated by higher forecast precision, reduced reserve capacity needs, and fewer curtailment instances.

2. Establish Ancillary Services Markets:

**Recommendation:** Create markets for ancillary services to support grid stability through frequency regulation and reserve capacity. Flexible generation resources, such as hydro (with an assumption that hydro is available) and battery storage, should be prioritized to address renewable variability. Additionally, leverage demand-side resources to enhance grid stability by encouraging consumer participation in managing peak demand and supporting grid operations during high variability in renewable energy.

**Rationale:** Prioritizing flexible resources and incorporating demand-side participation helps manage renewable variability and reduces strain during peak periods, enhancing system resilience and efficiency.

**Indicator:** Assess progress by tracking the volume of ancillary services transactions through market trading data, monitoring frequency stability metrics such as frequency deviations and response times using grid operation reports and evaluating the share of flexible resources like hydro and battery storage in grid operations through resource utilization statistics. Success is indicated by increased transaction volumes, improved frequency stability, and a growing share of flexible resources in supporting grid operations.

3. Modernize and Develop Smart Grid Technologies:

**Recommendation:** Invest in smart grid technologies, such as advanced meters, communication networks, and automation systems, to enhance grid efficiency and reliability.

**Rationale:** Advanced meters, communication networks, and automation systems provide real-time data, enabling better demand-response management and quicker response to grid issues. This leads to fewer outages, smoother integration of renewables, and a more resilient grid overall.

**Indicator:** Evaluate success by tracking the penetration rate of smart grid technologies through the percentage of smart meters, communication networks, and automation systems deployed, monitoring reductions in system outages using grid reliability reports, and assessing improvements in renewable integration capacity by analyzing the share of renewables successfully integrated into the grid. Success is indicated by higher deployment rates of smart grid technologies, fewer outages, and increased renewable energy integration capacity.

Smart grid technologies, which refer to the integration of digital communication and automation in electricity distribution systems, can enhance grid efficiency and reliability (DOE, 2024). These systems enable real-time monitoring and dynamic control of electricity flow, improving response to demand fluctuations and integrating renewable energy sources more effectively. By adopting these technologies, along with grid modernization efforts like advanced meters, communication networks, and automation systems, jurisdictions can better accommodate high levels of renewable penetration, reduce reliance on fossil fuels, stabilize electricity prices, and ensure long-term sustainability.

### 3.2.4 Energy Security and Diversification

Ensuring a reliable and resilient electricity supply requires a diversified energy mix and strategic planning for capacity. Energy security, which encompasses both availability and affordability, is crucial for maintaining stability. Availability refers to ensuring a constant and reliable supply of electricity, while affordability focuses on keeping electricity prices accessible to consumers (Ranjan & Hughes, 2014). Jurisdictions should explore cross-border interconnections, regional energy partnerships, and capacity mechanisms to secure backup generation during periods of low renewable output or high demand (World Bank, 2024). Diversification reduces dependency on a single energy source and mitigates the impact of global energy price fluctuations, enhancing energy security and providing price stability for consumers (ExxonMobil, 2023).

Energy security and diversification are central to Ireland's market stability. The development of the East-West Interconnector with the UK allowed for electricity imports and exports, ensuring a reliable supply during periods of low wind output (EIR Grid, 2024b). Gas-fired power plants complemented wind generation, providing flexibility and stability. This diversification reduced exposure to global energy price volatility, enhancing resilience. The East-West Interconnector cross-border link reinforces Ireland's energy security, ensuring a steady supply and stabilizing prices for consumers.

For Singapore's diversification strategy, given its reliance on imported natural gas, EMA has pursued regional energy partnerships, such as the Laos-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP), which allows Singapore to import renewable energy from neighboring countries (EMA, 2024c). Additionally, Singapore has diversified its supply sources by exploring hydrogen and alternative fuels (MTI, 2024). These efforts, detailed in the EMA's Energy Security and Sustainability Report, ensure a stable and resilient energy supply, reducing exposure to global price volatility.

New Zealand's electricity strategy prioritizes energy security and a diversified approach to ensure reliable supply. While hydro and geothermal power dominate the energy mix, the country has implemented capacity mechanisms to ensure sufficient generation during dry years when hydro levels are low (MBIE, 2024a). These mechanisms incentivize the availability of reserve capacity, ensuring the grid can meet demand even during periods of reduced renewable output. One such approach is the implementation of capacity markets, where electricity providers are compensated for maintaining reserve generation capacity that can be quickly brought online when needed. This reserve capacity acts as a buffer during times when renewable energy sources like hydro, wind, or solar are insufficient to meet demand. The Electricity Authority's Capacity Mechanism Framework emphasizes the importance of maintaining reserve generation to safeguard supply reliability (EA, 2024e). This framework outlines the need for mechanisms that ensure adequate generation capacity is available to meet peak demand and address potential shortfalls during periods of low renewable output. This diversified approach ensures a resilient energy system capable of withstanding seasonal and climatic variations, providing consumers with stable and predictable electricity prices.

## Actionable Strategies with Measurable Indicators

1. Diversify Energy Sources:

**Recommendation:** Develop a diverse energy mix using a variety of generation technologies that do not rely on the same energy resource, reducing dependency on any single source and enhancing grid stability.

**Rationale:** It helps mitigate the risks associated with supply disruptions, price volatility, and environmental concerns.

**Indicators(?):** Measure the proportion of renewable, non-renewable, and nuclear energy sources in the energy mix, track changes in fossil fuel dependency, and assess energy price stability, with a focus on fluctuations in prices due to the diversity of generation sources.

2. Implement Capacity Mechanisms:

**Recommendation:** Implement capacity mechanisms, such as capacity markets, to ensure sufficient reserve capacity is available to meet peak demand during low renewable output or other supply disruptions.

**Rationale:** Ensure sufficient reserve capacity during low renewable generation or supply disruptions, maintaining grid reliability. By providing financial incentives to capacity providers, they help reduce blackout risks and enhance stability, while also supporting renewable integration by addressing intermittency.

**Indicators:** Track the availability and utilization of reserve capacity, assess the number of capacity mechanisms in place, and monitor grid stability during high demand or low renewable generation.

3. Promote Distributed Generation:

**Recommendation:** Promote distributed generation, such as rooftop solar panels and local wind turbines, by targeting areas where they provide maximum grid value. This can be achieved through locational pricing, siting incentives, or geography-based Request for Proposals (RFPs).

**Rationale:** Enhances grid resilience by reducing dependence on centralized plants. Targeting areas with the highest benefit ensures optimal use of resources, reducing congestion and avoiding costly grid upgrades. This strategy lowers costs, improves reliability, and supports a cleaner energy mix.

**Indicators:** Measure growth in distributed generation capacity and local electricity production. Assess impact on grid stability by analyzing feeder-level data to determine improvements in resilience, cost reductions, and avoided infrastructure investments.

### 3.2.5 ISO Governance and Independence

Establishing an ISO that operates separately from generation and retail companies is crucial for maintaining impartiality and transparency in market operations. The ISO should be tasked with managing grid stability, overseeing market operations, and ensuring compliance with market rules. Strong regulatory oversight from an independent authority ensures that the ISO remains accountable, prevents anti-competitive behavior, and upholds market integrity. Transparent reporting and data dissemination further reinforce consumer and stakeholder confidence in the market's fairness.

The importance of independent governance was essential in maintaining fair market operations. EirGrid and SEMO operated separately from electricity generators, with regulatory oversight from the CRU (EIR Grid, 2024c; SEMO, 2024; CRU, 2024a). This ensured impartial grid management and market transparency. The CRU's Annual Market Monitoring Report outlined regular reviews of market performance and compliance enforcement, preventing anti-competitive behavior (CRU, 2024b). By ensuring transparency and accountability, Ireland's independent governance framework strengthened market confidence, fostering a competitive and consumer-friendly market environment.

Independent governance has been a hallmark of Singapore's electricity market. EMA operates independently of electricity generators and retailers, ensuring impartial regulation and oversight. PSO's role in managing grid operations is distinct from EMA's regulatory functions, ensuring unbiased decisions regarding grid stability and demand management. EMA's Annual Market Performance Report provides transparency through regular publication of market data, ensuring that all participants operate on an equal footing (EMA, 2024b). This governance structure has fostered a competitive, transparent market that benefits both consumers and industry stakeholders.

The success of New Zealand's electricity market is founded on its robust framework of governance. The Electricity Authority operates independently from market participants, ensuring impartial regulation and enforcement of market rules. Transpower, as the transmission system operator, maintains a separate role focused on grid management, ensuring that operational decisions are not influenced by generation interests

(Transpower, 2024). The Electricity Authority's Annual Market Review provides comprehensive monitoring of market behavior, pricing trends, and compliance, ensuring transparency and preventing anti-competitive behavior (EA, 2024d). This governance structure ensures that the market operates fairly and efficiently, fostering consumer confidence and promoting a competitive environment that drives down costs.

### Actionable Strategies with Measurable Indicators:

1. Implement Regular Market Monitoring and Performance Reviews:

**Recommendation:** Conduct regular market performance reviews, ensuring that the ISO's operations align with regulatory objectives and market rules.

**Rationale:** Essential to detect inefficiencies, prevent market manipulation, and ensure compliance with regulatory objectives. By continuously reviewing market performance, the ISO can identify pricing anomalies, assess system reliability, and address competitive imbalances before they escalate.

**Indicator:** Monitor the frequency and transparency of annual market performance reviews and measure improvements in market efficiency and stability over time.

2. Transparent Reporting and Data Dissemination:

**Recommendation:** Regularly publish market performance data, operational statistics, and compliance reports to ensure transparency and consumer trust.

**Rationale:** Transparent reporting builds trust among stakeholders by ensuring market operations are open, verifiable, and accountable. Regular publication of market data and performance reports reduces information asymmetry, allowing market participants to make informed decisions.

**Indicator:** Monitor the extent of published data accessibility to stakeholders and assess stakeholder engagement and trust levels through surveys or feedback mechanisms.

3. Promote Stakeholder Engagement and Building Consumer Confidence:

**Recommendation:** Facilitate regular engagement with stakeholders (including consumers, industry participants, and advocacy groups) to gather feedback, address concerns, and ensure consumer confidence in the ISO's operations.

**Rationale:** This enhances market responsiveness by incorporating feedback from consumers, industry participants, and regulators.

**Indicator:** Measure the frequency of stakeholder consultations, track the satisfaction levels through surveys, and assess the impact of stakeholder feedback on policy adjustments or market reforms.

### 3.2.6 Summary

This chapter explored the electricity market deregulation experiences of Ireland, New Zealand, and Singapore, highlighting the key factors that contributed to their successful transitions. Each country's approach to demand-side management, market access, renewable integration, energy security, and ISO governance was examined in detail, revealing common patterns that form the basis for a comprehensive FIDER toolkit.

The examples of Ireland, New Zealand, and Singapore illustrate diverse approaches to electricity market transitions, focusing on demand-side management, renewable integration, and market access strategies tailored to their unique energy resources and challenges. While these jurisdictions highlight the potential of renewables, FIDER is designed to be adaptable for areas with limited renewable resources, such as hydro or solar. In such cases, the Energy Security and Diversification component becomes pivotal, encouraging jurisdictions to explore a balanced energy mix that includes available resources like fossil fuels with carbon capture and storage and innovative storage solutions. Additionally, FIDER's focus on demand-side management and market access ensures that even resource-constrained regions can optimize energy usage and foster competitive market dynamics.

Although none of the case studies rely on nuclear energy, FIDER is flexible enough to accommodate jurisdictions where nuclear power plays a significant role. Nuclear energy aligns with the principles of Energy Security and Diversification, offering a stable, low-carbon baseload option that complements renewable resources. Its inclusion in FIDER would involve ensuring transparent market access for nuclear generation, fostering public trust through robust ISO Governance and Independence, and integrating nuclear into dynamic pricing and grid balancing mechanisms to meet system demands effectively. The diversity of strategies across the case studies point out the adaptability of FIDER, which is not prescriptive but serves as a flexible framework. By emphasizing universal principles like efficiency, transparency, and resilience, FIDER provides a robust approach for any jurisdiction, regardless of its reliance on renewables, nuclear energy, or other resources.

The formulation of FIDER synthesizes these commonalities into five key focus areas: demand-side management and participation, market access and liquidity, renewable energy integration strategy, energy security and diversification, and ISO governance and independence. Each focus area reflects the collective insights gained from the case studies, providing actionable guidance for jurisdictions seeking to implement successful electricity market deregulation.

The examples of Ireland, New Zealand, and Singapore highlight that even in jurisdictions where certain elements of FIDER, such as demand-side management or renewable integration, are already implemented by existing electricity suppliers or providers, the establishment of an ISO or Independent Electricity System Operator (IESO) offers distinct and necessary benefits. An ISO/IESO ensures impartiality in market operations by separating grid management and market oversight from the influence of individual market participants. This separation enhances fairness, fosters competition, and prevents potential conflicts of interest where vertically integrated utilities might prioritize their assets over others.

Moreover, an ISO/IESO institutionalizes a transparent framework for long-term grid planning and system operations, countering the risk that utilities might use their long-term planning processes to limit the review of alternatives and protect their market share. While utilities are generally required to pursue the most cost-effective solutions, there can be instances where their decisions do not fully align with the long-term interests of ratepayers. By operating independently, the ISO/IESO can better align grid management and energy system development with broader market and policy goals, such as promoting diverse energy sources, ensuring energy security, and fostering competition. These advantages go beyond what individual utilities can provide, even where some practices are already in place, making the establishment of an ISO/IESO a crucial step in achieving a more competitive, resilient, and transparent electricity market.

# 4 Applying the FIDER Toolkit to Nova Scotia

## 4.1 Demand-Side Management (DSM)

Nova Scotia has made meaningful strides in DSM through initiatives led by Efficiency Nova Scotia and Nova Scotia Power (NSP, 2024d). Key programs include:

1. Home Warming Initiative: Targets low-income households by providing free energy-efficient home upgrades, such as insulation, air sealing, and heating system improvements. These upgrades have collectively saved participants thousands of dollars annually in energy costs and reduced heating consumption and greenhouse gas emissions (Efficiency NS, 2025a).
2. Business Energy Solutions: Offers tailored energy assessments and implementation support for businesses to adopt efficient lighting, HVAC systems, and equipment upgrades (Efficiency NS, 2025).
3. Time-Varying Price (TVP) Program Pilots: Nova Scotia Power (NSP) has initiated pilot projects that charge varying electricity rates based on demand periods, incentivizing customers to use electricity during off-peak times (NSP, 2025a).

Efficiency Nova Scotia represents a unique model in Canada as an independent, regulated entity mandated to deliver DSM programs, a role that has historically been performed by utilities in most other jurisdictions. Since its inception in 2011, the organization has generated more than $5.6 billion in lifetime energy bill savings for households, businesses, and institutions, including $628 million for low-income customers alone (Efficiency One, 2024). Its programming has also avoided the release of 12.7 megatonnes of greenhouse gas emissions, equivalent to removing nearly 2.9 million gasoline-powered cars from the road for one year. In 2024 alone, Efficiency Nova Scotia achieved 172 GWh of electricity savings, 31 MW of demand savings, and nearly 299,000 GJ of non-electric savings, preventing 114,662 tonnes of GHG emissions (Efficiency One, 2024). The scale of its efforts is reflected in its network of over 460 delivery partners and a sector that now employs more than 5,000 people across the province, half of whom are located outside Halifax.

These achievements have helped position Nova Scotia among the leading provinces for energy efficiency performance and policy in Canada, demonstrating how DSM, when delivered through a dedicated and independent entity, can simultaneously lower system costs, reduce emissions, and stimulate broad-based economic development. However, some gaps remain in the adoption of comprehensive real-time pricing (RTP) and the deployment of smart metering systems, which are critical for fully realizing DSM’s potential.

## Potential Strategies and Measurable Indicators

1. Peak Demand Reduction

Nova Scotia Power has implemented TVP pilot programs for its new Time-Of-Use (TOU) pricing and Critical Peak Pricing (CPP).

TOU pricing establishes predetermined electricity rates based on the time of day, with higher rates during peak periods and lower rates during off-peak periods. The details for the TOU tariff are shown in Table 4 .

**Table 4: TOU Electricity Rates by Season and Period in Nova Scotia (NSP, 2025d)**

| Season | Time Period | Rate (¢/kWh) | Notes |
|---|---|---|---|
| Winter | Nov 1 – Mar 31 | | |
| | Peak: 7:00 a.m. - 11:00 a.m. | 35.492 | Weekdays only |
| | Peak: 5:00 p.m. - 9:00 p.m. | 35.492 | Weekdays only |
| | Off-Peak (all other times) | 18.561 | Includes weekends and holidays |
| Non-Winter | Apr 1 - Oct 31 | 13.056 | Flat rate at all hours, every day |

CPP, on the other hand, is designed to address extreme demand days by introducing significantly higher rates during critical peak events, which last for four hours and occur when higher-than-normal electricity demand is expected. Currently, the CPP program primarily targets residential consumers who have opted into the program. However, it may also apply to small business customers, depending on their eligibility. The rate structure includes a baseline price for normal usage, with surcharges applied during designated Critical Peak Events, typically announced in the afternoon before the event, with a minimum of 14 hours' notice. Table 5 presents the electricity rates applicable for the critical peak event during the period from November to March for the year.

**Table 5: CPP electricity rate in Nova Scotia (NSP, 2025h)**

| Period | Rate Type | Electricity Rate (¢/kWh) |
|---|---|---|
| November to March | Off-Peak | 15.852 |
| Critical Peak Event Days | Critical Peak Rate | 170.94 |
| All Hours Outside of Critical Peak Events | Flat rate | 15.852 |

Table 6 presents electricity consumption and peak demand trends from 2020 to 2024. In 2020, peak demand was 1666 MW, the lowest in the observed period; however, this may or may not be partially reflect the impacts of COVID-related economic disruptions. In

2021, peak demand increased slightly to 1684 MW, followed by a sharper rise to 1803 MW in 2022, the highest in the five-year period. Demand eased to 1737 MW in 2023, before climbing again to 1798 MW in 2024. These fluctuations suggest that while there has not been a consistent reduction in peak demand, recent growth is likely linked to factors such as electrification initiatives and population increases. These trends indicate that while peak demand has fluctuated, there has been no consistent downward trend, highlighting the need for further demand-side interventions.

In 2020, demand exceeded 1500 MW for an extended period, and this trend continued in subsequent years, with little evidence of lasting improvement. The 50% duration demand has varied inconsistently, with 1238 MW in 2022 and 1203 MW in 2024, but this has not translated into a sustained reduction in peak demand.

**Table 6: Peak and 50% Duration Electricity Demand in Nova Scotia (2020–2024) (NSP, 2025g)**

| Year | Peak Demand (MW) | 50% Duration Demand (MW) |
|---|---|---|
| 2020 | 1666 | 1203 |
| 2021 | 1684 | 1229 |
| 2022 | 1803 | 1238 |
| 2023 | 1737 | 1240 |
| 2024 | 1798 | 1240 |

Figure 1 illustrates the monthly participation trends in two electricity pricing pilot programs, TOU and CPP, from August 2021 to March 2024. The blue and orange stacked bars represent the number of customers enrolled in the TOU and CPP tariffs respectively, while the green line traces the total number of customers participating in either program. The data reveals three key phases of growth. Initially, between August and October 2021, there was a rapid increase in enrollment, with total participation rising from approximately 300 to over 1,000 customers. This was followed by a period of relative stability between November 2021 and September 2022, where total customer numbers remained consistent around 900 to 1,000, suggesting the pilot may have reached early saturation or limited expansion. A modest increase occurred again between October and November 2022, where total participation rose to around 1,400 customers.

The most significant change occurred between October and December 2023, where customer participation surged from around 1,300 to over 3,200, likely due to a major program expansion or promotional push. This level of participation was largely maintained through the first quarter of 2024. Overall, the chart demonstrates the gradual scaling and eventual acceleration of the pilot tariff programs.

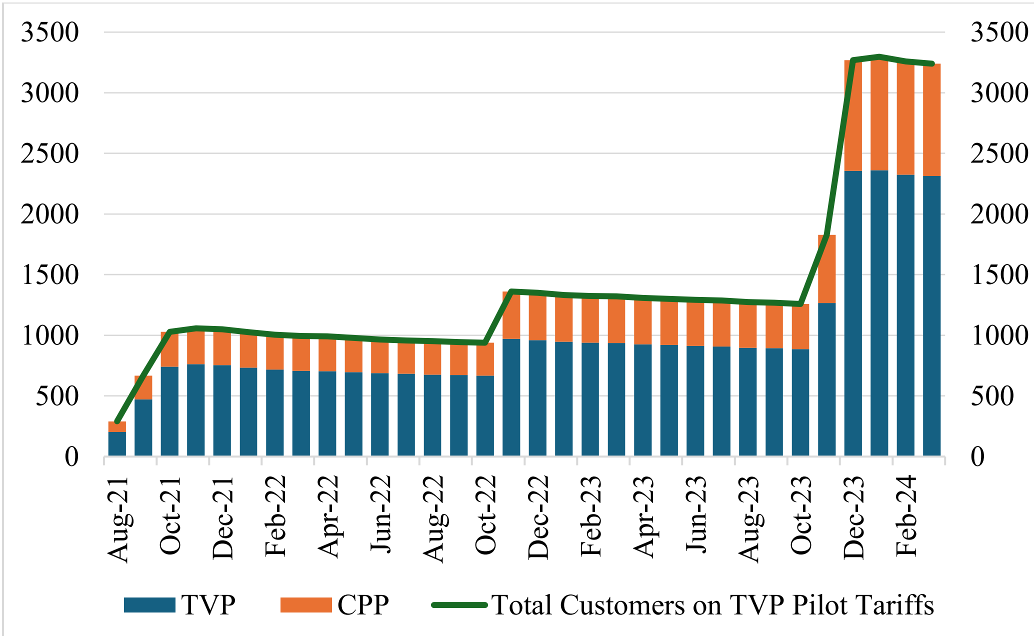


**Figure 1: Number of customers on TOU, CPP and total TVP pilot tariff (NSP, 2024)**

Table 6 and Figure 1 together illustrate the disconnect between peak demand trends and the scale of participation in TVP programs. **Error! Reference source not found.** shows t hat from 2020 to 2024, peak electricity demand in Nova Scotia has fluctuated without showing a consistent downward trend. For example, peak demand rose from 1666 MW in 2020 to a high of 1803 MW in 2022, with only a slight decline to 1737 MW in 2023 and a rebound to 1798 MW in 2024.

At the same time, Figure 1 shows that participation in TVP pilot programs TOU and CPP. Despite some growth, particularly between October and December 2023 when enrollment rose from around 1,300 to over 3,200 customers, this represents less than 0.7% of Nova Scotia's approximately 525,000 electricity customers, underscoring the small scale and limited impact of the pilot programs to date (NSP, 2025i). This limited uptake suggests that the impact of TVP programs on system-wide demand trends has so far been minimal. The persistent peak levels and extended high-demand durations explains the need for broader adoption of TVP.

Nova Scotia should focus on expanding DSM participation, particularly by including businesses, industrial consumers, and residential users. This could help reduce peak demand more effectively and strengthen grid stability. RTP would offer dynamic, hourly price signals, enabling consumers to adjust their usage based on real-time market conditions.

Public education campaigns are crucial to promoting these programs and explaining the benefits of these programs. Financial incentives, such as rebates for smart meter installation or bill credits for reducing energy use during peak times, could further encourage participation. Digital tools, like mobile apps, could also be leveraged to provide real-time pricing information, enhance consumer engagement, and foster energy-saving behaviors.

2. Consumer Participation Rates

Nova Scotia has been actively working on increasing consumer participation in DSM programs through various initiatives. The Efficiency One 2023-2025 Demand Side Management Plan emphasizes the need to increase participation and expand the reach of these programs (Efficiency One, 2025b). Unlike Time-Variant Pricing (TVP) or Real-Time Pricing (RTP) models, which focus on shifting electricity use based on price signals, Nova Scotia's DSM efforts primarily aim to reduce overall household energy consumption across multiple fuel types, not just electricity. To enhance participation, the implementation process includes designing marketing campaigns that highlight energy cost savings and environmental benefits, introducing performance-based rewards for participants who achieve predefined energy-saving targets, and collaborating with community groups to address barriers such as low awareness or upfront costs (Efficiency One, 2025b).

Existing programs include Efficiency One's various DSM initiatives, which have saved Nova Scotians over $4 billion in energy costs and cut overall greenhouse gas emissions of residential and industrial sector by 22% over the last decade (Efficiency One, 2025b). These savings were achieved through a wide range of residential and business, non-profit, and institutional (BNI) initiatives, strategically aligned with the principles of 3R's energy reduction, energy replacement, and energy restructuring.

In the residential sector, programs such as Instant Savings, Green Heat, New Home Construction, and Home Energy Assessments contributed to energy reduction by improving building efficiency and installing more energy-efficient appliances. Energy replacement efforts included replacing traditional baseboard heating systems and oil furnaces with heat pumps and electric alternatives, particularly through programs like Green Heat and the Mi'kmaw Home Energy Efficiency Project. Meanwhile, energy restructuring was supported by encouraging all-electric new home construction and shifting away from oil-based systems (Efficiency One, 2022).

In the business, non-profit, and institutional (BNI) sector, programs such as Business Energy Rebates, Custom Incentives, and Small Business Energy Solutions helped businesses reduce energy use and emissions. These initiatives supported energy reduction through Strategic Energy Management and Energy Management Information Systems, promoted energy replacement via upgrades to more efficient technologies, and facilitated energy restructuring by enabling a transition from fossil fuel use to cleaner electricity-based systems. Together, these comprehensive programs across both sectors have helped transform Nova Scotia’s energy landscape (Efficiency One, 2022).

To date, consumer participation in these DSM programs includes over 70,000 households in the residential sector and more than 9,000 businesses from business, non-profit, and institutional (BNI) customers. These figures reflect participation by unique account IDs; for example, a large organization or a residential property with more than one meter may be counted multiple times (Bligh, 2025).

Additionally, $35 million is allocated to help low-income Nova Scotians, including renters, live more comfortably in their homes, and $7 million is dedicated to helping Mi’kmaw communities reduce electricity costs and improve comfort while supporting local job creation. Furthermore, $20 million is set aside to help small businesses on their path to recovery (Efficiency One, 2025b).

To further improve consumer participation, Nova Scotia could enhance marketing and outreach efforts to raise awareness about the benefits of DSM programs, expand performance-based incentives to encourage higher participation rates and greater energy savings, provide more educational resources and engagement activities to help consumers understand the benefits of DSM programs, and address barriers such as upfront costs by offering financial assistance or rebates to make participation more accessible.

3. Adoption of Smart Metering Technology

In late 2019, Nova Scotia Power initiated a comprehensive project to modernize the province's electrical grid by deploying approximately 500,000 smart meters, with the goal of completing the installations by the end of 2020 (Global News, 2018). These smart meters are designed to record detailed energy usage data and transmit it over a secure wireless network, enabling customers to access daily information about their electricity consumption. This access empowers consumers to make more informed decisions and manage their electricity costs more effectively.

The implementation of smart meters is a key component in Nova Scotia Power's strategy to modernize the electricity grid, aiming to enhance reliability and support the integration of renewable energy sources (NSP, 2021a) . The project is expected to reduce costs in the electrical system by approximately $38 million over the next 20 years, contributing to more stable rates for customers (NSP, 2021). By providing detailed insights into energy usage, smart meters facilitate better energy management and support the province's goals for a sustainable energy future.

Given that Nova Scotia has already implemented smart meters, the focus should now be on enhancing their effectiveness (NSP, 2025). Improvements could include utilizing advanced data analytics to provide detailed insights into energy consumption patterns and implementing real-time feedback and alerts for users to manage their energy consumption more effectively (Eskandarnia, Al-Ammal, Ksantini, & Hammad, 2022). For example, predictive analytics can forecast high-demand periods, allowing utilities to issue proactive alerts and optimize grid operations. Machine learning algorithms can analyze historical consumption data to offer personalized energy-saving recommendations to households. Additionally, disaggregation analytics can break down energy usage by appliance, helping consumers identify inefficient devices and adjust their behavior accordingly. These enhancements would enable consumers to make more informed energy decisions, ultimately increasing the effectiveness of DSM programs.

Expanding demand response programs to incentivize users to reduce overall household or business energy consumption, not just electricity, during peak periods, increasing user education and engagement efforts, and enhancing security measures to protect user data are also crucial steps. These improvements aim not only to enhance energy efficiency but also to improve affordability for consumers. It is important to note, however, that while DSM programs can lower household emissions, such as when oil-heated homes shift to electric heating, they may inadvertently increase NSP's emissions if the additional electricity demand is met with fossil fuel generation. A well-coordinated strategy is necessary to manage these trade-offs and support the province's long-term climate and energy objectives.

## 4.2 Market Access and Liquidity

Nova Scotia's electricity market is currently dominated by NSP, a vertically integrated utility controlling generation, transmission, and distribution. This structure limits competition, with high interconnection costs deterring IPPs. Efforts such as Nova Scotia's 2030 Clean Power Plan and Climate Change Plan have encouraged some IPP participation but remain insufficient to create a competitive and liquid market (NSECC, 2022; NSNRR, 2022).

Nova Scotia faces several challenges in enhancing market access and liquidity. These challenges include a lack of competitive trading platforms, inadequate monitoring of market concentration, and outdated grid infrastructure that limits renewable integration and participation by smaller power producers. Below, actionable strategies and their measurable outcomes are discussed, focusing on how Nova Scotia can address these issues.

### Potential Strategies and Measurable Indicators

1. Establishing Day-Ahead and Real-Time Markets

Nova Scotia's electricity market is primarily regulated and controlled by NSP. The pricing of electricity is primarily determined through long-term power purchase agreements and contracts, rather than dynamic market-based pricing that reflects real-time supply and demand (Wallace, 2019). There are ongoing efforts about the need for increased market competition and transparency, especially as renewable energy integration grows, but the market currently lacks the necessary platforms to enable efficient price discovery and real-time grid adjustments (NSECC, 2022). As of now, there is no established day-ahead or real-time market in Nova Scotia, which restricts the flexibility and responsiveness of the electricity market.

In Nova Scotia, electricity pricing is determined through long-term Power Purchase Agreements (PPAs) and regulated rates set by the Nova Scotia Utility and Review Board (NSUARB). IPPs can participate by selling electricity to NSP through bilateral contracts, but there is no competitive market-based bidding process (NSP, 2007). While there is no real-time market in Nova Scotia, since 2012 most new generation additions have been procured through competitive processes by the Procurement Administrator, to secure the lowest-cost supply (Nova Scotia, 2020). This structure highlights the limited role of spot market competition, particularly in the context of encouraging additional capacity resources rather than energy resources.

With the establishment of the Nova Scotia Independent Energy System Operator (NSIESO) under the Energy Reform (2024) Act, the province's electricity settlement structure is expected to transition toward a market-based mechanism (Nova Scotia, 2024). This will introduce real-time and potentially day-ahead markets, where electricity prices will be dynamically set based on actual grid conditions and demand-supply fluctuations. The new market structure is expected to allow generators, including IPPs and renewable energy producers, to submit competitive bids to supply electricity. Initially, it appears that the NSIESO will lead a procurement approach to new energy resources rather than introducing a real-time market immediately. The NSIESO has the authority to oversee transparent price discovery, ensuring that market participants transact based on real-time economic signals rather than pre-negotiated contracts. This will promote efficiency by enabling the system operator to dispatch electricity more optimally, selecting the most cost-effective generation sources at any given time.

The two graphs presented reflect electricity system dynamics in Ireland on the 9th of July, over a 12-hour period from 12:00 AM to 12:00 PM. Figure 2 compares actual electricity generation (in MW) with actual system demand, while Figure 3 displays the imbalance settlement price (in €/MWh) alongside the net imbalance volume (NIV) measured in MWh. Together, these provide insight into both the physical balancing of supply and demand and the economic consequences of imbalance in the market.

Figure 2 plots actual generation as vertical bars and actual demand as a line graph. During the early morning hours (12:00 AM to approximately 5:00 AM), the system experienced relatively low demand, ranging between 2,700 MW and 3,100 MW. During this period, actual generation remained consistently higher than demand, indicating that the system was long producing more electricity than was consumed. Around 6:30 AM, demand began to increase significantly, driven by the morning ramp-up in residential and commercial activity. This rising trend peaked at around 9:00 AM, reaching just above 5,200 MW. Generation during this time also increased, closely tracking demand and ensuring sufficient supply. After 9:30 AM, both generation and demand began to decline gradually, suggesting a stabilization of system operations after the morning peak. This alignment between generation and demand indicates that Ireland's TSO was able to effectively balance the grid throughout the morning hours, avoiding significant supply shortfalls.

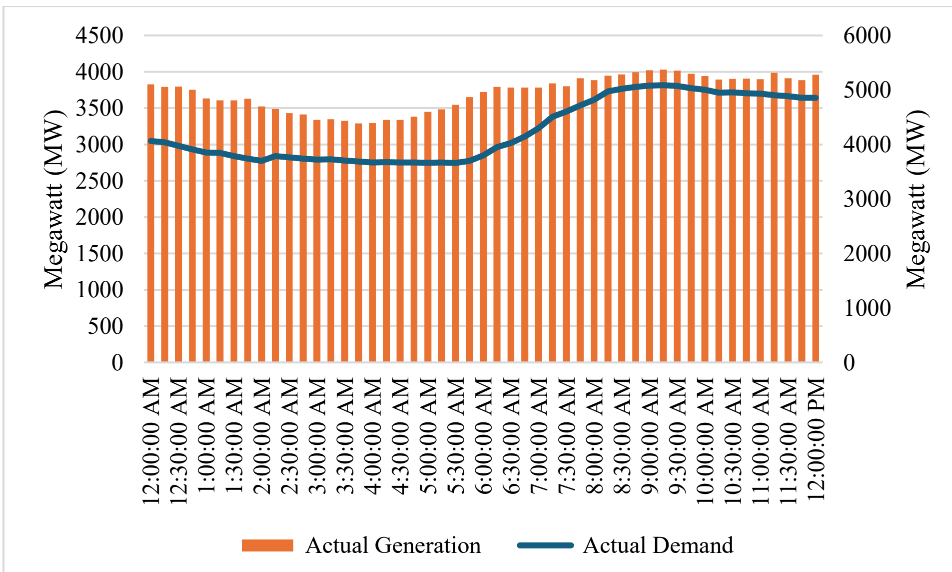


**Figure 2: Actual Generation and Demand in Ireland (12:00 AM - 12:00 PM, July 9) (EIR Grid, 2025d)**

Figure 3 provides a complementary economic perspective on the same 12-hour period, focusing on imbalance settlement prices and net imbalance volume. The imbalance settlement price reflects the cost incurred by the TSO to resolve supply-demand mismatches in each 30-minute settlement period. The net imbalance volume (NIV) indicates whether the system was long or short during each period, a negative NIV signals a short system (demand exceeds supply), while a positive NIV indicates a surplus of generation. From midnight to around 3:30 AM, the imbalance price dropped significantly, reaching a low point when the system was most short. This suggests that although demand was relatively low during these hours, it still exceeded available supply in real-time, necessitating corrective action by the TSO. From 5:30 AM onwards, the NIV began to rise toward zero, and the imbalance prices increased accordingly, peaking sharply around 8:30 AM. This price spike coincided with the peak in system demand observed in the Figure 2 and reflects the high cost of securing balancing energy during tight system conditions. After 9:00 AM, the NIV again became increasingly negative and the imbalance price dropped, indicating reduced stress on the system as demand began to fall and generation stabilized.

Overall, these graphs illustrate the interplay between physical system conditions and market signals in a liberalized electricity market. The system operator's ability to maintain close alignment between generation and demand reflects operational effectiveness, while the variation in imbalance settlement prices highlights the economic consequences of imbalances and the value of flexibility in the market. The observed trends underscore the importance of real-time balancing mechanisms, efficient price signals, and responsive market participants in ensuring system reliability and cost-effectiveness. This analysis is particularly relevant to understanding how Ireland's market design supports balancing and how lessons from this system can inform electricity market reforms in other jurisdictions.

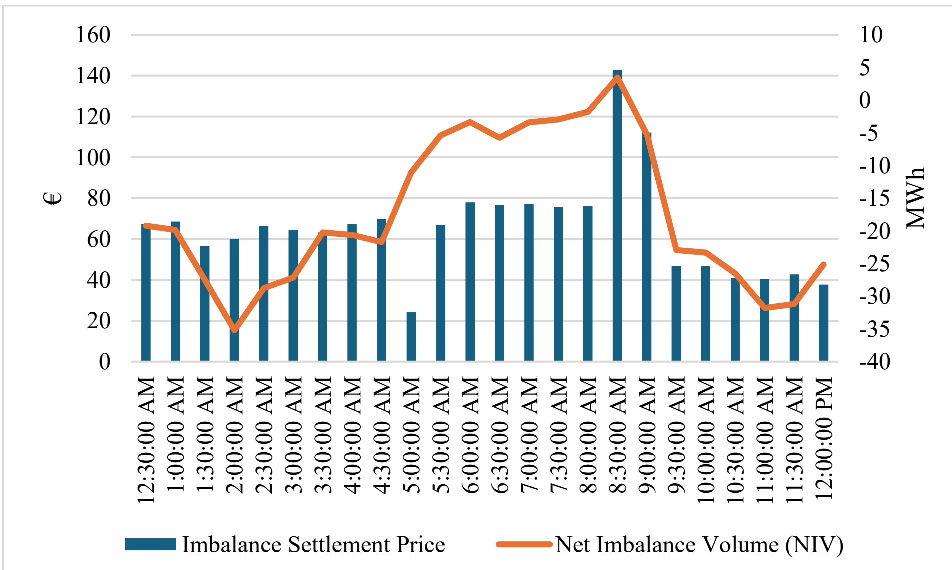


**Figure 3: Imbalance Settlement Price and Net Imbalance Volume (NIV) in Ireland (12:00 AM - 12:00 PM, July 9) (EIR Grid, 2025d)**

2. Monitoring Market Concentration using the Herfindahl-Hirschman Index (HHI)

Nova Scotia's electricity market is primarily regulated by the Nova Scotia Utility and Review Board (NSUARB), with a concentration of market share held by a few dominant suppliers (NSEB, 2025). However, the current market structure does not explicitly track or monitor market concentration using tools like the HHI, due to the historically monopolistic nature of the market and the limited number of participants. While the province has made strides toward integrating renewable energy sources and increasing market transparency, there is a lack of formal mechanisms to measure and ensure competition. As renewable energy integration grows and more IPPs enter the market, regularly monitoring the HHI will be crucial for assessing market dominance and fostering a more competitive environment.

Figure 4 shows the market concentration and HHI values for electricity generation in Nova Scotia over the period from 2015 to 2024, using actual annual generation data in Gigawatt-hours (GWh), and from 2025 onward, using forecasted values from the Integrated Resource Plan (IRP). In 2015, NSPI held approximately 85% of the province's total electricity generation, producing about 9412 GWh, resulting in an HHI of 7390 clearly indicating a highly concentrated market. Between 2016 and 2019, NSPI's production remained relatively stable, while generation from other parties gradually increased, primarily due to the entry of renewable energy projects and IPPs. This diversification helped reduce the HHI from 7390 in 2015 to 6902 in 2019, signaling a slight movement toward market diversification, though the system remained heavily dominated by NSPI.

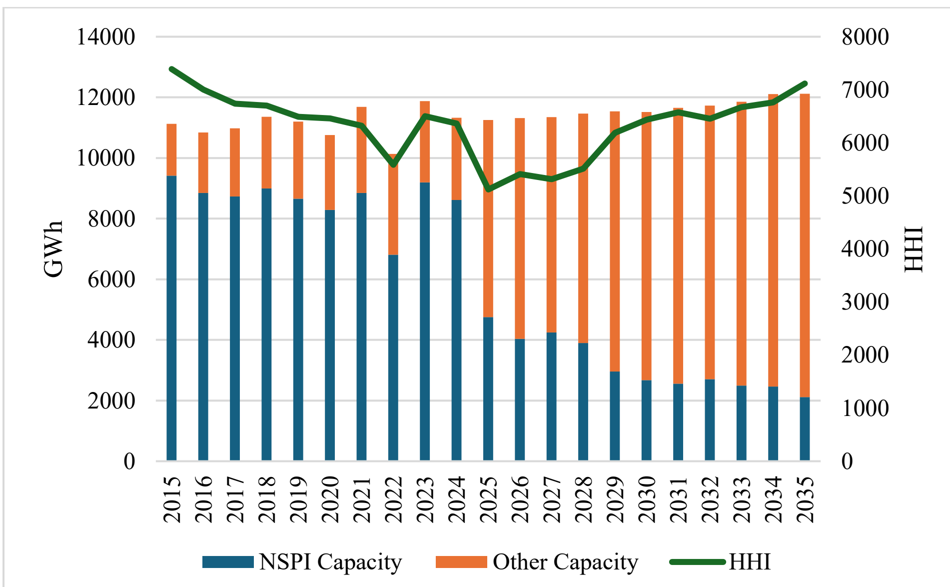


**Figure 4: HHI Values from period 2015-2035 (Emera, 2025; NSP, 2025f)**

The trend briefly reversed in 2020 when NSPI's market share peaked again at around 84%, causing the HHI to rise to 7260. This was largely driven by a temporary reduction in output from other producers. However, from 2021 onward, the market gradually began shifting, with the increased contributions of other parties, including IPPs, Community Feed-In Tariff (COMFIT) projects, and the integration of the Maritime Link with Newfoundland & Labrador Hydro (NLH). By 2024, NSPI's share fell to approximately 76%, with its generation dropping to around 8620 GWh, while other producers' generation rose to 2706 GWh. Consequently, the HHI declined to 6363, reflecting slow but meaningful progress toward a more diversified generation portfolio and a less concentrated market.

Looking ahead, the IRP forecast projects a transformation in the province's generation mix. NSPI's generation is expected to decline sharply, from 4751 GWh in 2025 to just 2117 GWh by 2035, while other producers' generation is projected to rise significantly, from 6506 GWh in 2025 to 10,005 GWh in 2035. This shift will initially bring the HHI down to its lowest point of 5122 in 2025, marking a substantial improvement in market competitiveness. However, over the following decade, the HHI is expected to gradually climb again, reaching 7177 by 2035. This indicates that while NSPI's dominance will decline, market concentration could rise if safeguards are not implemented to prevent a few new entrants from becoming overly dominant in the generation sector. Overall, the historical trend shows a slow path toward increased competition, whereas the outlook signals a more dynamic and diversified electricity market. However, ongoing attention will be needed to ensure that competitive gains are sustained and that market power does not simply shift from NSPI to a new set of dominant suppliers.

3. Facilitating Grid Modernization and Access

Nova Scotia is actively modernizing its grid to integrate renewable energy and enhance system reliability. NSP is developing three new grid-scale battery storage sites in Bridgewater, Annapolis Valley, and Halifax, aimed at storing surplus renewable energy to ensure stable power supply and reduce congestion (NSP, 2023a). NSP has financed some of the cost from Canada Infrastructure Bank and some from the Mi'kmaw-owned Wskijnu'k Mtmo'taqnuow Agency (CBC, 2024). The Maritime Link, completed in 2018 and achieving full commercial operations in 2020, albeit with limited energy transactions due to delays in energy supply from Newfoundland and Labrador, connects Nova Scotia's grid to Newfoundland and Labrador's, improving grid stability by enabling clean hydroelectric power import (EmeraNL, 2025).

Nova Scotia Power in investing $78 million between 2025 and 2029 in its Advanced Grid Modernization (AGM) initiatives to enhance the reliability and resilience of the electricity system (NSP, 2024b). These programs focus on integrating real-time monitoring, automation, and digital control systems to improve outage management, grid flexibility, and the integration of Distributed Energy Resources (DERs).

A significant portion of this investment, $65 million, will be allocated to the Connected Assets program, which aims to expand the telecommunications connectivity of intelligent field devices across the grid. This includes $21 million for deploying up to 58 additional Remote Terminal Units (RTUs) in substations, allowing for enhanced monitoring, fault detection, and remote operations. Additionally, $44 million will be invested in Downline Connectivity, expanding the communication path between reclosers and the Advanced

Distribution Management System (ADMS). This initiative will reduce outage durations, enhance asset management, and improve safety by enabling remote control operations.

Another key component is the Fault Location, Isolation, and Service Restoration (FLISR) program, which will receive $13 million in investment (NSP, 2024b). FLISR utilizes automated protection devices to improve distribution feeder reliability, minimizing the number of customers impacted by outages. By enhancing grid visibility and enabling remote reconfiguration, this program is expected to deliver significant improvements in system resilience, particularly during storms and major events.

**Table 7: Advanced Grid Modernization Programs (2025-2029) (NSP, 2024b)**

| Program Name | Investment ($ Million) | Description |
|---|---|---|
| Connected Assets | 65 | Expands grid connectivity through remote telemetry and intelligent field devices, improving outage management and asset monitoring. |
| Remote Terminal Units (RTUs) | 21 | Deploys 58 additional RTUs in substations to enhance remote monitoring, fault detection, and control capabilities. |
| Downline Connectivity | 44 | Connects reclosers to the ADMS system, enabling faster fault location, remote operation, and improved safety. |
| Fault Location, Isolation, and Service Restoration (FLISR) | 13 | Implements self-healing grid technologies that automatically reconfigure the network to minimize outage impacts. |

## 4.3 Renewable Energy Integration Strategy

A successful electricity market transition in Nova Scotia will depend significantly on the province's ability to integrate renewable energy into its system in a reliable, cost-effective, and scalable manner. Given Nova Scotia's ambitious decarbonization targets and growing wind and solar capacity, the integration of variable renewable energy must be supported by robust market and system design. This section examines how renewable energy integration strategies identified through the FIDER can be applied to the Nova Scotian context.

### Potential Strategies with Measurable Indicators

1. Invest in Advanced Forecasting Tools

Nova Scotia has a significant share of on renewable energy sources, particularly wind, as part of its commitment to achieving 80% renewable electricity by 2030 (NS Climate Change, 2022). A report prepared for the Nova Scotia Department of Energy highlights that technology, such as storage systems, advanced forecasting tools, and flexible demand-side resources, will be required to integrate variable energy resources (i.e., renewables indicating current limitations in managing variable renewable energy sources (London Economics, 2015). Nova Scotia Power's 10-Year System Outlook Report provides forecasts and assessments, indicating the necessity of adopting advanced predictive analytics and grid integration solutions to enhance renewable energy utilization and reduce reliance on system operating reserves. (NSP, 2025b).

Nova Scotia is on track to significantly expand its supply of renewable electricity, with wind generation projected to rise from 2,939 GWh in 2025 to 6,903 GWh in 2035 (NSP, 2025e) . However, the province currently operates with a 20% installed capacity planning reserve margin to maintain system reliability, in part because wind has a low marginal Effective Load Carrying Capability (ELCC) of about 10% (NSP, 2023). This means much of the growing wind capacity does not fully count toward meeting reserve needs, forcing the system to rely on costly spinning reserves of between about 150 to 200 MW and often curtailing wind output when penetration exceeds about 700 MW (NSP, 2025e).

As summarized in the Table 1, under current curtailment rates of 10%, Nova Scotia risks wasting up to about 690 GWh/year of clean wind energy by 2035, enough to power an estimated 69,000 homes. The province could cut curtailment rates to below 5% (NSP, 2025e), unlocking around 150–350 GWh/year of additional renewable generation (potential recovery) across the coming decade by, for example, adopting advanced forecasting tools, predictive analytics, and integration assets such as battery storage . This would not only supply electricity to an estimated 15,000–35,000 homes annually but could also lower reserve requirements by an estimated 10 to 15 MW, saving about $2–4 million per year in operating costs. Strengthening forecasting and optimizing reserve margins will therefore be essential for Nova Scotia to meet its 80% renewable electricity target while ensuring system reliability and affordability.

**Table 8: Estimated Wind Curtailment Recovery for 5% 2025-2035 (NSP, 2025f)**
(Based on average household electricity consumption of ~10,000 kWh/year in Nova Scotia (NSEB, 2025a). 1 GWh can supply approximately 100 homes annually.)

| Year | Wind Generation (GWh) | Curtailment at 10% (GWh) | Curtailment at 5% (GWh) | Potential Recovery (GWh) | Estimated Homes Powered |
|---|---|---|---|---|---|
| 2025 | 2,939 | 294 | 147 | 147 | ~14,700 |
| 2026 | 3,858 | 386 | 193 | 193 | ~19,300 |
| 2027 | 4,151 | 415 | 208 | 208 | ~20,800 |
| 2028 | 4,605 | 460 | 230 | 230 | ~23,000 |
| 2029 | 5,117 | 512 | 256 | 256 | ~25,600 |

| | | | | | |
|---|---|---|---|---|---|
| 2030 | 5,431 | 543 | 272 | 272 | ~27,200 |
| 2031 | 5,903 | 590 | 295 | 295 | ~29,500 |
| 2032 | 5,988 | 599 | 299 | 299 | ~29,900 |
| 2033 | 6,595 | 660 | 330 | 330 | ~33,000 |
| 2034 | 6,871 | 687 | 344 | 344 | ~34,400 |
| 2035 | 6,903 | 690 | 345 | 345 | ~34,500 |

2. Establish Ancillary Services Markets

In Nova Scotia, ancillary services are currently provided under a centralized framework provided by Nova Scotia Power rather than through a competitive market. Ancillary services refer to the essential support functions required to maintain the reliability and stability of the electricity grid. These include services such as frequency regulation (which keeps the grid's frequency within acceptable limits), spinning and non-spinning reserves (which provide backup power in case of sudden generation or demand changes), voltage control (which ensures power is delivered at the correct voltage level), reactive power support, and black start capability (the ability to restart the grid in the event of a total blackout).

The Nova Scotia Power System Operator (NSPSO), operating under the Nova Scotia Wholesale Electricity Market Rules established in 2007, is responsible for ensuring grid reliability through ancillary services (Nova Scotia, 2024). However, these services are primarily delivered by NSP. Under this structure, ancillary services such as frequency regulation, reserve capacity, and voltage control are provided through NSP’s Transmission Tariff rather than through an open, market-based procurement system. While it is technically feasible for IPPs to provide such services in a more competitive environment, the current structure reflects the critical importance of operational experience in maintaining system reliability. NSP's longstanding role in managing real-time grid operations and contingencies ensures stability in a relatively small and isolated grid. Any future transition toward market-based procurement of ancillary services would need to be carefully phased, with appropriate regulatory frameworks and technical safeguards to ensure reliability is not compromised. Looking ahead, the newly established NSIESO is empowered to conduct competitive procurements for ancillary services. Any transition toward such a framework will need to be carefully phased, with appropriate regulatory oversight and technical safeguards to ensure that system reliability is maintained.

A significant limitation in Nova Scotia’s current approach is the absence of a competitive ancillary services market, which contrasts with the recommendation to create markets for these services. The reliance on NSP rather than an open market restricts opportunities for IPPs and demand-side resources to contribute to grid stability. While the provincial government acknowledged this gap and commissioned a study in 2020 to explore potential procurement reforms, no substantial market-based mechanism has been implemented yet to allow renewables, battery storage, or demand-side resources to compete for ancillary service provision.

Table 9 summarizes the state of ancillary services in Nova Scotia and the challenges or gaps identified.

**Table 9: Ancillary services in Nova Scotia (NSP, 2024c)**

| Ancillary Service | Problems | Challenges or Gaps Identified |
|---|---|---|
| Frequency Regulation | Not publicly disaggregated | No competitive market<br>Limited participation from storage or renewables |
| Spinning/Operating Reserves | Growing with coal retirement | Fast-acting gas and battery storage identified as solutions, but no open procurement mechanism yet |
| Voltage Support | Provided system wide as needed | Voltage stability is complicated by increasing inverter-based renewable generation |
| Synchronous Inertia | Declining as coal units are phased out | Synchronous condensers and the Reliability Tie project are being pursued to address the deficit |
| Black Start Capability | Not disclosed in public filings | Modernization needed to ensure black start functionality in a renewables-heavy grid |

As coal units retire and variable renewable energy sources (like wind) increase, Nova Scotia's power system will face more frequent imbalances between supply and demand. The IRP Action Plan Update identifies this challenge and outlines a planned addition of 300 MW of fast-acting gas generation by 2028 with another 300 MW by 2030 under the Renewable Integration Power Sites (RIPS) initiative (NSP, 2024c). These plants will not only provide peaking capacity but also spinning reserves and fast frequency response. However, no competitive ancillary services market has been created to allow IPPs or battery storage developers to participate in the provision of these services.

Voltage regulation is increasingly strained by the integration of inverter-based renewable energy resources (IBRs), which are power generation sources such as wind turbines, solar PV, and battery storage systems that connect to the grid through electronic inverters rather than synchronous generators, IBRs do not inherently provide system strength, defined as the grid's ability to maintain stable voltage and recover from disturbances by supplying short-circuit current and supporting voltage control (NSP, 2025e). Unlike synchronous generators, IBRs do not inherently support voltage or system strength (NSP, 2025e). NSP's 2023 study on Large-Scale Integration of IBRs concluded that additional support will be required to manage voltage and maintain power quality (NSP, 2025e). Nova Scotia Power's solutions include new synchronous condensers and the NS-NB Reliability Tie, which will import system strength from neighboring jurisdictions like New Brunswick (NSP, 2025e).

The loss of synchronous inertia is one of the most pressing issues facing Nova Scotia's grid, especially as thermal plants are retired. The Reliability Tie, a 345 kV transmission line from Onslow (NS) to Salisbury (NB), is a centerpiece of NSPI's strategy to address this (NSP, 2025e). According to the IRP update, this project will reduce the system's Rate of Change of Frequency (RoCoF) under high wind penetration scenarios by providing additional system strength and inertia from New Brunswick (NSP, 2025e). However, this strategy raises an important challenge: New Brunswick is also increasing its share of inverter-based renewable energy, particularly wind. While this transition may reduce the share of synchronous generation over time, NB Power still operates a mix of synchronous assets, including hydroelectric, thermal, and nuclear facilities, which are expected to provide sufficient support in the near to medium term. More importantly, the benefit of the Reliability Tie lies not only in importing power but in interconnecting Nova Scotia with a larger synchronous AC system, which helps dilute the impact of local disturbances and stabilize frequency. Over the longer term, Nova Scotia will still need to invest in local solutions such as synchronous condensers and grid-forming inverters to maintain system strength as the broader region continues its transition to renewable energy.

The North American Electric Reliability Corporation (NERC) Interregional Transfer Capability Study identified Nova Scotia as one of the provinces facing persistent energy inadequacy, the power system's ability to supply sufficient energy to meet forecasted electricity demand across all hours of the year, even during periods of peak load or stressed conditions, challenges under scenarios of extreme weather and high renewable penetration (NERC, 2025). The study found that Nova Scotia experienced tight energy margins, defined as periods when the supply of available resources is only slightly above the expected demand, for 641 hours across 12 historical weather years analyzed, with a maximum hourly resource deficiency of 582 MW under 2033 load and resource projections (NERC, 2025). These deficiencies are compounded by the province's increasing reliance on variable renewable energy sources such as wind, which have lower effective capacity contributions to peak demand.

To address these risks, the NERC study proposes an increase of 500 MW in transfer capability between New Brunswick and Nova Scotia through planned but not yet completed enhancements to the existing Nova Scotia - New Brunswick Reliability Tie and related infrastructure upgrades (NERC, 2025). This increase would raise Nova Scotia's total import capacity from the current 170 MW (summer) and 100 MW (winter) to 670 MW in summer and 600 MW in winter. However, it is important to consider the potential scenario where New Brunswick may also require this power during periods of high demand, such as during extreme weather events. In such cases, the availability of surplus capacity from New Brunswick could be limited, potentially impacting Nova Scotia's ability to rely on this transfer capability. To mitigate this risk, it would be crucial to ensure that the enhancements to the reliability tie are designed to accommodate both provinces' needs during peak demand periods, with appropriate contingency plans in place for emergencies or system stresses.

The NERC analysis also emphasized that increasing transfer capability alone is not sufficient without verifying surplus availability from neighboring regions. Accordingly, coordinated resource planning with New Brunswick and the broader Eastern Interconnection, the vast synchronized electricity grid covering much of eastern North America, will be necessary to ensure that incremental imports can be reliably scheduled during tight system conditions. NERC's findings reinforce the importance of the Reliability Tie project within Nova Scotia's broader renewable integration and decarbonization strategy, serving as a critical enabler of both energy adequacy and operational reliability.

While black start services are still maintained by NSP, there is no detailed public reporting of their condition or modernization status. However, with the increasing role of distributed and non-synchronous resources, a shift toward a more resilient, decentralized black start system will be necessary in the long term.

3. Modernize and Develop Smart Grid Technologies

Nova Scotia has made substantial strides in modernizing its electrical grid by implementing smart grid technologies, including advanced meters, communication networks, and automation systems, with the aim of improving grid efficiency and reliability. One of the key projects is the Smart Grid Nova Scotia (SGNS) initiative, launched in 2019 (NRCan, 2025). This collaborative effort involves the federal and provincial governments, Siemens Canada, and other stakeholders, and is focused on deploying technologies that support renewable energy integration and enhance the overall intelligence of the grid. In this context, "intelligence" refers to the grid's ability to automatically monitor, analyze, and respond to changing electricity conditions in real time using data-driven control systems and digital infrastructure. Another important initiative, the Smart Grid Atlantic Initiative, also launched in 2019, seeks to create a more intelligent, resilient, and cleaner power grid across Atlantic Canada, including Nova Scotia (Siemens, 2025). It focuses on developing technologies that improve grid management, reduce consumer costs, and lower greenhouse gas emissions. Additionally, Nova Scotia Power's investment in battery energy storage systems, such as the installation of three large-scale systems funded in part by the Government of Canada, supports the transition from coal to wind energy, further advancing grid modernization and renewable energy integration (NRCan, 2025).

To improve its energy infrastructure, Nova Scotia should consider adopting several key recommendations inspired by successful practices from Ireland, Singapore, and New Zealand. For example, Nova Scotia could implement Digital Twin Technology, like Singapore's Grid Digital Twin project, to create virtual replicas of its grid. This technology would help manage and predict grid performance more effectively, particularly with the integration of renewable energy sources. Additionally, Nova Scotia could develop district-level smart grids in urban areas, incorporating technologies such as solar panels, EV charging stations, and energy storage systems to enhance local energy optimization and resilience. However, while such decentralized and digital solutions are promising, the need for system inertia and grid synchronization remains critical. These smart grids must be designed to ensure frequency stability and reliable operation, especially as traditional synchronous generators are phased out.

## 4.4 Energy Security and Diversification

Ensuring long-term energy security while diversifying the energy mix is a central challenge for Nova Scotia as it transitions toward a more liberalized and decarbonized electricity market. The province's historical dependence on coal and limited interconnection capacity increase its vulnerability to supply risks and price volatility. This section applies the Energy Security and Diversification component of FIDER to assess how Nova Scotia can improve supply resilience, reduce reliance on single fuel sources, and leverage domestic and regional opportunities. Strategies explored include diversifying generation technologies, strengthening grid interconnections, and improving access to firm and flexible capacity all aimed at supporting a secure and competitive market framework.

### Potential Strategies with Measurable Indicators

1. Diversify Energy Sources

Nova Scotia is undergoing a transformation in its electricity sector, with clear commitments to phase out coal, increase renewable energy adoption, and ensure long-term energy security through a diversified supply mix. The province has mandated a complete phase-out of coal-fired electricity by 2030, aligning with federal targets under the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations and Canada's commitment to achieve net-zero emissions by 2050 (NS Climate Change, 2022; Govt. of Canada, 2012). To support this transition, Nova Scotia is actively pursuing renewable energy development, particularly in wind and solar power, and expanding its transmission and storage infrastructure (NSDNRR, 2025). Programs like the Green Choice Program and the Rate Base Procurement Process are regulatory pathways used to attract independent renewable energy producers, while initiatives such as community solar projects, battery storage deployments, and grid modernization are being introduced to support renewable integration (NSRBP, 2025; NSGCP, 2025). Furthermore, the province is leveraging its geographical advantage through hydropower imports via the Maritime Link, enabling clean energy transmission from Labrador's Muskrat Falls (Nova Scotia, 2025a).

Figure 5 illustrates the potential outcome of these provincial strategies and policy shifts using IRP scenario C1-E1-R2 (Net Zero 2035, Current Polices and Trends, No Atlantic Loop). Scenario C1-E1-R2 was selected for the 2024 10-Year System Outlook because it is the planning scenario most closely aligned with Nova Scotia's Clean Power Plan, NS Power's Path to 2030, and the 2024 Load Forecast. It represents a net-zero 2035 pathway under current policy and electrification trends, excluding the Atlantic Loop. Importantly, it was also among the lowest-cost scenarios evaluated that can still meet the 2030 decarbonization goals and the federal target of achieving a net-zero electricity system by 2035 (NSP, 2024a). In 2025, coal still plays a significant role with 2,733 GWh of generation but is rapidly phased out and eliminated by 2030. This dramatic reduction is visibly offset by notable increases in renewable energy sources. Wind generation grows from 2,939 GWh in 2025 to over 7,600 GWh by 2050, emerging as the dominant source of electricity. Solar energy also sees substantial growth, rising from 306 GWh in 2025 to 1,245 GWh by 2050, with most gains occurring after 2040 a period.

Other renewable sources, domestic hydro, tidal, and biomass, maintain relatively stable contributions over the period, ensuring a baseline of firm or dispatchable capacity. Hydropower remains strong at around 900 to 1,000 GWh annually, while biomass offers consistent support, especially in industrial applications. Maritime Link imports also make a reliable contribution of 880-900 GWh annually, reflecting Nova Scotia's strategy to complement intermittent local renewables with stable, clean imports.

The role of battery storage (Battery 4H), as shown in Figure 5, becomes increasingly significant after 2035. Battery output grows from 0 GWh in 2025 to 675 GWh by 2050, illustrating the deployment of energy storage to mitigate variability and improve system reliability as variable renewables expand.

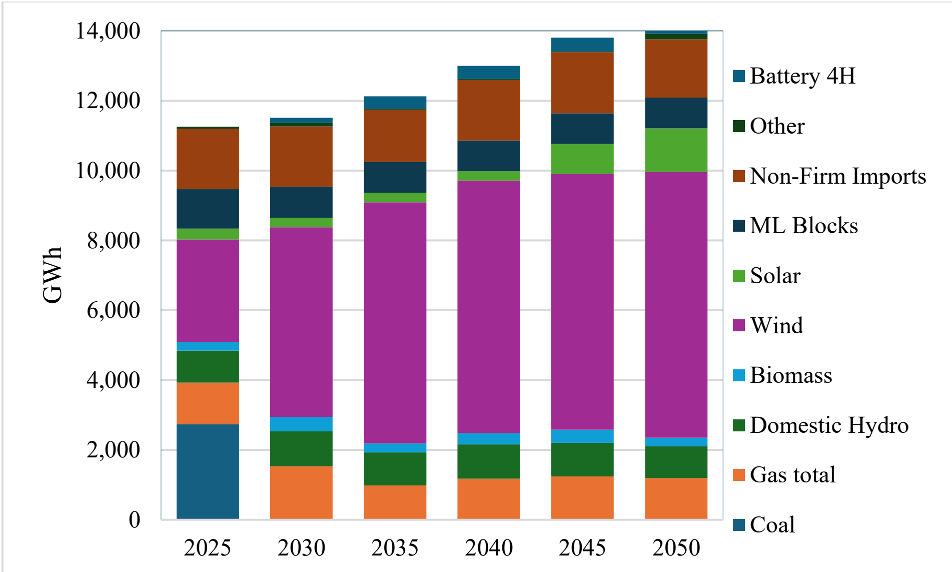


**Figure 5: Electricity Generation Forecast by Source, 2025–2050 (NSP, 2025c) (The scenario used for the graph is CE1-E1-R2 (No Atlantic Loop). The 'Other' category includes diesel combustion turbines (CTs), tidal energy, nuclear, and heavy fuel oil (HFO) conversions.)**

The graph visually reinforces the narrative of Nova Scotia's energy transformation. The province's energy planning is not only focused on decarbonization but also emphasizes system flexibility and resource diversity. Through a mix of policy mandates, market-based instruments, and infrastructure upgrades,

2. Implementing Capacity Mechanisms

Nova Scotia has not implemented a formal capacity market but is actively pursuing a comprehensive strategy to ensure sufficient reserve capacity through a combination of utility planning, demand-side programs, and resource diversification. According to the 2024 Ten-Year System Outlook prepared by the Nova Scotia Power System Operator (NSPSO), the province maintains a 20% planning reserve margin, significantly above the North American Electric Reliability Corporation's (NERC) typical benchmark of 15%, to account for load uncertainty, generator outages, and renewable variability (NSP, 2024a). This conservative approach reflects Nova Scotia's priority on system reliability as it phases out coal and increases reliance on variable renewable sources. Given that Nova Scotia is a winter-peaking jurisdiction, the highest system demand typically occurs between December and February, driven heavily by residential electric heating (NSP, 2024a).

To address increasing peak demand and variability in renewable output, Nova Scotia Power has outlined a range of future capacity additions and planning measures. For example, in scenario CE1-E1-R2 between 2025 and 2034, the utility forecasts a net increase of 372 MW in firm supply, complemented by 279 MW in demand-side measures comprising 241 MW from DSM and 38 MW from Demand Response programs (NSP, 2024a). These demand-side contributions are expected to flatten load curves and reduce reliance on peaking fossil assets (NSP, 2024a). Furthermore, battery storage is a major part of the firm capacity strategy, with 180 MW of installations planned through 2030, and assigned a high ELCC of 85% for four-hour duration systems (NSP, 2024a).

In addition to provincial generation, firm imports from New Brunswick via the existing intertie and the Maritime Link are expected to contribute approximately 300 MW of firm capacity, offering operational flexibility during tight conditions (NSP, 2024a). For instance, between 2025 and 2034, NS Power expects to add 180 MW of firm battery capacity, 600 MW of fast-acting generation, and 459 MW from coal-to-HFO conversions, alongside incremental wind additions with a diminishing ELCC due to increasing saturation of variable resources (NSP, 2024a). The peak demand is expected to grow steadily, projected at an average annual increase of 1.4%, further enhancements could include more structured capacity procurement processes, transparency in reserve margin tracking, and formalizing capacity commitments from distributed and emerging technologies (NSP, 2024a). These steps would strengthen the province's ability to deliver a reliable and decarbonized electricity system by 2030 and beyond (NSP, 2024a).

Table 10 provides a snapshot of Nova Scotia's estimated annual firm peak demand projections, required reserve margins, total capacity requirements, and anticipated firm supply over the next decade. It serves as an essential tool to assess how well the province is positioned to maintain grid reliability as it transitions away from coal and integrates more renewables.

Each year, NSP calculates its total required capacity by applying a 20% planning reserve margin on top of the forecast firm peak demand. This margin is a reliability safeguard meant to account for unexpected generator outages, renewable intermittency, demand surges, or extreme weather events. For example, in winter 2024/25, the firm peak demand is forecast at 2,259 MW, requiring an additional 452 MW in reserves, resulting in a total system requirement of 2,711 MW.

However, NS Power's total firm supply that year was only 2,567 MW, leaving a deficit of 144 MW. This deficit narrows slightly over the following years with new resource additions (like batteries, Demand Response/Demand Side Management programs, and converted generation), but it remains consistently negative across the decade. By 2033/34, the gap is projected to reach 159 MW, even after accounting for all planned additions and demand-side resources.

This persistent shortfall between available firm supply and required capacity signals two key issues:

1. Current plans are not enough to maintain long-term resource adequacy.
2. There is a growing need for additional firm, dispatchable, or capacity-accredited resources.

This data strongly supports the argument for developing or enhancing capacity mechanisms, whether through expanded procurement programs, increased demand response participation, storage incentives, or even exploring a structured capacity market. In short, the table shows that without additional action, Nova Scotia will consistently fall short of meeting its required capacity margins, which could threaten reliability, especially during peak winter periods when renewable output is low and heating loads are high. This makes a compelling case for policy and planning interventions aimed at closing the growing capacity gap.

**Table 10: Nova Scotia Power's Load and Firm Capacity Outlook (MW) (data from (NSP, 2024a))**

| Year | Firm Peak Demand | Required Reserve Margin (20%) | Total Required Capacity | Total Firm Supply | Capacity Surplus / Deficit |
|---|---|---|---|---|---|
| 2025 | 2,259 | 452 | 2,711 | 2,567 | -144 |
| 2026 | 2,267 | 453 | 2,720 | 2,617 | -103 |
| 2027 | 2,265 | 453 | 2,718 | 2,651 | -67 |
| 2028 | 2,283 | 457 | 2,740 | 2,682 | -58 |
| 2029 | 2,306 | 461 | 2,767 | 2,690 | -77 |
| 2030 | 2,360 | 472 | 2,832 | 2,771 | -61 |
| 2031 | 2,397 | 479 | 2,876 | 2,805 | -71 |
| 2032 | 2,438 | 488 | 2,926 | 2,835 | -91 |
| 2033 | 2,485 | 497 | 2,982 | 2,864 | -118 |
| 2034 | 2,542 | 508 | 3,050 | 2,891 | -159 |

3. Promoting Distributed Generation

Nova Scotia is actively advancing Distributed Generation (DG) to enhance grid resilience, reduce reliance on centralized power plants, and support a cleaner energy mix. The province has implemented several initiatives to promote DG, including the Community Solar Program, which enables non-profits, co-operatives, First Nations communities, municipalities, businesses, and educational institutions to develop solar gardens up to 10 MW. These installations allow residents unable to install rooftop panels to subscribe and receive a credit on their electricity bills (News Wire, 2024). The province has committed $5.2 million in 2024–25 to support these projects, with the first gardens expected to be operational by spring 2026 (Nova Scotia, 2024a).To further encourage DG, Nova Scotia has expanded its commercial net-metering program, increasing the capacity from 100 kW to 1 MW (McInnes Cooper, 2022; Canlii, 2025). This change facilitates larger-scale solar installations for businesses and institutions, promoting greater self-generation and reducing reliance on centralized power sources. Additionally, the province is investing in smart grid technologies, including the deployment of grid-scale batteries, IntelliRupters, (automated smart switches that help detect and isolate faults on the grid to improve reliability), and Remote Terminal Units (RTUs) (devices that collect data from field equipment and allow remote monitoring and control of the grid). The grid-scale battery projects are designed to operate both independently and in support of renewable energy generation, including wind and solar. While not exclusively paired with specific solar installations, these batteries will store excess electricity from the growing mix of renewables and discharge it during peak demand periods to stabilize the grid.

The Green Choice Program is another initiative, allowing large-scale electricity customers, including public institutions and businesses, to obtain access to clean electricity from renewable energy sources (Nova Scotia, 2025b). Supported by six new wind farms co-owned by private developers and Mi'kmaw communities, the program projects to add 2,000 gigawatt-hours of clean electricity annually by the end of 2028 (Environmental Journal, 2025). This initiative will be the single largest addition of clean electricity in Nova Scotia's history (Nova Scotia, 2025c).

SolarBank Corporation, in partnership with TriMac Engineering, has proposed a 10 MW solar project in Enon on Cape Breton Island, and three seven-MW projects in Sydney, Halifax, and Annapolis (CBC, 2024a) .

## 4.5 ISO Governance and Independence

As Nova Scotia transitions toward a competitive electricity market, the creation of the NSIESO under the 2024 Electricity Reform Act marks a foundational step (NS Legislature, 2025) . However, since the NSIESO is not yet operational, this section explores how effective market monitoring and performance review mechanisms have been embedded in the ISOs of Ireland, New Zealand, and Singapore. Drawing from these examples, a set of recommendations are presented for NSIESO to institutionalize strong performance governance from the outset.

### Potential Strategies with Measurable Indicators

1. Implement Regular Market Monitoring and Performance Reviews

In Ireland's all-island SEM (operated by EirGrid/SEMO under the SEM Committee), a dedicated Market Monitoring Unit (MMU) continuously engages with generators and participants to monitor short and long-term SEM outcomes (such as prices) and participant behaviour (SEM Committee, 2025). The MMU tracks key outcomes (prices, quantities, generation mix) and publishes its findings. Since April 2022 the MMU issues monthly monitoring reports detailing market performance metrics and trends (SEM committee, 2025a). For instance, the February 2025 report provided detailed analyses of day-ahead prices, volumes, and generation sources (SEM Committee, 2025b).

New Zealand's electricity market is closely monitored by the EA, an independent regulator that reviews system operator performance, market behavior, and compliance with codes (EA, 2025). These reviews examine metrics such as price volatility, supply-demand imbalances, frequency of price spikes, and offer prices relative to costs. For example, the EA's latest quarterly report analyzed six key indicators of competitiveness including the frequency of very low or separated prices and the share of offers above cost and concluded that recent price patterns reflected underlying conditions, consistent with competition (EA, 2024c). It also provides public data tools (e.g. the Electricity Market Information website, vSPD, JADE) so participants can perform their own monitoring (EA, 2025; EA, 2025b; EA, 2025c).

Singapore's power market National Electricity Market of Singapore (NEMS) relies on surveillance by the Energy Market Authority (EMA) and its Power System Operator (PSO). The EMA has established an independent Market Surveillance and Compliance Panel (MSCP) to oversee NEMS conduct. The MSCP (supported by the EMC's Market Assessment Unit) monitors market structure and participant behavior and investigates any breaches of the Market Rules (EMC-MSCP, 2025). Every quarter, the Market Assessment Unit (MAU) submits a detailed market watch report of monitoring and analysis, and the MSCP issues an annual report summarizing investigations. When non-compliance is found, the MSCP can impose financial penalties (EMC, 2025).

The common thread across these countries is the institutionalization of independent, transparent, and regular market performance evaluations. These systems function effectively because they are backed by regulatory independence, access to operational data, and performance indicators. Performance reviews are not just reactive but also forward-looking, identifying systemic risks and emerging inefficiencies. The following key principles can be extracted from these examples:

1. Establish clear and measurable Key Performance Indicator's (KPIs) for system operations.
2. Ensure oversight is independent and empowered to enforce compliance.
3. Publish performance metrics and findings regularly to build public trust.
4. Integrate stakeholder feedback into system evaluations.

To ensure NSIESO becomes a credible and effective market operator, it should adopt a structured and transparent market monitoring framework. First, NSIESO should work with provincial regulators and stakeholders to define annual KPIs across reliability, dispatch efficiency, system balancing, and integration of renewables. A Market

Monitoring Unit (MMU), either internal or independent, should be established to conduct ongoing analysis of market behavior, generator conduct, and ISO decision-making.

Second, NSIESO should commit to publishing quarterly and annual performance review reports that are accessible to all stakeholders, summarizing achievements, challenges, and areas for improvement.

Third, NSIESO should incorporate feedback loops, public consultations and stakeholder meetings to refine market rules and performance benchmarks over time. These steps can therefore support NSIESO's evolution into a reliable, transparent, and trusted institution capable of overseeing a well-functioning electricity market in Nova Scotia.

2. Transparent Reporting and Data Dissemination

EirGrid and Single Electricity Market Operator (SEMO) emphasize transparency by publishing both operational data and market reports. EirGrid's website provides a real-time dashboard with up-to-minute charts of system demand, generation by fuel type, and interconnector flows (EirGrid, 2025). It also offers downloadable historical datasets, including quarter-hourly demand, fuel mix and renewable curtailment, via its System and Renewable Data Reports page (EirGrid, 2025a). For example, EirGrid publishes fuel-mix pie charts and spreadsheets of generation by fuel, plus summaries of curtailment and constraint events, keeping users updated with our progress toward renewables targets. EirGrid and SEMO are obliged to increase wholesale market transparency. To this end, they routinely publish the inputs and outputs of the dispatch process: for instance, daily demand/wind forecasts and actual dispatch schedules (SEMO, 2025). The SEMO Transmissions System Operator (TSO) page notes that publishing such information forecasts, indicative schedules and dispatch instructions helps participants understand decisions.

New Zealand's grid operator and regulator likewise follow a policy of broad data publication. Transpower (the TSO) runs a System and Market Insights portal where it posts weekly technical reports on system performance (e.g. winter reviews, security assessments) (Transpower, 2025). These reports, though written for market participants, are publicly accessible and cover topics like demand-supply balance and new resource coordination. Transpower also offers a Live Data Dashboard: a web page showing real-time generation by fuel type, HVDC inter-island transfers, and zone-level load data (Transpower, 2025a). All active generation by source and HVDC flow are displayed in real time on this site, and historical values can be downloaded.

Singapore's market regulator (EMA) and operator (EMC) also practice strong data transparency. The National Electricity Market of Singapore (NEMS) provides daily market reports: EMC publishes a Public Daily Trading Report each business day, summarizing that day's demand, generation by type, uniform clearing price (USEP), reserve prices, and major events (EMC, 2025a). For example, daily reports include charts of forecast vs. actual demand and price trends. EMC additionally issues an annual NEMS Market Report (public since 2018) reviewing yearly market outcomes. The EMA also publishes an annual Singapore Energy Statistics compendium, an online, interactive report with charts and downloadable tables covering supply, demand, fuel mix and emissions (EMA, 2025).

Across all three jurisdictions, transparent electricity reporting serves not just as a tool for compliance, but as a vital instrument for building stakeholder confidence and guiding system evolution. These elements ensure that all market participants operate on a level playing field and that operational decisions are subject to public scrutiny.

To embed transparency into its governance from the outset, NSIESO should develop a centralized online portal to provide access to real-time market data, system performance indicators, and historical pricing trends. It should collaborate with the Nova Scotia Utility and Review Board (NSUARB) to publish quarterly and annual reports on system operations, compliance issues, and pricing trends.

Further, NSIESO should adopt open data standards that allow third-party developers, researchers, and consumer groups to use market data for independent analysis and innovation. Public consultation summaries, market rule changes, and performance audits should be made publicly accessible to ensure procedural transparency. By adopting these practices, NSIESO can establish itself as a trusted and credible entity capable of managing a transparent, competitive, and consumer-centric electricity market in Nova Scotia.

However, with greater transparency and data accessibility comes an increased responsibility to safeguard sensitive information. In May 2025, Nova Scotia Power experienced a significant cybersecurity breach (CBC, 2025). The ransomware attack led to unauthorized access and theft of sensitive personal information belonging to approximately 280,000 customers (CBC, 2025). The compromised data included names, contact details, service histories, billing records, driver's license numbers, Social Insurance Numbers, and bank account details. While the utility confirmed that the breach did not disrupt electricity generation, transmission, or distribution services, the exposure of such extensive personal information has raised serious concerns about the security measures in place to protect customer data (CBC, 2025).

3. Promote Stakeholder Engagement and Building Consumer Confidence

In Ireland, EirGrid explicitly commits to working with stakeholders, communities and industry. In practice, EirGrid tailors its engagement approach to each project using emails, brochures, public radio, webinars, social media and local open days, and invites feedback via surveys, community liaison officers, and one-on-one meetings (EirGrid, 2025b). Its formal approach is organized around four stages: Inform (share updates), Consult (formal feedback), Involve (reference groups/workshops) and Collaborate (co-design with advisory councils). EirGrid's 2020-25 strategy explicitly aims for "innovative new ways to engage" as it pursues ambitious renewables targets (EirGrid, 2025c).

New Zealand's electricity institutions similarly emphasize transparency and inclusion. The independent EA notes that ongoing and meaningful engagement promotes confidence in decisions and helps build and maintain trust in the electricity sector (EA, 2025a). In practice, New Zealand's transmission operator, Transpower, actively solicits stakeholder input. Transpower conducts periodic materiality assessments to identify what matters most to stakeholders and continuously updates this analysis. For example, stakeholders in Transpower's recent assessment highlighted how outages can seriously affect consumers; Transpower explicitly acknowledges working extensively with landowners and communities to build and maintain positive relationships so it can plan projects with minimal disruption (Transpower, 2025b). Transpower also publishes strategic plans and performance reports, further increasing transparency (Transpower, 2025c).

The key principles include structured and periodic consultations, mechanisms for publishing stakeholder feedback and responses, and tailored outreach to vulnerable or underrepresented consumer groups. Importantly, stakeholder engagement in these jurisdictions is treated as a continuous process integrated into regulatory and operational decision-making.

To promote stakeholder engagement and build consumer confidence, NSIESO should establish a Stakeholder Engagement department from the outset. This department could be tasked with coordinating public consultations, hosting technical working groups, and managing feedback loops with industry participants and consumers. NSIESO should also implement a transparent response mechanism, where feedback received during consultations is documented and addressed in public reports. Sector-specific forums, e.g., for renewable developers or large industrial users, and consumer satisfaction surveys should be employed to ensure ongoing dialogue. Through these practices, NSIESO can establish a participatory governance model that supports informed policymaking, increases market legitimacy, and ensures the electricity market evolves in line with public and stakeholder expectations.

A key feature of successful independent system operators internationally is their organizational and operational independence from both government and incumbent market participants. Independence ensures that the ISO can make objective decisions on system operations, market rules, and performance oversight without undue influence from political authorities, utilities, or other interests. In Ireland, EirGrid and SEMO operate at arm's length from government and generators, with independent boards and governance structures overseeing system operations and market rules. Similarly, New Zealand's Electricity Authority and Transpower maintain structural and operational independence, ensuring impartial dispatch, reliability management, and compliance monitoring. In Singapore, the Energy Market Authority and Power System Operator, supported by the Market Surveillance and Compliance Panel, regulate and monitor the market independently, including investigating rule breaches and imposing penalties. These examples show that structural, operational, and regulatory independence is critical for transparent, reliable, and trusted electricity market governance.

## 4.6 Summary

This chapter applied FIDER to evaluate Nova Scotia's electricity market transition and identify key areas for reform. The analysis focused on five critical dimensions essential to modern electricity markets: Demand-Side Management, Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. Each component is assessed using real-world data, regulatory filings, and policy documents to determine Nova Scotia's current progress, gaps, and opportunities.

In Demand-Side Management, the analysis highlighted the rollout of TOU and CPP programs but notes the absence of comprehensive real-time pricing and deeper industrial participation. A notable example of industrial DSM is Port Hawkesbury Paper (PHP), which participates in a special "extra large active demand control tariff" with Nova Scotia Power (NSP). Under this arrangement, PHP receives a discounted electricity rate, while NSP gains the ability to adjust the mill's electricity consumption to better balance the grid. This model demonstrates how industrial participants can provide flexibility to the system while also benefiting from reduced energy costs (NSP, 2025j). In terms of Market Access and Liquidity, the continued dominance of Nova Scotia Power and lack of real-time or day-ahead trading platforms reveal the need for regulatory and structural reforms. The Renewable Energy Integration component identified progress in wind capacity expansion but also underscored the challenges of high curtailment, limited forecasting tools, and the need for ancillary service markets. Under Energy Security and Diversification, the analysis points to strategic investments in interprovincial transmission and a diversified energy mix, while noting remaining vulnerabilities related to system strength and import reliance. Lastly, the ISO Governance and Independence assessment revealed the early-stage development of the province's independent system operator, with further action needed to establish transparency, operational autonomy, and regulatory accountability.

Together, the findings offer a clear and structured diagnosis of Nova Scotia’s electricity sector, accompanied by actionable strategies under each component. The chapter concludes that while foundational progress has been made, targeted reforms and system upgrades are needed to align the province’s electricity market with global best practices and to fully support its transition to an independent, competitive, and low-carbon energy future.

# 5 DISCUSSION

This chapter discusses the development and application of FIDER designed to guide the transition of electricity markets from regulated structures to competitive, ISO-led models. It begins by explaining how the toolkit was formulated using insights from practices observed in Ireland, Singapore, and New Zealand, three jurisdictions with electricity markets comparable in scale to Nova Scotia. This chapter then applies the toolkit to Nova Scotia's current market context, assessing its progress across five critical components. Together, this analysis provides a clear understanding of both the rationale behind FIDER and its practical relevance for shaping Nova Scotia's electricity future.

## 5.1 The FIDER toolkit

The development of FIDER in this study was guided by a comparative analysis of electricity market transitions in Ireland, Singapore, and New Zealand, three jurisdictions recognized for implementing world-best practices in moving from regulated, vertically integrated utilities to ISO-led competitive markets. These countries were specifically chosen because, like Nova Scotia, they operate relatively small electricity markets, making their experiences particularly relevant. Through a comprehensive review of academic literature, regulatory frameworks, and market data, five key components were identified: Demand-Side Management (DSM), Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. Each component was validated through evidence from these case studies, demonstrating tangible improvements in reliability, affordability, and transparency. The resulting toolkit distills these lessons into a modular, actionable framework that can guide Nova Scotia and other jurisdictions of similar scale in building a resilient, consumer-centric electricity market.

These components were selected based on their universal applicability, technical and regulatory relevance, and their demonstrable role in enabling system efficiency, reliability, and affordability. Each component was validated against real-world practices in the selected countries which provided evidence of successful implementation and measurable system improvements. For instance, EirGrid's DSM strategies in Ireland showed quantifiable reductions in peak demand and operating costs, while Singapore's transparent market access model demonstrated clear gains in competition and consumer pricing. These international insights were then synthesized into a generalized framework, forming FIDER that identifies actionable strategies and corresponding outcomes for each component. FIDER is designed to be modular and adaptable, allowing any jurisdiction, particularly small ones going through transition like Nova Scotia, to assess its current market state and apply targeted reforms. The resulting structure is both practical and analytical, offering a structured pathway toward building a transparent, decentralized, and resilient electricity market governed by an ISO.

## 5.2 Applying the FIDER toolkit to Nova Scotia

Nova Scotia has implemented a series of DSM initiatives, such as the Home Warming Program, Business Energy Solutions, and pilot programs for TOU and CPP. Over 70,000 residential and 9,000 non-residential participants have engaged in DSM programs. Smart meters have been deployed province-wide, and participation in TVP pilots increased sharply after 2023. However, load analysis from 2020 to 2024 indicates that peak demand has remained largely unchanged, with only short-term variations and no consistent downward trend. This can be the result of increasing electrification and customer growth, which are placing upward pressure on demand. While electricity consumption continues to show volatility during seasonal peaks and real-time consumer responsiveness to price signals remains limited, DSM measures appear to have moderated the rate of peak demand growth rather than eliminating it altogether. Energy efficiency improvements are therefore contributing to slowing the pace of demand increase, even if they have not yet produced a sustained absolute reduction in system peak load.

The electricity market in Nova Scotia remains highly concentrated, with NSP continuing to dominate generation, transmission, and distribution. No day-ahead or real-time markets currently exist. Electricity transactions occur through long-term bilateral contracts with regulated pricing. A simulated real-time dispatch model showed significant price variability depending on the generation mix, contrasting with the flat pricing of the current PPA-based structure. The HHI shows a modest decline in market concentration from 7390 in 2015 to 6363 in 2024, driven by gradual increases in non-NSP generation. Forecasted data suggests further reduction in NSP's market share through 2025, followed by potential reconsolidation depending on future market entrants. This indicates limited liquidity and weak competitive signals in the current structure, despite early signs of generation diversification.

Nova Scotia has made measurable progress in expanding renewable capacity, particularly wind. Wind output is expected to rise significantly through 2035. However, current system conditions show high levels of wind curtailment approximately 690 GWh annually by 2035 if trends continue. Wind has a low effective load carrying capability (ELCC), and current curtailment rates hover around 10%. Curtailment has become a persistent issue due to limitations in forecasting accuracy, insufficient reserve management, and a lack of dynamic response infrastructure. Ancillary services such as frequency regulation and spinning reserves are currently provided through centralized NSP operations, without open participation. As coal generation is phased out, new integration challenges are emerging due to reduced system inertia and increased variability from inverter-based resources. These trends reveal a grid under strain from variable generation and highlight the limitations of existing integration mechanisms.

Nova Scotia's generation mix is undergoing a structural transformation. Coal-fired generation is declining and expected to reach zero by 2030, while wind, solar, hydro, and imported hydroelectricity from Newfoundland and New Brunswick are increasing. Despite these shifts, firm capacity projections show persistent annual deficits across the next decade. Reserve margin targets are met only through high planning assumptions (20%) and reliance on imports and batteries. Peak winter demand continues to be a major stressor on the system. Distributed generation is growing, supported by policy programs and battery investments, but centralized planning still dominates system design. Overall, while energy diversification is advancing, long-term reliability risks remain due to the mismatch between peak demand growth and firm supply additions, a challenge that is further enhanced by increasing weather-related variability.

The formation of the NSIESO under the 2024 Electricity Reform Act represents a foundational institutional change. However, the new ISO has not yet begun operations and lacks clear operational structures, performance metrics, and transparency protocols. Existing system operations, including dispatch and ancillary services, continue to be managed by NSP. The transition to ISO-led governance remains in early stages, with no evidence yet of structural separation, published market monitoring reports, or stakeholder engagement mechanisms. While the legal framework is in place, the implementation status indicates that ISO independence and accountability mechanisms are not yet functional. The current arrangement reflects an incomplete institutional reform process, with foundational elements of ISO governance still under development.

## 5.3 Summary

This chapter discussed the formation and application of a practical toolkit designed to support electricity market transitions in small jurisdictions like Nova Scotia. Drawing on world best practices from Ireland, Singapore, and New Zealand, FIDER is built around five core components: Demand-Side Management, Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. The chapter explained how these components were selected, validated, and structured to provide actionable strategies and measurable outcomes. Applying FIDER to Nova Scotia revealed both progress and gaps across each component, offering a clear diagnostic of where the province stands and what steps are needed to move forward. Measuring the success of these components, through the development of specific criteria and indicators, is identified as a key area for future research, as noted in the Future Work section. Ultimately, this discussion showed FIDER's relevance not only for Nova Scotia, but also as a general framework that can guide similar jurisdictions pursuing independent, efficient, and sustainable electricity markets.

# 6 CONCLUSION

FIDER was developed in response to the growing need for a practical, structured framework to support jurisdictions, particularly small or transitioning ones like Nova Scotia, in reforming their electricity markets. Traditional models often fall short in addressing the complexities and unique constraints of emerging or limited-scale markets. Therefore, FIDER aims to guide these jurisdictions with a systematic transition toward Independent System Operator (ISO)-led, competitive, and consumer-centric electricity markets.

The toolkit is built around five critical components: Demand-Side Management (DSM), Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence. These components were selected after a rigorous literature review, benchmarking global best practices, and analyzing the operational features of mature electricity markets. Each component reflects a necessary pillar for a well-functioning electricity market, particularly in the context of smaller jurisdictions with limited market actors and grid interconnectivity.

## 6.1 Application of FIDER to Nova Scotia

The application of FIDER to Nova Scotia revealed a mix of foundational progress and systemic gaps across all five components. While the province has launched important initiatives, such as province-wide smart meter installations, renewable energy procurements, and legislative action to establish an ISO, many of these efforts remain incomplete to support meaningful transformation. The market continues to function under a largely vertically integrated structure, with Nova Scotia Power maintaining control over generation, transmission, distribution, and system operations.

What became clear through this application is that Nova Scotia has no shortage of policy ambition. The province has set strong targets for decarbonization, introduced pilot programs in demand-side management, and is in the process of institutional reform. However, without structured implementation pathways and institutional clarity, these efforts risk becoming symbolic. FIDER's framework clarified that policy commitment must be matched by regulatory certainty, transparent governance, measurable progress indicators, and a clear division of operational responsibilities between Nova Scotia Power and the NSIESO.

The toolkit also highlighted the importance of sequencing reforms. For example, expanding renewables without improving grid flexibility or establishing a real-time market can lead to inefficiencies and curtailment. Similarly, introducing an ISO without empowering it with dispatch control, data transparency, or stakeholder accountability mechanisms results in a passive rather than proactive institution.

By benchmarking Nova Scotia's progress against proven practices in Ireland, Singapore, and New Zealand, the application of FIDER exposed specific areas where the province can act with precision. These case studies affirmed that reforms must be designed not just for compliance, but for performance backed by data, incentives, and robust governance. It also emphasized the need to expand participation in the electricity market, not just by new generators and storage providers, but by consumers themselves through demand flexibility, pricing programs, and distributed energy options.

The following focused recommendations, drawn directly from the toolkit's strategic guidance and tailored to Nova Scotia's current market context, are intended to support policymakers and regulators in designing the next phase of electricity market reform:

Demand-Side Management (DSM)

- Implement a full-scale Real-Time Pricing (RTP) tariff as a standard tariff option to encourage peak demand reduction and increase grid responsiveness.
- Enhance program uptake through dedicated outreach, financial incentives, and consumer education targeting behavioral change.

Market Access and Liquidity

- Establish day-ahead and real-time energy markets under ISO oversight to replace fixed contract-based pricing with transparent competitive bidding.
- Introduce market monitoring indicators such as HHI and regularly publish reports to track market concentration and entry barriers.
- Mandate open-access interconnection rules for IPPs and distributed resources, including standardized connection timelines and cost structures.
- Phase out NSP's exclusive dispatch authority and assign real-time scheduling and settlement in NSIESO for neutrality and price efficiency.

Renewable Energy Integration

- Invest in advanced forecasting platforms integrated with ISO dispatch tools to reduce wind and solar curtailment and reserve requirements.
- Expand battery storage and demand-side reserves to mitigate variability, enabling higher renewable penetration without compromising reliability.
- Launch a formal ancillary services market that allows non-NSP assets, like batteries and renewables, to compete in frequency, voltage, and spinning reserves.

Energy Security and Diversification

- Develop a formal capacity market or procurement framework to secure firm resources and address long-term reserve margin shortfalls.

- Strengthen firm import agreements with New Brunswick and explore dual-fuel thermal generation options.
- Track and publicly report firm capacity projections and deficits annually to guide resource planning and investment signals.

ISO Governance and Independence

- Operationalize NSIESO with full separation from NSP, defined roles for market dispatch, and secure independent funding sources.
- Establish a Market Monitoring Unit (MMU) tasked with publishing quarterly reports on pricing, generator behavior, and system efficiency.
- Build a transparent, open-data portal managed by NSIESO for real-time system conditions, pricing trends, and curtailment reports.

## 6.2 Future Work

While this thesis presents a comprehensive ISO development toolkit, FIDER, to guide jurisdictions in transitioning toward an ISO-led, liberalized electricity markets, future research is needed to support the long-term operational success of the ISO, once established. The current study focuses on identifying the foundational components required for ISO formation, but a critical next step is to develop a mechanism to periodically evaluate and track the performance of these components over time. This would help ensure that the ISO not only starts on strong footing but continues to evolve and improve its effectiveness, transparency, and reliability.

Performance tracking is a critical aspect of ensuring the long-term success of any newly formed ISO. Once the foundational components outlined in this thesis are implemented, it becomes essential to assess their effectiveness in practice. To support this, the thesis proposes a performance scoring framework as a continuation of the current research. This framework would allow jurisdictions to evaluate the progress of each component in the toolkit over time, ensuring that implementation is not only initiated but also monitored for impact and improvement. By introducing a structured scoring mechanism, decision-makers can promote accountability and identify areas where further development or corrective action is needed. This continuous feedback loop will help ensure the ISO remains aligned with its intended goals of reliability, competitiveness, and consumer-centric operation.

This scoring framework could classify the progress of individual strategies under each component into three simple categories:

*Completed*: fully implemented with supporting policies and measurable outcomes.

*In Progress*: partially implemented or undergoing development.

*Yet to Be Introduced*: not initiated or lacking in policy direction.

For example, under the “Market Access and Liquidity” component, a jurisdiction may have already started publishing market concentration data using the Herfindahl-Hirschman Index (HHI), this would be scored as Completed. If IPP access has been legislated but remains limited due to a lack of trading platforms, the strategy would be In Progress. If there is no initiative to develop a day-ahead or real-time energy market, that would fall under Yet to Be Introduced. Over time, such a framework could evolve into a scorecard or dashboard to track progress across all five components, enabling regular internal reviews and stakeholder reporting. This structured assessment would not only help measure the ISO’s performance but also inform continuous policy and operational improvements.

## 6.3 Summary

FIDER was created as a structured response to the unique challenges faced by small or transitioning electricity markets. It provides a comprehensive, actionable roadmap to help jurisdictions transition toward Independent System Operator (ISO)-led operations and liberalized electricity market structures. Its five components, Demand-Side Management (DSM), Market Access and Liquidity, Renewable Energy Integration, Energy Security and Diversification, and ISO Governance and Independence, were carefully selected through benchmarking with global best practices and reviewing reform experiences from small jurisdictions such as Ireland, New Zealand, and Singapore.

Each component is supported by key indicators and metrics, enabling policymakers to evaluate existing conditions, measure progress, and identify policy gaps. The toolkit helps in structuring reform steps in a phased and measurable manner, fostering transparency, independence, and market competition.

In applying the toolkit to Nova Scotia, this thesis revealed both areas of early progress and systemic gaps. Nova Scotia has initiated efforts in renewable expansion, pilot DSM programs, and the formation of an ISO body. However, market design elements, institutional independence, and system flexibility are still limited. The province lacks competitive market platforms like day-ahead or real-time markets, and DSM remains underutilized across sectors. Renewable integration is challenged by grid constraints, lack of ancillary markets, and curtailment issues.

Based on these findings, FIDER provided targeted recommendations that can guide Nova Scotia toward a more robust, independent, and competitive electricity sector. Moreover, it offers a transferable framework that can be adapted by other small jurisdictions with similar aspirations. With a structured approach, ongoing performance monitoring, and institutional commitment, jurisdictions can realize meaningful electricity market reform through the application of FIDER.

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# 8 APPENDIX

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Demand-Side Management | | | | |
| Percentage reduction in MW during peak periods | Reduction in electricity demand during peak periods. | Analyze historical and current grid data to identify MW reductions during peaks. | Before and after DSM program implementation; during extreme weather/high-demand events. | A significant reduction in peak demand compared to historical data; increased grid resilience in stress scenarios. |
| Proportion of eligible consumers actively participating in DSM programs | Consumer engagement in DSM programs. | Track enrollment numbers and participation rates over time for RTP, TOU, and demand-response programs. | Quarterly or yearly after program rollout. | Increasing participation rates; higher percentage of eligible consumers actively engaged over time. |
| Proportion of consumers equipped with smart meters | Deployment of smart metering technology. | Count the total number of installed smart meters against the number of eligible consumers. | At key milestones in smart meter rollout schedules. | High percentage of consumers equipped with smart meters within the planned timeline. |
| Number of accurate data reports from smart meters | Frequency and accuracy of data from smart meters. | Count the number of error-free, timely data reports generated by smart meters. | Periodically after smart meter deployment. | At least 95% of data reports are accurate and timely, with minimal reporting errors. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Amount of energy shifted to off-peak hours (kWh) | Effectiveness of demand-shifting initiatives. | Measure the total kWh shifted from peak to off-peak hours using smart meter data. | Monthly or quarterly. | A tangible increase in the total kWh shifted to off-peak hours; a target increases over the baseline. |
| Market Access and Liquidity | | | | |
| Market Participation Rates (Share of IPPs) | The proportion of electricity generated by Independent Power Producers (IPPs) relative to total market generation. | Track the percentage of total electricity generated by IPPs versus traditional utilities over a specific period. | Continuously, with periodic assessments (quarterly or annually). | A growing share of electricity generation from IPPs, indicating an increase in competition and market diversification. |
| Market Liquidity (Volume of Electricity Traded) | The total volume of electricity traded in day-ahead and real-time markets. | Measure the sum of electricity volumes bought and sold in day-ahead and real-time markets. | Quarterly or annually. | A higher volume of electricity traded, reflecting improved market liquidity and efficiency. |
| Herfindahl-Hirschman Index (HHI) | The level of market concentration, indicating how evenly the market share is distributed among participants. | Calculate the HHI by summing the squared market shares of all firms, and monitor its trend over time. | Quarterly or annually. | A declining HHI, indicating reduced concentration and greater competition in the market. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Grid Capacity Additions | The increase in the grid's total capacity to accommodate additional energy generation. | Track the total amount of new grid capacity (in MW) added through infrastructure upgrades. | Annually or after significant infrastructure projects. | A consistent increase in grid capacity, supporting greater participation and minimizing congestion. |
| New Market Participants Integrated | The number of new market participants (e.g., renewable generators, small IPPs) successfully integrated into the grid. | Track the number of new participants integrated into the grid system, including renewable and non-renewable sources. | Annually or after major integration events. | A growing number of new participants integrated into the grid, indicating better market access and inclusivity. |
| Grid Congestion Reduction | The frequency and severity of grid congestion events, indicating the efficiency of the grid. | Measure the number of congestion events and analyze their impact on the grid's ability to handle the load. | Continuously, with annual assessments. | Fewer instances of congestion, reflecting a more efficient and capable grid infrastructure. |
| Share of Renewables in the Energy Mix | The percentage of total electricity generated from renewable energy sources (e.g., wind, solar). | Calculate the proportion of total energy generated from renewable sources compared to the overall generation mix. | Annually, with long-term tracking. | A higher percentage of energy generation from renewables, supporting a transition to a sustainable energy system. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Curtailment Reduction | The reduction in renewable energy generation that is not utilized due to grid limitations. | Measure the amount of renewable energy generation curtailed (i.e., unused) because the grid cannot accommodate it. | Quarterly or annually. | A significant decrease in renewable energy curtailment, showing better grid integration and capacity to manage variable energy sources. |
| Renewable Energy Integration Strategy | | | | |
| Forecast Accuracy Improvements | Accuracy of renewable energy forecasts (e.g., wind and solar output). | Compare predicted energy output to actual generation, calculating forecast errors and improvements over time. | Continuously, with periodic reviews (quarterly or annually). | Decreasing forecast errors, indicating more accurate prediction of renewable energy generation. |
| Reduction in Reserve Capacity Requirements | The amount of reserve capacity required to balance supply and demand. | Measure the reduction in reserve power needed improved because of forecasting and grid management. | Annually or after significant grid improvements. | A consistent decrease in reserve capacity requirements, indicating better supply-demand forecasting. |
| Decrease in Renewable Curtailment | The amount of renewable energy generation that is curtailed (unused). | Measure the percentage of renewable energy curtailed due to grid limitations compared to total generation. | Quarterly or annually. | A reduction in renewable energy curtailment, indicating better integration and grid management. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Ancillary Services Transaction Volume | The volume of ancillary services transactions, indicating market activity. | Track the number of ancillary services transactions (e.g., frequency regulation, reserve capacity) over time. | Monthly or annually. | An increasing volume of ancillary services transactions, reflecting active support for grid stability. |
| Frequency Stability Metrics | Frequency stability of the grid, indicating the balance between supply and demand. | Measure the frequency of grid frequency deviations, using metrics like frequency deviations (Hz) and regulation response time. | Continuously, with periodic evaluations (e.g., monthly or annually). | Stable grid frequency with fewer deviations, indicating effective grid balancing and stability. |
| Share of Flexible Resources in Grid Operations | The proportion of flexible resources (e.g., hydro, battery storage) in grid operations. | Track the percentage of flexible generation resources used for grid balancing and renewable integration. | Monthly or annually. | A higher share of flexible resources being used, supporting efficient grid management and renewable integration. |
| Smart Grid Technology Penetration Rate | The adoption rate of smart grid technologies (e.g., advanced meters, communication networks). | Measure the percentage of the grid equipped with smart grid technologies, including automated systems and smart meters. | Annually or after major technology rollouts. | A growing percentage of smart grid technologies deployed, indicating improved grid automation and monitoring. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Reduction in System Outages | The frequency and duration of system outages. | Track the number of outages and their durations, comparing them before and after smart grid technology implementation. | Continuously, with annual reviews. | A decrease in both the frequency and duration of outages, indicating improved grid reliability and responsiveness. |
| Improvements in Renewable Integration Capacity | The capacity to integrate renewable energy without curtailment or instability. | Measure the percentage increase in renewable energy integration capacity, considering grid stability and generation mix. | Annually or after smart grid implementation. | An increase in the capacity to integrate renewable energy while maintaining grid stability and reliability. |
| Energy Security and Diversification | | | | |
| Proportion of Renewable and Non-Renewable Sources in the Energy Mix | The share of renewable versus non-renewable energy sources in the overall energy mix. | Measure the percentage of renewable energy (e.g., solar, wind, hydro) and non-renewable energy (e.g., natural gas, nuclear) used for electricity generation. | Annually or after major energy mix changes. | A higher share of renewable energy, with a gradual reduction in fossil fuel dependency. |
| Changes in Fossil Fuel Dependency | The reliance on fossil fuels (coal, natural gas, oil) over time. | Track the percentage of total electricity generation from fossil fuels, comparing over multiple years. | Annually. | A decrease in fossil fuel dependency, indicating a transition to cleaner energy sources. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Energy Price Stability | The stability of energy prices over time, especially in relation to fossil fuel price fluctuations. | Track energy price fluctuations over time, comparing periods of high fossil fuel prices with periods of low renewable generation. | Quarterly or annually. | Reduced price volatility, indicating a more balanced and resilient energy mix. |
| Cross-Border Interconnection Capacity and Usage | The capacity and usage of cross-border interconnections and regional energy partnerships. | Measure the total interconnection capacity with neighboring countries and track the energy traded via these interconnectors. | Monthly or annually. | Increased usage of interconnectors during peak demand, showing improved access to external energy sources. |
| Volume of Energy Traded with Neighboring Countries | The volume of electricity exchanged with neighboring countries. | Track the amount of energy imported or exported through interconnections with neighboring countries. | Monthly or annually. | A higher volume of energy traded, indicating effective regional cooperation and energy sharing. |
| Availability and Utilization of Reserve Capacity | The availability and use of reserve capacity to meet peak demand or disruptions. | Measure the amount of reserve capacity available and track its utilization during times of high demand or low renewable generation. | Monthly or annually. | A higher utilization rate of reserve capacity during peak demand, ensuring grid stability. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Number of Capacity Mechanisms in Place | The number of capacity mechanisms (e.g., capacity markets) available to ensure grid reliability. | Track the implementation of capacity markets and other mechanisms, such as demand response programs. | Annually. | A greater number of capacity mechanisms in place, providing more options for grid balancing. |
| Grid Stability During High Demand or Low Renewable Generation | The stability of the grid during high demand periods or low renewable generation. | Monitor grid performance during peak demand or low renewable generation events, focusing on outages and supply-demand balance. | During high-demand events or low renewable generation periods. | Fewer outages and stable grid operations during these events, indicating successful grid management. |
| Growth in Distributed Generation Capacity | The increase in local generation capacity from distributed sources (e.g., rooftop solar, local wind turbines). | Track the growth in installed capacity of distributed generation systems over time. | Annually. | An increasing number of distributed generation systems being installed, contributing to local energy resilience. |
| Percentage of Electricity Generated Locally | The share of electricity generated locally through distributed systems. | Measure the percentage of total electricity generated by local systems (e.g., rooftop solar, wind turbines) compared to centralized power plants. | Annually. | A growing percentage of locally generated electricity, indicating greater decentralization. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Impact of Distributed Generation on Grid Stability and Demand During Peak Times | The impact of distributed generation on grid stability during peak demand. | Measure the reduction in demand from centralized plants and the impact on grid stability due to distributed generation during peak times. | During peak demand periods. | Reduced strain on the grid during peak demand, showing the positive impact of distributed generation. |
| ISO Governance and Independence | | | | |
| Frequency and Transparency of Annual Market Performance Reviews | The frequency and openness of market performance evaluations. | Measure the number of market reviews conducted annually, track how detailed and transparent the reports are. | Annually. | A higher number of performance reviews conducted annually with detailed and accessible reports. |
| Improvements in Market Efficiency and Stability Over Time | The progress in enhancing market efficiency and stability. | Measure key performance indicators (KPIs) such as transaction times, bid-ask spreads, and price volatility. | Annually or after market reviews. | A clear trend toward improved market efficiency, with reduced volatility and more competitive pricing. |
| Extent of Data Accessibility to Stakeholders | The level of accessibility of market performance and operational data to stakeholders. | Measure the availability of performance reports, operational statistics, and compliance data for public access. | Quarterly or annually. | Increased availability of data and ease of access for stakeholders. |

| Indicator | What is Measured | How It is Measured | When It is Measured | What Indicates Success |
|---|---|---|---|---|
| Stakeholder Engagement and Trust Levels | The level of stakeholder engagement and trust in the ISO's operations. | Measure the frequency of stakeholder meetings or consultations and track satisfaction levels through surveys. | Annually or after consultations. | Higher engagement levels and improved satisfaction in stakeholder surveys. |
| Impact of Stakeholder Feedback on Policy Adjustments or Market Reforms | The extent to which stakeholder feedback influences market policies or reforms. | Track the number of policy changes or reforms that directly result from stakeholder feedback. | Annually. | A greater number of policy adjustments or reforms driven by stakeholder input. |