The background is a vertical collage of four panels: a blurred waterfall, autumn leaves against a blue sky, a bright sunburst, and a blurred blue background.

Beyond Levelized Cost of Electricity (LCOE)

A Multi-Criteria Analysis of Ontario Electricity Generation Options

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Beyond Levelized Cost of Electricity (LCOE): A Multi-Criteria Analysis of Ontario Electricity Generation Options

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Executive Summary

Long-term electricity system planning increasingly requires comparing generation technologies with fundamentally different cost structures, operating characteristics, asset lifetimes, and system roles. While levelized cost of electricity (LCOE) remains a useful indicator of the levelized cost of delivering electricity over an asset's economic lifecycle, it does not, on its own, capture the full range of aggregate system benefits that different resources provide, particularly with respect to grid benefits, environmental, socioeconomic, and policy considerations. Depending on the rigor with which it is carried out, a detailed Integrated Resource Planning (IRP) study reflects many aspects of the system-level contributions. Nevertheless, as the resource mix evolves and non-energy services become more material to system performance, there is a growing need for complementary planning metrics that reflect both cost and system value. These metrics can provide useful information to stakeholders outside of the detailed IRP planning cycle.

This study develops and applies a lifetime-adjusted, multi-criteria framework to assess the comparative aggregate system benefits of four electricity generation technologies: waterpower, gas-fired generation, wind power, and solar power. The analysis combines cost information derived from the IESO 2024 Outlook Planning Report with structured benefit assessments obtained through an Analytic Hierarchy Process (AHP). Aggregate system benefits are evaluated across four criteria groups: grid and system benefits, environmental impacts, socioeconomic considerations, and policy alignment. Benefits are then adjusted over the assumed economic life of each technology to ensure consistency with the lifetime basis of LCOE. Cost ranges reported by international sources such as NREL and Fraunhofer ISE are shown to illustrate the breadth of cost estimates observed across jurisdictions and studies, and to place the IESO assumptions within a broader industry context. These international ranges are not used as inputs to the core analysis. The IESO cost values are adopted as the base case to maintain consistency with Ontario context.

The results demonstrate that cost alone is an incomplete proxy for the aggregate system benefits of a technology. Across the cost-value representations, technologies with similar LCOE or similar cost shares exhibit materially different lifetime-adjusted aggregate system benefits. The study shows that lifetime-adjusted benefits do not scale proportionally with relative cost, indicating that differences in operational role, flexibility, reliability support, and system integration dominate over LCOE in determining aggregate system benefits. This confirms the importance of complementing cost-based metrics with explicit aggregate system value indicators when evaluating long-term investment options.

The lifetime adjustment of aggregate system benefits is shown to be a structural determinant of comparative results. Long-lived assets that provide multiple system services accumulate value across several decades in ways that shorter-lived or more narrowly scoped assets do not. Aligning the time horizon of benefits with the lifetime basis of LCOE materially affects relative technology positioning and avoids systematically disadvantaging long-lived infrastructure assets. The lifetime-adjusted framework therefore represents a core modelling assumption rather than a secondary technical refinement.

Distinct and persistent patterns emerge in the cost-value space. Across all representations, non-dispatchable technologies form a clearly defined low-cost, lower-benefit cluster, while dispatchable technologies occupy distinct and differentiated positions rather than a single cluster. Hydropower consistently occupies the high-cost, high-benefit region of the cost-benefit space and remains well above the value-proportional-to-cost reference line under all scenarios examined. Its position reflects a diversified benefit profile across all criteria

Gas-fired generation occupies an intermediate position, delivering moderate lifetime-adjusted aggregate benefits relative to its cost range. Its relative positioning exhibits greater sensitivity to changes in evaluation priorities compared to other technologies, reflecting the composition of its benefit profile across criteria. Wind and solar power consistently occupy the low-cost, lower-benefit region, reflecting their primary contribution to energy supply and emissions reduction, alongside more limited contributions to system operability.

The sensitivity analysis indicates that while changes in criteria weighting lead to observable shifts in relative system value, the broad ordering, grouping, and cost-benefit positioning of technologies remain relatively stable under plausible variations in evaluation priorities. The comparative structure of the results is therefore robust to changes in weighting perspective. Policy priorities influence relative magnitudes, but do not materially alter the fundamental aggregate system roles or clustering of technologies.

The value-per-dollar representation provides a complementary metric that integrates cost, lifetime, and multi-criteria benefit into a single decision-oriented indicator. The study shows that technologies differ substantially in how effectively aggregate system value is delivered per unit cost (LCOE). This perspective highlights differences in cost effectiveness that are not apparent from LCOE metrics alone and supports interpretation of trade-offs between direct costs and aggregate system benefits.

The analysis has several implications for long-term system planning. First, the results indicate that generation comparison could benefit from explicitly recognizing the long-term value creation associated with technologies that provide benefits in multiple domains, even where upfront costs are higher. Second, the findings suggest that approaches that reflect complementary system roles and other environmental and socioeconomic benefits can complement other approaches that focus primarily on minimizing cost. Finally, the results highlight the value of valuation frameworks that more fully reflect the range of aggregate system benefits provided by different technologies, including reliability, flexibility, and grid support.

This study provides a practical framework for integrating lifetime-adjusted multi-criteria benefit assessment with lifetime-adjusted economic metrics (LCOE) in a transparent and internally consistent manner. The study offers a systematic pathway for developing value-adjusted LCOE measures and for extending traditional comparisons of technologies beyond single-metric comparisons.

Overall, the results indicate that comparisons of technologies could be supported by integrating both cost-based and value-based comparative frameworks. Such an approach enables explicit trade off among affordability, reliability, sustainability, and long-term system resilience, in an evolving electricity system.

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1 Introduction

Ontario is facing a projected close to 75% increase in electricity demand over the next 25 years (IESO, 2025), driven by the electrification of industries such as transportation, economic growth, population expansion, and decarbonization initiatives.

To help evaluate various sources of electricity generation, the Levelized Cost of Energy (LCOE) is typically used to compare various sources of generation such as thermal, wind, solar and waterpower. While LCOE offers important insights in comparing generation alternatives, it does not include the integration costs of technologies such as wind and solar and also does not help to consider other very important aspects such as: ‘How do different technologies support grid reliability?’ ‘How well do they align with environmental goals?’ ‘How do they contribute to job creation and support public priorities?’ ‘For every dollar spent to generate electricity, which option provides the most value, relatively speaking?’ ‘How do long-lived assets compare to shorter-lived assets in terms of intergenerational value’. When each question is considered in isolation, perspectives tend to oversimplify decisions that are fundamentally multidimensional.

To help address the challenge of evaluating the multidimensional considerations, the development of a Multi-Criteria Analysis (MCA) framework is proposed to bring these dimensions together and allow for the comparison of generation technologies relative to one another. This approach can help respond to the question: How well do different generation alternatives (waterpower, wind, solar, and gas-fired generation) support Ontario’s priorities, relative to each other.

Instead of treating this question as a mathematical problem to be solved and aimed at producing a single “optimal” solution, this approach allows for structured and transparent policy-informing process for weighing trade-offs, considering multiple outcomes, and engaging diverse perspectives. As such, this framework is built to inform, not to conclude, and to help decision-makers explore various generation technologies more holistically, consider strengths and weaknesses, and gain clarity even when the data is uncertain.

This analysis, therefore, represents a conversation starter designed to bring together insight, experience, and judgment in a structured and transparent way.

2 Purpose of the Analysis

The objective of this analysis is to provide an approach to help support Ontario’s electricity planning decisions with a process that captures the relative value of generation options (waterpower, wind power, solar power and gas-fired generation), beyond cost. The proposed framework was developed to compare alternatives based on their contributions to grid and system benefits, environmental performance, socioeconomic benefits, and policy alignment; supporting decision-makers in exploring the various trade-offs, clarifying priorities, and quantifying the benefits that each option provides over its lifetime to serve Ontario’s needs.

3 Methodology

This analysis applies a systematic approach called the Analytic Hierarchy Process (AHP) to equitably compare the benefits of electricity generation options. AHP is a structured method for making complex decisions by breaking them down into smaller, more manageable pieces that can be compared side-by-side. The benefits for each option are then weighted against the cost for that technology to evaluate the relative benefits or return on investment. Prior to comparing the benefits with the cost, the benefit score is adjusted to account for the lifetime of each asset over which the cost is levelized. This allows for a consistent comparison between the two variables. The main steps followed in this systematic approach were as follows:

- Create a Comprehensive Picture:** Four main criteria (Level 1) that matter most when choosing how to generate electricity were identified: grid and system benefits (how well each technology keeps the lights on and supports the power system), environmental impact and benefits (effects on air, water, land, and climate), socioeconomic considerations (impacts on job creation, economic benefits, and public acceptance), and policy alignment (how well each option supports Ontario's policies and goals).
- Break It Down Further:** Each of the Level 1 criteria was then characterized further into Level 2 and Level 3 criteria (where warranted). For example, grid and system benefits were defined to consider reliability, flexibility, and grid support services along with equipment lifespan.
- Determine What Matters Most:** Each criterion was then weighted through a systematic comparison approach using a questionnaire approach. For example, 'Is reliability more important than environmental impact, and if so, how much more important?'
- Comparing the Alternatives:** Each generation technology was evaluated through pairwise comparisons against the others for every criterion across the lowest level criteria, to determine their relative performance under each consideration.
- Putting Everything Together:** All individual scores were then combined, and weighting was applied to provide an overall score. A sensitivity analysis was then applied to test the stability and consistency of the results given different perspectives.
- Weighting the Benefits Against the Cost:** Finally, cost was considered. Total cost over the life of each generation alternative was assessed together with the weighted benefit criteria, with benefit weights relatively adjusted to account for differences in asset lifetimes over which those benefits are delivered. This approach ensures a consistent comparison between long- and short-lived technologies and enables a cost-benefit assessment of overall value, answering the question: 'For every dollar spent, which generation alternative provides the most value in

For consistency, a standard scale of pairwise comparison was applied. This scale, developed by researcher Thomas Saaty for use in AHP is backed by extensive research and widely used around the world to support equitable decisions when comparing options and allowing the user to determine if one criterion is equal, moderately, strongly, very strongly, or extremely more important than another . These comparisons automatically generate numerical weights which represent the relative importance, ensuring that the most important considerations have the biggest influence on the results.

Pairwise Comparison Scale

| Acronym | Definition |
|---------|-----------------------------|
| EX | Extremely: ~9 or more times |
| VS | Very Strongly: ~ 7 times |
| S | Strongly: ~ 5 times |
| M | Moderately: ~ 3 times |
| Eq | Equal |

terms of reliable electricity, environmental performance, jobs, and alignment with Ontario’s policy goals?’ This final step is crucial, as one must consider that even if a generation alternative is the lowest-cost option, it may not provide enough value to make practical sense. Conversely, the highest cost option might provide enough value to justify the cost.

Overall, this systematic AHP approach for aggregate benefit evaluation, in addition to the cost-value assessment, provides a basis for informed decision-making about Ontario's electricity future, ensuring a transparent, comprehensive, repeatable analysis, based on an equitable comparison of all relevant factors.

4 Alternatives - Electricity Generation Technologies

For the purpose of this analysis, the generation alternatives evaluated are waterpower (hydropower), wind, solar and gas-fired (thermal) generation.

Waterpower is included given its long-standing role in Ontario’s electricity mix and its capability for firm and clean generation. Wind and solar are evaluated as the primary non-waterpower renewable options, reflecting their growing deployment and potential in the province. Gas-fired generation is considered because it represents a dominant and efficient form of flexible, dispatchable generation in Ontario and can sustain a high-capacity factor when required for reliability. Table 1 provides a summary of these alternatives, along with their descriptions.

Only utility-scale wind and solar are considered given that they have the most significant impact on Ontario’s electricity supply mix, align with current procurement processes, and are consistent with the system-level planning priorities. Residential or small-scale distributed installations do not offer the same level of contribution to the grid and are therefore excluded.

Nuclear is not included as one of the alternatives because the nuclear fleet is already a backbone of the provinces’ supply, and further nuclear development presents unique considerations that are significantly distinct from other generation alternatives.

Battery energy storage systems (BESS) are not included as a standalone generation alternative because they do not generate electricity but rather store and discharge energy produced by other generation sources. While BESS provide valuable grid services, they require an underlying generation source causing fundamental analytical inconsistency.

Hybrid technology combinations such as wind-solar-battery systems, or other hybrid configurations, are not considered in this comparative analysis to maintain clarity and focus on the fundamental characteristics of individual generation technologies, although it is acknowledged that hybrid systems can offer multiple advantages to the grid. In establishing the baseline performance and relative benefits of each generation alternative, future system planning can optimize hybrid generation configurations. However, hybrid system optimization depends heavily on site-specific conditions, and economic factors that vary significantly across applications, making project-specific alternatives analysis more appropriate.

Table 1 Generation Alternatives

| Type | Description |
|----------------------|---|
| Waterpower | Hydropower inclusive of run-of-river and reservoir storage |
| Solar and Wind Power | Utility-scale solar photovoltaic facilities |
| Gas-Fired Generation | Natural Gas-fired inclusive of Simple Gas Turbines (SGT) and Combined Cycle Gas Turbine (CCGT) Power Stations |

5 Assumptions

This report is focused on the Ontario electricity sector. As such, all evaluations, assumptions, and comparisons have been made in an Ontario context.

The electricity market and stakeholder priorities in Ontario are dynamic and continuously evolving and this analysis reflects a static point in time. As such, all criteria, weights, and data reflect Ontario today and does not include consideration for future shifts, emerging needs or the potential for advancement in technologies.

This analysis has been conducted at a strategic, policy level, providing broad guidance on technology value and general policy priorities rather than the detailed operational and technical system planning typically conducted by the system operators. While system planning focuses on specific transmission needs, capacity requirements, and operational constraints, this analysis offers a higher-level framework for understanding the overall value proposition of different generation technologies. The findings can help inform long-term strategic direction and policy development, complementing the technical analysis required for day-to-day system planning and operations.

In this analysis, we evaluate each electricity generation technology according to its inherent technical characteristics which assumes the best that each option can deliver under ideal conditions. However, there are a few exceptions where real world limitations, like local geography, fuel/resource availability, or permanent environmental regulations, have a bigger impact than the technology's theoretical capability. In these instances, historical performance in an Ontario context is used to perform the evaluation. For example, Waterpower facilities in Ontario are fundamentally limited by river flows. As such, historical capacity factors have been considered. Likewise, for wind and solar the analysis has been based on real Ontario data given performance is influenced mainly by local weather and resource patterns. For other criteria, the technical maximum has been applied, even when the generation technology potential is limited by other constraints (e.g., changing policy, market, and operational constraints) to keep the evaluation equitable. Constraints that may limit the generation alternatives technical characteristics are addressed through criteria weighting. This approach provides a balanced and transparent comparison, balancing both the potential of each technology and the practical limitations that shape how that technology performs in Ontario.

References were selected to reflect available and relevant information at the time of this analysis for general consideration and additional context. Where gaps or uncertainties exist, reasonable professional judgment has been applied.

6 Evaluation Criteria - Defining What Matters

This section defines the criteria used to evaluate the generation alternatives which have been developed through a structured process and reflect the diverse values that matter to Ontario’s electricity future. The full structure of the evaluation criteria, organized using the AHP, is presented in Figure 1. A detailed breakdown of the evaluation criteria and corresponding guiding questions are provided in Table 2. Detailed definition of each criterion is provided in the subsections that follow.

Figure 1 Evaluation Framework Hierarchy: Criteria for Comparative Benefit Assessment

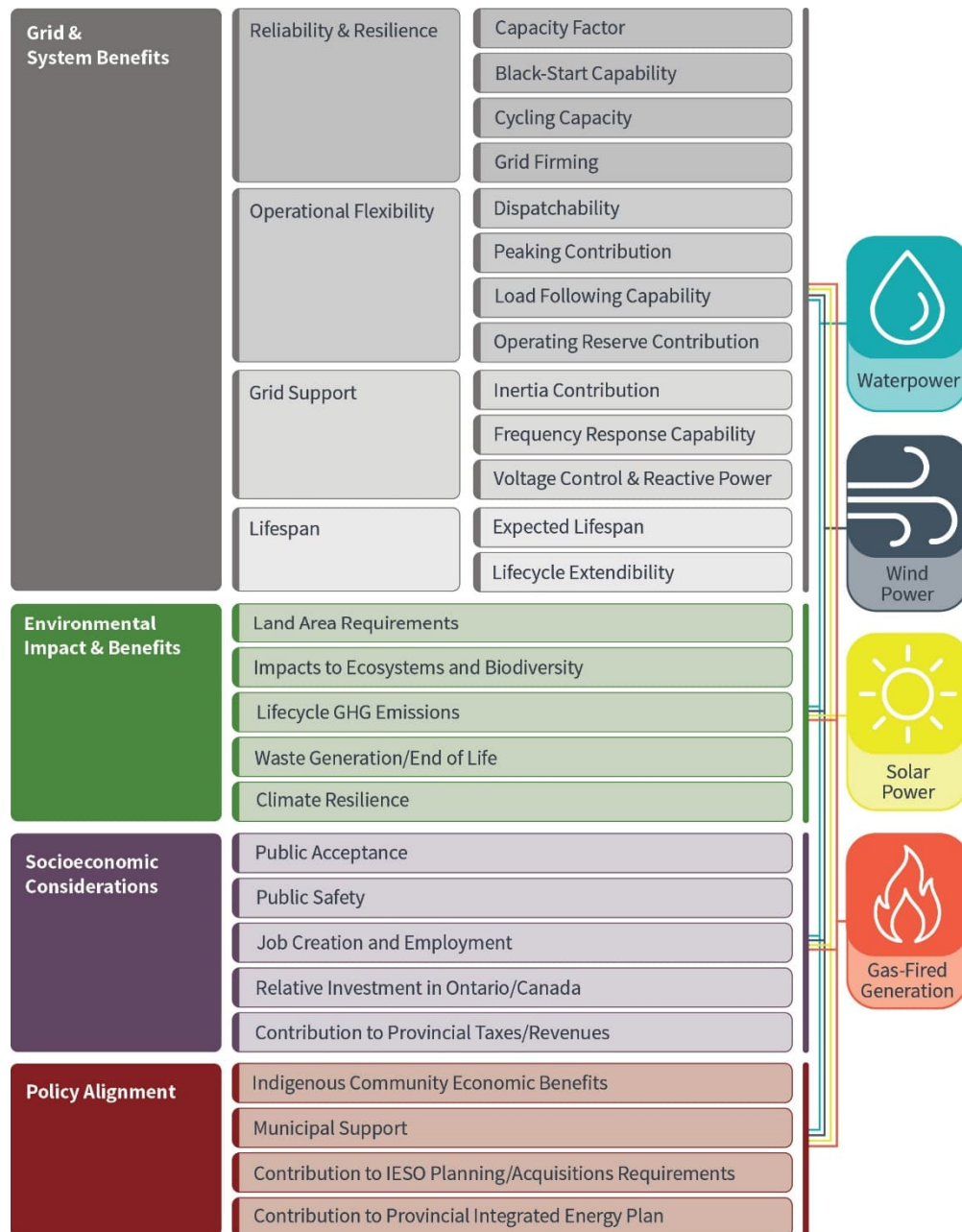


Table 2 Criteria Guiding Questions

| Benefit Category (Level 1 Criteria) | Key Area (Level 2 Criteria) | Specific Criteria (Level 3 Criteria) | Guiding Questions |
|--|---------------------------------------|--|---|
| Grid and System Benefits | Reliability and Resilience | Capacity Factor | What percentage of the facility capacity can typically be available over a period of time (e.g., a year) to generate energy? |
| | | Black-Start Capability | Can the facility restart itself independently after a blackout and support restoration of the grid? |
| | | Cycling Capability | To what extent can this generation technology be turned on/off frequently without significant impact on it wearing out or damage? |
| | | Grid Firming | How well can the facility stabilize variable generation sources? |
| | Operational Flexibility | Dispatchability | To what extent can this generation technology be turned on or off as needed to respond to system conditions? |
| | | Load Following Capability | How well can this generation technology adjust its output to match demand fluctuations? |
| | | Peaking Contribution | How suitable is this generation technology for meeting short-term, high-demand periods (daily or seasonal peaks)? |
| | | Operating Reserve Contribution | How effectively can this generation technology provide backup energy in case of unexpected outages or shortfalls elsewhere in the system? |
| | Grid Support | Inertia Contribution | How much can this generation help slow down changes in grid frequency? |
| | | Frequency response | How well can this generation react when frequency is changing? |
| | | Voltage Control | How well can this generation keep the voltage steady? |
| | Lifespan and Lifecycle Considerations | Expected Lifespan | How long can this generation technology operate effectively before requiring major overhaul / replacement? |
| | | Lifecycle Extendibility | How well can the operational lifespan of this generation technology be extended through refurbishment, upgrades, or replacement? |
| | Environmental Impact and Benefits | Land Area Requirements | How much land does this generation option require? |
| Impacts to Ecosystems and Biodiversity | | How does this generation affect ecosystems and biodiversity? | |
| Lifecycle Greenhouse Gas (GHG) Emissions | | What are the total GHG emissions over its lifecycle? | |

| Benefit Category (Level 1 Criteria) | Key Area (Level 2 Criteria) | Specific Criteria (Level 3 Criteria) | Guiding Questions |
|-------------------------------------|--|--------------------------------------|--|
| | Waste Generation/End of Life | | How much waste is produced by this generation type and how is it handled? |
| | Climate Resilience | | How well can this type of generation system withstand and adapt to climate change? |
| Socioeconomic Considerations | Public Acceptance | | Will the public support the development of this type of generation? |
| | Public Safety | | How does this generation impact public health and safety? |
| | Job Creation and Employment | | How many jobs and what kind of employment does this type of generation create? |
| | Relative investment in Ontario/Canada | | Does this type of generation support local manufacturing and services? |
| | Contribution to Provincial Taxes/Revenues | | How much revenue does this type of generation generate for provincial governments? |
| Policy Alignment | Indigenous community Economic Benefits | | Does this type of generation create lasting benefits for Indigenous communities? |
| | Municipal Support | | Is this type of generation aligned with local community goals and plans? |
| | Contribution to IESO Planning/Acquisition Requirements | | Does this type of generation align with IESO's planning and reliability goals? |
| | Contribution to Provincial Integrated Energy Plan | | Is this type of generation compatible with long-term provincial policy directions? |

6.1 Grid and System Benefits

6.1.1 Reliability and Resilience

Refers to a power generation technology's ability to provide consistent, dependable electricity with minimal disruption and to recover quickly from failures or grid disturbances.

6.1.1.1 Capacity Factor

This is the ratio of actual energy produced by a facility over a given period to the maximum possible energy it could generate if it operated at full capacity.

6.1.1.2 Black-Start Capability

Some power facilities can restart without an external source of power. This is important for restoring electricity quickly in emergencies or blackout conditions. This criterion describes the ability of a generation unit to start-up independently without an external power source following a total grid blackout.

6.1.1.3 Cycling Capability

This relates to the ability of a facility to operate at a wide range of output levels and to be turned on and off relatively quickly. This is important for meeting fluctuating electricity demand. This criterion is a measure of a power plant's ability to ramp up and down and/or to handle frequent start-ups and shutdowns without excessive wear and efficiency loss recognizing that cycling does incur costs. This is different from rapid output adjustments (covered by load following capability under operational flexibility) and focuses on mechanical and operational resilience (durability) under cycling stress.

6.1.1.4 Grid Firming

Some power sources, like wind and solar, produce electricity intermittently because they depend on local weather conditions. Grid firming ensures that electricity remains steady and available by either making the power source more stable or pairing it with backup systems. The better the grid firming for a generation source, the more reliable the electricity supply. Additionally, the reliability of renewables increases when there are more projects spread over wider geographic areas, since local weather conditions are less likely to affect all sites at once. This criterion refers to the ability of a generation source to provide stable and continuous power without requiring additional balancing sources.

6.1.2 Operational Flexibility

Refers to a power generation technology's ability to rapidly adjust its output to match fluctuating electricity demand and respond to grid disturbances.

6.1.2.1 Dispatchability

Some power facilities can be turned on and off whenever needed, while others (like solar or wind) depend on weather conditions. This criterion refers to the ability of a facility to be dispatched on demand, meaning it can start, stop, or adjust output as needed.

6.1.2.2 Peaking Contribution

Electricity demand in Ontario fluctuates throughout the day and year, with peak times usually occurring late afternoon/evening on the hottest summer days. With decarbonization, heating peak times may shift to cold winter evenings. Peaking contribution measures how well a facility can provide additional power during these critical times. This criterion refers to the ability of a generation source to supply power during periods of highest electricity demand, which can be on a daily (e.g., late afternoon/evening), seasonal (e.g., summer cooling or winter heating), or unforecasted load increase.

6.1.2.3 Load Following Capability

Electricity use changes throughout the day, some hours require more power, others less. Load following capability measures how “quickly and smoothly” a facility can increase or decrease its electricity output to match demand. This criterion refers to the ability of a generation unit to rapidly (seconds/minutes) and continuously adjust its power output in response to real-time changes in electricity demand, helping to ensure grid stability. Load following is critical for system operators to balance supply and demand, especially with variable renewables and fluctuating consumption patterns. This criterion is different from the cycling capability criterion (covered by reliability and resiliency) given that it focuses on the rapid response to changing load rather than equipment durability.

6.1.2.4 Operating Reserve Contribution

Power facilities must provide backup energy in case another facility fails, or demand suddenly spikes without the ability to meet that demand increase using existing non-reserve resources. Operating reserve contribution measures how much spare power a facility can offer to keep the grid stable. In other words, can it stand by, ready to help if something else fails? This criterion refers to the portion of a generation unit's capacity that can be quickly dispatched to serve as a reserve for contingency or frequency regulation, typically classified as spinning reserve (online but unloaded, e.g., immediately available) or non-spinning reserve (offline but available, e.g., available within a short time, such as 10-30 minutes) to ensure grid stability during contingencies or demand fluctuations.

6.1.3 Grid Support

Refers to a power generation technology's ability to help maintain voltage stability, frequency regulation, and overall grid reliability.

6.1.3.1 Inertia Contribution

Some power facilities help keep the grid stable by preventing sudden electricity fluctuations, just like a flywheel keeps a machine running smoothly. In other words, how much it helps dampen changes in grid frequency. This criterion refers to the amount of rotational energy stored in large spinning generators (e.g., waterpower turbines, gas turbines), helping stabilize grid frequency during disturbances (e.g., sudden loss of generation or load). On the other hand, non-synchronous technologies (e.g., wind, solar) don't contribute at all, or contribute less directly unless equipped with synthetic inertia capabilities.

6.1.3.2 Frequency Response Capability

The power grid is intended to operate at a constant frequency (e.g., 60 Hz within a narrow acceptable band in North America). If too much or too little electricity is supplied, the frequency can shift outside the design band, leading to blackouts. Frequency response capability measures how well a facility can adjust its output to correct these shifts and keep the grid stable. In other words, how fast it reacts when frequency goes off target. This criterion refers to the ability of a facility to detect and rapidly respond to deviations in grid frequency by adjusting its output within seconds to maintain grid stability. This includes primary (immediate, within seconds), secondary (within minutes), and tertiary frequency control (sustained adjustments). Frequency response is critical for maintaining grid stability during disturbances like sudden generation loss or load changes.

6.1.3.3 Voltage Control and Reactive Power

Voltage control helps keep electricity flowing smoothly by ensuring the right voltage levels across the power grid. In other words, how well it keeps the voltage steady and supports power flow. This criterion refers to the ability of a facility to regulate voltage levels and adjust reactive power (measured in volt-ampere reactive, or VAR) to compensate for voltage drops across transmission lines, ensuring grid stability and preventing equipment damage. Reactive power supports voltage control by compensating for reactive loads (e.g., from motors or transformers) and transmission line losses, ensuring proper voltage levels to prevent equipment damage and maintain power quality.

6.1.4 Lifespan and Lifecycle Considerations

Refers to expected operational duration of a power generation technology before major refurbishments or decommissioning, as well as its ability to be upgraded or extended beyond its original design life.

6.1.4.1 Expected Lifespan

Some power facilities last longer than others. This measures how many years a facility can run before needing major repairs or replacement. In other words, how many years can it reliably operate before wearing out. The actual operating life may be longer with appropriate investments. As such, this is addressed separately in the life extendibility criterion (Section 6.1.4.2). This criterion refers to the estimated number of years a facility can operate before requiring major replacement or refurbishment. Expected lifespan can be a function of usage level and reflects durability, maintenance requirements, and technological obsolescence, impacting long-term reliability and cost-effectiveness.

6.1.4.2 Lifecycle Extendibility

While all power facilities can, in principle, have their lifespan extended through upgrades, repairs, or refurbishments, there comes a point when further investment is no longer economically viable (when the cost of continued repairs outweighs the benefits of additional operation). For this criterion, alternatives are measured based on how easy it is to refurbish compared to replace, how many cycles of major upgrades or refurbishments each technology can typically undergo before reaching that economic limit, as well as the average operational life added by each cycle. This reflects not just whether life extension is possible and how easy it is to incorporate, but how reliably and efficiently it can be achieved across the technology's service life. This criterion refers to the ability of a generation technology to undergo upgrades, component replacements, or refurbishments to extend its operational life and the duration of the life extension beyond the technology's average design life.

6.2 Environmental Performance

6.2.1 Land Area Requirements

The spatial footprint of a power generation facility is a key consideration in project planning. This criterion evaluates the total land area required for the installation, operation, and maintenance of a generating station, which can vary significantly depending on the technology type.

6.2.2 Impacts to Ecosystems and Biodiversity

Power generation projects can have varying degrees of influence on the surrounding natural environment. This criterion evaluates the potential ecological impacts associated with the development, construction, and operation of generating stations. Key considerations include risks of contamination, disruption of natural habitats, fragmentation of ecosystems, and adverse effects on species at risk.

6.2.3 Lifecycle GHG Emissions

Understanding the full environmental impact of power generation requires a comprehensive assessment of GHG emissions across the entire lifecycle of a project. This criterion evaluates the total GHG emissions produced from initial construction and equipment manufacturing, through operational activities, to eventual decommissioning and considers the emissions intensity measured as the quantity of GHGs released per unit of electricity generated. Generation technologies with lower lifecycle emissions are preferred, as they contribute more effectively to climate change mitigation and support provincial and national decarbonization goals.

6.2.4 Waste Generation/End of Life

The long-term sustainability of power generation projects also depends on how they manage decommissioning and waste disposal. This criterion examines the types and volumes of waste produced during the operation of generating stations, including hazardous and non-hazardous waste. It also considers the processes and

responsibilities involved in safely decommissioning facilities at the end of their lifecycle, including dismantling infrastructure, managing residual materials, and restoring sites. Generation options that incorporate robust waste management practices and responsible end-of-life planning are viewed more favorably.

6.2.5 Climate Resilience

As climate-related risks become increasingly prevalent, the ability of energy systems to withstand and adapt to changing environmental conditions is essential. This criterion evaluates the resilience of power generation technologies to climate stressors such as extreme weather events, temperature fluctuations, flooding, drought, and wildfire risk. It considers both the design and operational strategies that minimize vulnerability and ensure continuity of energy supply under adverse conditions. Generation options that incorporate adaptive infrastructure, robust risk management, and long-term climate planning are better positioned to support reliable and sustainable energy delivery in a changing climate.

6.3 Socioeconomic Considerations

6.3.1 Public Acceptance

Gaining and maintaining public support is a critical factor in the successful development and long-term operation of power generation projects. This criterion evaluates the level of acceptance and endorsement from the general public, local stakeholders, and other interest groups. A high degree of public acceptance can reduce project risks, streamline permitting processes, and enhance social license to operate, ultimately contributing to smoother implementation and sustained community trust.

6.3.2 Public Safety

Ensuring the health and safety of individuals is a foundational requirement in the planning and execution of power generation projects. This criterion examines the safety measures, protocols, and risk mitigation strategies implemented to protect workers, nearby residents, and the broader public throughout the lifecycle of the project. It includes considerations such as emergency response planning, environmental hazard controls, and adherence to regulatory safety standards.

6.3.3 Job Creation and Employment

Energy generation projects play a vital role in driving employment across multiple phases, including development, construction, operation, and maintenance. This criterion examines the job opportunities created, spanning various sectors and skill levels from trades and technical roles to professional services. By fostering workforce participation and supporting long-term employment, these projects contribute meaningfully to local, provincial, and national economic growth.

6.3.4 Relative Investment in Ontario/Canada

This section highlights the importance of domestic economic participation in power generation projects. It focuses on the extent to which materials, components, and labour are sourced locally within Ontario and across Canada. By prioritizing local procurement and workforce engagement, generation alternatives can help strengthen national industries, foster job creation, and promote regional economic resilience. Projects that demonstrate a strong contribution to the local economy are viewed more favorably under this criterion.

6.3.5 Contributions to Provincial Taxes/Revenue

This criterion assesses the degree to which a generation alternative contributes to the provincial economy through the payment of taxes and generation of public revenue. It includes direct fiscal contributions such as

corporate income taxes, property taxes, and royalties, as well as indirect economic impacts like employment-related taxes and local business stimulation. A generation option that yields higher and more sustained contributions to provincial revenue is considered more favorable in terms of its economic value to the region.

6.4 Policy Considerations

Alignment with government policy is a critical factor in evaluating the viability and strategic fit of power generation options. This criterion assesses how well a proposed generation alternative supports broader public policy objectives, including sustainability, reliability, affordability, and environmental protection. It involves ensuring that project development is coordinated with current regulatory frameworks, energy strategies, and long-term planning goals. For example, alignment with policy directions outlined in publications such as Ontario's Affordable Energy Future: The Pressing Case for More Power (Ministry of Energy and Electrification, October 2024) is a key consideration.

6.4.1 Indigenous Community Economic Benefits

This criterion evaluates the economic benefits that Indigenous communities may derive from the planning, construction, and operation of power generation facilities. These benefits can include direct employment opportunities, capacity building, revenue sharing agreements, equity participation, and support for community-led initiatives. Projects that are developed in partnership with Indigenous communities and that contribute meaningfully to their economic well-being are considered more favorable, particularly when aligned with principles of reconciliation, respect for Indigenous rights, and long-term community empowerment.

6.4.2 Municipal Support

Support from municipal governments plays a key role in the successful implementation of power generation projects. This criterion assesses how well a generation alternative aligns with local planning priorities, land use policies, and long-term municipal objectives such as sustainability, economic development, and infrastructure resilience. Consistency with municipal strategies and active engagement with local authorities and communities are more likely to lead to streamlined approvals, public endorsement, and integration of power generation projects into broader regional development plans.

6.4.3 Contribution to IESO Planning/Acquisition Requirements

Strategic alignment with the IESO is essential for ensuring that power generation projects contribute effectively to Ontario's electricity system. This criterion evaluates how well a generation alternative supports IESO's planning and procurement objectives, including system reliability, long-term energy demand forecasting, and responsiveness to current market needs. Projects that are consistent with IESO's resource adequacy frameworks, acquisition strategies, and operational priorities are more likely to be integrated efficiently into the provincial grid and receive regulatory and market support.

6.4.4 Contribution to Provincial Integrated Energy Planning

Provincial integrated energy planning refers to reviewing proposed generation options against Ontario's strategic energy and land use policies, specifically the *Provincial Planning Statement* (2024), which guides land use planning and development, and *Energy for Generations: Ontario's Integrated Plan to Power the Strongest Economy in the G7* (2025), which outlines a long-term, integrated approach to managing all aspects of Ontario's energy system.

7 The Value Framework – Defining What Matters the Most

The Value Framework outlines how the relative importance (weight) of each criterion is established using the AHP.

Pairwise comparison is a structured and widely accepted approach built into AHP. This method allows evaluators to directly compare two criteria at a time, indicating which is more important and by how much. This approach is simple and clear and mirrors the way people naturally make decisions. Also, this method provides mathematically consistent weighting. By using pairwise comparisons, expert judgment can be captured in a transparent and traceable way.

To understand which criteria matter most, the people who know the system best have been engaged. Also, to reflect the different kinds of judgment needed at each level, the evaluation of the criteria was divided. The top levels (Level 1 and 2) of the framework (those that speak to system-wide outcomes like grid benefits, environmental impact, socioeconomic value, and policy alignment) were evaluated by policymakers and system planners who bring a broad, strategic lens. The more detailed criteria underneath (Level 3), like capacity factor or black start capability, required a different kind of technical expertise. These were assessed by subject matter experts with hands-on experience with the generation alternatives. By matching the right people to the right decisions, the framework captures both strategic relevance and technical depth.

To support this process, the ExpertChoice Comparison® platform was used to allow for the creation of secure digital evaluation forms which automatically captured responses into the AHP model. Before beginning the exercise, each participant was given a brief overview of the objective, the scope of the analysis, and how their input would be used.

7.1 Evaluation of Level 1 and Level 2 Criteria

The relative importance of evaluation criteria, both at the Level 1 and Level 2 hierarchy, was assessed through structured input from industry experts (industry experts group) and waterpower-focused specialists (OWA board members group) to mimic real decisions that rarely come from just one lens. The results of this analysis are based mainly on the evaluations done by the Industry Experts. Sensitivity analysis was done to show how the results change if the weighting of the criteria is done using the OWA board members evaluations. The sensitivity analysis was done in Section 9.2 and Section 10.3 and shows that the final results are not sensitive to either of the two groups.

These two groups see the grid with a different focus, and bringing both groups into the process strengthens the analysis, revealing where assumptions differ, setting the stage to test the stability of the results, and creating a more defensible foundation with consideration for competing priorities and plurality of thought. The results from the two evaluations have been kept separate to provide perspectives. The input from industry experts was used as the basis for the analysis, while the OWA board input was used to perform the sensitivity analysis and create an opportunity for dialogue.

The weighting exercise was conducted anonymously between April 1 and April 7 of 2025, ensuring independent thought. Participants were asked to evaluate the relative importance of each criterion using the AHP through structured pairwise comparisons. Participation was voluntary, and individuals were invited only if they had relevant experience in system-level decision-making.

To support the credibility of the analysis, we applied a consistency check to each participant’s responses using the AHP methodology. In AHP, the consistency ratio is a measure of how logically coherent the judgments are in a pairwise comparison matrix. We eliminated judgment groups that have an inconsistency ratio that is greater than 20%.

7.1.1 Industry Expert Evaluation

This group included industry experts with diverse and broad perspectives and system-level knowledge such as policymakers and system planners. These individuals have a high-level understanding of Ontario’s electricity system and were selected for their relevant expertise.

The evaluation was sent to nine anonymous participants. Each evaluation included 38 judgments to be made on Level 1 and 2 criteria. Eight of the nine evaluators completed the 38 judgments, while one completed 12 of the 38 judgments. The result of the evaluation is presented in Figure 2.

7.1.2 OWA Board Member Evaluation

The OWA board Members evaluation was sent to seven anonymous participants. The evaluation included 38 judgments to be made on level 1 and 2 of the AHP hierarchy. Six of the seven evaluators completed the 38 judgments, while one evaluator completed 12 of 38 judgments. The result of the evaluation is shown in Figure 3.

7.1.3 Interpreting the Differences

The industry expert group brought a view that was shaped by system planning, reliability, and policy alignment, emphasizing grid and system benefits. On the other hand, the OWA board members gave more weight to socioeconomic and environmental considerations, placing a higher value on factors like job creation, environmental performance, and public acceptance. Table 3 summarizes the differences between the evaluation done by the two groups.

Table 3 Industry Expert vs OWA Criteria Evaluation

| Generation Technology | Industry Experts | OWA Board | Relative Difference |
|------------------------------------|------------------|-----------|---------------------|
| Grid and System Benefits | 63.3% | 43.2% | -31.8% = ~(-30%) |
| Environmental Impacts and Benefits | 10.2% | 20.3% | +99.0% = ~(+100%) |
| Socioeconomic Considerations | 8.5% | 25.4% | +198.8% = ~(+200%) |
| Policy Considerations | 18% | 11.0% | -39.9% = ~(-40%) |

7.2 Evaluation of Level 3 Criteria

The evaluation of Level 3 Criteria was carried out by the Hatch project team’s internal subject matter experts. These individuals bring deep technical experience across the relevant generation technologies, including waterpower, wind power, solar power, gas-fired generation, and environmental, social, and policy domains. The team used pairwise comparison and worked through a group consensus process to determine the relative importance of each criterion.

When making the judgments, the focus was on what the system needs most to keep the lights on and the grid running smoothly. This means starting with what matters most for day-to-day reliability, then considering how flexible the system needs to be to handle changes and new technologies and finally making sure all the important technical services are covered. By looking at each detailed criterion from the perspective of system

needs (reliability, flexibility, and critical grid support), the weighting reflects what actually keeps Ontario’s power secure and dependable.

The results of the Level 3 evaluation are integrated into the industry experts and the OWA board evaluations as shown in Figure 2 and Figure 3. The details of the evaluation are presented in Appendix B.

Figure 2 Criteria Evaluation Results by the industry experts (Levels 1 and 2) and Hatch’s SMEs (Level 3)

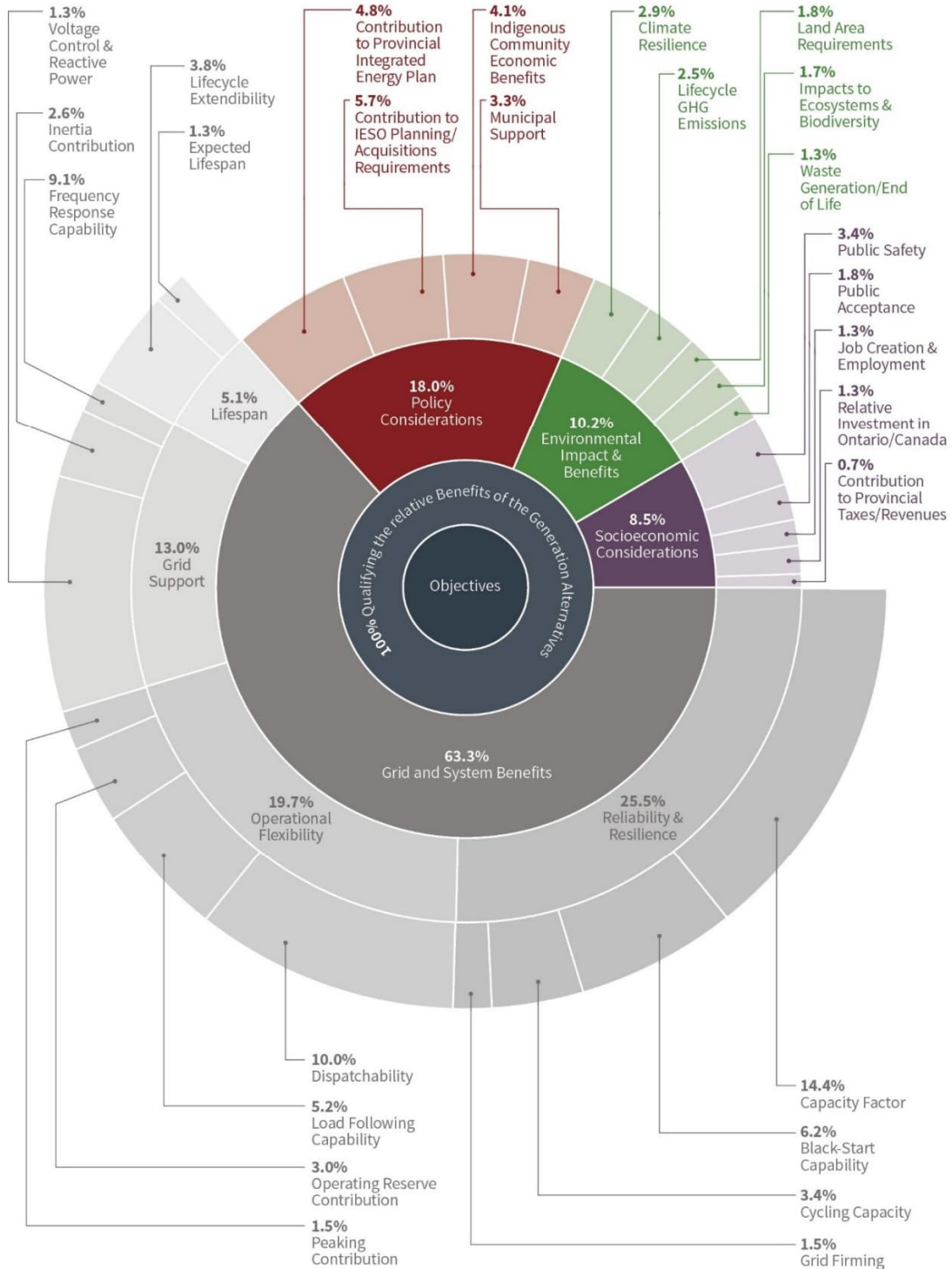
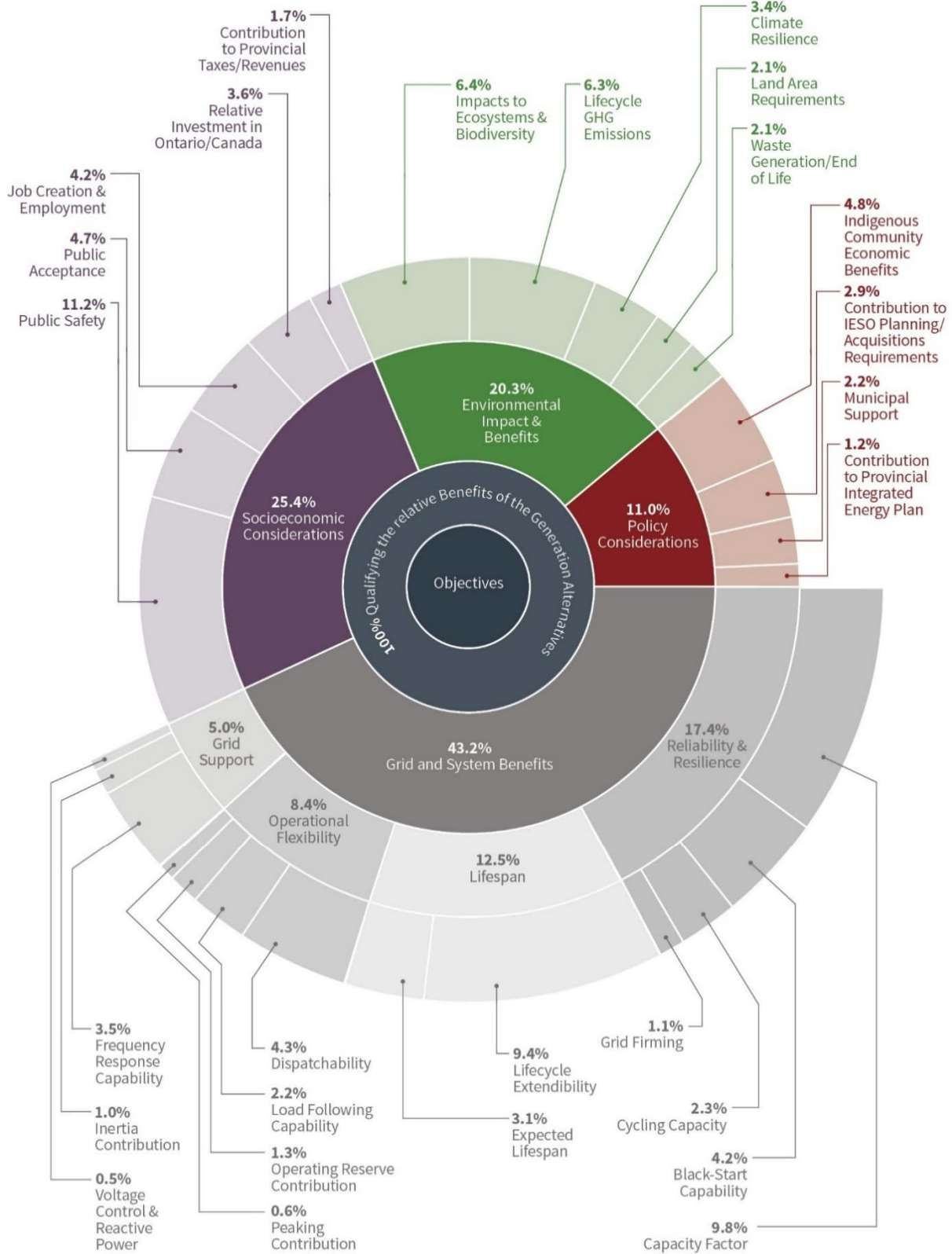


Figure 3 Criteria Evaluation Results by the OWA Board (Levels 1 and 2) and Hatch’s SMEs (Level 3)



8 Alternatives Evaluation – Comparing the Alternatives

This section explains how each generation alternative was assessed after the framework and weights were established. The evaluation process is based on structured measurement scales, judgment from SMEs, and data sources based on previous research.

When absolute scores are not available or carry a lot of uncertainty, the evaluation is then performed based on relative comparisons. In that case, the alternatives are evaluated in the context of each other, not in isolation. This approach allows for a meaningful exploration of strengths, weaknesses, and trade-offs.

8.1 Grid and System Benefits

8.1.1 Reliability and Resilience

8.1.1.1 Capacity Factor

8.1.1.1.1 General Considerations

Waterpower: Capacity factor depends on water availability, demand patterns, maintenance requirements, and regulatory constraints. To get a representative number, we will rely on actual historical operational capacity factor in Ontario given the local context. We have used the capacity factor that was reported in the Ontario Auditor General’s 2022 report for the period of 2015-2021 and then confirmed that by calculating the actual capacity factor for 2024 using the most recent IESO data.

According to the Ontario Auditor General’s 2022 report on OPG’s waterpower facilities (Office of the Auditor General of Ontario, 2022), OPG’s waterpower generating stations operated at 48-51% of their total installed capacity over the seven-year period from 2015-2021. In this analysis, an average capacity factor of 49% was used.

The Capacity Factor for waterpower in Ontario can be calculated using the most recent available data from the Independent Electricity System Operator (IESO). The Capacity Factor is calculated using the formula:
$$\text{Capacity Factor} = \frac{\text{Actual Energy Produced (GWh)}}{\text{Installed Capacity (MW)} * 8760 \text{ hrs}}$$
. In 2024, Ontario’s transmission-connected waterpower generation was 37.8 TWh (37,800 GWh), as reported in the IESO’s Supply Overview (IESO, n.d.-a). According to the March 2024 Annual Planning Outlook report, (IESO, 2024), the waterpower installed capacity was 9.3 GW. Thus, the average capacity factor for waterpower in Ontario for 2024 is approximately 40.6.

Wind Power: An average capacity factor of 31% was reported for wind power in Ontario between 2020 and 2023 (Sepulveda, 2025). In 2024, Ontario’s wind power was 13.4 TWh (13,400 GWh), as reported by the IESO Supply Overview (IESO, n.d.-a). Installed Capacity: The IESO 2024 Annual Planning Outlook (IESO, 2024) reports 5.5 GW of wind capacity. This corresponds to an actual capacity factor of ~28%. Given that most of the wind turbines in Ontario are old (in the range of 20 years old), and given the rapid advancement in the technology, it can be assumed that installing new wind turbines in Ontario would allow for slightly higher capacity factor. As such, an upper range of 40% was used, which allows an average value of 34% that was used in the analysis.

Solar Power: In 2022, the capacity factor for actual Ontario solar power was reported to be 17%-19% according to the Power Worker’s Union, Submission to the IESO on the Pathway to Decarbonization Study (Power Workers’ Union, 2022). In 2024, Ontario’s solar power was 0.8 TWh (800 GWh), as reported by the IESO Supply Overview (IESO, n.d.-a). The IESO 2024 Annual Planning Outlook (IESO, 2024) reports 2.6 GW of solar capacity. However, most solar in Ontario is distribution-connected (478 MW transmission-connected, while the rest is distribution-connected) as mentioned in IESO Progress Report on Contracted Electricity Supply (IESO, n.d.-b). To estimate total solar power, we scale the transmission-connected generation proportionally based on the following information:

- Transmission-connected (0.478 GW) generated 800 GWh.
- Projected total generation from the total capacity of 2.6 GW is ~4,351 GWh.

The above numbers reflect a capacity factor of ~19% in 2024. An average value of 18% is used in this analysis.

Gas-Fired Generation: Gas turbines can theoretically operate at a high-capacity factor close to 80-99% if run continuously, as their fuel (natural gas) is not a limiting factor, unlike waterpower and renewables. However, practical limits like operational/regulatory constraints reduce this capacity factor.

An example of these limitations is represented by the current capacity factor for gas-fired generation in Ontario of approximately 19%. This is based on data from the IESO June 2025 Reliability Outlook (IESO, 2025a), which reports that the outlook for Ontario gas-fired generators production is 8,919 GWh of electricity from a total installed capacity of 10,468 MW during the second half of 2025.

In this analysis, we will use 90% capacity factor to reflect the inherent technical capability of modern gas-fired generation when operated continuously (maximum potential). This ensures that the evaluation is based on actual engineering characteristics, while operational constraints are accounted for separately through the weighting of relevant criteria. This avoids mixing technology performance with contextual restrictions as mentioned in Assumptions Section 5.

Table 4 provides a summary of the capacity factor ranges that are used to score the different generation technologies.

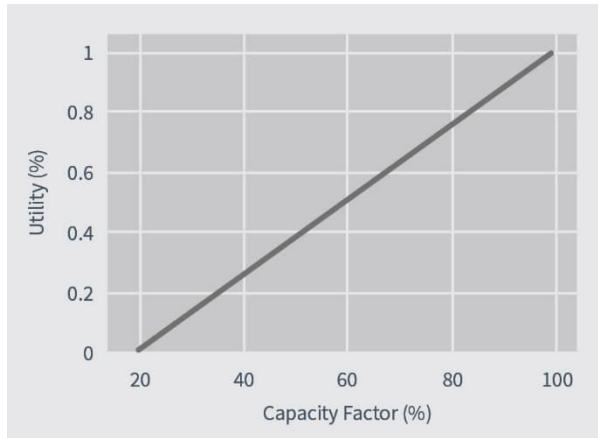
Table 4 Capacity Factors Average Range for the Different Generation Technologies in Ontario

| Generation Technology | Capacity Factor (%) | Comments |
|-----------------------|---------------------|---|
| Waterpower | 48-51% | Varies with water availability |
| Wind | 27-40% | Intermittent by nature, varies by site |
| Solar | 17-19% | Limited by daylight, hour, and weather |
| Gas | 85-95% | Dispatchable, available year-round except for time needed for maintenance |

8.1.1.1.2 Measurement Scale

For this criterion, we are using a utility curve as our measurement scale because capacity factor is a continuous and quantitative value. A utility curve translates raw capacity factor percentages from each generation technology into normalized scores that can be compared directly. To keep things simple, we are using a linear utility curve (each increase in capacity factor results in a proportional increase in score), as shown in Figure 4.

Figure 4 Priorities Using Quantitative Scale and a Linear Utility Curve



In this study, we have set 17% (the lowest capacity factor among the technologies considered) to correspond with a utility score of 0, and 99% (the highest) to a score of 1. Any values in between will fall on a straight line between these two points. The relative comparison of the technologies will derive relative scoring based on that input.

8.1.1.1.3 Scoring

Using the capacity factor numbers provided in Table 5, the utility/score for each technology is derived using the utility curve shown in Figure 5. The results are then

normalized and presented in Figure 5.

Table 5 Average Capacity Factor Considered for Each Technology

| Generation Technology | Capacity Factor (%) | Normalized Scores (%) |
|-----------------------|---------------------|-----------------------|
| Waterpower | 49% | 26.0% |
| Wind | 34% | 13.8% |
| Solar | 18% | 0.8% |
| Gas | 90% | 59.3% |
| Total | 191% | 100% |

Figure 5 Alternatives Priorities with Respect to Capacity Factor



8.1.1.2 Black-Start Capability

The requirements for Black-Start are defined in the Ontario Power System Restoration Plan (OPSRP) (IESO, n.d.-c). As mentioned in the Annual Planning Outlook, Portability, April 2025 (IESO, 2025b), this service is provided through certified black start resources. Also, the report mentions that waterpower and natural gas resources provide black start capability in Ontario. The IESO has developed a methodology to assess back-start needs in Ontario which is based on the ability to energize nuclear units, geographic diversity, resiliency, and dependability as mentioned in the 2021 Annual Planning Outlook – Ancillary Services (IESO, 2021).

The Black Box of Black-start by NASEO (National Association of State Energy Officials, 2022) provides useful background information on black-start units and process that was used to support the discussion below. The report gives an idea about the “typical” characteristics of a black-start unit such as having ample on-site fuel inventory and have the ability to vary their output and tolerate frequency variations. As such, black-start generators are often small units that can quickly ramp up and down. The following sections provide a summary of the black-start capability for the different generation technologies.

8.1.1.2.1 General Considerations

Waterpower: Waterpower generators are ideal for black start as they can generally start quickly and independently using water available on-site, with minimal external power required. The role of waterpower in restoration of the grid back in the 2003 blackout is highlighted in the 2003 Waterpower Canada Report on waterpower’s Value to a Net-Zero Electricity Grid, A Guidebook for policymakers (Waterpower Canada, 2023).

Wind and Solar Power: These do not reliably provide back-start capability on their own because their output depends on variable wind and sunlight. As such, they cannot guarantee immediate power when needed for grid restoration. The IESO’s Market Manual on System Operations, System Restoration Plan (IESO, n.d.-d) mentions that Wind and/or Solar generators are disconnected in blacked-out areas until the latter stages of restoration.

Gas-Fired Generation: Gas facilities can be designed for black start as black start is not an inherent characteristic of some facilities. Reciprocating engines can be started with compressed air storage. Combined or simple cycle engines with black start capability have reciprocating engines in the plant. Combined cycle gas facilities are generally less suited because they may have higher internal power needs and take longer to restart though some in Ontario do contribute as part of the black start portfolio.

8.1.1.2.2 Measurement Scale

Pairwise comparison is used because black start capability is a qualitative, categorical feature (certain technologies can provide it while others generally cannot). There is not a meaningful continuous or quantitative metric to apply a utility curve for this criterion.

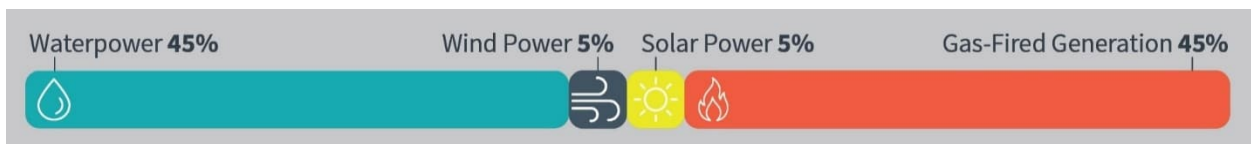
8.1.1.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 6 Priority scoring of the different alternatives is shown in Figure 7.

Figure 6 Alternatives Pairwise Scoring with Respect to Black-Start Capability



Figure 7 Alternatives Priority Scoring with Respect to Black Start Capability



8.1.1.3 Cycling Capability

8.1.1.3.1 General Considerations

Waterpower: Waterpower facilities can ramp their output up and down quickly by adjusting water flow within the regulated limits for water flow and short-term storage available for run-of-river facilities. As such they offer important technical potential for cycling capability. When operated for this purpose, waterpower is able to respond to changes in electricity demand throughout the day. However, most Ontario waterpower stations were originally designed for steady, baseload generation rather than frequent cycling. Although they are capable of cycling, regular ramping or start-stop operation can lead to increased wear and maintenance needs compared to their historical usage. Despite these practical considerations, waterpower remains one of the most flexible resources available for grid support. Also, new waterpower installations or major refurbishments can be engineered for frequent cycling while minimizing the impact on maintenance.

Solar Power: Solar power output follows the daily pattern of sunlight and cannot be increased or decreased by operator request (other than decreased through curtailment). As a result, wind and solar play a minimal role in providing the cycling capability needed for active grid balancing in Ontario.

Wind Power: Wind turbines can theoretically ramp up and down their output rapidly, but only when wind conditions permit. As such, their cycling ability is constrained by local weather. Also, the ramp up capability can only happen if wind output is deliberately kept below its potential creating a headroom for ramping up. They have limited dispatchability on demand (can only be dispatched down by inverter controls), so they have limited reliability to supply flexible grid support for rapid cycling.

Gas-Fired Generation: Ontario's gas fleet contains both simple cycle and combined cycle units. Simple cycle turbines and reciprocating engines are built for fast starts, quick shutdowns, and frequent output changes, making them ideal for cycling capability. Combined cycle gas units are more complex and typically designed for efficient, steady generation, but they can also cycle daily and ramp and adjust output (though with slower response and higher maintenance costs if cycled as much as simple cycle units). As a portfolio, gas-fired generation provides excellent operational flexibility for Ontario system needs.

8.1.1.3.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives. Cycling capability is a qualitative and categorical feature (certain technologies can provide it while others generally cannot). As such, there is not a meaningful continuous or quantitative metric to apply a utility curve for this criterion.

8.1.1.3.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 8. The normalized priority scoring of the different alternatives is shown in Figure 9.

Figure 8 Alternatives Pairwise Scoring with Respect to Cycling Capability



Figure 9 Alternatives Priorities with Respect to Cycling Capability



8.1.1.4 Grid Firming

8.1.1.4.1 General Considerations

Waterpower: Waterpower is highly effective for grid firming. Its ability to rapidly adjust output (ramping up or down as needed) helps meet fluctuations in demand and variable renewable supplies. Because waterpower can store water in reservoirs or manage flow through run-of-river facilities, it provides dependable support for keeping the power system balanced and maintaining firm supply during peak times or dips in wind and solar output.

Wind Power: Wind power offers poor grid firming capability. Its output is variable and depends entirely on wind conditions, which can change rapidly and is not predictable on short timescales. Wind farms cannot provide firm, dispatchable supply; instead, their variability needs to be balanced by other firming resources in the system.

Solar Power: Solar power also has poor ability to provide grid firming on its own. While its production can be forecast based on daylight hours, it cannot be controlled or dispatched to meet demand. Cloud cover and weather changes can cause unpredictable drops in output, requiring backup from firm resources.

Gas-Fired Generation: Gas facilities (both simple cycle and combined cycle) are excellent for grid firming. They can be dispatched quickly and reliably, making them valuable for filling in gaps left by intermittent resources. Their moderate to fast ramping speeds and high availability mean they are often used to ensure the grid remains firm and reliable during periods of variable renewable output or sudden demand changes.

8.1.1.4.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives. Grid Firming capability is a qualitative and categorical feature (certain technologies can provide it while others generally

cannot). As such, there is not a meaningful continuous or quantitative metric to apply a utility curve for this criterion.

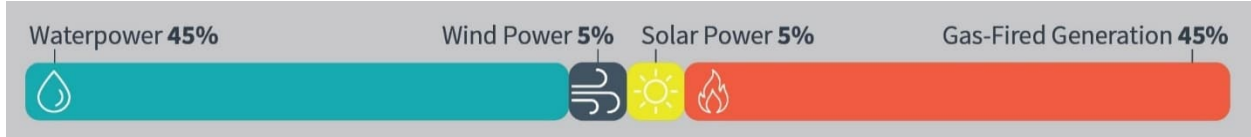
8.1.1.4.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 10. The normalized priority scoring of the different alternatives is shown in Figure 11.

Figure 10 Alternatives Pairwise Scoring with Respect to Grid Firming Capability



Figure 11 Alternatives Priorities with Respect to Grid Firming Capability



8.1.1.5 Key Insights for the Alternatives with Respect to Reliability and Resilience

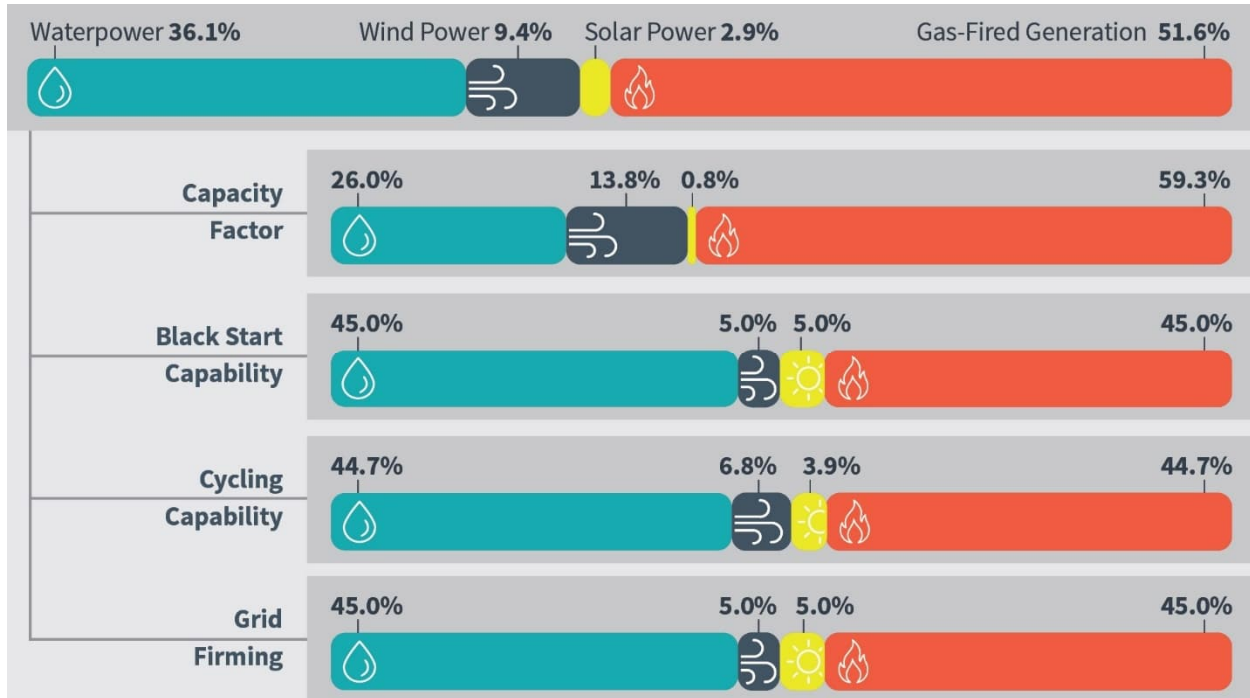
The overall scoring breakdown for Reliability and Resilience provides a comparative perspective on how each generation technology contributes to dependable and robust grid operation across several key criteria (capacity factor, black start capability, cycling capability, and grid firming). These scores represent a synthesis of the detailed relative evaluations for each criterion along with the relative weight of these criteria in Section 7. This is summarized in Figure 12 from this high-level view:

- **Waterpower and gas-fired generation** dominate all aspects of reliability and resilience, together scoring ~ 88% of total system benefits in this category. These two technologies play a critical role in system reliability and resilience because they are dispatchable and can be counted on for consistent performance. They provide secure capacity, offer dependable black start capability, and support cycling and firming services so the grid can respond flexibly to changes in demand or supply. Gas scored higher than waterpower because it delivers steady output year-round and is not affected by water availability or location.
- **Wind and solar power** are limited in supporting reliability and resilience because their output depends on variable local weather conditions. Though wind offers moderate capacity support when resources are available, both technologies cannot be relied upon for black start or firming services without external

support. Their variability means they cannot serve as primary secure resources for critical grid functions, highlighting the need for complementary dispatchable resources in a balanced electricity system.

In summary, the scoring highlights that both gas and waterpower resources have the diverse technical features needed for system reliability and resilience, while wind and solar do not. The results also reflect that the value-based-insights are based on aggregate, normalized scores across several dimensions, not on a single aspect of performance.

Figure 12 Breakdown of the Alternatives Scoring with Respect to Reliability and Resilience



8.1.2 Operational Flexibility

8.1.2.1 Dispatchability

8.1.2.1.1 General Considerations

Waterpower: Waterpower facilities generally offer strong dispatchability, especially those with reservoir storage. Operators can control output in real-time, quickly ramping generation up or down to follow system needs or match demand shifts. However, some run-of-river waterpower units may have more limited dispatch flexibility due to local flow constraints or environmental requirements.

Wind Power: Wind is non-dispatchable. Its output depends on wind availability and cannot be controlled or ramped on command. While modern wind farms allow curtailment (reducing output when directed), they cannot provide additional generation beyond what the wind resource allows at any moment.

Solar Power: Solar is also non-dispatchable. Electricity production is tied directly to sunlight and follows predictable daily and seasonal patterns. While grid operators can curtail solar output, they cannot increase generation when demand or system needs require it.

Gas-Fired Generation: Gas-fired facilities (both simple cycle turbines and combined cycle units) are highly dispatchable resources in Ontario. They can be started, stopped, and directed to produce power at any time

(subject to fuel supply and technical limits). Simple cycle units excel at rapid dispatch, whereas combined cycle facilities offer dispatchability across longer intervals.

8.1.2.1.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because dispatchability is a qualitative and categorical feature. Some technologies can be dispatched on demand (waterpower and gas), while others (wind, solar) cannot, except for being curtailed.

8.1.2.1.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 13. The normalized priority scoring of the different alternatives is shown in Figure 14.

Figure 13 Alternatives Pairwise Scoring with Respect to Dispatchability



Figure 14 Alternatives Priorities with Respect to Dispatchability



8.1.2.2 Peaking Contribution

8.1.2.2.1 General Considerations

Waterpower: Reservoir waterpower facilities can provide excellent peaking contribution. They can increase output quickly during periods of high demand, making them valuable for Ontario’s grid during daily and seasonal peaks. Run-of-river waterpower, however, has less flexibility and limited peaking ability due to the dependency on immediate water flow and regulatory limits.

Wind Power: Wind power cannot be relied on for peaking, since its output is determined by wind conditions, which may or may not coincide with grid peaks. While wind can contribute if it happens to be available, it is unpredictable and not dispatchable for planned peaks.

Solar Power: Solar power is tied to daylight hours, with its highest output during mid-day. It can contribute to peaks during sunny periods (especially summer afternoons) but is not controllable and does not align with

evening or winter peaks. This is why its overall contribution to peaking is considered as moderate at best and highly seasonal.

Gas-Fired Generation: Gas-fired generation (especially simple cycle turbines and reciprocating engines) is designed for peaking service. These units can ramp up rapidly and provide full output almost immediately. Combined cycle facilities are less ideal but can also contribute when operated for peaking (with longer startup times). Ontario’s gas fleet is used to support the system reliability during demand spikes.

8.1.2.2.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because peaking contribution is a qualitative and categorical feature. Some technologies can deliver reliable peaking service (waterpower with storage, gas), other technologies are limited by uncontrollable resource availability (wind, solar).

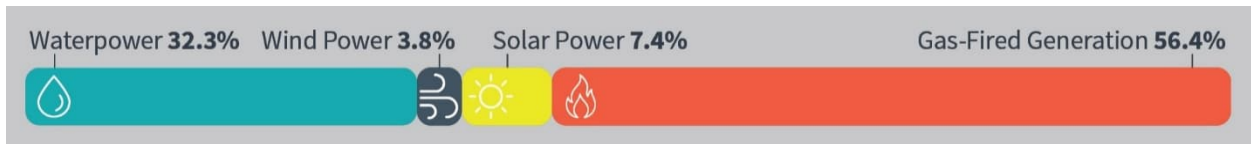
8.1.2.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 15. The normalized priority scoring of the different alternatives is shown in Figure 16.

Figure 15 Alternatives Pairwise Scoring with Respect to Peaking Contribution



Figure 16 Priorities with Respect to Peaking Contribution



8.1.2.3 Load Following Capability

8.1.2.3.1 General Considerations

Waterpower: Reservoir-based waterpower facilities are excellent at load following. Operators can quickly adjust output to match real-time changes in electricity demand. Some run-of-river waterpower may have less flexibility, but overall, waterpower is highly valued for this capability.

Wind Power: Wind power is poor for load following because its output is governed by wind conditions. Wind power cannot be increased on demand, only curtailed if supply exceeds demand. As such, its ability to follow the load is very limited and unpredictable.

Solar Power: Like wind, solar power cannot follow demand except for potential curtailment. Output follows the profile of sunlight throughout the day. While it naturally aligns with daytime demand, it cannot ramp up or down to follow rapid changes or evening peaks.

Gas-Fired Generation: Gas facilities (both simple cycle and combined cycle units) are suited to load following. They can ramp their output quickly and are routinely dispatched to balance daily and hourly demand fluctuations.

8.1.2.3.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because load following is a qualitative and categorical feature. Some technologies can be used for load following (waterpower, gas), other technologies are limited by uncontrollable resource availability (wind, solar).

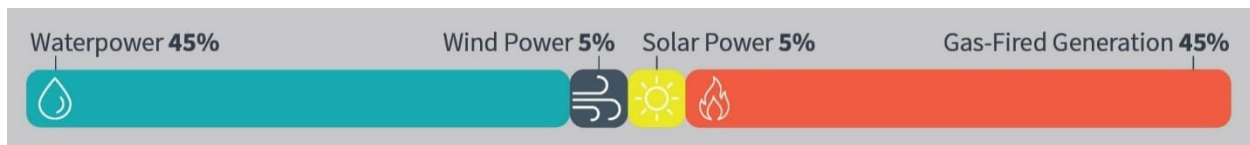
8.1.2.3.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 17. The normalized priority scoring of the different alternatives is shown in Figure 18.

Figure 17 Alternatives Pairwise Scoring with Respect to Load Following Capability



Figure 18 Priorities with Respect to Load Following Capability



8.1.2.4 Operating Reserve Contribution

8.1.2.4.1 General Considerations

Waterpower: Waterpower stations, especially with reservoir storage, are ideal providers of operating reserve in Ontario. They can respond rapidly to dispatch signals, delivering quick increments of power when grid needs

arise (contingency reserve, frequency regulation, etc.). Their flexible output makes waterpower valuable for both primary and supplemental reserve requirements.

Wind Power: Wind power has poor operating reserve contribution since its output is weather dependent and cannot be increased on demand. Wind may be curtailed to create some reserve margin but is not relied for rapid or guaranteed response when reserve is needed.

Solar Power: Solar is similarly poor for operating reserves. Its contribution is limited to sunny daytime hours; it cannot provide reserve ramping after sunset or during unpredictable cloud cover. Solar cannot be dispatched upward on request, so its reliability for system reserves is very limited.

Gas-Fired Generation: Gas units can be relied upon for operating reserves. They can start, ramp, and adjust output quickly, filling reserve needs as standby facilities or by ramping down output to create reserve headroom. Their reliability and controllability ensure they meet reserve criteria.

8.1.2.4.2 Measurement Scale:

Pairwise comparison is used to compare the performance of the different generation alternatives because operating reserve is a qualitative and categorical feature. Some technologies can be used as operating reserve (waterpower, gas), other technologies cannot (wind, solar).

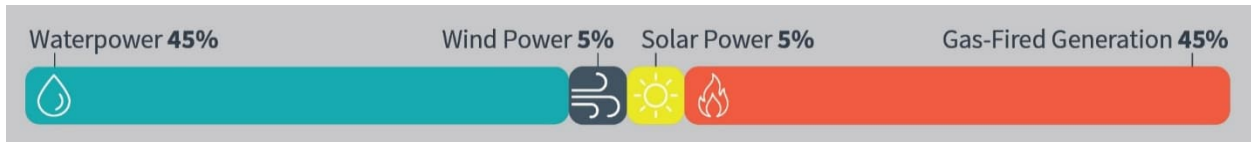
8.1.2.4.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 19. The normalized priority scoring of the different alternatives is shown in Figure 20.

Figure 19 Alternatives Pairwise Scoring with Respect to Reserve Contribution



Figure 20 Alternatives Priorities with Respect to Reserve Contribution



8.1.2.5 Key Insights for Alternatives with Respect to Operational Flexibility

The scoring breakdown for Operational Flexibility as illustrated in Figure 21 offers a clear comparison of how each generation technology responds to real-time grid needs through dispatchability, peaking contribution,

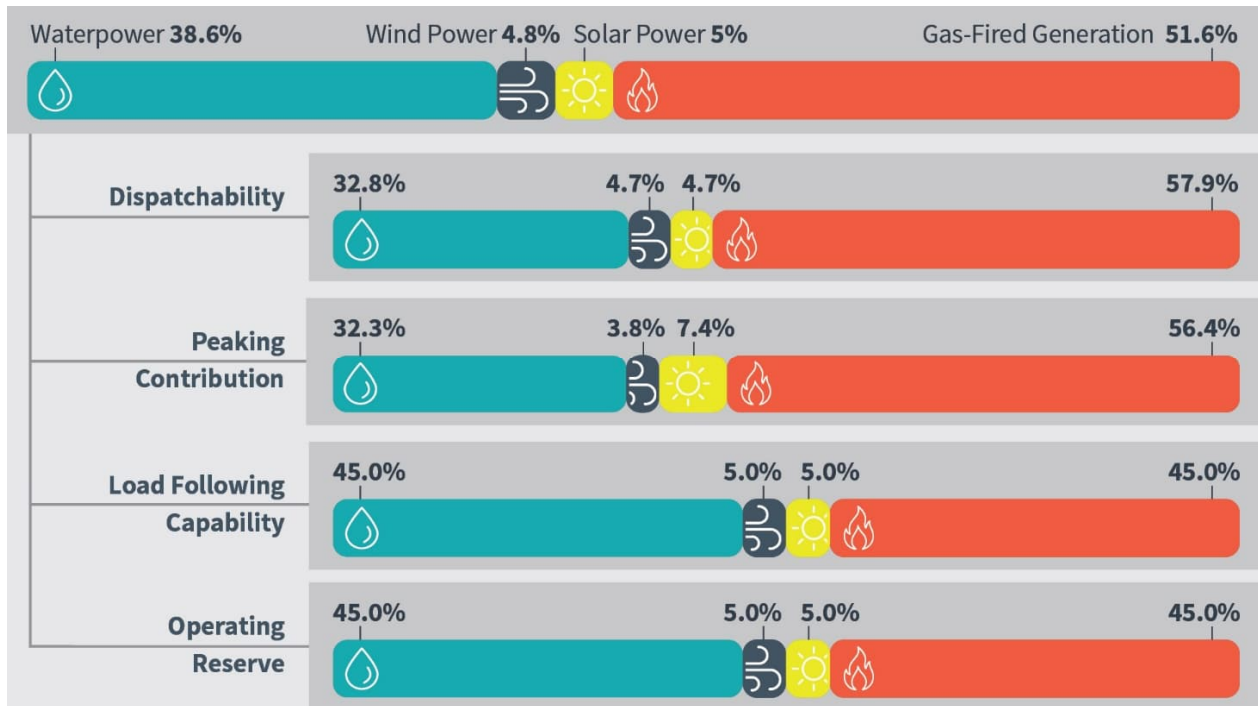
load following, and operating reserve support. These scores reflect a synthesis of relative capability across these core operational criteria.

Waterpower and gas-fired generation are the primary contributors to operational flexibility, together supplying over 90% of all system benefit in this category. Both can be dispatched on demand, reliably follow load, and provide substantial peaking and reserve services, making them essential for grid operations that require fast and effective adjustments. Gas outperforms waterpower primarily due to greater dispatchability and peaking contribution as it is not resource dependent.

Wind and solar power offer very limited support for operational flexibility because their output is determined by variable weather and cannot be controlled in real time. Even though solar provides a modest peaking contribution and wind can help with load following capability when available, these technologies cannot be depended upon to supply reserves or adjust output on command. These results highlight the challenges variable renewables face in delivering grid services beyond energy production. Their inability to be dispatched or reliably follow system needs further reinforces the necessity of pairing them with flexible, dispatchable resources.

In summary, the scoring demonstrates that both gas-fired and waterpower resources have the technical features needed for high operational flexibility, while wind and solar do not. Wind and solar, given their limited flexibility, remain reliant on the dispatchable technologies (such as waterpower and gas) for system integration and balancing. The results underline the importance of a balanced resource mix, where variable renewables are complemented by technologies capable of delivering consistent and responsive system services.

Figure 21 Breakdown of the Alternatives Scoring with Respect to Operational Flexibility



8.1.3 Grid Support

8.1.3.1 Inertia Contribution

8.1.3.1.1 General Considerations

Waterpower: Waterpower units are connected to the grid using large synchronous generators, which contribute significant system inertia. When a disturbance occurs, the rotating mass of waterpower turbines and generators instantly helps stabilize system frequency by resisting rapid changes. This makes waterpower a very important technology for grid inertia.

Wind Power: Wind turbines are considered poor for inertial support due to decoupling from the grid through power electronics (inverters). Even though there are some technology advancements in this area that may enable wind turbine to provide synthetic inertia, the technology is still limited at this stage.

Solar Power: Solar power is considered poor for inertial contribution. Solar power uses inverter-based systems without rotating mass, so it provides no real system inertia.

Gas-Fired Generation: similar to waterpower, both simple cycle and combined cycle gas facilities employ synchronous generators, adding substantial inertia to the grid. Their rotating machinery provides immediate support to grid frequency during disturbances.

8.1.3.1.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because inertia contribution is a qualitative and categorical feature. Some technologies can provide inertia support to the grid (waterpower, gas), while other technologies cannot or have very limited contribution (wind, solar).

8.1.3.1.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 22. The normalized priority scoring of the different alternatives is shown in Figure 23.

Figure 22 Alternatives Pairwise Scoring with Respect to Inertia Contribution

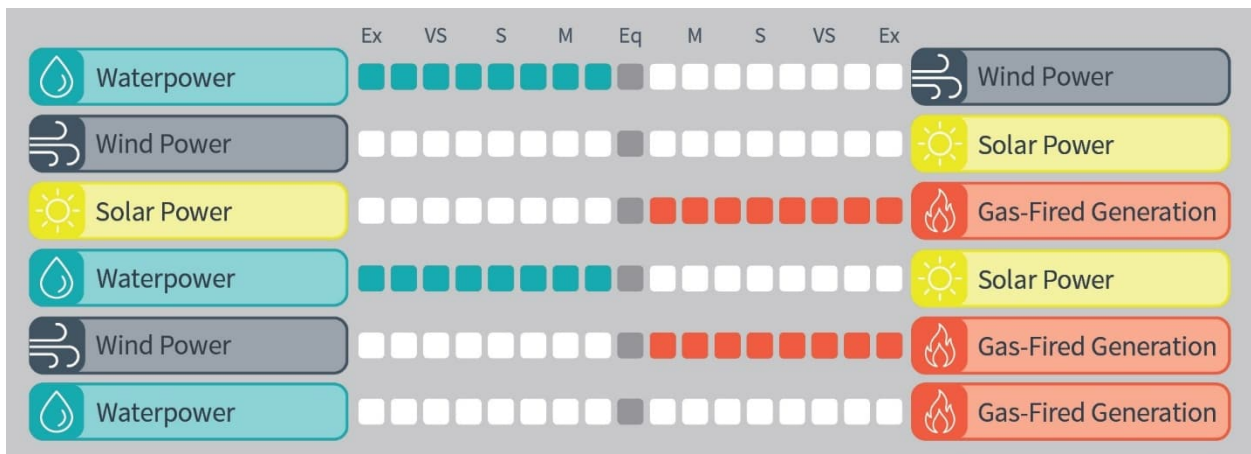


Figure 23 Alternatives Priorities with Respect to Inertia Contribution



8.1.3.2 Frequency Response Capability

8.1.3.2.1 General Considerations

Waterpower: Waterpower facilities with synchronous machines provide excellent frequency response. Their turbine governors sense changes in grid frequency and automatically adjust output to help stabilize the system delivering both primary (immediate) and secondary (slower, sustained) control.

Wind and Solar Power: Solar and wind facilities have limited frequency response that can be supplied by the inverters. While inverters can rapidly reduce output or inject small bursts for frequency deviation events, their ability to provide continuous and substantial response is much less than waterpower or gas. Solar and wind facilities are generally not counted on for reliable frequency control.

Gas-Fired Generation: Gas turbines and combined cycle facilities also supply strong frequency response via synchronous generators and fast-acting governors. They can quickly increase or decrease output to counteract shifts in grid frequency.

8.1.3.2.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because frequency response is a qualitative and categorical feature. Some technologies can be used for frequency response (waterpower, gas), while other technologies cannot/limited (wind, solar).

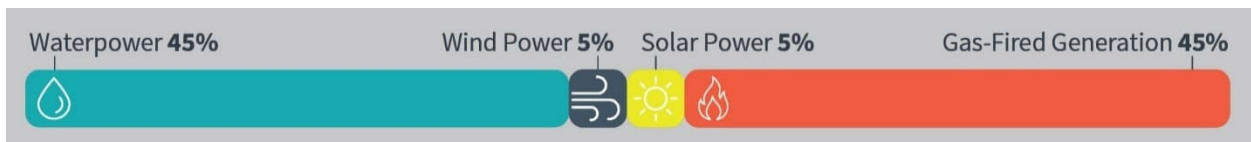
8.1.3.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 24. The normalized priority scoring of the different alternatives is shown in Figure 25.

Figure 24 Alternatives Pairwise Scoring with Respect to Frequency Response



Figure 25 Alternatives Priorities with Respect to Frequency Response



8.1.3.3 Voltage Control and Reactive Power

8.1.3.3.1 General Considerations

Waterpower: Waterpower facilities equipped with synchronous generators are highly effective in providing voltage control and managing reactive power. Their excitation systems can quickly and smoothly adjust the flow of reactive power, helping maintain grid voltage and stability over a range of operating conditions.

Wind and Solar Power: Solar power facilities and wind facilities use inverters, which can be programmed to produce some reactive power, but the overall capability is limited compared to synchronous machines. Solar and wind facilities are not usually relied on for significant voltage control or reactive support, and its ability to help with grid stability is restricted mostly to times of generation.

Gas-Fired Generation: same as waterpower facilities.

8.1.3.3.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives because voltage control and reactive power capability is a qualitative and categorical feature. Some technologies can be used for voltage control and reactive power (waterpower, gas), while other technologies cannot or are limited (wind, solar).

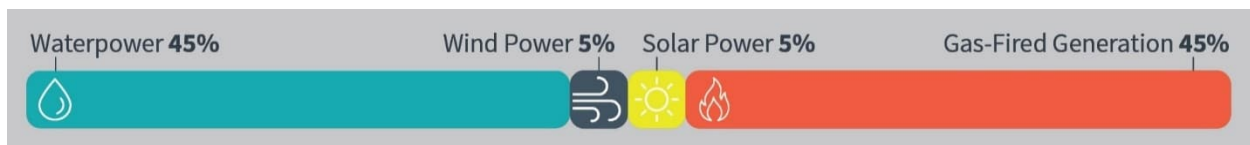
8.1.3.3.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 26. The normalized priority scoring of the different alternatives is shown in Figure 27.

Figure 26 Alternatives Pairwise Scoring with Respect to Voltage Control and Reactive Power



Figure 27 Alternatives Priorities with Respect to Voltage Control and Reactive Power



8.1.3.4 Key Insights for Alternatives with Respect to Grid Support

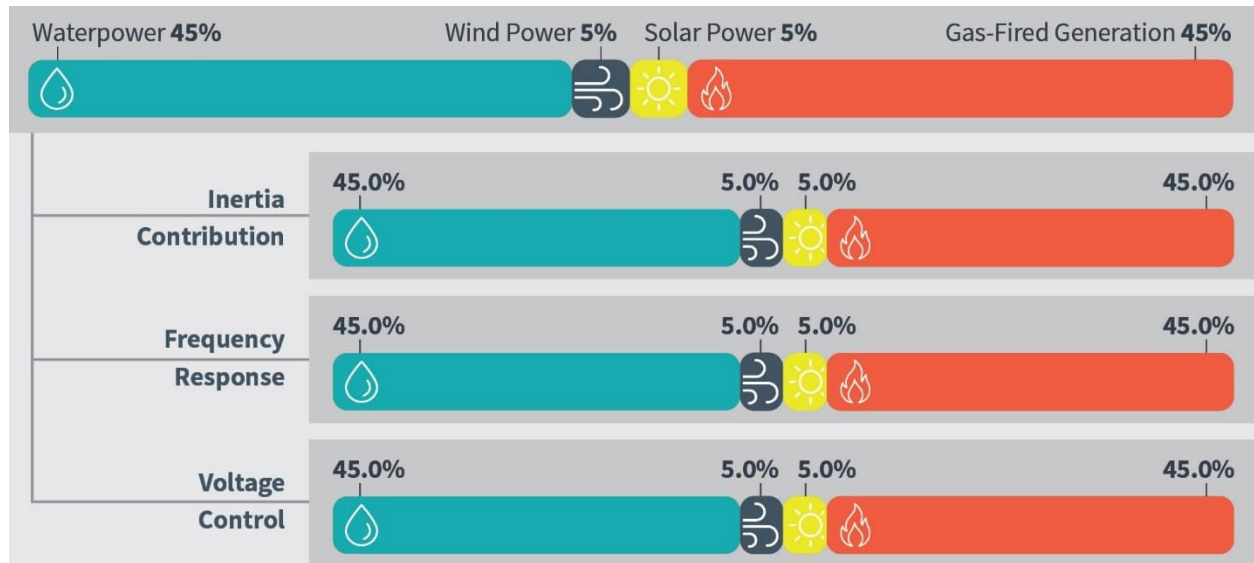
The comparative scoring for grid support provides a clear perspective on how each technology contributes to critical grid stability functions. This includes inertia contribution, frequency response, and voltage control and reactive power. The results synthesize relative capabilities across these ancillary service criteria, as summarized in Figure 28.

Waterpower and gas-fired generation both provide very strong grid support, each scoring 45.0% overall. Their synchronous machines support essential system services given that they deliver strong inertia, fast and reliable frequency response, and strong voltage/reactive support. These technologies are fundamental to maintaining power system stability, especially as inverter-based resources (solar and wind) expand their role in Ontario’s grid. The similar scores for waterpower and gas highlight their shared ability to maintain grid support under a high-level, system-wide view.

Wind and Solar Power have considerably lower overall scores (5% each), highlighting the challenges these variable inverter-based technologies face in supplying core grid support services. While there are some advancements in this area, these technologies are still limited in providing inertia support, frequency support, and reactive power.

In summary, grid support in Ontario relies mainly on large synchronous units (waterpower and gas). Their physical and control characteristics allow fast response and voltage management. Wind and solar, while improved by emerging technology, remain supplementary for most grid support needs. These findings reinforce the need for a balanced generation mix to safeguard system stability as the energy transition progresses, especially at higher levels of renewable penetration.

Figure 28 Breakdown of the Alternatives Scoring with Respect to Grid Support



8.1.4 Lifespan and Lifecycle Considerations

8.1.4.1 Expected Lifespan

8.1.4.1.1 General Considerations

Wind Power: Wind turbines have a minimum design life of 20-25 years (Business Norway, 2024), (Holzmüller, 2016), (WTW, 2023). New turbines can get design lifetimes up to 35 years (especially in Ontario wind regime). An average value of 20 years is used in this analysis to account for lifetime before any major component rehabilitation.

Solar Power: Standard lifespan for solar panels is about 25-30 years (All Energy Solar, 2024a), (All Energy Solar, 2024b). However, the inverter (major component) typically needs to be replaced after ~15 years. Similar to Wind, an average value of 20 years is used in this analysis.

Waterpower: Waterpower facilities are recognized for their durability. Civil structures (dams, tunnels) last well over 75-100 years according to Canadian Waterpower Association (Natural Resources Canada [NRCan], 2023) and a Waterpower Canada report (Hatch Ltd., 2023), while mechanical and electrical components are typically refurbished every 40-50 years (Hatch Ltd., 2023). An average value of 45 years is used in this analysis.

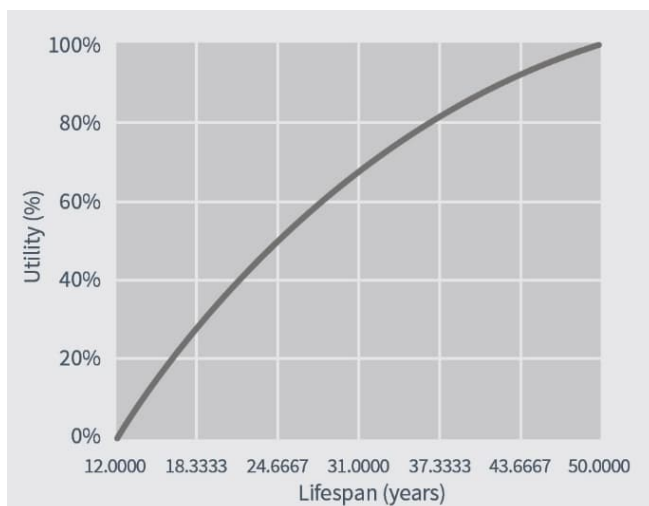
Gas-Fired Generation: Gas facilities are built for operational lives around 25-30 years (Bhat and Foelske, 2022), (Keck Group International, 2017), (Allied Power Group, 2024) with a global average 37 years of service (Martos, 2024). An average value of 35 years is used in this analysis.

8.1.4.1.2 Measurement Scale

A utility curve is used to evaluate extended lifespan to capture diminishing marginal utility for longer lives. This is consistent with asset economics and operational practices:

- Longer lifespans reduce annualized capital costs and provide better return on investments.
- Mature technologies with longevity offer greater planning certainty.
- Assets with longer design lives support more stable grid planning.

Figure 29 Priorities Using Quantitative Scale and a Concave Utility Curve



8.1.4.1.3 Scoring

Using the lifespan numbers provided in Table 6, the utility/score for each technology is derived using the utility curve shown in Figure 29. The results are then normalized and presented in Figure 30.

Table 6 Average Lifespan Considered for Each Technology

| Generation Technology | Lifespan (years) | Normalized Scores (%) |
|-----------------------|------------------|-----------------------|
| Waterpower | 45 | 39.2% |
| Gas | 35 | 14.4% |
| Wind | 20 | 14.4% |
| Solar | 20 | 32.0% |
| Total | 120 | 100% |

Figure 30 Alternatives Priorities with Respect to Lifespan



8.1.4.2 Lifecycle Extendibility

8.1.4.2.1 General Considerations

Waterpower: Major refurbishments can extend turbine life by an additional 50 years beyond the typical 50-year cycle (American Waterpower, n.d). The life of civil works can extend to 100+ years (Hatch Ltd., 2023).

Wind Power: Full repowering involves complete turbine replacement. Partial repowering can extend turbine life beyond the design limit through component upgrades (mainly rotor and blade replacement) while retaining foundations and towers. However, unlike gas turbines or waterpower facilities, wind turbines face mechanical fatigue limitations that restrict multiple extension cycles. The Strategy for extending the Useful Lifetime of a Wind Turbine Report (Megavind, 2016) has a histogram showing wind turbine age when decommissioned in Denmark. The data suggests turbines can extend 5-10 years beyond the typical decommissioning age.

Solar Power: Solar systems can extend life through inverter replacement every 10-15 years (Uncommon Solar, 2024), while panels can continue producing power beyond their 25-30 year warranties even though their performance degrades over time (~0.5 – 1.0% per year).

Gas-Fired Generation: Lifecycle extensions are achievable through comprehensive rotor refurbishment and component replacement programs, with manufacturers allowing extensions of 50,000 – 100,000 additional hours per major overhaul cycle (Scheibel, Swaminathan, and Dean, 2014). This is equivalent to 6-15 years of additional operation per lifecycle extension (assuming 85%-90% capacity factor).

8.1.4.2.2 Measurement Scale

A pairwise comparison scale is used for lifecycle extendibility assessment. The scale considers both the magnitude of individual extension periods and the feasibility of multiple extension cycles throughout the asset’s total operational lifetime.

8.1.4.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure . The normalized priority scoring of the different alternatives is shown in Figure 32.

Figure 31 Alternatives Pairwise Scoring with Respect to Lifecycle Extensibility



Figure 32 Alternatives Priorities with Respect to Lifecycle Extensibility



8.1.4.3 Key Insights with Respect to Lifespan and Lifecycle Considerations

The results for this criterion highlight differences in how long each generation technology can provide value on the power system, and how easily that value can be renewed over time. This is summarized in Figure 33.

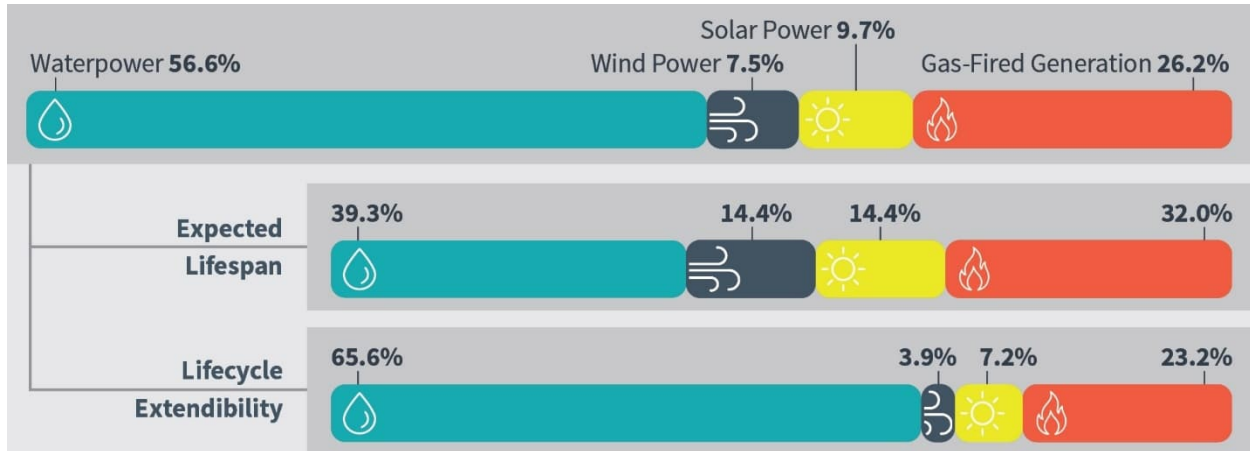
Waterpower is the clear leader in long-term system value, providing over half of the total benefit (~57%) in this category. Its advantage comes from both a high expected lifespan (~40%) and especially strong lifecycle extensibility (~66%). Waterpower facilities are uniquely suited to long operational lives and incremental life extension via upgrades, making them the most enduring investment among all options.

Wind and solar power deliver the lowest scores for long-term value, reflecting the shorter operational lifespans and limited extensibility of these technologies. Wind contributes ~8% in total while Solar shows similar patterns, with ~10% overall. Their fixed design life and reliance on continuous component replacement limit their long-term contribution compared to gas and waterpower.

Gas-fired generation offers the next highest overall benefits at ~26%. While gas facilities have reasonable lifespans, their ability to be economically extended or refurbished is limited compared to waterpower, resulting in much lower total score for life extensibility.

Together, these results reveal that waterpower assets deliver excellent long-term stability, minimizing reinvestment risk. Gas offers reasonable/moderate longevity but should be planned for more frequent turnover. Wind and solar, on the other hand, has the shortest lifespan and extensibility potential.

Figure 33 Breakdown of the Alternatives Scoring with Respect to Lifespan and Lifecycle Considerations



8.1.5 Key Insights with Respect to Grid and System Benefits

The evaluation of grid and system benefits reveals how each generation technology contributes across the full spectrum of power system needs. As shown in Figure 34, these results synthesize performance across four critical dimensions that determine each technology's overall contribution to Ontario's electricity system.

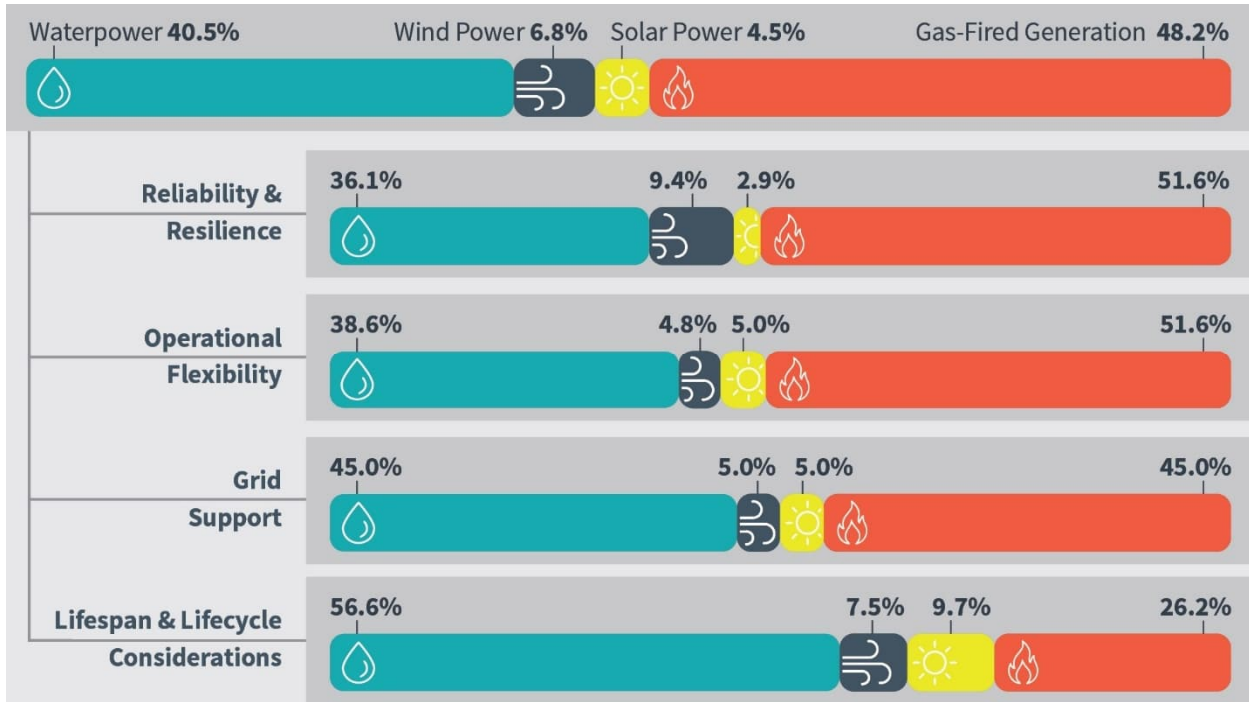
Waterpower and Gas-fired generation are the backbone of Ontario's grid benefits with combined total score equal to ~ 89%. These technologies excel across all system service criteria. Their consistent, controllable output ensures dependable system service under almost all conditions. Waterpower distinguishes itself in long-term value, leading in lifespan and lifecycle considerations. While its overall grid benefit is slightly behind gas given that it relies on the availability of the water while gas is not dependent on the resource availability, waterpower's enduring infrastructure and ability to extend service life through upgrades give it strategic long-term value for the grid.

Wind and solar power make much smaller contributions to grid and system benefits, providing ~7% and 5%, respectively. Their performance is limited across all criteria by inherent variability, lack of dispatchability, and very restricted capability for system services such as black start, firming, and operational reserves. These technologies typically rely on complementary support from gas and waterpower to fulfill system needs.

The analysis confirms complementary technology roles, with waterpower and gas forming the backbone for system stability and reliability, while wind and solar require dispatchable resources to ensure grid security and operational flexibility.

In summary, the analysis reveals a clear distinction between dispatchable synchronous technologies (waterpower and gas) and long-lived assets that can provide full-spectrum grid and system benefits, and variable renewable technologies that contribute primarily through energy production. This emphasizes the critical importance of maintaining adequate dispatchable generation capacity to ensure grid stability, reliability, and comprehensive system support as Ontario's electricity system continues to evolve.

Figure 34 Breakdown of the Alternatives Scoring with Respect to Grid and System Benefits



8.2 Environmental Performance

The environmental performance of the generation alternatives can vary and include effects on local ecosystems and fish populations, emissions of air pollutants and GHGs, as well as challenges related to hazardous materials and waste management. To support a balanced and informed comparison of these alternatives, the following sections explore key environmental performance considerations and how they relate to each generation type. In developing this analysis, relevant sources were reviewed to ensure the most current and accurate information was incorporated, reflecting evolving technologies, regulatory standards, and ecological information.

8.2.1 Land Area Requirements

In Ontario, where agriculture, conservation, and urban development must coexist with energy infrastructure, land use efficiency has become an increasingly important factor when evaluating energy generation technologies. The direct land footprint defined as the area physically disturbed by infrastructure such as turbine pads, access roads, substations, and solar arrays varies significantly across generation types.

8.2.1.1 General Considerations

Waterpower: Waterpower projects exhibit wide variability in land requirements depending on the facility type and scale. Large dams can inundate thousands of hectares, primarily due to reservoir creation. It is important to distinguish between the total land footprint (including reservoirs) and the direct facility footprint, which includes only the generation station, transmission infrastructure, and access roads. For large waterpower facilities, the direct footprint typically ranges from 0.8 to 4 hectares (Blomqvist, 2022). Ontario’s reliance on run-of-river systems and existing reservoirs helps minimize new land disturbance. Accordingly, areas of inundation associated with the creation of new reservoirs have not been considered.

Wind Power: In early 2000’s wind power facilities in Ontario typically required between 0.2 to 2 hectares per MW of installed capacity, considering only the direct physical infrastructure (Denholm et al., 2009). Based on updated technology and experience, this number today sits around 0.2 to 1 hectare per MW. Although turbines are spaced widely, this does not result in exclusive land use. Agricultural activities can continue between turbines, preserving land productivity.

Solar Power: Ground-mounted solar power systems typically require a substantial land footprint, though recent studies show this has decreased due to advances in module efficiency and system design. Modern utility-scale PV installations generally use 1.8 to 2.8 hectares per MW, depending on system configuration and site-specific factors (Bolinger, Mark, and Greta Bolinger, 2022). This includes the area occupied by solar arrays, access roads, substations, and service buildings. Despite the spatial demands, solar PV systems can be designed to support agrivoltaics, enabling dual land use for both energy generation and agricultural activities.

Gas-Fired Generation: Natural gas-fired generation is known for its compact footprint. In Ontario, these facilities generally require about 0.2 hectares per MW, including the facility and associated infrastructure such as pipelines and access roads (Jordaan et al., 2017; NGS, 2017).

8.2.1.2 Measurement Scale

Pairwise comparison is used to compare the land area requirements of the different generation alternatives qualitatively, with consideration for the quantitative references above.

8.2.1.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 35. The normalized priority scoring of the different alternatives is shown in Figure 36.

Figure 35 Alternatives Pairwise Scoring with Respect to Land Area Requirements

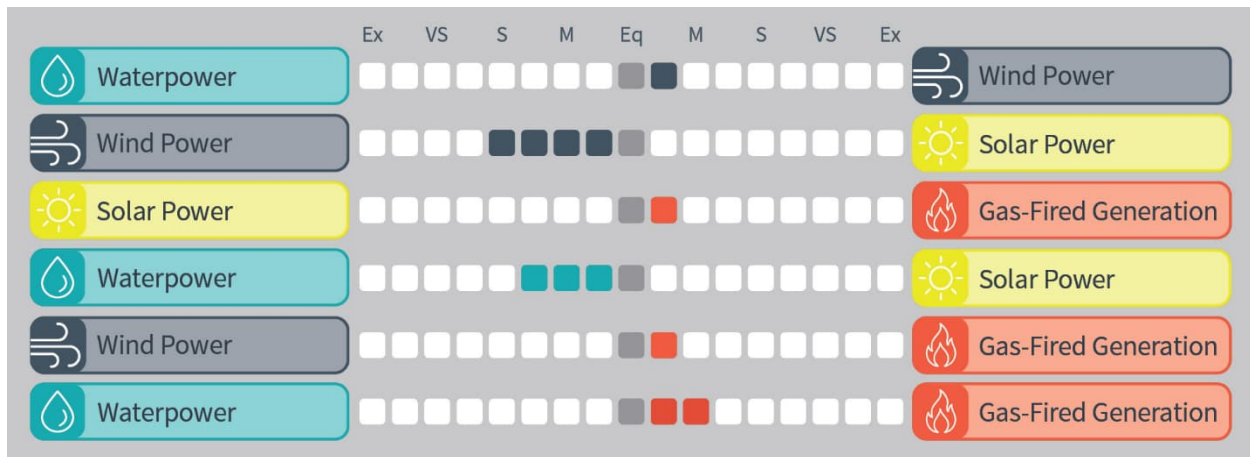


Figure 36 Alternatives Priorities with Respect to Land Area Requirements



8.2.2 Impacts to Ecosystems and Biodiversity

Impacts to ecosystems and biodiversity encompass the various ways in which energy generation technologies and their operations effect the natural environment. The extent and nature of these impacts can vary significantly depending on the generation type.

8.2.2.1 General Considerations

Waterpower: Waterpower provides low-carbon electricity but can have significant localized ecosystem impacts, especially related to river systems. Dams alter natural water flows, disrupt sediment transport, and can obstruct fish migration and spawning grounds. Large reservoirs can flood extensive terrestrial habitats, affecting species at risk and fragmenting ecosystems. However, in Ontario, where many waterpower sites are "run-of-river" or on existing legacy reservoirs, the marginal new impact is relatively limited compared to new builds elsewhere.

Wind Power: Wind power requires large tracts of land, though the actual turbine footprint is relatively low. Key concerns include bird and bat mortality from turbine collisions and disruption of migration corridors. Proper siting and technological advances, such as radar-activated shutdowns, have shown promise in mitigating risks, however, have not eliminated these risks and are not a standard practice. Wind farms can also cause habitat loss and fragmentation, impacting local ecosystems.

Solar Power: Solar PV projects can impact ecosystems by clearing large areas of land, particularly if built on natural landscapes rather than brownfields. Ground-mounted solar can disrupt soil, affect water drainage, and displace species. However, co-location with agriculture (agrivoltaics) and pollinator-friendly installations are emerging as best practices to mitigate these impacts.

Gas Fired Generation: Natural gas-fired power facilities pose risks of contamination through water use, thermal pollution from cooling systems, and air emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The operation of these facilities can lead to air and water pollution, affecting local ecosystems. The infrastructure required for natural gas production such as pipelines and extraction sites can fragment landscapes and disrupt habitats. Emissions from natural gas combustion contribute to air quality issues and GHG emissions and in addition methane leakage is a key contributor to atmospheric warming and ecosystem stress, impacting both human health and biodiversity.

8.2.2.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; impacts to ecosystems and biodiversity are a qualitative feature.

8.2.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 37. The normalized priority scoring of the different alternatives is shown in Figure 38.

Figure 37 Alternatives Pairwise Scoring with Respect to Impacts and Biodiversity Impacts



Figure 38 Alternatives Priorities with Respect to Impacts Ecosystem and Biodiversity Impacts



8.2.3 Lifecycle GHG Emissions

When evaluating energy generation options in Ontario and Canada, it is crucial to consider the total lifecycle GHG emissions. This encompasses emissions produced throughout a technology’s entire lifecycle, from resource extraction and construction to operation, maintenance, and decommissioning. According to the Canadian Energy Regulator (CER, 2023) and the Intergovernmental Panel on Climate Change (IPCC, 2022), renewable technologies such as wind, solar, and waterpower exhibit the lowest lifecycle GHG emissions. In contrast, natural gas and coal are among the highest emitters when considering both upstream and downstream emissions.

8.2.3.1 General Considerations

Waterpower: Waterpower in Ontario exhibits some of the lowest lifecycle GHG emissions globally. According to the Intergovernmental Panel on Climate Change (IPCC), the median lifecycle GHG emissions for waterpower are approximately 24 gCO₂e/kWh, with run-of-river and temperate-climate reservoir systems typically falling well below this threshold (IPCC 2022). Unlike tropical waterpower projects where newly flooded vegetation can emit significant methane, Ontario’s waterpower systems benefit from cooler climates and mature reservoirs, which substantially reduce biogenic emissions over time. Furthermore, many of Ontario’s waterpower projects employ run-of-river configurations, which avoid large-scale flooding and associated methane emissions (IEA, 2021; NRCan, 2023).

Wind Power: Lifecycle emissions from wind power in Canada are relatively low, estimated at approximately 8–20 gCO₂e/kWh (IPCC, 2022). Most emissions originate from manufacturing turbine components, but ongoing improvements in materials and recycling, particularly within Ontario’s growing green supply chain, continue to mitigate these impacts (CER, 2023; NRCan, 2023).

Solar Power: Solar PV systems in Canada have lifecycle emissions ranging from 20–35 gCO₂e/kWh (IPCC, 2022). Ontario’s early investment in solar manufacturing under its Green Energy Act has helped reduce transportation emissions, and newer high-efficiency panels are driving down lifecycle emissions.

Gas-Fired Generation: Natural gas-fired generation through combined cycle gas turbines (CCGT), has lifecycle emissions between 400–500 gCO₂e/kWh (IPCC, 2022) with more recent experience suggesting that this number is anticipated to be closer to 350 gCO₂e/kWh. Emissions stem from extraction (including methane leakage), pipeline transport and combustion-related CO₂ (IPCC, 2022). Although natural gas plays an important role in reliability and peaking today, its long-term compatibility with net-zero targets remains uncertain. The potential for future use of refined renewable diesel may also serve to mitigate this concern.

8.2.3.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives qualitatively, with consideration for the quantitative references above.

8.2.3.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in and Figure 39. The normalized priority scoring of the different alternatives is shown in Figure 40.

Figure 39 Alternatives Pairwise Scoring with Respect to Lifecycle GHG Emissions



Figure 40 Alternatives Priorities with Respect to Lifecycle GHG Emissions



8.2.4 Waste Generation/End of Life

End-of-life management and waste generation are critical factors in evaluating the overall sustainability of energy generation technologies. Proper planning for decommissioning, recycling, and disposal is essential to minimizing environmental impacts and maximizing resource recovery. Different technologies present distinct waste challenges and opportunities. This perspective aligns with the IPCC emphasis on life-cycle sustainability assessments in energy systems (IPCC, 2022).

8.2.4.1 General Considerations

Waterpower: Waterpower generation produces relatively low material waste throughout its lifecycle and facilities often operate for more than a century with major refurbishments rather than full decommissioning. When waterpower facilities are eventually retired, much of the infrastructure, such as dams and waterways, remains integrated into the local landscape, however, decommissioning results in significant waste in comparison to other technologies, and can vary based on geographic location. Some concrete and mechanical components require demolition and disposal, but these volumes are relatively small compared to other technologies.

Wind Power: Wind power projects produce significant quantities of waste at end-of-life, particularly from turbine blades made of composite materials (Rathore and Panwar, 2023). While towers and nacelles are largely recyclable (steel, copper), current recycling options for fiberglass blades are limited, often resulting in landfill disposal (U.S. Department of Energy, 2023; Moseman, 2023). However, research into blade recycling technologies, including blade repurposing and thermal recovery, is advancing.

Solar Power: Solar PV systems generate waste primarily from decommissioned panels, inverters, and mounting hardware. Solar panels contain valuable materials such as glass, aluminum, silicon and rare metals that can be recovered through recycling. However, the practice of recycling solar panels is not widely adopted nor is it considered a cost-effective option (U.S. Department of Energy, 2023).

Gas-Fired Generation: Natural gas-fired generation results in moderate waste production at end-of-life. Dismantling gas turbines, heat recovery units, and associated infrastructure generates scrap metals, piping, and hazardous materials such as oils and lubricants. While metals are highly recyclable, decommissioning gas facilities requires careful hazardous waste handling and site remediation to address potential soil and groundwater contamination (Ermakova et. al., 2025). There is limited opportunity for material reuse due to thermal stress and corrosion (Integrated Global Services, 2025).

8.2.4.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; waste generation/end of life are a qualitative feature.

8.2.4.3 Scoring

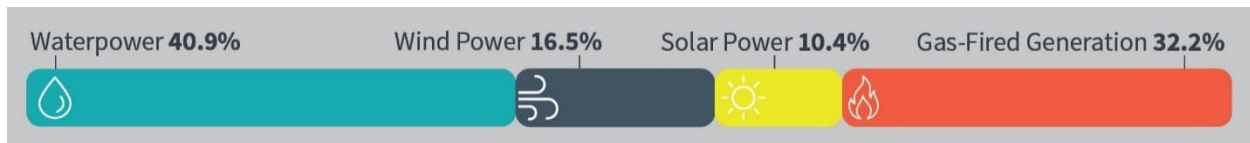
Waterpower projects present the lowest waste challenge, while solar and wind require more robust recycling and end-of-life management strategies. Advancing circular economy solutions, such as component reuse and recycling mandates, will be essential to minimizing the environmental footprint of Ontario's future energy system (Energy Savings Lab, 2025).

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 41. The normalized priority scoring of the different alternatives is shown in Figure 42.

Figure 41 Alternatives Pairwise Scoring with Respect to Waste Generation/End of Life



Figure 42 Alternatives Priorities with Respect to Waste Generation/End of Life



8.2.5 Climate Resilience

As Ontario’s climate changes, energy generation technologies must demonstrate resilience to extreme weather events, changing temperature patterns, and shifting precipitation regimes. Climate resilience in the energy sector involves the ability to maintain reliable operations, recover quickly from disturbances, and adapt infrastructure to withstand evolving environmental conditions. The IESO, the Ministry of Energy, and international bodies such as the IPCC emphasize the importance of integrating physical climate risk considerations into long-term system planning (EETP, 2023; IPCC 2022; Ontario Energy Board, 2023). The following were considered in defining climate resilience:

- **Resistance to Extreme Weather:** Wind, floods, wildfires, ice, heatwaves.
- **Water Dependency:** Sensitivity to drought or water availability.
- **Grid Reliability Impact:** Ability to function in extreme grid/load stress conditions.
- **Adaptability to Environmental Shifts:** Capacity for modular upgrades, decentralization, or relocation.

8.2.5.1 General Considerations

Waterpower: Waterpower generation faces both strengths and vulnerabilities regarding climate resilience. While waterpower facilities are durable and have lifespans exceeding 100 years, they are sensitive to changes in precipitation, river flows, and extreme flooding events. Prolonged droughts or highly variable water patterns can impact generation output. While individual waterpower facilities will face more direct consequences of climate change, looking at waterpower through a portfolio lens spreads risk across multiple watersheds and climatic zones, reducing vulnerability to localized droughts or floods. Waterpower facilities located in different regions can balance seasonal variability (e.g. snowmelt in one area vs. rainfall in another).

Wind Power: Wind power has moderate climate resilience to extreme weather. Modern turbines are designed to withstand high winds and icing events, although extreme storms can lead to shutdowns or damage. Climate change projections suggesting higher frequency of severe weather events necessitate enhanced turbine designs and siting practices to minimize exposure. Ontario’s turbines are typically equipped with cold climate packages, including heating elements and ice detection to mitigate ice buildup.

Solar Power: Solar PV systems demonstrate strong resilience to a wide range of climate conditions. While extreme heat can reduce panel efficiency slightly, modern modules are engineered to withstand thermal cycling, damp heat, and mechanical stress, with top-performing panels showing minimal degradation under these conditions. Ground-mounted systems now incorporate adaptive mounting structures using lightweight, corrosion-resistant materials and modular designs tailored to local environmental stressors. These advancements enhance structural integrity and reduce vulnerability to wind uplift, debris impact, and seismic activity.

Gas-Fired Generation: Natural gas generation is generally considered moderately resilient to climate-related risks. Gas facilities are less directly affected by precipitation or wind variability. Their flexibility in ramping up and down also provides critical grid balancing during extreme weather events. However, Gas units face significant derating during prolonged high temperature events. At the other end of the scale, extreme cold can also be problematic for gas facilities (incl pipelines) if the plant has not been "cold hardened" like most facilities in Ontario. Also, reliance on natural gas pipelines could introduce vulnerabilities if extreme weather disrupts fuel supply chains.

8.2.5.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; climate resilience is a qualitative feature.

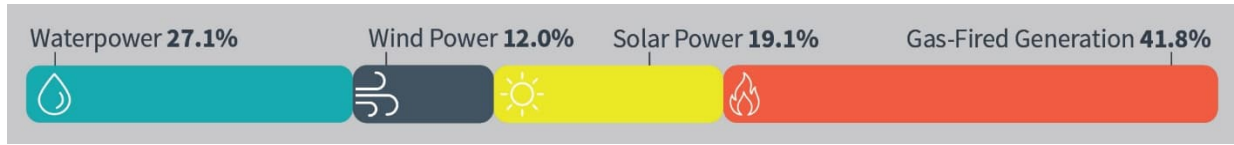
8.2.5.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 43. The normalized priority scoring of the different alternatives is shown in Figure 44.

Figure 43 Alternatives Pairwise Scoring with Respect to Climate Resilience



Figure 44 Alternatives Priorities with Respect to Climate Resilience



8.2.6 Key Insights with Respect to Environmental Considerations

Ontario’s energy future hinges on a delicate balance between environmental stewardship and climate resilience. Each generation technology offers distinct advantages and trade-offs when evaluated across selected criteria, namely land use, ecosystem impacts, lifecycle GHG emissions, waste generation, and adaptability to climate uncertainty. The synthesized results for this set of criteria are presented in Figure 45.

Waterpower offers low lifecycle GHG emissions and long operational lifespans, often exceeding a century. Once constructed, waterpower facilities have minimal ongoing environmental impact, and decommissioning is rare, with infrastructure often integrated into the landscape. Dams disrupt river ecosystems, sediment transport, and fish migration, and large-scale flooding can affect species at risk. In Ontario, these impacts are moderated by the prevalence of legacy reservoirs and run-of-river systems, which reduce new land disturbance. Waste generation is generally low, but full-scale decommissioning can be costly and produce significant material waste. Climate resilience is moderate, with vulnerabilities to droughts, flooding, and shifting precipitation patterns.

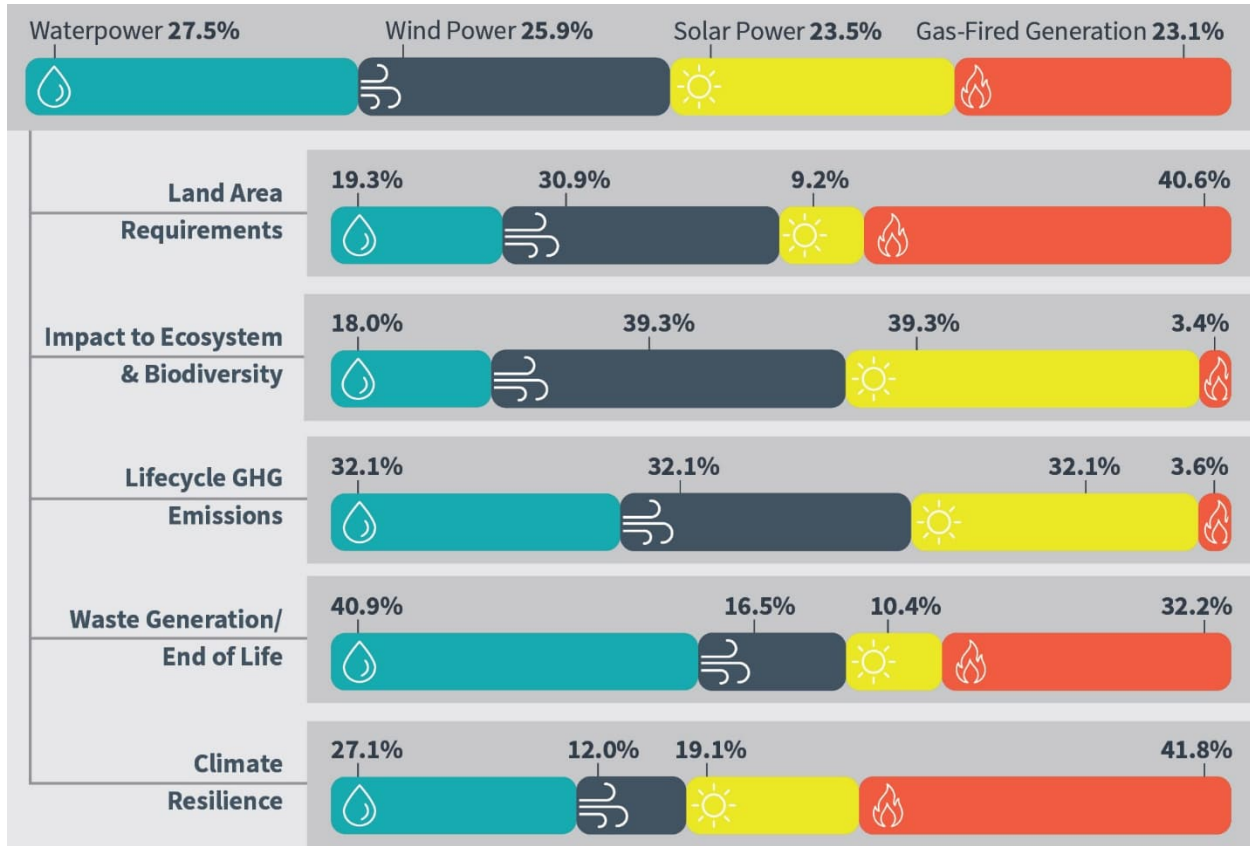
Natural gas-fired generation is the most efficient option from a land use perspective. It also ranks high in climate resilience, capable of operating across wide temperature ranges and providing flexible ramping during grid stress. These attributes make gas a reliable contributor to system stability. However, gas performs the poorest across most environmental metrics. It has the highest lifecycle GHG emissions and ecosystem impacts can be severe.

Solar’s environmental profile is mixed. Ground-mounted systems require significant land, often leading to habitat disruption. Solar also typically generates the most waste per MWh, and while the majority of panel materials are technically recyclable, current infrastructure and costs make large-scale recycling unfeasible.

Wind power stands out for its modest land area requirement, outperforming other renewables in spatial efficiency. Technological advancements have reduced land needs and agricultural activities can continue between turbines, preserving land productivity. However, wind power is not without environmental costs. It poses moderate risks to ecosystems, particularly through bird and bat mortality. Wind’s climate resilience is moderate, and turbines are designed to withstand high winds and icing, but extreme storms can lead to shutdowns or damage, limiting reliability under severe weather conditions.

From an environmental perspective, decision-making must balance conservation and ecosystem management priorities with the need for climate-resilient solutions that secure long-term energy supply. The analysis indicates that diversification of generation options currently provides the best balance across these priorities. While no single technology excels in all areas, each contributes uniquely to Ontario’s energy landscape.

Figure 45 Breakdown of Alternatives Scoring with Respect to Environmental Performance



8.3 Socioeconomic Considerations

Social considerations refer to public acceptance as well as real or perceived safety risks while economic considerations are those associated with direct, indirect and induced benefits from a project over its lifespan.

8.3.1 Public Acceptance

8.3.1.1 General Considerations

Waterpower: The Ontario Waterpower Association engaged Innovative Research Group to understand attitudes towards waterpower (and other generation technologies) among Ontarians, and a telephone survey was conducted with 953 Ontarians, aged 18 and older, between February 15th and 28th, 2022. Waterpower continues to be the most favored form of energy generation among Ontarians. The survey conducted by Innovative Research Group reveals that 90% of respondents support waterpower, with strong support increasing from 64% in 2018 to 68% in 2022. This technology enjoys widespread approval across various demographics, reflecting its perceived benefits in renewable energy generation and its role in maintaining a reliable electricity system. The public's positive attitude towards waterpower has remained stable over the years, with high support for its development in cooperation with Indigenous communities. This indicates a strong recognition of the importance of inclusive and collaborative approaches in energy projects. Additionally, 71% of respondents favor the development of pumped storage systems, showcasing broad acceptance of innovative waterpower solutions that enhance energy storage and grid stability. (OWA, 2022).

Wind Power: Wind power garners substantial support, with 76% of respondents in favor (OWA, 2022). Despite some variations in support among different groups, wind power remains a popular choice for many Ontarians. This reflects its perceived benefits in renewable energy generation and its contribution to reducing greenhouse gas emissions. The support for wind power underscores the public's willingness to embrace diverse renewable energy sources to achieve a sustainable and resilient energy system.

Solar Power: Solar power is highly supported, with 88% of respondents expressing their approval (OWA, 2022). This support is widespread across various demographics, indicating a strong belief in its value and potential as a sustainable energy source. Solar power is perceived positively for its environmental benefits and its role in diversifying Ontario's energy mix. The high level of support suggests that Ontarians are keen on adopting clean and renewable energy technologies to address climate change and reduce carbon emissions.

Gas-Fired Generation: Natural gas is supported by 70% of respondents, indicating a favorable view of this energy source among those who prioritize economic and reliability aspects of energy generation (OWA, 2022). Natural gas is seen as a less favorable option, however, may be perceived as a transitional fuel that can complement renewable energy sources while ensuring a stable and reliable supply of electricity. The support for natural gas highlights the public's pragmatic approach to balancing environmental concerns with energy security and affordability.

8.3.1.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; public acceptance is a qualitative feature.

8.3.1.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 46. The normalized priority scoring of the different alternatives is shown in Figure 47.

Figure 46 Alternatives Pairwise Scoring with Respect to Public Acceptance



Figure 47 Alternatives Priorities with Respect to Public Acceptance



8.3.2 Public Safety

Public safety is a critical dimension when evaluating energy generation technologies. Different technologies present distinct safety risks during construction, operation, maintenance, and decommissioning. Ontario's regulatory frameworks, including the Technical Standards and Safety Authority (TSSA) and the Electrical Safety Authority (ESA), provide comprehensive oversight to ensure that energy facilities meet stringent safety standards (ESA, 2025; IESO, 2025; TSSA, 2025). Nonetheless, inherent technology-specific risks must be managed through design, training, and emergency preparedness.

The ranking of energy generation technologies based on public safety is influenced by several key factors:

- **Frequency and Severity of Incidents:** Technologies are evaluated based on how often safety incidents occur and the potential severity of these incidents. For example, wind power and solar power systems have low incident rates and have been decreasing as technologies improve (Moura Carneiro et. al., 2013; NREL, 2018).
- **Effectiveness of Safety Measures:** The presence and effectiveness of safety measures, such as fire suppression systems, real-time monitoring, and emergency preparedness plans, are crucial. Technologies with more advanced and effective safety protocols rank higher.
- **Regulatory Oversight and Compliance:** The extent of regulatory oversight and the strictness of compliance requirements play a significant role. Technologies that are subject to rigorous inspections and stringent safety standards tend to have better safety records.
- **Technological Maturity and Reliability:** Well-established safety protocols and unexpected issues (Moura Carneiro et. al., 2013; NREL, 2018).
- **Human Factors and Operational Safety:** The role of human error and the effectiveness of operational safety management are also critical. Technologies that require less human intervention and have automated safety systems tend to be safer.
- **Environmental and Site-Specific Factors:** The specific environmental conditions and site characteristics can influence safety. For example, waterpower facilities need to consider the risk of flooding, while wind farms need to account for ice shedding in colder climates.

Ongoing updates to fire codes, operational standards, and public engagement are critical to maintaining safety across the evolving energy landscape.

8.3.2.1 General Considerations

Waterpower: Waterpower generating stations generally have a strong public safety record when properly maintained. The primary risks involve structural failures, natural hazards such as flooding, and human activity including worker hazards, with risk potential increasing as dams age. Ontario's large waterpower facilities are subject to rigorous dam safety inspections under provincial regulations and employ extensive real-time monitoring and emergency preparedness planning to minimize risks. Public safety measures include warning signs, barriers, and emergency response plans to protect the public from hazardous areas around dams and spillways. (MNR, 2023). Operators prioritize communities downstream and individuals around facilities through comprehensive safety programs. This includes early warning systems, automated flow control, and continuous surveillance to detect anomalies before they escalate.

Wind Power: Wind power facilities have a relatively low public safety risk profile. Incidents typically involve ice throw, mechanical failure or tower collapse, events that are rare. Public safety around wind farms is enhanced

through proper siting, for instance, mandatory setbacks from public roads and neighbouring properties in Ontario, as well as regular maintenance.

Solar Power: Solar power systems are considered low-risk for public safety when properly installed and maintained. The primary risks involve electrical shock and, rarely, fires associated with faulty wiring or panel failures. Compliance with ESA installation codes and fire safety standards significantly mitigates these risks. Safety measures include clear labeling of electrical components and regular inspections to ensure system integrity.

Gas-Fired Generation: Public safety concerns include those related to fire, explosion, and gas leaks, and facilities must adhere to strict fire code, environmental, and operational safety standards, including compliance with the TSSA. The IESO recognizes natural gas's role in grid reliability but acknowledges that facility safety is heavily reliant on continuous maintenance and emergency response planning. Standard safety features and operational protocols including regular safety drills, gas leak detection systems, and fire suppression systems have largely eliminated these risks.

8.3.2.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; public safety is a qualitative feature.

8.3.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 48. The normalized priority scoring of the different alternatives is shown in Figure 49.

Figure 48 Alternatives Pairwise Scoring with Respect to Public Safety

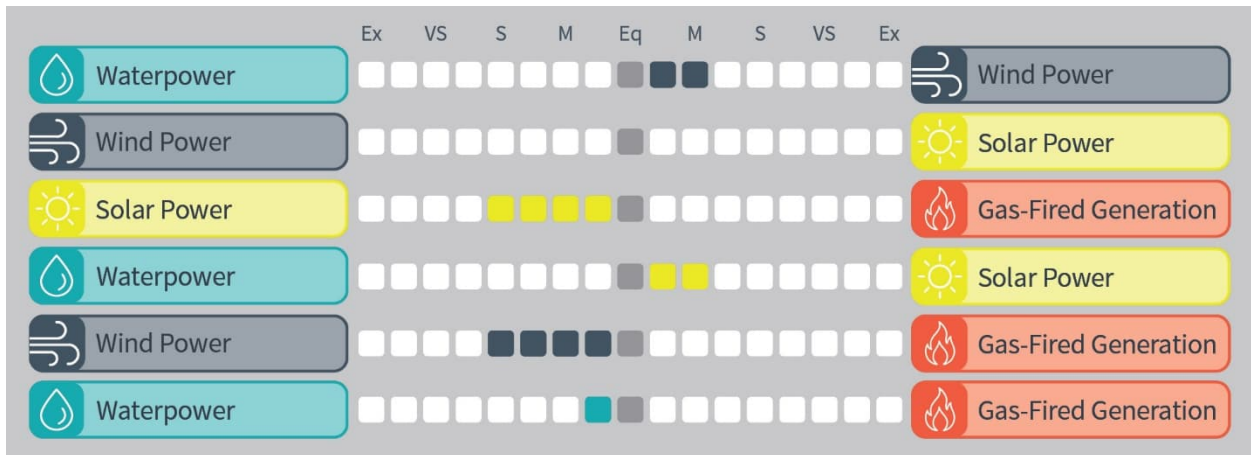


Figure 49 Alternatives Priorities with Respect to Public Safety



8.3.3 Job Creation and Employment

Energy generation projects play a critical role in creating jobs and supporting workforce development across Ontario. The employment impacts vary by technology, spanning construction, operations and maintenance, supply chain manufacturing, and emerging technical services.

Each technology generates direct, indirect, and induced employment, with varying degrees of effect across the different phases of the project lifecycle. The following sections explore the employment impacts of each technology in Ontario, highlighting their contributions to both direct job creation and broader economic activity. Renewable energy technologies (solar, wind, and waterpower) offer strong employment benefits for Ontario, supporting construction, skilled trades, technical operations, and long-term economic development.

8.3.3.1 General Considerations

Waterpower: Waterpower provides steady, long-term employment primarily in operations, skilled trades, and civil engineering. Refurbishment projects not only ensure continued system reliability but also support highly skilled trades and technical careers. Waterpower upgrades typically involve high local labor content during construction and create stable operations jobs over decades.

- **Direct Employment:** Waterpower projects in Ontario require a diverse workforce for development, including engineers, environmental scientists, and regulatory experts. During construction, the sector creates jobs for skilled tradespeople such as electricians, heavy equipment operators, and civil engineers. Operation and maintenance of waterpower facilities require technicians and facility operators.
- **Indirect Employment:** Waterpower projects also support indirect employment, particularly in the supply chain. Material suppliers, including those providing cement, steel, and turbines, as well as transport and logistics companies, are essential for delivering materials and equipment. Local businesses near more remote waterpower facilities also benefit from increased demand for services such as accommodation and food.
- **Induced Employment:** Local communities near waterpower facilities experience an increase in induced employment due to the presence of energy projects, with local businesses thriving in response to the influx of workers and ongoing operations.

Wind Power: Wind power has historically provided substantial employment during construction phases, including jobs for electricians, crane operators, and civil contractors. Although construction jobs are temporary, ongoing operation and maintenance of wind farms also provide permanent technical roles, particularly in rural communities. CanREA has also noted that wind development has created significant regional employment benefits in Ontario (2023).

- **Direct Employment:** Wind power development in Ontario provides employment in engineering, site assessment, and environmental impact studies, while construction requires crane operators, electricians, and civil engineers. The operation and maintenance phase requires skilled technicians and turbine specialists.
- **Indirect Employment:** Wind power projects create indirect jobs in the manufacturing of wind turbine components, such as blades, nacelles, and towers. Companies in Ontario are integral to the supply chain, and transport companies play a role in the delivery of large-scale turbine components.
- **Induced Employment:** Rural communities in Ontario benefit from induced employment through increased demand for local services.

Solar Power: Solar power projects are labor-intensive during development and installation, supporting a wide

range of employment from site assessors to electricians and construction laborers. Ongoing maintenance needs are modest but still create local technician roles.

- **Direct Employment:** Solar power facilities require engineers, site planners, and environmental consultants for development. During construction, workers are needed for solar panel installation, electrical setups, and infrastructure development. Ongoing operation and maintenance involve technicians for system monitoring and panel upkeep.
- **Indirect Employment:** Ontario benefits from the presence of solar component manufacturers based in the province. This contributes to the development of local manufacturing and logistics sectors.
- **Induced Employment:** Communities near solar installations experience a boost in induced employment, with local businesses expanding to meet the needs of workers involved in the solar sector.
- **Induced Employment:** Communities surrounding natural gas facilities experience economic growth as local businesses meet the needs of facility workers, boosting retail, service, and hospitality sectors.

Gas-Fired Generation: Natural gas generation supports several high-paying jobs in operations, maintenance, and technical fields such as turbine maintenance and facility operation.

- **Direct Employment:** Natural gas power facilities require a skilled workforce for development, including engineers, environmental consultants, and regulatory experts. Construction requires workers in specialized trades, such as welders and electricians. Operation and maintenance positions include facility operators and safety specialists.
- **Indirect Employment:** The natural gas supply chain includes manufacturers of turbines and compressors, as well as contractors providing services like security, waste management, and maintenance.

8.3.3.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; job creation and employment is a qualitative feature.

8.3.3.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 50. The normalized priority scoring of the different alternatives is shown in Figure 51.

Figure 50 Alternatives Pairwise Scoring with Respect to Job Creation and Employment

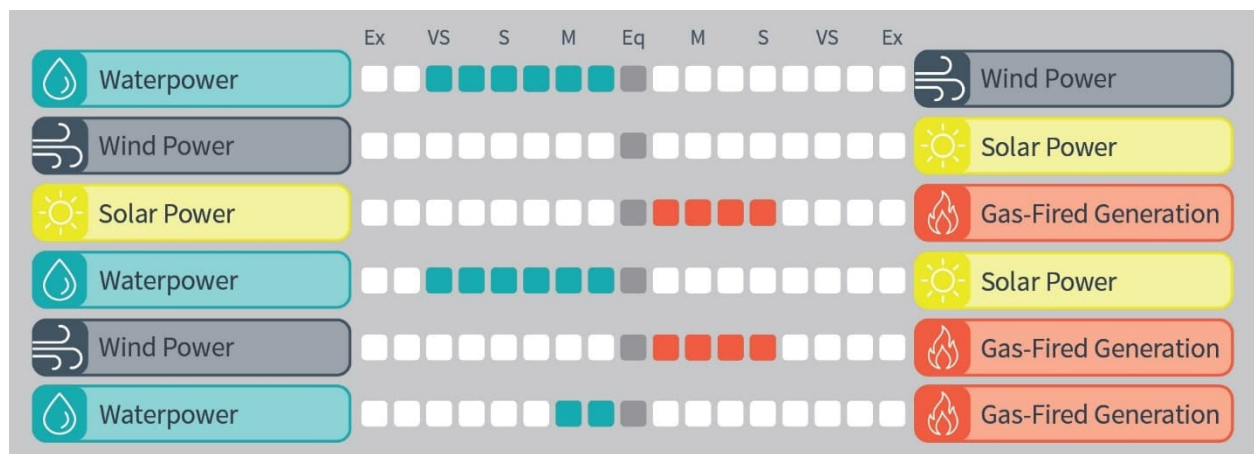


Figure 51 Alternatives Priorities with Respect to Job Creation and Employment



8.3.4 Relative Investment in Ontario/Canada

Local procurement of materials, components, or labour used in the construction and operation of power generation which supports local industries, creates jobs, and stimulates local economic growth.

The degree to which energy generation projects invest locally in Ontario and Canada varies significantly by technology. These investments encompass capital expenditure (Capex), operational expenditure (Opex), supply chain development, employment, and community benefits. The extent of local economic impact depends on factors such as manufacturing presence, construction labor, services sourcing, and ongoing operations.

8.3.4.1 General Considerations

Waterpower: Waterpower Projects typically exhibit high local investment despite turbines and generators being largely produced outside of Ontario. Engineering services and construction materials (such as concrete and steel) are predominantly sourced within Ontario, while Indigenous and local partnerships further enhance regional economic benefits.

Wind Power: Wind Projects historically had a strong local content requirement under Ontario’s Feed-in Tariff (FIT) Program, driving investments in blade, tower, and assembly facilities in Ontario (e.g., Windsor and Tillsonburg) (Ministry of Energy and Mines, 2022). Although some manufacturing capacity has declined post-FIT, construction, logistics, and maintenance services still ensure a proportion of local investment.

Solar Power: Solar power Projects exhibit moderate local investment. Panel manufacturing remains largely offshore (e.g., Asia, U.S.), but installation labor, electrical equipment, racking systems, and project development services are often sourced in Ontario. Studies show significant total project costs contribute to the local economy during construction and ongoing operations and maintenance services also contribute to local job creation (CanREA, 2023).

Gas-Fired Generation: Natural Gas Generation also results in significant Ontario-based investment, particularly during construction and early operation. However, turbine and major equipment manufacturing is often sourced internationally, reducing the total Canadian investment ratio.

8.3.4.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; relative investment in Ontario/Canada is a qualitative feature.

8.3.4.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 52. The normalized priority scoring of the different alternatives is shown in Figure 53.

Figure 52 Alternatives Pairwise Scoring with Respect to Relative Investment in Ontario and Canada



Figure 53 Alternatives Priorities with Respect to Relative Investment in Ontario and Canada



8.3.5 Contributions to Provincial Taxes/Revenues

Energy generation projects contribute to Ontario's Consolidated Revenue Fund (CRF) through a variety of tax and revenue mechanisms, supporting public services such as healthcare, education, and infrastructure development. These contributions vary by generation technology based on corporate structures, operating models, and associated regulations. All generation technologies contribute meaningfully to Ontario's revenue base, though waterpower and gas-fired generation currently provide the largest direct fiscal contributions.

8.3.5.1 General Considerations

Waterpower: In Ontario, water rental fees are charged to waterpower producers (like OPG and private operators) for the use of Crown-owned water resources. These fees are essentially royalties paid to the provincial government for using water to generate electricity and are an important source of non-tax revenue for the province. Waterpower Generation makes significant contributions to provincial revenues through water rental charges, corporate taxes, and Payments in Lieu of Taxes (PILs) where facilities are owned by public entities such as OPG. Water rental fees are calculated based on a percentage of the gross revenue from electricity generation and are a consistent source of public income. Additionally, OPG's earnings, which include waterpower profits, contribute to the provincial government through dividends and PILs.

Wind and Solar Power: Solar power and wind power contribute through corporate income taxes, property taxes, and sales taxes on construction materials and ongoing services and large-scale solar and wind farms are assessed for property taxes at a fixed rate per megawatt capacity (e.g., \$40,000/MW for wind projects). Community benefit agreements, although separate from formal taxes, can also involve substantial local investments.

Gas-Fired Generation: Natural Gas Generation provides substantial contributions through corporate income taxes, property taxes, and compliance with Ontario's Emissions Performance Standards (EPS) program, which

imposes charges for carbon emissions. Gas facilities, typically privately owned, pay regular commercial property taxes assessed by the Municipal Property Assessment Corporation (MPAC). Additional tax revenue is also generated from the purchase of natural gas.

8.3.5.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; contributions to Provincial Taxes/Revenues are a qualitative feature.

8.3.5.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 54. The normalized priority scoring of the different alternatives is shown in Figure 55.

Figure 54 Alternatives Pairwise Scoring with Respect to Contributions to Provincial Taxes/Revenues



Figure 55 Alternatives Priorities with Respect to Contributions to Provincial Taxes/Revenues



8.3.6 Key Insights with Respect to Socioeconomic Considerations

The socioeconomic performance of energy generation technologies in Ontario is shaped by a diverse set of factors, including public safety, tax revenues, employment opportunities, local investment, and public acceptance. These dimensions interact in complex ways, and the relative performance of each generation alternative varies accordingly. The analysis reveals that while no single technology excels in every category, waterpower consistently outperforms across most socioeconomic metrics. These results are depicted in Figure 56.

While waterpower ranks lower in public safety due to risks associated with dam failure and flooding, particularly in aging infrastructure, it excels in every other category. Waterpower enjoys the highest level of public support, with 90% of Ontarians expressing approval, a figure that has grown steadily over recent years. This strong social perception is reinforced by its inclusive development practices, particularly in collaboration with Indigenous communities. Economically, waterpower contributes significantly to Ontario’s fiscal health. It generates revenue through water rental fees, corporate taxes, and dividends from publicly owned entities such as OPG.

These mechanisms provide a consistent and diversified stream of income for the province. Furthermore, waterpower supports long-term employment across construction, operations, and refurbishment phases. The requirement for permanent staff ensures sustained direct and indirect job creation, which in turn stimulates induced employment in surrounding communities. Its deep integration with Ontario's economy through local sourcing of materials, engineering services, and Indigenous partnerships makes it a cornerstone of regional development.

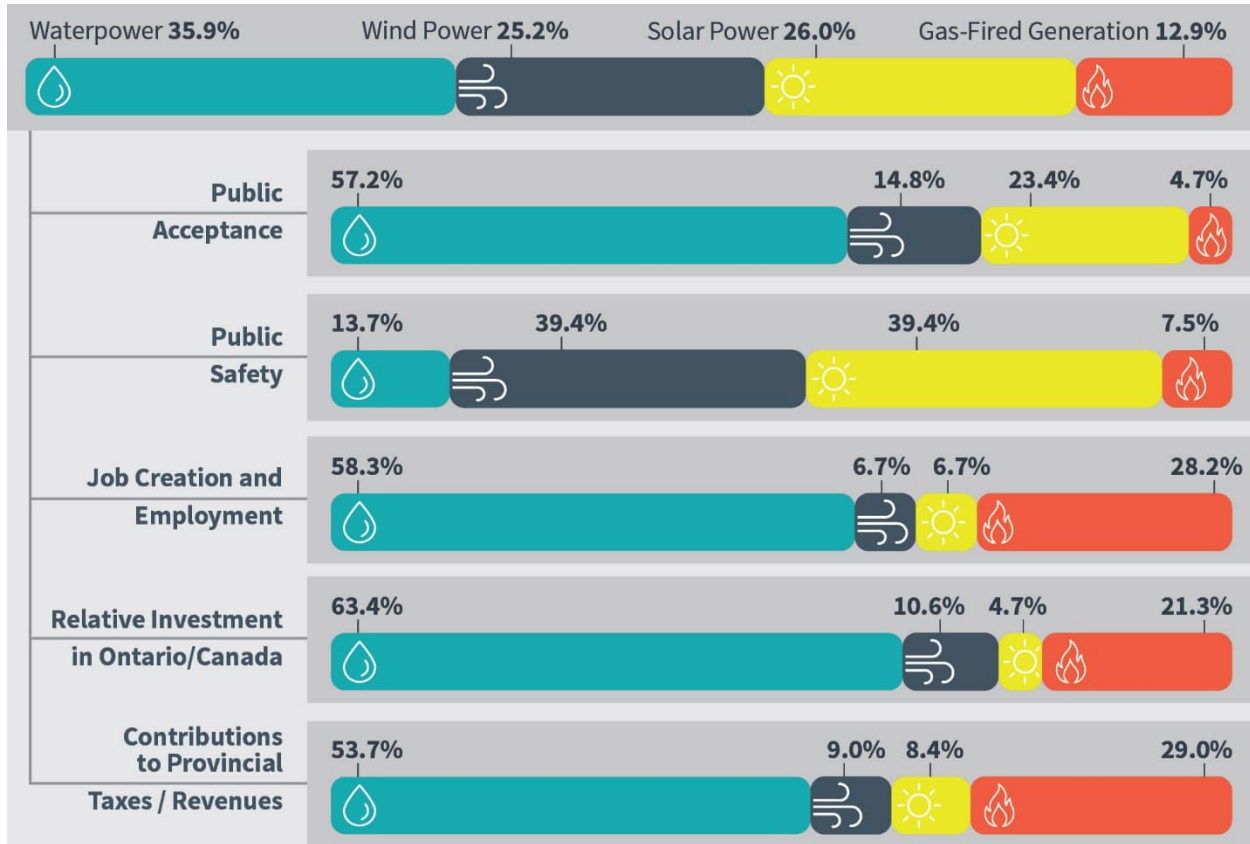
Gas-fired generation occupies a middle ground in the socioeconomic spectrum, performing moderately well across most dimensions. Public safety risks are mitigated through stringent safety protocols, and the technology supports sustained, high-skilled employment during operations. Gas-fired facilities contribute meaningfully to provincial revenues through corporate and property taxes, carbon emission charges, and fuel taxes. Although public preference leans strongly toward renewables, natural gas maintains a 70% approval rate, indicating that Ontarians recognize its role in ensuring energy reliability and affordability during the transition to a low-carbon grid.

Solar power, by contrast, is among the safest technologies, with minimal public safety risks when properly installed and maintained. It enjoys high public approval and creates substantial employment during the installation phase. However, its economic contributions are more limited. Most solar panels are manufactured offshore, reducing the potential for upstream job creation and local investment. While solar projects do contribute through standard taxation mechanisms, they lack unique fiscal policies such as royalties or carbon pricing that could amplify their economic impact.

Wind power shares many of solar's strengths and limitations. It is also considered a safe technology and maintains strong public support. Wind projects generate local employment during planning and construction, particularly in rural areas. However, the cancellation of Ontario's FIT program has diminished the investment value of wind projects, especially as domestic component manufacturing has declined. While wind continues to contribute through construction and maintenance services, its long-term employment and fiscal contributions are more modest compared to waterpower and gas.

This analysis highlights the dynamic nature of socioeconomic considerations in energy planning. Technological advancements such as improved safety systems and policy shifts like the introduction of carbon pricing or the repeal of the FIT program continue to shape the relative performance of each generation option. At present, waterpower stands apart due to its ability to deliver long-term employment, strong local investment, consistent fiscal contributions, and broad public support. Solar and wind remain socially favored and safe but are economically constrained, while gas-fired generation offers operational stability and fiscal value, albeit with lower public enthusiasm.

Figure 56 Breakdown of Alternatives Scoring with Respect to Socioeconomic Considerations



8.4 Policy Considerations

Ensuring that the development of a generation option is coordinated and consistent with overarching public policy goals such as sustainability, reliability, affordability, and economic development.

8.4.1 Indigenous Community Economic Benefits

In recent years, Indigenous communities across Ontario have increasingly participated in energy generation projects driven by a combination of provincial policy, regulatory frameworks, and the proactive efforts of developers who recognize the importance of Indigenous partnerships in advancing reconciliation and ensuring equitable participation in the clean energy transition.

One of the most significant avenues for economic participation has been through equity ownership. By co-owning energy projects, Indigenous communities gain direct financial return and long-term revenue stability. Indigenous participation and partnerships in waterpower, solar and wind power projects are increasing across Canada, and in Ontario, there are over 450 renewable energy projects that are owned by or partnered with Indigenous communities (IESO, 2025).

Revenue sharing agreements have further bolstered economic benefits, guaranteeing annual payments that can fund essential community services and infrastructure.

Capacity building initiatives have been important in empowering Indigenous communities with the skills and knowledge needed to thrive in the clean energy sector. Through these initiatives, communities develop technical, business, and governance expertise, positioning them as key players in the energy transition.

Finally, employment and training opportunities for Indigenous communities have also grown, including in construction, operations, environmental monitoring, and administrative positions. These roles not only offer immediate job opportunities but also contribute to the long-term development of technical, business, and governance expertise within Indigenous communities.

8.4.1.1 General Considerations

Waterpower: Waterpower projects have historically been a cornerstone of Indigenous economic participation. Numerous waterpower projects across Northern Ontario are co-owned or jointly operated with Indigenous communities, providing long-term benefits. The \$2.6 billion Lower Mattagami Waterpower redevelopment, one of Ontario's largest waterpower redevelopments, has resulted in long-term economic benefits, employment and training opportunities for the Moose Cree First Nation including a 25% equity stake in the project.

Wind Power: Wind power projects have also seen substantial Indigenous engagement. Partnerships often involve equity stakes, lease agreements, or community benefit agreements (CBAs). The Henvey Inlet Wind Project, co-developed by the Henvey Inlet First Nation and Pattern Energy, demonstrates large-scale Indigenous participation, resulting in significant economic benefits and infrastructure improvements.

Solar Power: Solar power projects are increasingly pursued by Indigenous communities, both independently and through partnerships. Notable examples include the 100 MW Grand Renewable Solar facility in which the Six Nations of the Grand River have a 10 % equity investment.

Gas-Fired Generation: Indigenous participation in gas-fired electricity generation has been limited in Ontario, with no known equity partnerships. However, nationally, there are emerging models of Indigenous involvement such as the Cascade Power Project in Alberta, where six First Nations became equity partners in a 900 MW natural gas-fired facility through a \$93 million loan guarantee (Alberta Indigenous Opportunities Corporation, 2025).

8.4.1.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; indigenous economic benefits are a qualitative feature.

8.4.1.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 57. The normalized priority scoring of the different alternatives is shown in Figure 58

Figure 57 Alternative Pairwise Scoring with Respect to Indigenous Community Economic Benefits

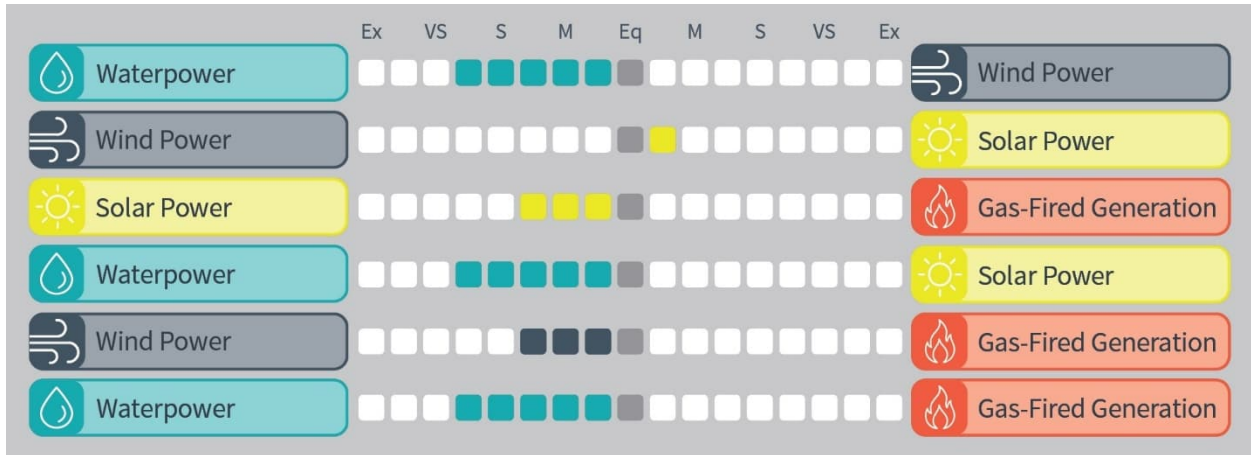


Figure 58 Alternatives Priorities with Respect to Indigenous Community Economic Benefits



8.4.2 Municipal Support

Ontario municipalities are increasingly prioritizing energy planning as part of their long-term strategies, leveraging programs like the Municipal Energy Plan (MEP) Program to achieve sustainability, resilience, affordability, economic development, and community engagement goals. This comprehensive approach involves various generation technologies, each aligning differently with local objectives.

8.4.2.1 General Considerations

Waterpower: Waterpower projects offer long-term sustainability and reliable power, fitting well with municipal resilience goals. While new large-scale waterpower projects are rare, retrofits of existing small waterpower stations, often in partnership with Indigenous communities are increasingly common. The Town of Bracebridge, for example, supports small-scale waterpower retrofits as part of its Community Energy Plan (Corporate Energy, 2024; Harris, 2018).

Wind Power: Wind power aligns well with municipal sustainability and rural economic development goals. Municipalities like Chatham-Kent have actively hosted multiple wind projects, generating significant community benefits through lease payments and taxes. However, community acceptance plays a crucial role, as seen in Dutton Dunwich's decision against new wind development following local referendums (Farmers Forum, 2024). As of September 2024, 159 municipalities in Ontario encompassing rural and urban areas have passed resolutions stating an unwillingness to host new industrial wind power sites citing health and safety concerns, environmental impacts and impacts to aesthetics and property value (Wind Concerns Ontario, 2024).

Solar Power: Solar power stands out as a key technology supporting municipal sustainability and economic development priorities. It contributes to greenhouse gas reduction targets, offers distributed generation opportunities, and promotes local job creation. For instance, Toronto's "TransformTO" strategy emphasizes local solar projects to achieve its 2040 net-zero target (City of Toronto, 2017), while Vaughan has adopted a

blanket municipal support resolution to encourage solar and BESS projects (City of Vaughan, 2022). Similarly, Guelph's "Community Energy Initiative" focuses on expanding rooftop solar to enhance energy independence (City of Guelph, 2025).

Gas-Fired Generation: Natural gas generation faces increasing scrutiny at the municipal level due to misalignment with local climate action plans aimed at achieving net-zero emissions. Some municipalities, like Halton Hills, have voiced concerns over approving new natural gas facilities (Chown Oved, 2023). In contrast, Chatham-Kent supported a small natural gas cogeneration project linked to local agricultural operations, citing economic benefits and grid support (Chatham Kent, 2022).

8.4.2.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; municipal support is a qualitative feature.

8.4.2.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 59. The normalized priority scoring of the different alternatives is shown in Figure 60.

Figure 59 Alternatives Pairwise Scoring with Respect to Municipal Support



Figure 60 Alternative Priorities with Respect to Municipal Support



8.4.3 Contribution to IESO Planning/Acquisition Requirements

Ontario's IESO focuses on three core planning and procurement objectives: system reliability, long-term energy demand fulfillment, and alignment with current market needs. Various energy generation alternatives differ in their ability to meet these priorities.

8.4.3.1 General Considerations

Waterpower: Waterpower remains a critical contributor to Ontario's reliability objectives and is highly valued for its reliability and ability to provide consistent, base-load power. It aligns well with IESO's objectives for system reliability and long-term energy demand.

Wind Power: Wind power is considered a key component of Ontario's renewable generation strategy. However, its intermittent nature poses challenges for system reliability. The IESO's procurement processes emphasize dispatchable sources, which can match electricity supply with demand more effectively (IESO, 2024). Its intermittency requires complementary resources like BESS to ensure reliability. Wind participates primarily in energy markets but has limited standalone capacity value without firming solutions.

Solar Power: Solar power aligns well with long-term energy demand and market needs, although its intermittent nature requires careful management to ensure system reliability. On its own, solar power cannot deliver firm capacity and requires storage or other flexible resources to meet peak demand reliably. As storage integration grows, solar power's market compatibility is expected to improve (IESO, 2022). While both solar and wind power have their merits, solar power tends to align better with the IESO's planning and procurement objectives due to its scalability, declining costs, and potential for integration with storage solutions. Wind power, despite its significant contributions, faces more challenges related to reliability.

Gas-Fired Generation: Gas-fired generation is highly flexible and can quickly ramp up or down to meet changing demand, making it crucial for system reliability (Koenek, 2024) and providing a stable and dispatchable source of power, aligning well with IESO's objectives for meeting long-term energy demand and current market needs (IESO, 2025b). Gas-fired generation also play a significant role in balancing the grid, especially when renewable sources like wind and solar are not producing (IESO, 2022).

Wind and solar are essential to meeting long-term decarbonization goals but require integration with storage solutions. Natural gas remains a necessary transitional resource but is increasingly misaligned with Ontario's long-term clean energy strategy.

Pairwise comparison is used to compare the performance of the different generation alternatives; contribution to IESO planning/acquisition is a qualitative feature.

8.4.3.2 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 61. The normalized priority scoring of the different alternatives is shown in Figure 62.

Figure 61 Alternatives Pairwise Scoring with Respect to Contributions to IESO Planning/Acquisition Requirements



Figure 62 Alternative Priorities with Respect to Contributions to IESO Planning/Acquisition Requirements



8.4.4 Contribution to Provincial Integrated Energy Plans

The Provincial Planning Statement (PPS) 2024 emphasizes sustainable development, efficient resource use, and the integration of renewable energy sources to address climate change and improve air quality. It does not prescribe specific technologies but supports energy conservation, efficiency, and renewable energy broadly. Ontario’s Integrated Energy Plan (IEP) complements the PPS by:

- Establishing a planning horizon to 2050
- Integrating electricity, natural gas, waterpower, biofuels, and emerging energy sources into one coordinated framework
- Aligning energy infrastructure decisions with land use, housing, and economic development priorities
- Embedding the principles of affordability, security, reliability, and clean energy into all aspects of energy planning.

Relevant PPS 2024 sections include:

- Section 2.9 – Energy Conservation, Air Quality, and Climate Change: Encourages renewable and alternative energy systems to reduce reliance on non-renewable sources.
- Section 3.1 – Infrastructure and Public Service Facilities: Supports infrastructure planning aligned with sustainability and renewable energy goals.

Together, these policies provide a cohesive framework for evaluating energy projects in Ontario, ensuring they contribute to a resilient, sustainable, and economically competitive energy future.

8.4.4.1 General Considerations

Waterpower: Waterpower projects align well with the PPS 2024's goals of protecting natural resources and promoting sustainable development and is aligned with both PPS 2024 and the IEP. New waterpower projects in Northern Ontario (e.g., Nine Mile Rapids and Grand Rapids) are being co-planned with Indigenous communities, supporting sustainable development, reconciliation, and long-term clean energy supply. These projects support efficient use and management of water resources, which is a key aspect of the PPS. However, ensuring minimal environmental impact and maintaining water quality are critical considerations for waterpower development.

Waterpower projects exhibit a high degree of in-province investment retention. For new waterpower developments, approximately 75 % of total capital investment remains within Ontario, reflecting the dominance of locally delivered civil works, engineering, construction, and project services. For sustaining investments in existing hydroelectric assets, the proportion retained within the province is even higher, at approximately 90 % of total expenditure, due to the long-term nature of refurbishment programs, domestic operations and maintenance, and locally delivered asset management activities (OWA Knowledge Center, n.d.).

Wind and Solar Power: Supported by both PPS 2024 and the IEP. The IEP promotes competitive procurement and energy storage integration to improve reliability and affordability. Solar and wind are strongly aligned with the PPS 2024's objectives of promoting sustainable land use and supporting renewable energy development. Ground-mounted solar projects are only permitted in prime agricultural areas as an on-farm diversified use and so there remains a tension between solar development and agricultural land preservation, while wind power supports the PPS 2024's goals of efficient use of land.

Wind and solar projects retain a smaller fraction of lifetime investment within Ontario, as major components are typically imported and in-province value is concentrated primarily in site development and operations.

Gas-Fired Generation: Recognized in the IEP as a strategic resource for reliability during peak demand and nuclear refurbishments. While PPS 2024 supports necessary infrastructure, the IEP emphasizes emissions management, energy efficiency, and the gradual integration of low-carbon fuels like renewable natural gas. The IEP also affirms that a premature phase-out of natural gas generation would compromise affordability and reliability. Gas-fired generation supports system reliability during nuclear refurbishments and periods of variable renewable output, and provides a platform for the gradual integration of lower-carbon fuels. Consistent with the IEP, this transitional role enables an orderly and affordable pathway toward a zero-emission electricity system while maintaining reliability during the transition.

Gas-fired generation retains a moderate share of investment through domestic engineering, construction, operations, and fuel supply chains.

8.4.4.2 Measurement Scale

Pairwise comparison is used to compare the performance of the different generation alternatives; contribution to Provincial Energy Planning is a qualitative feature.

8.4.4.3 Scoring

The pairwise comparison scoring is based on the context provided above with a summary provided in Figure 63. The normalized priority scoring of the different alternatives is shown in Figure 64.

Figure 63 Alternatives Pairwise Scoring with Respect to Contributions to Provincial Integrated Energy Plans

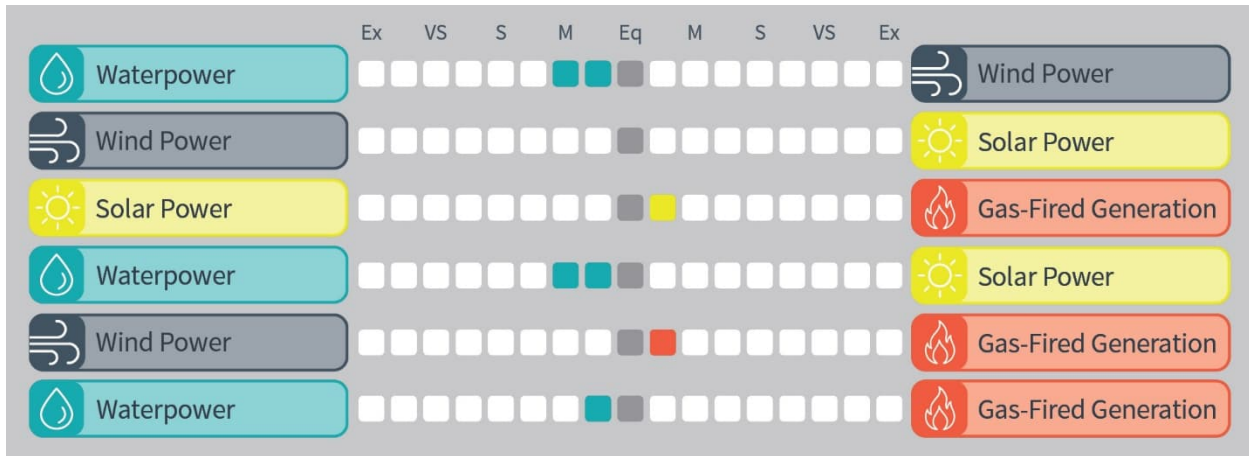


Figure 64 Alternative Priorities with Respect to Contributions to Provincial Integrated Energy Plans



8.4.5 Key Insights with Respect to Policy Considerations

A high-level review of applicable policies reveals a shared commitment to the development and expansion of renewable energy generation in Ontario. Additional priorities emphasized across policies include reliability of supply and social and economic impacts to local communities. The synthesized results for all policy considerations are presented in Figure 65.

Waterpower is the strongest performer across all policy considerations. It uniquely combines renewable generation with high reliability, offering consistent baseload capacity that directly supports IESO’s planning and acquisition requirements. Its long-standing track record of Indigenous co-ownership and joint operation provides a proven foundation for future partnerships. Waterpower also aligns well with municipal resilience goals and provincial planning frameworks, particularly through retrofits. Its ability to deliver economic, social, and environmental benefits makes it the most policy-aligned technology in Ontario’s current energy landscape.

Wind Power, while renewable and aligned with long-term decarbonization goals, faces growing challenges under current policy conditions. Municipal opposition has intensified, with over 150 municipalities expressing unwillingness to host new wind projects due to health, safety, and aesthetic concerns. Comparatively, wind delivers fewer economic benefits to Indigenous communities and is less scalable in the current context. Its reliability limitations also hinder its alignment with IESO procurement goals, though this may improve with the maturation of storage technologies.

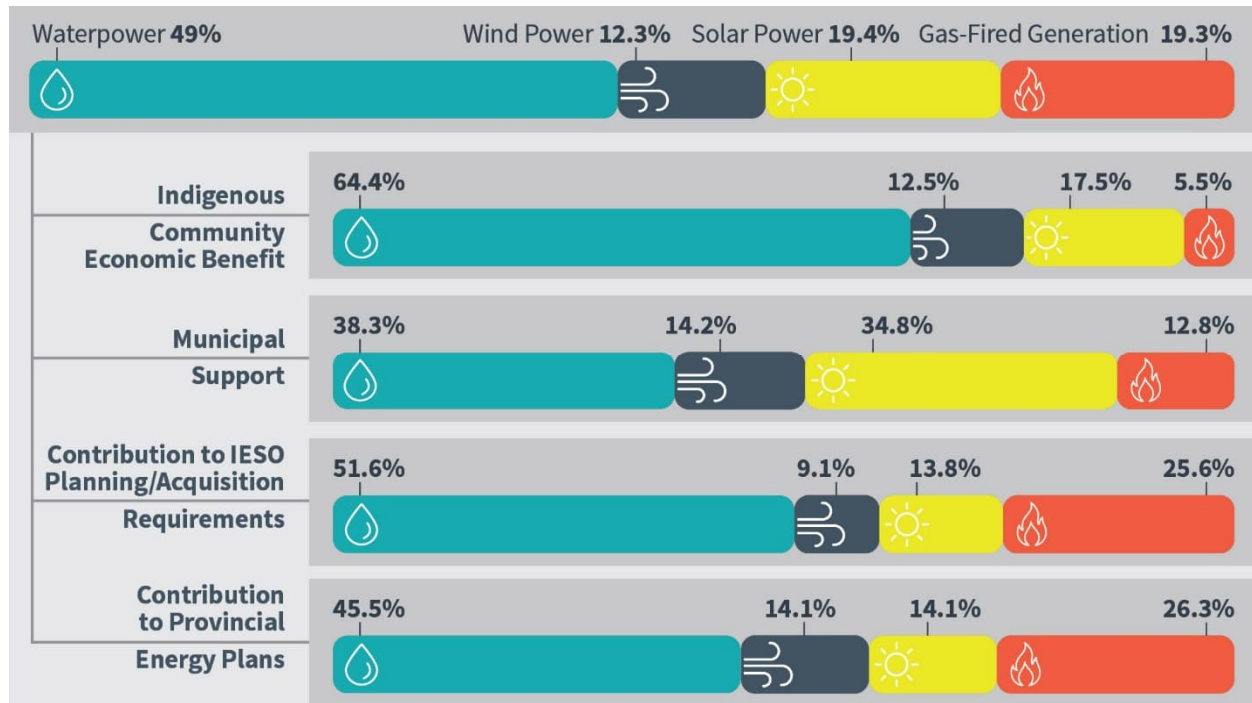
Solar power is a strong contributor from a policy perspective due to its renewable nature and scalability. Indigenous communities are increasingly leading or co-developing solar projects, which enhances local economic benefits and technical capacity. While solar faces reliability challenges due to its intermittency, its alignment with IESO objectives is expected to improve as energy storage technologies advance. Solar’s

compatibility with distributed generation and its potential for integration with storage make it a key pillar of Ontario’s clean energy future.

Gas-fired generation conflicts with net-zero emissions goals and faces increasing municipal resistance. However, it remains a critical transitional resource due to its dispatchability and flexibility, which are essential for grid reliability and balancing intermittent renewables. IESO continues to rely on gas to meet peak demand and ensure system stability. While gas performs well in terms of operational reliability, its long-term role is constrained by environmental and policy considerations, emphasizing the need for low-carbon alternatives and expanded storage infrastructure.

Overall, policy analysis results strongly favours renewable energy technologies that contribute to positive outcomes for municipalities and Indigenous communities. In doing so, these policies indirectly highlight the need to enhance flexibility and storage capacity of renewables through the establishment of storage infrastructure. Conventional facilities continue to play a critical role in ensuring supply reliability, as recognized by IESO objectives, and remain while storage technologies continue to advance.

Figure 65 Breakdown of the Alternatives Scoring with Respect to Policy Considerations



9 Results and Insights - Putting Everything Together

9.1 Relative Benefits of the Generation Alternatives

This section presents the evaluation results and explores what they mean. Instead of declaring a “winner,” the analysis highlights how alternatives differ in their value/benefit contributions, and where those differences matter most, as summarized in Waterpower achieves its leading overall performance through its exceptional grid and system benefits contribution combined with strong policy considerations’ weighting. Gas-fired generation reaches comparable total performance primarily through its substantial grid and system benefits contribution, despite receiving lower policy support. In contrast, wind and solar power show significantly constrained grid service provision but benefit from moderate policy positioning.

This pattern underscores that the primary value differentiation among generation alternatives lies in their weighted contributions to essential grid services and their alignment with current policy frameworks, rather than in environmental or socioeconomic factors.

As shown in Figure 66, Waterpower achieves its leading overall performance through its exceptional grid and system benefits contribution combined with strong policy considerations’ weighting. Gas-fired generation reaches comparable total performance primarily through its substantial grid and system benefits contribution, despite receiving lower policy support. In contrast, wind and solar power show significantly constrained grid service provision but benefit from moderate policy positioning.

This pattern underscores that the primary value differentiation among generation alternatives lies in their weighted contributions to essential grid services and their alignment with current policy frameworks, rather than in environmental or socioeconomic factors.

Waterpower is the most well-rounded: Waterpower consistently scores either first or second in every category. This consistency suggests that waterpower is a highly versatile option that brings both reliability and well-rounded value to an energy portfolio.

The value of wind power and solar power generation is marginally similar in several areas: For example, wind power and solar power perform almost identically on environmental and socioeconomic factors. However, solar power outperforms wind power on policy considerations due to its compatibility with distributed generation, storage integration potential, and stronger alignment with Ontario’s clean energy goals. Wind power faces growing policy challenges including municipal opposition from over 150 municipalities, community concerns, and lower economic benefits to Indigenous communities. Although both wind power and solar power have limited grid and system benefits, wind power has a slight edge in this criterion as wind power outperforms solar power in that it has higher capacity factor. These policy and operational differences mean project choices may hinge on whether policy alignment or grid services (mainly capacity factor) are prioritized, along with local conditions, community acceptance, and cost.

A portfolio approach is needed: Given how each technology leads in some categories and lags in others, there is a real argument for diversifying. Waterpower brings stability (scores well across all benefits categories) in addition to longevity; gas-fired generation excels in grid and system benefits but falls short on policy considerations; while renewables (solar power and wind power) are especially strong on policy and environmental considerations. Relying on a blend rather than a single technology is a smart risk management move for planners and decision-makers.

Value differentiating factors: While the breakdown provided in Waterpower achieves its leading overall performance through its exceptional grid and system benefits contribution combined with strong policy considerations' weighting. Gas-fired generation reaches comparable total performance primarily through its substantial grid and system benefits contribution, despite receiving lower policy support. In contrast, wind and solar power show significantly constrained grid service provision but benefit from moderate policy positioning.

This pattern underscores that the primary value differentiation among generation alternatives lies in their weighted contributions to essential grid services and their alignment with current policy frameworks, rather than in environmental or socioeconomic factors. Figure 66 examined the relative performance of each technology within individual criteria categories, a similar perspective emerges when viewing the breakdown of the absolute contribution each technology makes to the overall system value. The combined results visualization shown in Figure 67 presents the same multi-criteria evaluation data through a different analytical lens, showing how each technology's total contribution is distributed across the four major criteria dimensions

Figure 67 reveals that technology differentiation occurs primarily in two critical dimensions: grid and system benefits and policy considerations, which together drive the fundamental differences in overall technology performance. While environmental performance and socioeconomic considerations vary modestly, the decisive differentiating factors emerge in grid services and policy alignment.

Waterpower achieves its leading overall performance through its exceptional grid and system benefits contribution combined with strong policy considerations' weighting. Gas-fired generation reaches comparable total performance primarily through its substantial grid and system benefits contribution, despite receiving lower policy support. In contrast, wind and solar power show significantly constrained grid service provision but benefit from moderate policy positioning.

This pattern underscores that the primary value differentiation among generation alternatives lies in their weighted contributions to essential grid services and their alignment with current policy frameworks, rather than in environmental or socioeconomic factors.

Figure 66 Breakdown of the Alternatives Scoring with Respect to Quantifying the Relative Benefits of The Generation Alternatives

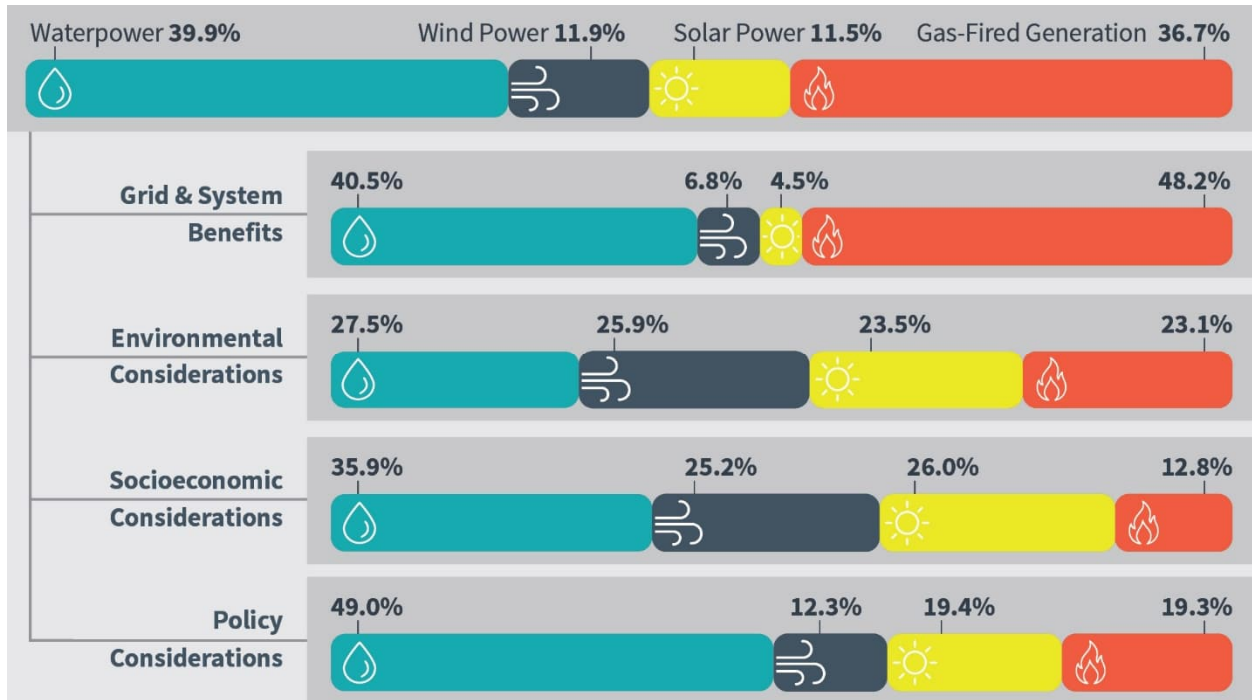
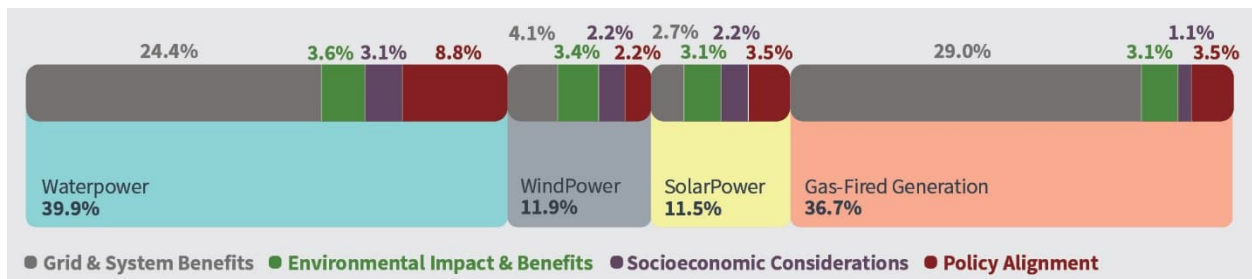


Figure 67 Weighted Scoring Breakdown for Generation Technologies by Criteria Category



9.2 Sensitivity Analysis

Sensitivity analyses are used to explore scenarios. Given that the scoring provided is based on the criteria weighing derived from the industry experts evaluation, how would the final scoring results differ if we rely on the criteria derived from the OWA Board evaluation? Alternatively, how would the final scoring look like if we use equal weight for all criteria? The purpose of this sensitivity analysis is to provide a range or results so that trends could be understood.

One important question when making complex decisions (specially at such a high-level evaluation) is whether the results would change if different people placed different levels of importance on various factors. To test this, we conducted a sensitivity analysis using the criteria weights that were evaluated by two separate groups of stakeholders as discussed in Section 7.1 while keeping the performance evaluation of the alternatives the same. This approach helps us understand whether our conclusions are robust (meaning if they hold up even when

people have different priorities and perspectives about what matters most in choosing electricity generation options for Ontario).

The sensitivity analysis compares how the overall results change when we use the criteria weights from the industry experts versus OWA Board, while keeping everything else the same. If the results stay relatively similar between the two groups, it gives us confidence that our findings are reliable and not overly dependent on any one person's or group's particular viewpoint. On the other hand, if the results change dramatically, it would indicate that the decision is highly sensitive to how we prioritize different factors, which would require more careful consideration of whose priorities should guide the final recommendations.

The differences in the criteria weight are summarized and explained in Section 7.1.3. Given that the performance of the different technologies against the environmental impacts and benefits was relatively close, the change in scoring is going to be more driven by the other three criteria (grid and system benefits, socioeconomic considerations, and policy considerations). The results using the two different criteria weights are presented in Figure 68 (Case a and b). Comparing the two scores reveals the following:

- Waterpower maintains its leadership position in both scenarios, scoring ~40% and ~38% using the weights by industry expert group and OWA Board group, respectively. The ~2%-point difference is negligible. This demonstrates that waterpower's overall and comprehensive strengths are robust across different stakeholder perspectives and weighting priorities.
- Gas-fired generation shows a drop from ~37% (Industry Experts) to ~26% (OWA Board). This large ~11%-point decrease suggests that gas-fired generation's relative benefits are more sensitive to how different criteria are prioritized than waterpower. This is a reflection of the fact that OWA Board placed higher emphasis on environmental and socioeconomic considerations as discussed in Section 7.1.3 where gas-fired generation performs less favorably than the other technologies.
- Wind power and solar power show moderate variation, with both moving from ~12% to ~18%. These modest increases of ~6% are a reflection of the fact that OWA Board placed higher emphasis on environmental and policy considerations as discussed in Section 7.1.3 where renewable technologies perform more favorably.
- Despite the scoring changes, the fundamental hierarchy and its proportion remain intact, where waterpower leads, gas-fired generation holds second place, and renewables follow. Although the score for waterpower dropped slightly, the gap between the top two technologies (waterpower and gas-fired generation) slightly grows (from ~3% to ~12%). Also, the gap between renewables and dispatchable technologies decreases from ~28% to ~19% for waterpower and from ~25% to ~7% for gas-fired generation. Despite the above, the competitive landscape remains unchanged.
- The sensitivity analysis demonstrates that the relative overall picture does not change. Waterpower's dominance remains consistent with larger lead over gas-fired generation, and the relative positioning of other technologies stays within expected ranges. This stability indicates that the evaluation framework produces reliable results that are not overly dependent on specific weighting assumptions, providing confidence for policy decision-making regardless of stakeholder emphasis variation.

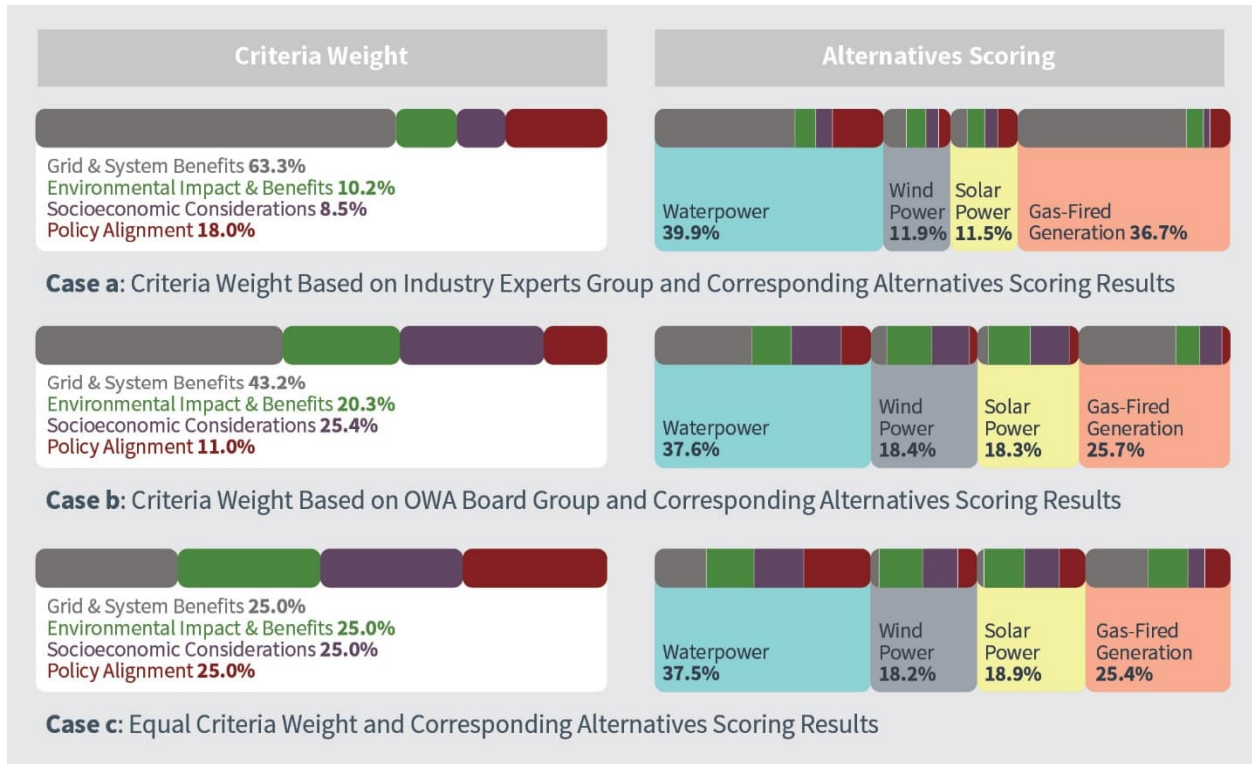
Let's also look at how the results change if we give all criteria equal weight (25% each). This is a hypothetical scenario that is meant to explore the directional change of the results rather than reflecting on the current priorities for the province. The following results, as presented in Figure 68 (Case c), show some interesting changes that help us understand what drives each technology's performance:

- The overall ranking stays the same with waterpower first, gas-fired generation second, then solar power and wind power, but the differences between them become smaller. This equal-weight analysis confirms that our original results were not just driven by how we prioritized different criteria but reflect real differences in how well each technology performs across the full range of these criteria given that the bias for criteria preferences is removed.
- Waterpower's relatively stable performance (~40% → ~38% → 38 %) indicates that the independent evaluation found it strong across multiple criteria with only a decrease of 2.4%, making it appealing regardless of stakeholder emphasis. This means that even if the way waterpower's performance was rated on one individual factor (such as environmental impact or policy alignment) was changed or debated, it is extremely unlikely to affect its overall ranking. This makes it the most likely candidate for building broad consensus in multi-stakeholder planning processes.
- Gas-fired generation shows the largest variation (~11% decrease) across scenarios (~37% → ~26% → ~25%), demonstrating that its score is driven to how the criteria are weight. In particular, it is sensitive to the weight given to Grid and System Benefits compared to the other criteria. The relative performance of gas-fired generation compared with the other technologies is much better for Grid and System Benefits compared to the remaining three criteria.
- Wind power and solar power show modest improvements compared to the weighted results, with the score for wind power increasing by ~6% (~12% → ~18% → ~18%) and solar power increasing by ~7% (~12% → ~18% → ~19%). This suggests that these renewable technologies score more when environmental and policy considerations get equal weight alongside technical factors. Under equal weighting, the gap between renewables and the traditional technologies narrows further, more when compared to gas than waterpower.

For the equal-weight scenario, the criteria weight were adjusted from the Industry Expert Group evaluation to reflect equal importance across all criteria (using the software capability for performing dynamic sensitivity analysis). A separate AHP case with independently elicited equal weights was not conducted; therefore, the results are intended to provide an approximate comparison and illustrate directional sensitivity rather than represent a fully independent evaluation

Based on the sensitivity analysis above, even when we remove any bias (Figure 68, Case c) toward particular criteria, the basic competitive relationships remain unchanged. This gives us confidence in the robustness and stability of our findings.

Figure 68 Overall Results Comparison Based on the Criteria Weight for the Industry Expert Group, OWA Board Group, Criteria Weight with Equal Value (25% each)



10 Cost Benefit Analysis - Bringing Cost into the Picture

Public opinion around electricity generation technologies often centers on simplified narratives such as claims that one source is "the most economical", "the most environmentally friendly," or "the most reliable". However, the economic realities are considerably more complex. Construction and operating costs can vary substantially based on project-specific factors, site conditions, and market dynamics. Also, each technology contributes a distinct combination of value types to the electricity system, as revealed in Section 9.

This cost-benefit analysis examines what each technology option delivers relative to its cost, using cost ranges and quantified benefit assessments. This approach presents a systematic comparison of the generation technologies while accounting for both cost variability and comprehensive system benefits. The objective is not to identify a single optimal technology, but to provide a transparent, evidence-based assessment that reveals the trade-offs inherent in electricity generation choices. This approach enables informed evaluation of technology options based on quantifiable performance metrics rather than conventional judgment.

10.1 Cost Data

This analysis uses the LCOE cost measure, which is the average cost for building and running a facility divided by how much power it will produce during its entire life.

Table 9 summarizes the Levelized Cost of Energy (LCOE) values drawn from established industry sources, including NREL Annual Technology Baseline (National Renewable Energy Laboratory, 2024) for Waterpower, Wind, and Solar; the Fraunhofer Institute 2024 report (Fraunhofer ISE, 2024) for Gas-fired Generation; and the Independent Electricity System Operator's (IESO) 2024 Annual Planning Report for all technologies. These references offer a blend of U.S., global benchmarks, and Ontario-specific values. In addition to using single-point LCOE values, the table shows cost ranges that reflect real-world variation.

Values are expressed in the currency they were reported in and then converted to 2025 CAD. Given that the benefit scoring for the generation options is conducted within the context of the current timeframe, the LCOE for 2025 is used when available. All values that were not originally expressed in 2025 CAD were converted to 2025 CAD using an annual inflation rate.

10.1.1 NREL Waterpower, Wind, and Solar LCOE

For waterpower, wind power, and solar power, the cost ranges were sourced from the 2025 data published in the NREL Annual Technology Baseline, which provides detailed cost ranges for each technology rather than single-point estimates. For NREL data, the following parameters were selected to obtain the LCOE data:

- Scenario: Moderate
- Financials: Market
- Cost Recovery Period: Technical life
- Technology Maturity: Mature
- Technology Details: All

In the context of the NREL Annual Technology Baseline, the “technical life” parameter is equivalent to the definition of “economic life” adopted in this report, representing the period over which the asset is assumed to deliver value and over which costs are evaluated.

Waterpower shows the largest cost variation among all technologies, reflecting the unique challenges of waterpower investments. According to NREL's detailed analysis, this wide range stems from several key factors:

- **Site-Specific Characteristics:** Unlike other technologies where equipment costs dominate, waterpower costs are heavily influenced by site-specific factors including water flow rates, hydraulic head, water conveyance length, and distance to transmission infrastructure. For example, NREL's representative facilities range from high-flow, high-head sites with optimal conditions to low-flow, low-head sites requiring extensive infrastructure.
- **Resource Depletion Effect:** The most productive waterpower sites with high water flow and head have already been developed over decades. Remaining potential sites tend to have lower water flow and head, requiring proportionally more civil works and infrastructure investment per unit of electricity generated. This explains why many of the remaining sites fall into NREL's "High Cost" and "Very High Cost" categories. However, the context for this effect is relevant to the U.S. and may not necessarily be relevant to the Canadian context.
- **Development Categories:** The cost range encompasses two distinct development types: retrofitting existing non-powered dams (NPD) with generation equipment, and new stream-reach developments (NSD) along previously undeveloped waterways. Base year estimates of overnight capital cost (OCC) for NPD sites range from \$3,045/kW to \$20,043/kW depending on site conditions, while NSD sites typically cost \$6,574/kW to \$8,611/kW but represent smaller-scale developments than historical projects. These values are reported in USD. The corresponding breakdown for LCOE values is shown in Table 7.

2022 USD values were converted to CAD using the 2022 annual-average exchange rate of 0.77 (Bank of Canada), then escalated to 2025 CAD using an inflation factor. The inflation factor was calculated based on the CPI adjustment from 2022 to 2025 using observed annual-average CPI values for 2022-2024 from Statistics Canada and a projected 2025 inflation rate of approximately 2% consistent with the Bank of Canada Monetary Policy Report. As such, the following CPI values are used: 2022: 151.2, 2024: 160.9, 2025: 164.1. The resulting cumulative inflation factor from 2022 to 2025 is approximately 1.085.

Table 7 2025 LCOE Ranges Breakdown for Waterpower (NSD, NPD) in 2025 CAD/MWh (NREL)

| Technology and Its Sub-technology | LCOE Range $\left(\frac{USD_{2022}}{MWh}\right)$ | LCOE Range $\left(\frac{CAD_{2025}}{MWh}\right)$ |
|-------------------------------------|--|--|
| Waterpower | \$48 - \$267 | \$68 - \$376 |
| NSD (non-powered dams) | \$48 - \$81 | \$68 - \$105 |
| NPD (new stream-reach developments) | \$58 - \$267 | \$82 - \$376 |

10.1.1.1 Selection of NREL LCOE Default Values Based on Ontario-Specific Adjustments

The National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) provides default LCOE values for each generation technology. These defaults are not intended to represent best-case or site-specific conditions, but rather a representative configuration aligned with recent or anticipated near-term installations. As documented by NREL, the default technology case is selected to support comparability across technologies and scenarios, and to reflect typical deployment conditions rather than extremes.

Accordingly, this report presents the NREL default values as the starting point for all technologies, with some adjustments made when Ontario-specific conditions can easily be applied.

Hydropower:

No Ontario-specific parameters were identified because the NREL ATB waterpower cost structure is driven overwhelmingly by site-specific physical characteristics (such as hydraulic head, flow regime, conveyance length, and existing civil works conditions) that cannot be reasonably generalized across Ontario. Therefore, the NREL default hydropower LCOE values are retained without modification for Ontario.

Wind:

For land-based wind, NREL defines default LCOE values by wind speed class, with Class 4 designated as the default. NREL explicitly notes that Wind Speed Class 4 represents a moderate-quality wind regime and is intended to be representative of most U.S. wind projects installed to date.

For this report, Wind Speed Class 7 was selected instead, reflecting Ontario's development reality. This adjustment better reflects expected wind resource projects in Ontario.

Solar:

For utility-scale solar PV, NREL provides default LCOE values by solar resource class, with Class 5 identified as the default representative case. However, given Ontario's characteristics, Solar Class 4 was considered more applicable to Ontario conditions.

This choice reflects a more realistic representation of Ontario's solar resource availability while maintaining alignment with NREL's standardized class definitions.

10.1.2 Fraunhofer Institute Gas-Fired Generation LCOE

For gas-fired generation, the LCOE data were taken from the Fraunhofer ISE, 2024 report as NREL did not include comparable gas-fired generation data for 2025.

Based on the Fraunhofer study, gas-fired generation exhibits a large range among the technologies analyzed, reflecting multiple operational and technical factors:

- **Technology Types:** The range encompasses two fundamentally different gas-fired generation facility types. CCGT facilities achieve the lower end of the cost range, while simple gas turbine (GT) power facilities designed for flexible, short-term operation reach the upper range. The corresponding breakdown for LCOE values is shown in Table 8.
- **Variable Cost Components:** Unlike renewable technologies with minimal operating costs, gas-fired generation facilities face ongoing fuel expenses and carbon costs. The Fraunhofer study projects natural gas fuel costs to remain relatively stable but notes that carbon certificate prices are expected to rise significantly, substantially impacting the upper cost range.
- **Carbon Pricing Impact:** Rising CO₂ certificate costs significantly affect the upper range, with prices projected to increase from current levels to €175-375/tonne by 2045. This carbon pricing mechanism particularly penalizes lower-efficiency GT units operating at reduced capacity factors.
- **Capacity Factor Sensitivity:** The study emphasizes that gas-fired generation facility LCOE shows high sensitivity to utilization rates. As renewable energy penetration increases, conventional gas-fired generation

facilities increasingly transition from baseload to backup/flexible operation roles. This reduces their capacity factors and pushes costs toward the upper range of the LCOE spectrum.

The values were converted from 2024 EUR to 2025 CAD using a 2% annual inflation rate and a EUR to CAD conversion rate of 1.47. The range includes costs for both combined cycle gas turbine (CCGT) and simple gas turbine (GT).

It is recognized that gas generation in Europe differs materially from North American contexts, including differences in installed capacity, market role, fuel pricing, carbon pricing regimes, and technology pathways. As a result, Fraunhofer ISE estimates; while informative from a comparative standpoint, are not considered representative of Ontario conditions. All base-case cost assumptions used in this study are drawn from the IESO 2024 Outlook Planning Report.

Table 8 2025 LCOE Ranges Breakdown for Gas Technologies (CCGT-CH4, GT-CH4) in 2025 CAD/MWh (Fraunhofer ISE)

| Technology and Its Sub-technology | LCOE Range $\left(\frac{EUR_{2024}}{MWh}\right)$ | LCOE Range $\left(\frac{CAD_{2025}}{MWh}\right)$ |
|---------------------------------------|--|--|
| Gas | \$109 - \$325 | \$163 - \$487 |
| CCGT-CH4 (Combined-cycle Gas Turbine) | \$109 - \$181 | \$163 - \$271 |
| GT-CH4 (Simple Gas Turbine) | \$151 - \$325 | \$226 - \$487 |

10.1.3 IESO LCOE

The Levelized Cost of Energy (LCOE) values used in this analysis are sourced directly from the Independent Electricity System Operator’s (IESO) 2024 Annual Planning Outlook, which provides Ontario-specific cost estimates for major generation technologies.

While global benchmarks from NREL and Fraunhofer ISE are presented for comparison, the IESO LCOE values serve as the primary cost inputs for the analysis. This ensures that the cost-benefit assessment aligns with local market conditions, regulatory frameworks, and the resource mix anticipated in Ontario’s long-term planning.

For Gas-Fired Generation, the IESO value includes projected fuel costs and the full federal carbon price and is therefore a suitable representation of the cost of new gas-fired capacity in Ontario.

10.2 Cost-Benefit

The purpose of the cost-benefit analysis is to bring together the benefit assessment and the cost assessment into a single, coherent evaluative framework that supports comparison across generation alternatives. It aims to answer a simple question: If we spend one dollar, which technology gives us more useful outcomes once both benefits and costs are expressed on a comparable basis? Cost-benefit analysis is therefore required to answer the question neither framework can answer on its own. The intent is to establish a consistent basis for comparing relative value across technologies that differ substantially in cost structure, operational role, and longevity.

In this study, benefits and costs are developed separately and using different analytical tools; benefits are assessed using a structured multi-criteria framework (AHP), while costs are represented using Levelized Cost of Electricity (LCOE), which expresses the average cost of producing electricity over the assumed operating life of each technology.

Evaluating benefits and costs separately can lead to misleading conclusions when technologies differ fundamentally in how and over what period they deliver value. In particular, technologies with lower upfront costs but shorter operating lives may appear attractive on a cost basis alone. On the other hand, technologies with higher capital intensity but long operating lives may appear disadvantaged unless their benefits are evaluated over an appropriate time horizon. Cost-benefit analysis allows these differences to be examined explicitly by relating benefit outcomes to the costs incurred to achieve them.

A key principle of the cost-benefit analysis in this study is consistency in the time horizon. LCOE represents costs that are averaged over an assumed operating life for each technology. If benefits are evaluated without reference to that same life assumption, the resulting comparison implicitly treats all technologies as if they deliver benefits over the same duration. This introduces a structural bias, particularly when comparing long-lived generation technology assets with shorter-lived ones.

Accordingly, the cost-benefit framework requires an explicit consideration of the operating life assumed in the cost model, so that benefits and costs are aligned on a common basis for the time horizon.

The following sections describe how this integration is implemented, including the introduction of an economic life factor to ensure consistency between benefit and cost treatment.

10.2.1 Analysis

10.2.1.1 Economic Life Multiplier for Benefits

This section introduces an economic life adjustment to the benefits to ensure that benefits and costs are evaluated over consistent time horizons. Without this adjustment, costs are implicitly evaluated over the full economic life of each technology (through LCOE), while benefits are treated as if they occur over an equal, unspecified duration across all technologies. This creates a structural inconsistency that can bias the cost-benefit results when combining these two dimensions in the same domain.

Electricity generation technologies differ materially in how long they provide value to the system: Some assets deliver benefits for multiple decades with predictable reinvestment pathways (e.g., hydropower); others provide value over shorter operating lives or require full replacement to continue delivering benefits (e.g., wind, solar, gas).

The AHP benefit scores capture the relative quality and importance of benefits, but do not encode how long those benefits persist. In contrast, LCOE explicitly spreads costs over an assumed economic lifetime, reflecting the total period over which capital, operating, and fuel costs are incurred and electricity is produced. If benefits are not adjusted to reflect duration, technologies with short economic lives are implicitly treated as delivering the same total value as long-lived technologies; even though they must be rebuilt or replaced to continue contributing to the system.

The introduction of an economic life factor aligns the benefit assessment with the cost framework (LCOE) used in the analysis. It corrects a structural inconsistency that would otherwise undervalue long-lived assets and overstate the relative contribution of short-lived technologies.

10.2.1.1.1 Economic Life versus Technical Life

The AHP includes a “Lifespan & Lifecycle Considerations” criterion that captures technical durability, ease of refurbishment, and strategic extendibility of the asset. This criterion is retained because it reflects qualitative differences in lifecycle characteristics, not duration alone. In this criterion, technical life (expected lifespan) is

defined as the expected physical operating period before major refurbishment/replacement, as discussed in Section 6.1.4.

On the other hand, economic life is the total period over which the asset can deliver electricity and system benefits, including planned refurbishments and reinvestments, consistent with how LCOE is calculated. The economic life is the appropriate basis for aligning benefits with costs, because it represents the time horizon over which society incurs costs and receives value.

The economic life scaling introduced here captures the quantity of benefit over time, while the AHP criterion, Lifespan & Lifecycle Considerations, captures the quality and robustness of the lifecycle pathway. These two elements address different dimensions and do not double-count the same effect.

10.2.1.1.2 Aligning Benefits with Economic Life

To ensure consistency with the cost assessment, the analysis applies a post-AHP economic life scaling factor to the total benefit scores before performing cost-benefit comparisons.

The approach is as follows:

- AHP benefit scores are calculated and normalized in the usual manner. These scores represent relative benefit scores, not duration.
- Economic life assumptions are assigned to each technology based on planning references. NREL values (National Renewable Energy Laboratory [NREL], 2024) are used given that these assumptions are not available for the IESO LCOE values. The values are shown in Table 9.
- A life scaling factor is calculated relative to the minimum economic life among the generation technologies. These scaling factors are shown in Table 9.
- The total AHP benefit score for each technology is multiplied by this factor to calculate the lifetime-adjusted aggregate benefits. The final scores are shown in Table 9.

This adjustment is applied after the AHP aggregation, so it does not interfere with the internal weighting or consistency of the AHP framework.

10.2.1.1.3 Interpretation of Lifetime-Adjusted Benefits

The resulting metric should be interpreted as a relative estimate of the total benefit delivered over the economic life of the asset, consistent with how costs are represented through LCOE.

It is not a new AHP weight, nor does it change stakeholder preferences embedded in the AHP. Instead, it reflects how long those preferred attributes are available to the system.

10.2.1.1.4 Why Linear Scaling Is Used

Linear scaling directly reflects duration of benefit availability and is easily understood and considered adequate for this high-level evaluation. The intent is to correct for a lifetime bias in a simple manner to get an overall understanding of the impact of such adjustment. Sensitivity analysis can be used to test alternative assumptions if required. Performing a full net present value optimization of benefit streams would be a more accurate methodology, but this would require a level of data granularity and modeling complexity that is beyond the scope of the present study and not necessary to support the comparative, system-level insights sought here. The following is the formula used to calculate the lifetime-adjusted benefit score:

$$\text{Economic Lifetime Adjusted Benefit Score} = \text{Economic Life Factor} * \text{AHP Benefit Score}$$

10.2.1.1.5 Implications for the Cost-Benefit Results

Introducing the economic life adjustment has the following effects:

- Long-lived infrastructure assets receive proportional recognition for sustained system contribution.
- Short-lived assets are evaluated based on the duration over which their benefits persist without full replacement.
- Cost-benefit comparisons become consistent with the time horizon implicit in LCOE.

This ensures that results reflect long-term total value, rather than a snapshot view that implicitly assumes equal asset lifetimes.

10.2.1.2 Absolute Cost Compared to Lifetime-Adjusted Total Benefits

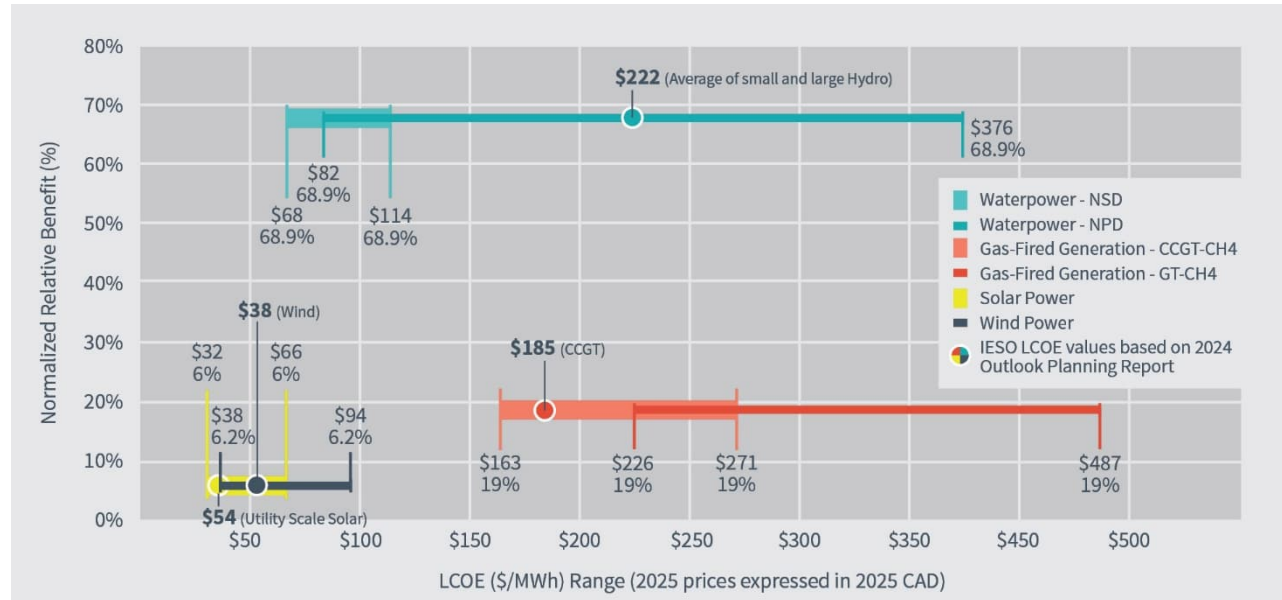
Figure 69 presents a cost-benefit comparison that relates the absolute levelized cost of electricity (LCOE) of each electricity generation technology to its normalized, lifetime-adjusted total benefit derived from the multi-criteria analysis. The horizontal axis represents the range of LCOE values for each technology, reflecting uncertainty and variability in cost assumptions. These LCOE range values correspond to NREL data for waterpower, wind, and solar; and the Fraunhofer Institute data for gas-fired generation. The vertical axis shows the corresponding normalized relative benefit, expressed as a percentage of total value over the technology lifetime. Both LCOE and benefit values are shown in Table 9.

Each technology is represented by a horizontal line spanning its LCOE range and positioned at a constant vertical level corresponding to the evaluated benefit of the parent technology. Although individual sub-technologies may exhibit different performance characteristics, the benefit assessment was conducted at the parent-technology level, capturing the aggregate value across the range of sub-technology configurations considered in the analysis. This representation intentionally separates cost variability from benefit evaluation, allowing both dimensions to be interpreted without introducing additional complexity.

In addition to the cost ranges, a discrete marker is shown for each technology to indicate the corresponding cost value used by the Independent Electricity System Operator (IESO) in its planning and assessment processes. These points provide a consistent, externally referenced benchmark within each cost range and enable direct comparison between the cost ranges and those currently used in Ontario's system planning practice.

Despite the simplifying assumptions inherent in this visualization, the figure provides useful insight into the relationship between absolute cost and lifetime-adjusted total benefit. Technologies positioned higher on the vertical axis contribute more strongly to overall system objectives beyond energy production alone, while the horizontal extent of each line illustrates potential economic trade-offs associated with cost uncertainty. Overall, the figure illustrates how absolute cost levels and lifetime-adjusted total benefits relate across technologies.

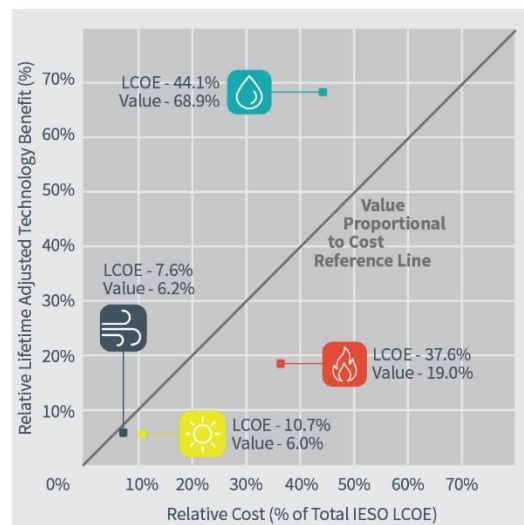
Figure 69 Cost-Benefit Trade-Off Analysis for Electricity Generation Technologies



10.2.1.3 Normalized Cost vs. Lifetime Technology Value

Figure 70 represents a normalized cost-benefit scatter plot that compares electricity generation technologies on a consistent, system-level basis over their lifetime. The horizontal axis represents the normalized IESO LCOE for each technology, expressed as a percentage of the total LCOE across all technologies included in the analysis, thereby reflecting each technology’s relative share of total cost. The vertical axis represents the normalized, lifetime-adjusted total benefit for each technology, expressed as a percentage of total system value, and reflects each technology’s contribution to overall total benefits after accounting for differences in assumed economic life. Both LCOE and benefits values are shown in Table 9.

Figure 70 Relative Cost vs. Lifetime-Adjusted Technology Benefit



Each point on the plot corresponds to a generation technology. The dashed diagonal line represents a reference condition in which a technology’s contribution to total value is proportional to its contribution to total cost.

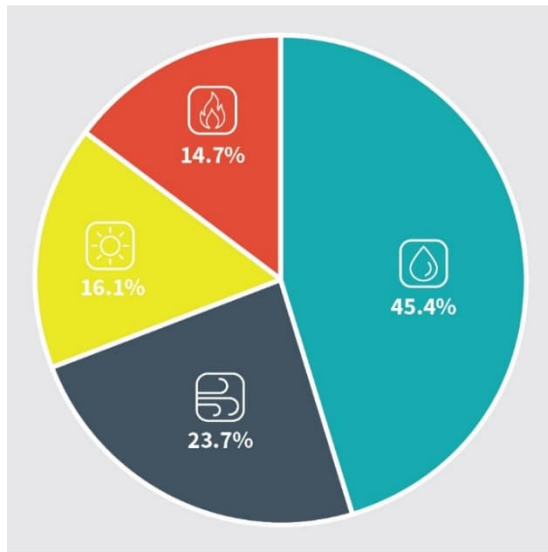
Technologies plotted above this reference line deliver a greater share of total value relative to cost, while those plotted below the line deliver a lower share of value relative to cost, with the distance from the line indicating the magnitude of this divergence.

Figure 71 presents the normalized distribution of relative total value delivered per one dollar spent to generate 1 MWh of electricity across the technologies considered.

10.2.1.4 Relative Aggregate System Benefit Per Dollar Spent

The values shown are derived by dividing each technology’s lifetime-adjusted, normalized benefit score by its corresponding normalized LCOE, thereby expressing the efficiency with which cost is converted into total value on a relative basis.

Figure 71 Relative Overall Benefit Per 1\$ Spent to Generate 1 MWh of Electricity



The results are presented as proportional shares that sum to 100%, enabling a direct comparison of how total benefit per unit cost is distributed across technologies within the analysis. Each slice of the chart represents a technology’s relative contribution to total benefit per dollar spent, based on the same cost and benefit normalization framework used in the preceding sections.

Table 9 2025 LCOE Data and Value per LCOE Calculation

| | Economic Life (L_e) * | LCOE | | | | | | | | AHP Benefit/Value | | | | Lifetime-Adjusted Value Per LCOE = $\left(\frac{V_F}{LCOE}\right) * 100$ | | |
|-----------------------------|---------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|----------------|-------------------|--|--|-------------------------|--|--|----------------|
| | | Fraunhofer ISE LCOE Range ** | NREL LCOE Range ** | NREL & Fraunhofer ISE LCOE Range ** | NREL Default LCOE Value *** | | IESO LCOE **** | | | Value Score (V) | Economic Life Factor $F_{L_e} = \frac{L_e}{\min(L_e)}$ | Lifetime-Adjusted / - Factored Value Score $V_F = V * F_{L_e}$ | Lifetime-Adjusted Value | Lifetime-Adjusted Value per NREL & Fraunhofer ISE LCOE Range | Lifetime-Adjusted Value per IESO LCOE | |
| | Years | $\left(\frac{EUR_{2024}}{MWh}\right)$ | $\left(\frac{USD_{2022}}{MWh}\right)$ | $\left(\frac{CAD_{2025}}{MWh}\right)$ | $\left(\frac{USD_{2022}}{MWh}\right)$ | $\left(\frac{CAD_{2025}}{MWh}\right)$ | $\left(\frac{CAD_{2024}}{MWh}\right)$ | $\left(\frac{CAD_{2025}}{MWh}\right)$ | Normalized (%) | (%) | -- | (%) | Normalized (%) | $\left(\frac{\%}{\frac{CAD_{2025}}{MWh} * 100}\right)$ | $\left(\frac{\%}{\frac{CAD_{2025}}{MWh} * 100}\right)$ | Normalized (%) |
| Waterpower | 100 | -- | \$48 - \$267 | \$68 - \$376 | \$60 | \$85 | \$218 | \$222 | 44.1% | 39.9% | 3.33 | 132.9% | 68.9% | 0.18 - 1.02 | 0.31 | 45.6% |
| Wind Power | 30 | -- | \$27 - \$67 | \$38 - \$94 | \$23 | \$32 | \$37 | \$38 | 7.6% | 11.9% | 1.00 | 11.9% | 6.2% | 0.07 - 0.16 | 0.16 | 23.5% |
| Solar Power | 30 | -- | \$23 - \$47 | \$32 - \$66 | \$31 | \$44 | \$53 | \$54 | 10.7% | 11.5% | 1.00 | 11.5% | 6.0% | 0.09 - 0.18 | 0.11 | 16.2% |
| Gas-Fired Generation | 30 | \$109 - \$325 | -- | \$163 - \$487 | -- | -- | \$185 | \$189 | 37.6% | 36.7% | 1.00 | 36.7% | 19.0% | 0.04 - 0.12 | 0.10 | 14.7% |
| Sum | -- | -- | -- | -- | -- | -- | -- | \$503 | 100% | 100% | -- | 193% | 100% | -- | 0.68 | 100% |

Notes:

* The economic life represents the duration over which the LCOE is calculated. According to NREL, the economic life assumptions are: Waterpower = 100 yrs; Wind, Solar, & Gas = 30 yrs

** The 2025 LCOE ranges for Waterpower, Wind, and Solar are sourced from NREL. Gas-fired generation 2024 LCOE values are based on Fraunhofer ISE (2024).

*** Default NREL LCOE values are provided for comparison only. The default value represents the LCOE for the technology configuration defined by NREL to be most closely aligned with recent or near-term installations. Adjustments were applied to reflect Ontario-specific conditions for: Wind: Land-based wind, Class 7, Technology 1; Solar: Utility PV, Class 4. The Waterpower LCOE was not adjusted given its wide cost range and high sensitivity to site-specific characteristics.

**** IESO 2024 LCOE values are sourced from the 2024 Annual Planning Report. The Waterpower LCOE used here represents the average of small hydro and large hydro values.

10.2.2 Insights

The cost–benefit analysis presented in Figure 69, Figure 70, and Figure 71 provides complementary perspectives on how different electricity generation technologies convert cost into lifetime benefit/value.

- Figure 69 illustrates how absolute cost ranges relate to lifetime-adjusted benefits.
- Figure 70 shows relative cost–value positioning once both dimensions are normalized.
- Figure 71 summarizes relative value per dollar spent, across technologies.

Taken together, these figures support several key insights regarding the relationship between cost and long-term benefits.

10.2.2.1 Long-Lived, Flexible Assets Exhibit Higher Lifetime-Adjusted Benefit

Technologies characterized by long asset lives and operational flexibility occupy higher positions on the lifetime-adjusted benefit axis. This reflects the cumulative nature of benefits delivered over extended planning horizons and across multiple system conditions. When benefits are evaluated over the assumed economic life embedded in the LCOE framework, the LCOE and the benefit can be compared objectively. Assets that remain operationally relevant over longer periods contribute more strongly to overall system objectives than those whose value is concentrated over shorter horizons.

10.2.2.2 Absolute Cost and Lifetime Benefit Are Weakly Correlated

Figure 70 shows that technologies with similar or overlapping LCOE ranges can deliver significantly different levels of lifetime-adjusted benefit. While the horizontal extent of each technology reflects uncertainty and variability in cost assumptions, its vertical positioning derived from the lifetime-adjusted benefit assessment remains distinct across technologies.

This indicates that absolute cost alone is not a reliable proxy for overall system contribution. Technologies with higher LCOE ranges may nevertheless deliver substantially greater value over their assumed economic life, reflecting contributions that extend beyond energy production, such as operational flexibility, reliability support, and alignment with long-term system objectives. Conversely, lower-cost technologies may provide more limited value despite favorable cost metrics.

10.2.2.3 Overall Aggregate Benefit Does Not Scale Proportionally with Cost

Figure 70 directly compares relative cost and relative lifetime technology benefit on a normalized basis and introduces a reference condition where value would scale proportionally with cost. The observed deviations from this reference line demonstrate that technologies do not convert cost into value at a uniform rate.

The analysis demonstrates that higher cost does not necessarily correspond to higher overall benefit. Technologies positioned above the proportional reference line deliver greater lifetime-adjusted overall benefit per unit of relative cost, while those below the line deliver less. This divergence illustrates that differences in overall contribution are driven by qualitative attributes (such as dispatchability, operational adaptability, and contribution to system adequacy) that are not captured by cost metrics alone. As a result, cost-based comparisons that assume proportionality risk mischaracterizing technologies that provide disproportionate overall benefit relative to their cost.

10.2.2.4 Cost–Benefit Alignment Varies by Technology Role

Taken together, the figures illustrate that technologies serve different roles within the electricity system and that their cost–benefit profiles reflect these roles. Some technologies contribute primarily through energy provision, while others provide broader system services that enhance operability, reliability, and long-term adaptability. The analysis underscores that a balanced resource portfolio cannot be evaluated solely on the lowest-cost criteria but must consider how different technologies contribute complementary forms of value across planning horizons.

10.2.2.5 Relative Value per Dollar Highlights Differences in Cost Effectiveness

Figure 71 reframes the cost–benefit relationship by expressing each technology’s share of lifetime overall benefit relative to the cost required to generate electricity. This perspective highlights differences in value efficiency, rather than absolute cost or absolute benefit.

The results show that technologies contribute unevenly to overall benefit per dollar spent, reinforcing the conclusion that least-cost generation does not necessarily correspond to highest benefit generation. While this representation does not replace absolute cost or benefit metrics, it provides an intuitive lens for understanding how efficiently different technologies translate expenditure into system-wide benefits.

10.2.2.6 Implications for Technology Comparison and Planning Interpretation

Across all three figures, the analysis consistently demonstrates that cost, value, and value efficiency are distinct dimensions that must be interpreted together. Absolute LCOE ranges (Figure 69), normalized cost–value positioning (Figure 70), and relative value-per-dollar (Figure 71) each highlight different aspects of overall contribution.

Taken together, these perspectives emphasize that technology comparisons based solely on cost risk overlooking important dimensions of overall performance. Incorporating lifetime-adjusted overall benefit score alongside cost enables a more complete and transparent comparison framework, supporting planning discussions that recognize both economic efficiency and broader objectives.

10.3 Cost-Benefit Sensitivity to Criteria Weight

10.3.1 Analysis

The results of a cost–benefit analysis can shift depending on how different priorities are weighted. For example, if decision-makers emphasize grid reliability more heavily (using the base case of the criteria weights established by the industry experts evaluation), technologies that provide stability and dispatchable capacity will rise in importance. On the other hand, if more weight is placed on environmental or socioeconomic benefits (criteria weights established by OWA board evaluation), renewables may appear more favorable. This sensitivity analysis helps us understand how robust the results are when the criteria are weighted differently.

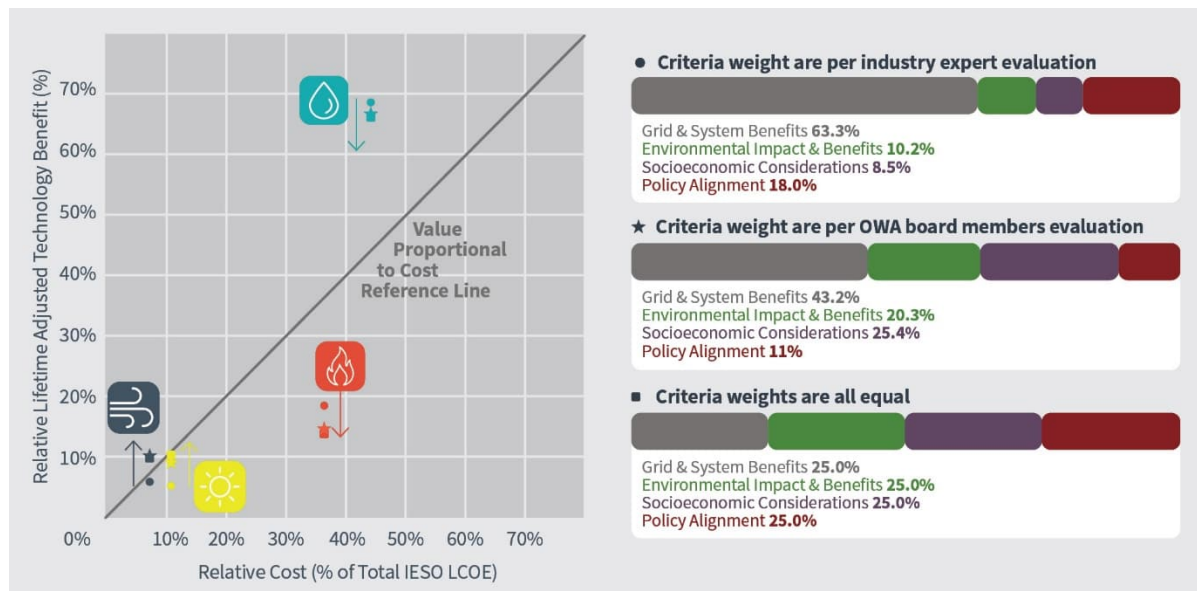
Figure 72 shows how generation technologies move on the cost–benefit chart when the criteria weights change across three cases similar to what was performed in Section 9.2:

- **Case A - Industry Experts Evaluation:** A great emphasis is given on the Grid and System Benefits Criteria with a total weight of ~63%, followed by policy considerations (~18%), and then almost equal weight for environmental impact and socioeconomic considerations (~10%, and ~9% respectively). This is the base case to which Case B and C will be compared.

- Case B – OWA Board Evaluation:** Slightly less emphasis is given on the Grid and System Benefits and Policy Considerations with a total weight of about ~43% and ~11% respectively. More weight is given to Environmental Impact and Socioeconomic Considerations (~20%, and ~25% respectively). The picture shifts slightly in favor of wind power and solar power. It is interesting to see that the benefits for waterpower compared to its cost has the lowest change because waterpower still performs well in the Environmental Impact and Socioeconomic Considerations criteria. Gas-fired generation sees the greatest decrease in attractiveness due to significant lowering of its overall benefits.
- Case C – Equal Weight:** This is a neutral point where all benefits are valued equally to take away stakeholder’s bias and focus on the technology’s pure performance against its cost. In this scenario, balanced technologies that score well on all criteria like waterpower perform well. So, with equal weights waterpower tends to remain strong, even if it lost some of its score when not given extra credit for grid support. Wind power and solar power remain attractive for their low costs and clean benefits, but the equal weighting also means their lack of dispatchability is accounted for just as much as any other factor. Gas-fired generation benefits score decreases dramatically, making its cost more disproportionate to its benefits despite the benefits it provides.

It is important to note that all benefit scores presented in this analysis are lifetime-adjusted and evaluated using a common set of criteria weights across technologies. As a result, aggregate benefit scores reflect the cumulative contribution of each technology over its assumed economic life, rather than the intensity or timing of individual services. Under the OWA Board and equal-weight scenarios, this lifetime aggregation, combined with equal weighting across grid, environmental, socioeconomic, and policy dimensions, allows persistent long-term contributions from non-dispatchable renewables to accumulate in a manner that approaches the lifetime-adjusted benefits of dispatchable technologies. This convergence in aggregate scores should therefore be interpreted as an outcome of the evaluation framework, rather than as evidence of equivalence in operational role or system function.

Figure 72 Sensitivity of the Relative Cost vs. Lifetime-Adjusted Benefit Analysis to the Criteria Weight



10.3.2 Insights

Figure 72 illustrates the sensitivity of the relative cost versus lifetime-adjusted system benefit comparison to changes in criteria weighting. The figure presents three evaluation perspectives: industry expert weighting, OWA board weighting, and an equal-criteria weighting scenario, overlaid on the same cost–value space to assess how shifts in evaluation priorities influence the relative positioning of electricity generation technologies.

Across all weighting scenarios, the overall structure of the cost–value landscape remains intact. Technologies continue to occupy distinct regions of the plot corresponding to their cost levels and aggregate lifetime contributions, indicating that changes in criteria weights influence relative value magnitudes without fundamentally altering the broader cost–benefit picture. However, the degree and direction of sensitivity differ meaningfully between technologies.

Waterpower exhibits relatively limited sensitivity to changes in criteria weighting. While its lifetime-adjusted benefit decreases modestly as greater weight is assigned to environmental and socioeconomic considerations, it consistently remains positioned in the high-value, high-cost region of the plot and well above the value-proportional-to-cost reference line. This stability reflects the diversified nature of waterpower’s benefit profile, which spans grid reliability, operational flexibility, long asset life, environmental performance, and policy alignment. As a result, shifts in emphasis among criteria redistribute value internally rather than materially changing waterpower’s overall aggregate system contribution.

Gas-fired generation shows greater sensitivity to criteria weighting than waterpower, particularly in the vertical (benefit) dimension. As weighting moves away from grid and system benefits, toward environmental and socioeconomic considerations, gas-fired generation’s lifetime-adjusted benefit decreases and approaches that of non-dispatchable renewables. Importantly, this convergence reflects a change in the composition of evaluated value rather than equivalence in system role. Gas-fired generation continues to derive a larger share of its value from dispatchability, availability, and reliability services, while non-dispatchable technologies derive value primarily from environmental and socioeconomic dimensions that accumulate over the asset lifetime.

Non-dispatchable renewable technologies (wind and solar) display comparatively modest sensitivity across the weighting scenarios. Their positions shift slightly upward as greater emphasis is placed on environmental and socioeconomic criteria, but they remain clustered in the low-cost, lower-value region of the plot. This indicates that while their relative attractiveness improves under broader sustainability-focused objectives, their aggregate lifetime system contribution remains constrained by limited operational and grid-support capabilities.

Taken together, the sensitivity analysis demonstrates that changes in criteria weighting influence relative value distribution rather than overturning the fundamental distinctions between technologies. Waterpower retains a consistently strong lifetime-adjusted total benefit across perspectives, gas-fired generation remains sensitive to the balance between grid operational and non-operational objectives, and non-dispatchable renewables benefit most from increased emphasis on environmental and socioeconomic considerations. These results reinforce the importance of clearly articulating evaluation priorities, as different weighting schemes highlight different dimensions of value without altering the underlying system roles played by each technology.

11 Conclusions

Cost Alone Is an Incomplete Proxy for System Benefit

This study indicates that levelized cost of electricity (LCOE), while an important metric for comparing costs to produce electricity, does not by itself fully describe the system-level contribution of different generation technologies.

The results presented in Figure 69 and Figure 70 indicate that relative system value does not scale proportionally with relative cost across technologies. In other words, technologies with comparable LCOE or cost shares can exhibit materially different lifetime-adjusted overall benefits. This indicates that LCOE alone does not fully capture differences in overall system benefits, such as operational role, flexibility, reliability support, etc.

This highlights the importance of complementing cost-based metrics with system value indicators when evaluating long-term investment options.

Value Differentiating Factors Among Electricity Generation Technologies

This analysis has demonstrated that when weighted, grid and system benefits and policy considerations are the primary differentiating factors among electricity generation technologies (Figure 66 and Figure 67).

Lifetime-Adjusted Benefits Significantly Influence Comparative Results

Assessing system benefits over the assumed economic life of each technology materially affects the comparative results (Table 9). Long-lived assets that provide multiple system services accumulate value over longer planning horizons than shorter-lived or more narrowly scoped assets. Consequently, the use of lifetime-adjusted benefits represents a core modeling assumption that directly influences the relative assessment of technologies in a long-term system planning context.

Consistency Between Cost and Benefit Time Horizons Is Required

In this study, LCOE represents a levelized cost expressed over the assumed economic life of each asset. For the cost-benefit comparison to remain methodologically consistent, aggregate system benefits must be evaluated over a comparable lifetime horizon. If benefits are assessed only on a short-term or annual basis while costs are levelized over several decades, long-lived assets are systematically disadvantaged, as their full-life costs are accounted for without recognizing their full-life system contributions. The application of lifetime-adjusted benefits therefore ensures consistency between the temporal treatment of costs and benefits in the comparative framework.

Waterpower Emerges as a High-Cost, High-Value System Asset

Across all representations (Figure 69, Figure 70, and Figure 71), waterpower consistently occupies the high-cost, high-benefit region of the cost-benefit space and remains well above the proportionality reference line. Its position is stable under cost uncertainty and under changes in criteria weighting, reflecting a diversified benefit profile that combines long asset life, dispatchability, storage, grid support, and policy alignment. Waterpower functions not merely as an energy source, but as a long-term system infrastructure asset.

Gas-Fired Generation Delivers High Operational Value with Strong Sensitivity to Evaluation Priorities

Gas-fired generation provides substantial system benefit driven primarily by dispatchability, availability, and reliability services. However, its relative position is sensitive to criteria weighting, particularly when environmental and socioeconomic considerations are emphasized (Figure 72). This indicates that gas-fired generation's value, within the framework used in this study, is policy-dependent, rather than structurally dominant across all planning perspectives.

Non-Dispatchable Renewables Remain Low-Cost, Lower-System-Value Assets

Wind and solar consistently occupy the low-cost, lower-value region of the cost-benefit space (Figure 69, Figure 70, and Figure 71). Their relative position improves when environmental and socioeconomic criteria are emphasized, but their aggregate lifetime overall contribution remains constrained by limited operational flexibility and grid-support capabilities. This confirms that their primary contributions are energy and emissions reduction, rather than system operability.

Technology Ranking and Cost-Benefit Positioning Is Relatively Stable Under Plausible Weighting Variations

Across the cost ranges and criteria-weighting scenarios examined, the relative ordering, grouping, and cost-benefit positioning of technologies remain broadly consistent (Figure 72). While changes in criteria weighting lead to observable shifts in relative system value, these shifts are generally limited in magnitude and do not materially alter the overall positioning of dispatchable and non-dispatchable technologies in the cost-benefit space. This suggests that the broad comparative structure of the results is robust to plausible variations in evaluation priorities.

Value per Dollar Provides a Complementary Planning Metric

The value-per-dollar representation presented in Figure 71 indicates that technologies differ in how efficiently system value is delivered per unit of expenditure. By integrating cost, assumed economic life, and multi-criteria system benefits into a single ratio-based indicator, this perspective provides a complementary lens for comparing technologies alongside absolute cost and benefit measures. This approach supports planning interpretation by highlighting differences in cost effectiveness that are not apparent from LCOE metrics alone.

A Multi-Criteria, Lifetime-Based Framework Supports Long-Term Planning

The results indicate that combining multi-criteria benefit assessment with lifetime-adjusted economic metrics provides a consistent framework for comparing technologies with fundamentally different cost structures, operating characteristics, and service profiles. This approach supports long-term system planning by enabling explicit consideration of trade-offs among different criteria, rather than relying on single-metric comparisons.

Grid Integration Challenges and Opportunities

The analysis highlights the critical role of grid integration in renewable energy deployment. While wind and solar offer potential cost advantages, their limited contribution to grid stability increases reliance on dispatchable resources as their share grows. This has significant implications for Ontario's system planning, indicating that high-renewable scenarios will require substantial investment in grid stabilization infrastructure or dispatchable backup capacity.

The strong grid support capabilities of waterpower and gas-fired generation position them as essential for system reliability. Together, they contribute ~90% of total grid and system benefits, underscoring their unique role in maintaining stability as variable renewable generation expands (Figure 66).

Strategic Findings for Ontario's Energy Future

Portfolio Optimization: The analysis suggests that an optimal generation mix should leverage the complementary strengths of each technology, rather than rely on mandates or cost alone. Waterpower can anchor long-term value creation, gas-fired generation provides essential flexibility and reliability, and renewables contribute to energy diversity and low emissions while acknowledging their grid service limitations.

Investment Prioritization: Waterpower's strong performance across multiple criteria supports prioritizing continued investment in development, modernization, and expansion. Its exceptional lifecycle value justifies higher upfront costs when viewed through a long-term lens.

Grid Modernization: The limited grid services provided by renewables highlight the need for parallel investments in grid modernization, energy storage, and management systems to support growing renewable penetration while maintaining reliability.

Policy and Regulatory Considerations

The analysis underscores the importance of value-based planning that considers the full range of system benefits, not just energy costs or environmental metrics. Regulatory frameworks should recognize and appropriately value the diverse contributions technologies make to grid stability, reliability, and resilience (Figure 72).

It also highlights the need for technology-neutral policies that let market mechanisms optimize the generation mix based on comprehensive value assessments. This approach naturally favors technologies that deliver the highest system value while ensuring diversity and resilience.

Lifetime-Value-Adjusted Economic Assessment Framework

This analysis provides essential inputs for developing Value-Adjusted Levelized Cost of Electricity (VLCOE) calculations that go beyond traditional LCOE. By quantifying each technology's contributions to grid and system benefits such as reliability, flexibility, and grid support, it establishes the foundation for valuing ancillary services. The findings show that technologies contribute very differently to system value, resulting in VLCOE profiles that diverge significantly from simple energy-cost comparisons. The lifetime adjustment to the VLCOE should also be accounted for to account for the value delivery over the full lifecycle of the assets similar to how cost is leveled over the asset life for LCOE.

The multi-criteria framework can be extended to include environmental, policy, and socioeconomic dimensions, translating qualitative assessments into quantitative value adjustments. This ensures VLCOE reflects true societal value, not just technical or economic metrics.

This study's key contribution is a systematic methodology for converting multi-criteria analysis into actionable VLCOE inputs. While existing literature focuses on technical grid services, this approach offers clear pathways for incorporating broader value dimensions. It provides a practical blueprint for researchers and policymakers to move beyond traditional LCOE toward more holistic assessment approaches.

The framework enables economically informed decisions that account for full system costs and benefits. It can also support electricity market operators in compensating generators for their comprehensive contributions to grid stability and long-term sustainability.

11.1 Final Thoughts

This analysis lays the groundwork for future research on topics such as system integration costs for variable renewables and optimizing hybrid portfolios for maximum system value. The framework is adaptable to other jurisdictions and evolving technologies.

When comparing different generation technologies, this approach adds transparency in weighting and integration of both quantitative and qualitative criteria, especially for non-cost dimensions such as policy and socioeconomic factors, complementing and enhancing existing planning processes.

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A Evaluation Data for Level 1 and 2 Criteria

Appendix A

Evaluation Data for Level 1 and 2 Criteria

Figure A-1 Industry Expert Evaluation Data

| <input type="checkbox"/> | Email | Participant Name | Permission | Evaluation Status  | | | Actions |
|--------------------------|----------------------------|------------------|------------|---|---------------------|---------------------|---|
| | | | | Has... | Evaluation Progress | Last Judgment Ti... | |
| <input type="checkbox"/> | Anonym-6582-7313_2g27idrij | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/3/2025, 7:47 AM |     |
| <input type="checkbox"/> | Anonym-6582-7313_dd5gcsv7 | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/1/2025, 1:36 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_km90m1y7 | Anonymous | Evaluator | Yes | 31.6% (12/38) | 4/1/2025, 1:48 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_nwv1przh | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 5:17 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_oyhbnylh | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 12:09 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_rdt4k3zd | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 4:02 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_ry9hn5qf | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 12:32 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_sfvt9ea | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/5/2025, 6:00 PM |     |
| <input type="checkbox"/> | Anonym-6582-7313_sg9sg5wt | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 12:22 PM |     |

The evaluation was sent to 9 anonymous participants. The evaluation included 38 judgments to be made on level 1 and 2 of the AHP hierarchy. 8/9 evaluators completed the 38 judgments, while 1 **completed 12/38**

Figure A-2 Industry Expert Evaluation Data After Removing Inconsistencies higher than 20%

Participants

| <input type="checkbox"/> | Email | Participant Name | Permission | Evaluation Status ↻ | | | Actions |
|--------------------------|---------------------------|------------------|------------|--|---------------------|---------------------|---|
| | | | | Has... | Evaluation Progress | Last Judgment Ti... | |
| <input type="checkbox"/> | Anonym-6582-7313_sg9sg5wt | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 12:22 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_dd5gcsv7 | Anonymous | Evaluator | Yes | 100.0% (26/26) | 4/1/2025, 1:36 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_2g27idj | Anonymous | Evaluator | Yes | 100.0% (32/32) | 4/3/2025, 7:47 AM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_oyhbnylh | Anonymous | Evaluator | Yes | 100.0% (26/26) | 4/7/2025, 12:09 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_sfivt9ea | Anonymous | Evaluator | Yes | 100.0% (6/6) | 4/5/2025, 6:00 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_ry9hn5qf | Anonymous | Evaluator | Yes | 100.0% (28/28) | 4/7/2025, 12:32 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_rdt4k3zd | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 4:02 PM | 🔗 🔍 ➔ 👁 |
| <input type="checkbox"/> | Anonym-6582-7313_nwv1przh | Anonymous | Evaluator | Yes | 100.0% (26/26) | 4/7/2025, 5:17 PM | 🔗 🔍 ➔ 👁 |


Judgments that have inconsistency ration that is larger than 20% inconsistencies were eliminated from the model

Figure A-3 OWA Board Evaluation Data

| <input type="checkbox"/> | Email ↑ ▼ | Participant Name ▼ | Permission ▼ | Evaluation Status ↻ | | |
|--------------------------|--|---|---|--|--|--|
| | | | | Has... ▼ | Evaluation Progress ▼ | Last Judgment Ti... ▼ |
| <input type="checkbox"/> | Anonym-6582-7313_9icuiw49 | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/7/2025, 11:48 AM |
| <input type="checkbox"/> | Anonym-6582-7313_akduvknw | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/8/2025, 10:29 AM |
| <input type="checkbox"/> | Anonym-6582-7313_bm52fqfh | Anonymous | Evaluator | Yes | 31.6% (12/38) | 4/3/2025, 12:27 AM |
| <input type="checkbox"/> | Anonym-6582-7313_ew64lrop | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/9/2025, 11:22 AM |
| <input type="checkbox"/> | Anonym-6582-7313_gaeh9vi7 | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/1/2025, 4:17 PM |
| <input type="checkbox"/> | Anonym-6582-7313_rdjp9jzl | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/1/2025, 1:59 PM |
| <input type="checkbox"/> | Anonym-6582-7313_td76j0l7 | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/1/2025, 11:17 AM |

The evaluation was sent to 7 anonymous participants. The evaluation included 38 judgments to be made on level 1 and 2 of the AHP hierarchy. 6/7 evaluators completed the 38 judgments, while 1 completed 12/38 judgments.

Figure A-4 OWA Board Evaluation Data After Removing Inconsistencies higher than 20%

| <input type="checkbox"/> | Email | Participant Name | Permission | Evaluation Status  | | |
|--------------------------|---------------------------|------------------|------------|---|---------------------|---------------------|
| | | | | Has... | Evaluation Progress | Last Judgment Ti... |
| <input type="checkbox"/> | Anonym-6582-7313_td76j0I7 | Anonymous | Evaluator | Yes | 100.0% (32/32) | 4/1/2025, 11:17 AM |
| <input type="checkbox"/> | Anonym-6582-7313_rdj9jzl | Anonymous | Evaluator | Yes | 100.0% (26/26) | 4/1/2025, 1:59 PM |
| <input type="checkbox"/> | Anonym-6582-7313_gaeh9vi7 | Anonymous | Evaluator | Yes | 100.0% (38/38) | 4/1/2025, 4:17 PM |
| <input type="checkbox"/> | Anonym-6582-7313_bm52fqfh | Anonymous | Evaluator | Yes | 31.6% (12/38) | 4/3/2025, 12:27 AM |
| <input type="checkbox"/> | Anonym-6582-7313_9icuiw49 | Anonymous | Evaluator | Yes | 100.0% (18/18) | 4/7/2025, 11:48 AM |
| <input type="checkbox"/> | Anonym-6582-7313_akduvknw | Anonymous | Evaluator | Yes | 100.0% (32/32) | 4/8/2025, 10:29 AM |
| <input type="checkbox"/> | Anonym-6582-7313_ew64lrop | Anonymous | Evaluator | Yes | 100.0% (6/6) | 4/9/2025, 11:22 AM |

Judgments that have inconsistency ration that is larger than 20% inconsistencies were eliminated from the model

B Weight Derivation for Level- 3 Criteria

Appendix B

B.1 Criteria Weight Derivation Under Reliability and Resilience

Table B-1 Pairwise Comparison for Criteria Under Reliability and Resilience

| Pairwise comparison | Winner | Score | Comments |
|--|------------------------|-------------------------------|--|
| Capacity Factor vs Black-Start Capability | Capacity Factor | Strongly more important (5) | Capacity Factor provides consistent baseline reliability, while black-start is critical but only needed during rare system-wide failure. |
| Black-Start Capability vs Cycling Capability | Black-Start Capability | Moderately more important (3) | Both important for reliability, but consistent generation (capacity factor) is slightly more fundamental than cycling ability. |
| Cycling Capability vs Grid Firming | Cycling Capability | Moderately more important (3) | Capacity factor ensures steady power supply, while grid firming supports but does not replace base generation. |
| Capacity Factor vs Cycling Capability | Capacity Factor | Moderately more important (3) | Black-start is essential for complete system recovery, cycling is important for daily operations, but less critical. |
| Black-Start Capability vs Grid Firming | Black-Start Capability | Strongly more important (5) | Black-start enables system restoration from total blackout; grid firming provides support but is not as essential. |
| Capacity Factor vs Grid Firming | Capacity Factor | Strongly more important (5) | Cycling capability helps match supply with demand changes, grid firming is valuable, but more supplementary. |

Figure B-1 Alternatives Pairwise Scoring for Criteria Under Reliability and Resilience

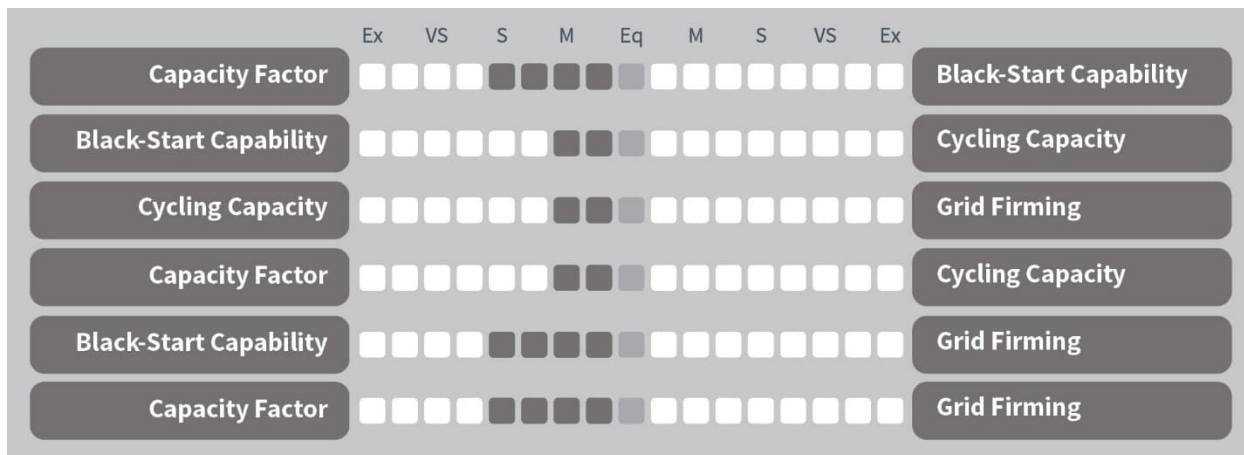
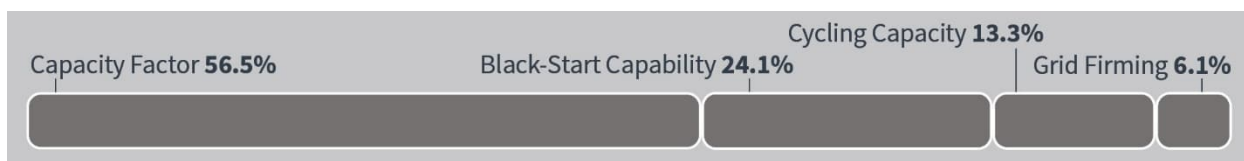


Figure B-2 Derived Priorities of Criteria Under Reliability and Resilience



B.2 Criteria Weight Derivation Under Operation Flexibility

Table B-2 Pairwise Comparison for Criteria Under Operation Flexibility

| Pairwise comparison | Winner | Score | Comments |
|--------------------------------------|-------------------|-------------------------------|---|
| Dispatchability vs Peaking | Dispatchability | Strongly more important (5) | Dispatchability provides broad operational control, peaking is important but more specific function to address high-demand period |
| Peaking vs Load Following | Load Following | Moderately more important (3) | Load following provides continuous system balance, while peaking addresses specific high-demand periods. |
| Load Following vs Operating Reserve | Load Following | Moderately more important (3) | Load following maintains continuous supply-demand balance, reserves provide security backup but used less frequently. |
| Dispatchability vs Load Following | Dispatchability | Moderately more important (3) | Both are core for flexibility, but dispatchability encompasses broader operational control including load following |
| Peaking vs Operating Reserve | Operating Reserve | Moderately more important (3) | Operating reserves ensure system security at all times; peaking contribution is important but more periodic. |
| Dispatchability vs Operating Reserve | Dispatchability | Moderately more important (3) | Dispatchability enables operating reserve. Operating reserves are important but depend on dispatchable resources. |

Figure B-3 Alternatives Pairwise Scoring for Criteria Under Operation Flexibility

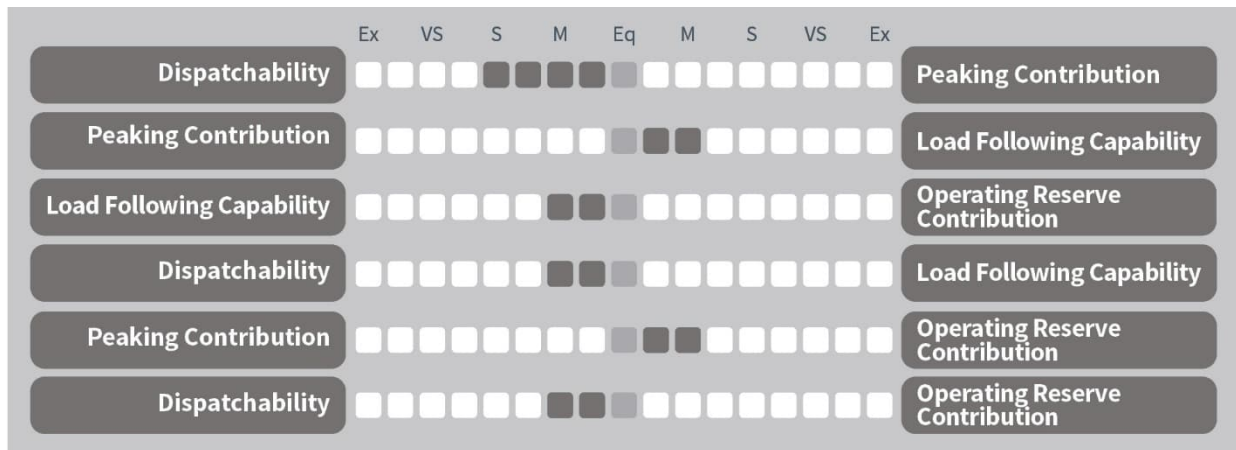
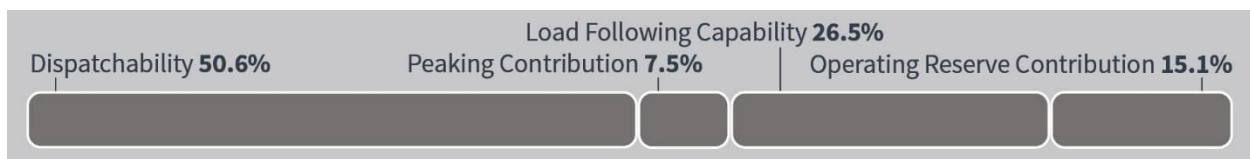


Figure B-4 Derived Priorities of Criteria Under Operation Flexibility



B.3 Criteria Weight Derivation Under Grid Support

Table B-3 Pairwise Comparison for Criteria Under Grid Support

| Pairwise comparison | Winner | Score | Comments |
|--|----------------------|-------------------------------|--|
| Inertia Contribution vs Frequency Response | Frequency Response | Strongly more important (5) | Frequency response directly addresses system imbalances making it more critical overall |
| Frequency Response vs Voltage Control and Reactive Power | Frequency Response | Strongly more important (5) | Frequency response directly addresses system imbalances making it more critical overall for system security (essential for preventing system blackouts). Voltage is the next most essential. |
| Inertia Contribution vs Voltage Control and Reactive Power | Inertia Contribution | Moderately more important (3) | Inertia provides immediate automatic system stability, which is very important for reliable operation |

Figure B-5 Alternatives Pairwise Scoring for Criteria Under Grid Support

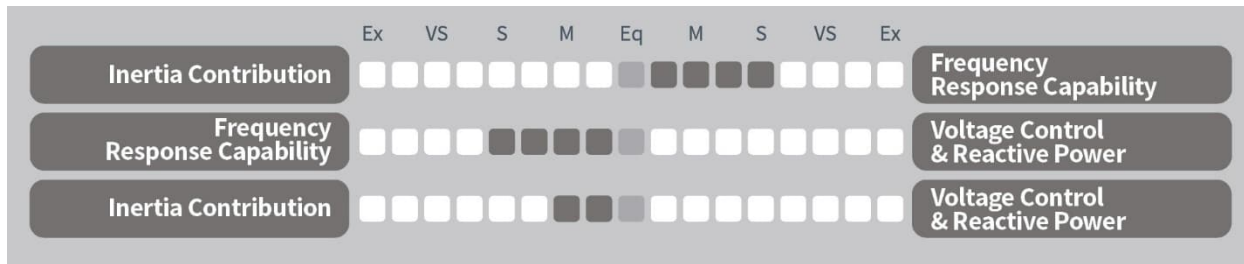
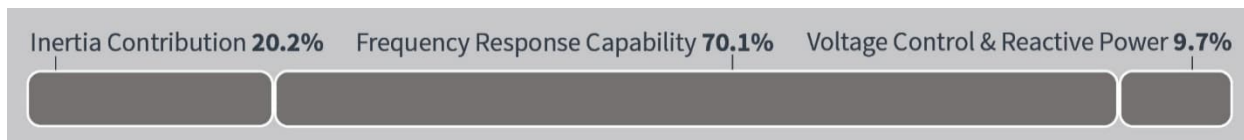


Figure B-6 Derived Priorities of Criteria Under Grid Support



B.4 Criteria Weight Derivation Under Lifespan and Lifecycle Considerations

Table B-4 Pairwise Comparison for Criteria Under Lifespan and Lifecycle Considerations

| Pairwise comparison | Winner | Score | Comments |
|--|-------------------------|-------------------------------|--|
| Expected Lifespan vs Lifecycle Expendability | Lifecycle Expendability | Moderately more important (3) | The ability to extend the lifespan of a facility provides greater long-term system value than just the initial planned lifespan. |

Figure B-7 Alternatives Pairwise Scoring for Criteria Under Lifespan and Lifecycle Considerations

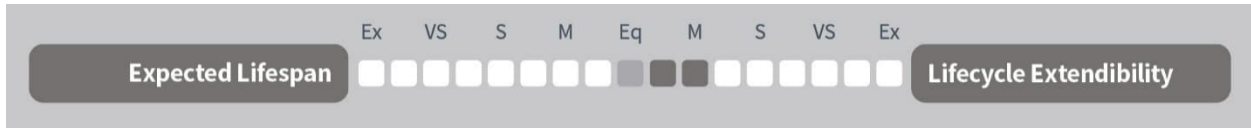
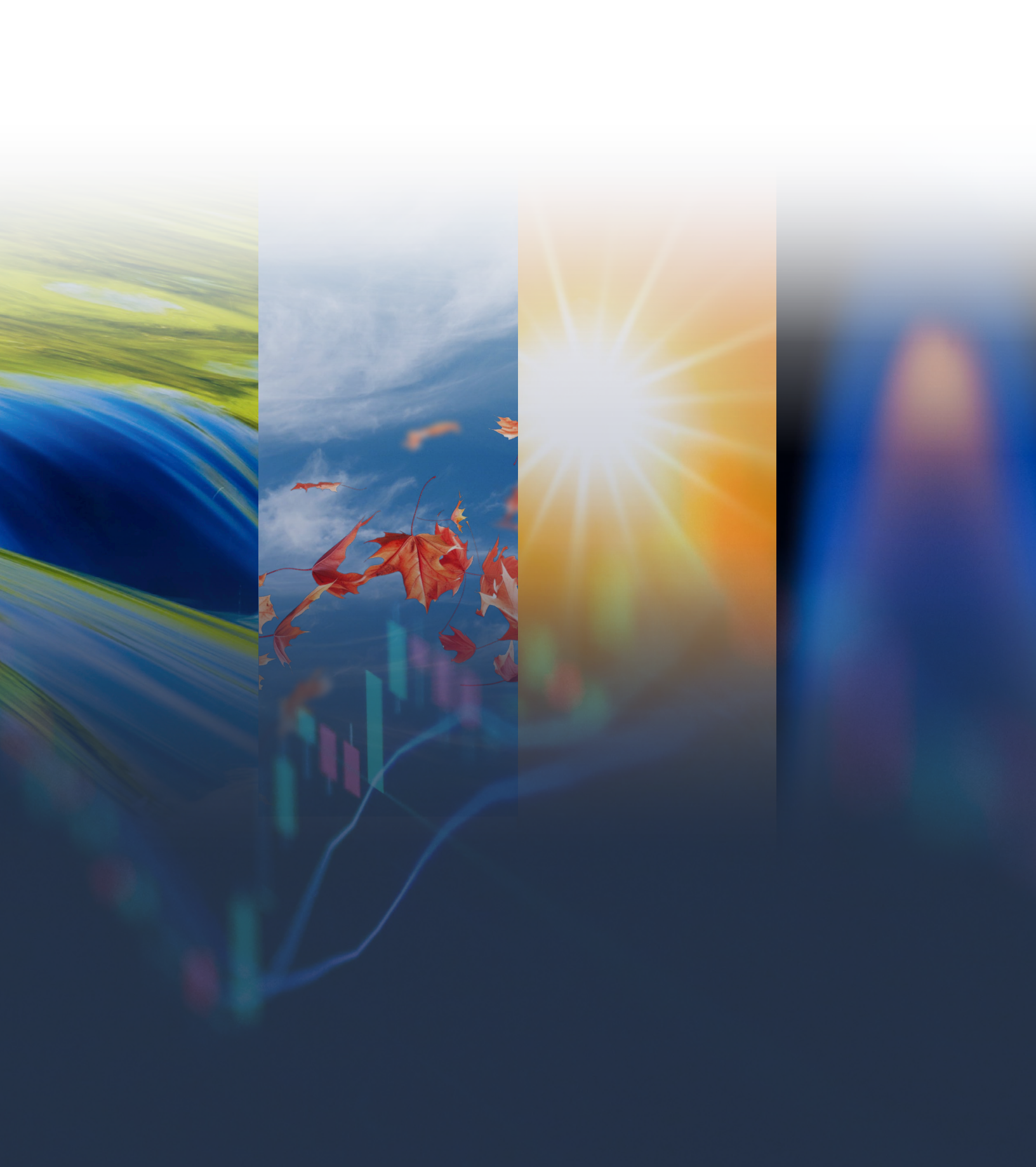


Figure B-8 Derived Priorities of Criteria Under Lifespan and Lifecycle Considerations





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