

LIGHTSPARK

Scaling Energy Modelling in Canada:

The AI Opportunity to Meet National Retrofit Targets

Validation of Statistical Prediction and Digital Audit Models Against 59,773 EnerGuide Audits

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Executive Summary

Canada's residential building stock accounts for a significant share of national greenhouse gas emissions, yet fewer than 6% of homes have undergone an energy audit. Physical EnerGuide audits — the current policy instrument — cost approximately \$600 per home and require several hours on-site, making national-scale deployment economically prohibitive.

Lightspark has developed two complementary machine-learning approaches that replicate EnerGuide results at a fraction of the cost and time:

- **Statistical Prediction** — an ML model driven by publicly available GIS and property data, validated against 44,093 EnerGuide audits across five cities and three climate zones, achieving a Mean Bias Error (MBE) of -3.6 GJ (-1.1% of EnerGuide value).
- **Digital Audit** — a short homeowner survey of fewer than 25 questions, validated against 15,680 simulated audit responses, achieving an MBE of 0.0 GJ (1.2% of EnerGuide value).

Key Finding: Lightspark's Digital Audit achieves 100% Absolute Accuracy and 97.5% Weighted Accuracy — outperforming published competitor benchmarks by a significant margin, while requiring substantially less time and homeowner effort.

1. The Policy Context: Why Scale Matters

1.1 Canada's Carbon Reduction Commitments

Canada has committed to reducing greenhouse gas emissions from residential buildings by 38% relative to 2005 levels by 2030 — equivalent to eliminating 17 megatonnes (MT) of CO₂e per year. As of 2019, residential emissions remained at 2005 levels, leaving the country approximately 11 years to close a gap that would require cutting roughly 1.5 MT per year.

The 2050 target is equally demanding: heat pumps should supply half of Canada's space heating needs, yet only 7% of homes used them as of 2023.

38%

Reduction in residential
GHG required by 2030

17 MT

CO₂e to be eliminated
annually

7%

Homes currently using
heat pumps

6%

Homes audited to date

1.2 The Scaling Problem

Physical audits alone cannot reach the required scale. Three structural barriers prevent meaningful deployment:

- **Missing Data:** Fewer than 6% of Canadian homes and less than 1% of U.S. homes have been audited. Only 240,000 retrofits were completed under the Canada Greener Homes Program — less than 1% of the 13.2 million homes that must be upgraded by 2050.
- **Cost:** Auditing 90% of the housing stock through traditional EnerGuide methods would cost an estimated \$13 billion in Canada and \$56 billion in the United States.
- **Consumer Experience:** The current homeowner conversion rate to government retrofit programs stands at just 0.37%, driven by complexity and a lack of personalised guidance.

To reach all 13.2 million homes by 2050, retrofits must accelerate to at least 460,000 homes per year — 3.5× the current rate. AI-driven digital modelling is the only practical mechanism to bridge this gap.

2. Lightspark's Approach: AI-Driven Energy Modelling

2.1 Theoretical Foundation

Lightspark applies predictive and prescriptive machine learning — the two most information-rich tiers of the analytics hierarchy — to residential energy modelling. Unlike traditional physics-based simulation tools such as HOT2000, which require exhaustive building surveys, ML models identify the high-information parameters that dominate energy consumption outcomes and derive accurate predictions from a compact set of inputs.

This approach draws on Information Theory principles: not all building details contribute equally to energy output. Lightspark's models are trained to locate and exploit the highest-signal variables — heating system efficiency and fuel type, interior floor area, air tightness, insulation levels, and window characteristics.

Lightspark follows the same Standard Operating Conditions as EnerGuide (occupancy patterns, thermostat setpoints), ensuring results are directly comparable to the federal benchmark.

2.2 The Two-Stage Modelling Pipeline

The Lightspark Residential Energy Model (REM) operates in two complementary stages, each building on the previous:

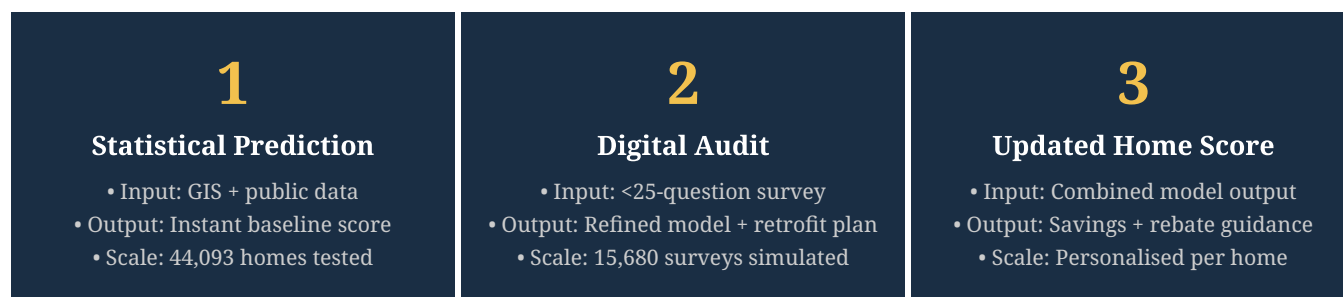


Figure 1 — Lightspark's three-stage energy modelling pipeline, from statistical baseline to personalised retrofit planning.

Stage 1: Statistical Prediction

Using publicly available and proprietary data sources, Lightspark generates a unique energy model for every residential property without any homeowner interaction:

- Home size is estimated using Geographic Information Systems (GIS), remote sensing data, and Lightspark's proprietary spatial modelling methods.
- Heating system efficiency and fuel type are statistically predicted from regional building stock distributions.
- Air tightness (ACH₅₀) is modelled from vintage and building type.
- Insulation values are derived via ML from sample EnerGuide data collected in each city.

The result is an instant baseline energy score for every home in a region — enabling municipalities, utilities, and program designers to identify high-consumption properties before any homeowner contact is made.

Stage 2: Digital Audit

The Digital Audit refines the statistical baseline using a short, visually engaging homeowner survey of fewer than 25 questions. Questions focus on the details most likely to differ from the statistical default — primarily heating equipment type, window specifications, and obvious insulation upgrades. Responses are mapped directly into the Lightspark REM, producing an updated energy score, a personalised list of retrofit recommendations, projected savings, and available rebates.

2.3 Method Comparison

Feature	EnerGuide Audit	Statistical Prediction	Digital Audit	Hybrid Advanced
Time to Results	Days–Weeks	Instant	~5 Minutes	10–15 Minutes
Homeowner Input	Minimal	None	Web survey	AI-guided collection
Site Visit	Yes (several hours)	No	No	Remote only
Cost	~\$600/home	Near zero	Near zero	Low
Scalability	Very low	National scale	National scale	High

Figure 2 — Comparative overview of audit approaches by time, cost, and scalability.

The Statistical Prediction and Digital Audit approaches are complementary: the former provides immediate, zero-touch coverage of an entire housing stock; the latter enables precise, actionable guidance at the household level once a homeowner is engaged.

3. Validation Methodology

3.1 Benchmark Standard

Validation follows a comparative approach consistent with the principles of ASHRAE Standard 140 (Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs). EnerGuide audit results serve as the known reference value against which Lightspark model outputs are compared. Because actual measured energy consumption is not available for all homes, the study uses the term 'difference' rather than 'error'.

The signed difference is defined as:

$$\text{Difference} = \text{Lightspark Model} - \text{EnerGuide Audit}$$

3.2 Test Coverage

Lightspark conducted validation across five Canadian cities spanning three distinct climate zones, ensuring the model generalises across Canada's diverse building stock and weather conditions. Two independent test sets were assembled:

- Statistical Prediction: 44,093 individual single-family dwellings with EnerGuide audits on record. GIS-based modelling was used to estimate home size; no homeowner-provided data was used.
- Digital Audit: 15,680 simulated homeowner survey responses, generated from actual EnerGuide audit records to replicate realistic, limited homeowner input. Homes were randomly selected, independent of the ML model development process, ensuring unbiased validation.

3.3 Statistical Metrics

A comprehensive suite of statistics characterises model performance, as simple averages can obscure the shape of the error distribution:

- MBE (Mean Bias Error) — average signed difference; indicates systematic over- or under-prediction.
- MAE (Mean Absolute Error) — average magnitude of difference regardless of direction.
- RMSE (Root-Mean-Square Error) — penalises large individual differences more heavily than MAE.
- NMBE / NMAE / NRMSE — normalised variants (divided by the data range $\times 100$) enabling cross-study comparison.
- AA (Absolute Accuracy) — defined as $100 - |\text{NMBE}|$; reflects freedom from systematic bias.
- WA (Weighted Accuracy) — defined as $100 - |\text{NRMSE}|$; reflects overall prediction reliability.

4. Results

4.1 Statistical Prediction Performance

Across all 44,093 homes tested, the Statistical Prediction produced a mean signed difference of -3.6 GJ relative to EnerGuide — equivalent to approximately -1.1% of the median EnerGuide value. The model tends to slightly underestimate energy consumption for the highest-consuming homes (-15% for homes above 161 GJ/yr) and slightly overestimate for the lowest-consuming homes (+10% for homes below 114 GJ/yr). The median difference across the full sample is -3% per year.

4.2 Digital Audit Performance

The Digital Audit score achieved a mean signed difference of 0.0 GJ — effectively zero systematic bias relative to EnerGuide. The median percentage difference is +1.16% per year, with tighter error bounds than the Statistical Prediction across all quantiles. For the highest-consuming homes (above 205 GJ/yr), the Digital Audit underestimates by approximately 3%; for the lowest-consuming homes (below 139 GJ/yr), it overestimates by approximately 4.5%.

4.3 Full Accuracy Statistics vs. Competitors

Metric	Lightspark SP	Competitor 1	Lightspark DA	Competitor 2
N	44,093	7,000	15,680	1,300
MBE (GJ)	-3.6	31	0.0	1
MAE (GJ)	28.9	44	12.1	16
RMSE (GJ)	40.7	61	18.4	30
NMBE (%)	-0.5%	4.5%	0.0%	0%
NMAE (%)	3.8%	6%	1.7%	4.5%
NRMSE (%)	5.4%	9%	2.5%	8%
Absolute Accuracy	99.5%	94%	100.0%	95.5%
Weighted Accuracy	94.6%	91%	97.5%	92%

Figure 4 — Full accuracy statistics comparing Lightspark models to published competitor benchmarks. SP = Statistical Prediction; DA = Digital Audit.

Lightspark's Digital Audit achieves an Absolute Accuracy of 100.0% and Weighted Accuracy of 97.5% — compared to 95.5% and 92.0% respectively for the best-performing competitor result, which used a smaller, single-region sample with trimmed mean reporting.

4.4 Competitor Benchmark Comparison

Competitor 1 (Statistical Prediction benchmark): Used housing authority-provided building details for fewer than 7,000 homes in a single region with a grey-box model. Their approach depends on data not widely available outside property tax assessment systems, limiting geographic scalability.

Competitor 2 (Digital Audit benchmark): Employed remote video-conferencing with trained energy advisors to collect home data — an approach that is labour-intensive, time-consuming, and prone to human error. Results were reported using a trimmed mean (retaining only 64–68% of data by excluding the largest errors), inflating apparent accuracy. On this same trimmed metric, Lightspark's Statistical Prediction is within 92% of EnerGuide (vs. 77% for Competitor 2), and the Digital Audit is within 96% (vs. 84%).

5. PCAF Data Quality Alignment

The Partnership for Carbon Accounting Financials (PCAF) Standard defines five data quality tiers for estimating financed building emissions. Lightspark's data architecture is designed to meet multiple PCAF scores, enabling banks and institutional lenders subject to OSFI B-15 climate risk disclosure requirements to use Lightspark data directly in their financed-emissions reporting.

Score	Option	Description	Lightspark Position
1	Option 1a: Actual emissions (metered + supplier factors)	Metered consumption with supplier-specific emission factors	Available in Phase 2 via Lightspark Engage energy bill ingestion
2	Option 1b: Actual emissions (metered + avg factors)	Metered consumption with average emission factors	Available in Phase 2 via digital audit / EnerGuide data ingestion
3	Option 2a: Floor area + energy label	EnerGuide-calibrated consumption estimates × emission factors	Current standard — Lightspark meets this score today
4	Option 2b: Floor area + statistical data	Location-specific statistical consumption per floor area	Met for remote regions with limited dwelling data
5	Option 3: Per-building statistical data	Aggregate dwelling count + climate zone for coarse GHG estimate	Available when building-level details are unavailable

Figure 5 — Lightspark's PCAF data quality coverage map. The platform currently delivers Score 3 data for all properties and is on a roadmap to deliver Score 1 and 2 data via Phase 2 Engage Platform enhancements.

6. Conclusions

6.1 Summary of Findings

Lightspark has demonstrated that machine learning can replicate EnerGuide audit results at national scale with a level of accuracy that exceeds published competitor benchmarks. Key findings:

- The Statistical Prediction model covers 44,000+ homes instantly, using only publicly available data, with a mean bias of -1.1% relative to EnerGuide.
- The Digital Audit model achieves effectively zero mean bias (0.0 GJ) using a simple homeowner survey, with an Absolute Accuracy of 100%.
- Both methods substantially outperform published competitor benchmarks on every statistical metric, using larger and more geographically diverse test sets.
- The Digital Audit's 5-minute survey format maintains homeowner engagement — a critical factor given the current 0.37% program conversion rate.

6.2 Implications for Canadian Policy

Lightspark's approach addresses all three barriers identified in Section 1: data scarcity (statistical prediction covers 100% of homes immediately), cost (near-zero marginal cost per property vs. \$600 for a physical audit), and consumer engagement (visual, personalised interface with instant results).

Deployed at national scale via the Lightspark Engage Platform and Carbon Navigator, this infrastructure can support the 460,000 retrofits per year required to meet Canada's 2050 targets — and provide the data quality necessary for institutional lenders to report financed emissions in compliance with OSFI B-15 and PCAF standards.

The technology to meet Canada's 2030 and 2050 retrofit targets exists today. What remains is the policy and institutional infrastructure to deploy it at scale.

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