Backcasting: A Retrospective Impact Assessment of Canada's R-2000 Initiative

Kevin Monte de Ramos, KMDR Research, Toronto, ON, CANADA
Bruce Williams, Evtrex, Toronto, ON, CANADA

Abstract

KMDR Research was contracted by Natural Resources Canada (NRCAN) to conduct a retrospective impact assessment of the R-2000 Standard across the residential sector. The study focused on energy efficiency improvements to new homes achieved through the application of construction techniques, products, energy systems, software (hot2000), and other measures introduced as part of evolving R-2000 performance standard.

The assessment involved a non-experimental research design that leveraged a series of deep interviews with industry stakeholders and on-line market actor surveys to establish performance estimates. Through structured equation modeling and backcasting, we were able to report the historical impact of the R-2000 Standard on the residential construction market.

Subject matter experts (SMEs) served as oracles to inform us on the development and evolution of the R-2000 Standard; from its introduction in 1982 through present-day construction practices. We identified two key focus group. The first consisted of SMEs from the certified building community and the other consisting of home energy advisors.

For the 5.8 million Canadian housing starts over a 30 year period, the realized energy savings equated to 572 PJ. Industry experts weighted each factor in a confidential survey. The responses suggest that the R-2000 program drove 22% of the 572 PJ of energy efficiency realized over the past 30 years. Our study attributed energy savings of 126 PJ to NRCAN’s R-2000 initiative. The cumulative impact will continue to grow at a rate of 22 PJ/year, plus an additional 0.5 PJ per million of newly constructed homes across Canada.

Methodological Nomenclature

Market transformational programming requires special analytical techniques to quantify persistent long-term market impacts from other short-lived market effects. This section identifies key terminology and concepts used by KMDR Research in the study of historical impacts resulting from codes and standards implementation.

> **Market Impediments:** The combination of market hurdles and market barriers, which inhibit the adoption of desired behaviors by relevant market actors.
>
> **Market Hurdles:** Temporary obstacles that discourage actor adoption of desired behaviors; generally, hurdles are associated with the purchasing decision and are overcome through the use of incentives. Hurdles are addressed by resource acquisition programs.
>
> **Market Barriers:** Persistent obstacles that prevent actor adoption of desired behaviors; generally, barriers are associated with the market structure and require systemic changes in business operations and/or processes. Barriers are addressed by market transformational programs.

CSB Construct™: A framework used by KMDR Research to plan and evaluate market-oriented or behavioral change-based initiatives. The premise of the construct is that market actor Cognition must be supported by the current market Structure in order for desired Behaviors to materialize.

Backcasting: A regression technique that extends time series observations beyond the date of the first observation in the dataset. This is analogous to forecasting; except that the trends are projected back in time, not forward in time.

Structural Equation Modeling: An analytical technique used to confirm and explore causal relations using a combination of statistical data and qualitative causal assumptions.

DELPHI Method: An iterative interview technique that leverages a panel of subject matter experts to estimate an impact or to forecast likely outcomes. Quantitative estimates are formed through a consensus estimate.

Attribution Pathway: A visual representation of causal attribution; represented as a series of testable hypotheses used to assign cause to effect.

Triangulation of Findings: The use of three or more measurements to monitor a particular performance metric or to quantify a point estimate within a complex multivariate assessment.

Program Description

In 1982, the Government of Canada officially launched the R-2000 program. R-2000 is operated by Natural Resources Canada (NRCAN), the Office of Energy Efficiency. Participation in the program is voluntary. In short, the R-2000 program promotes the use of cost-effective energy-efficient building practices and technologies for new dwellings to meet a published R-2000 Performance Standard. Builders who opt into the program and adhere to the voluntary performance standard are able to label their properties as R-2000 certified. A network of home energy advisors review new home designs, assess savings opportunities, and verify builder compliance using the HOT2000 modeling software. Since program inception, over 400 builders have been trained for the R-2000 Program and 14,000 homes have received the R-2000 label across Canada.

The R-2000 Program establishes and updates an energy performance standard that exceeds building requirements. A computer-based energy analysis tool was provided to a network of builders and service providers trained in energy–efficient building practices. A close collaboration with the home building industry distinguished R-2000 from other initiatives. The R-2000 Standard also concerned itself with indoor air quality and promoted the use of environmentally-friendly products via ‘pick lists’ offered to builders.

Ongoing research, feedback from program participants, and contributions from the housing industry associations have informed revisions to the R-2000 Standard; such that, innovation in energy-efficient housing has been encouraged over the tenure of the program. NRCAN released an update of the R-2000 Standard in 2012, which “… increases the energy efficiency requirement for R-2000 homes by an impressive 50%”.

R-2000 publications were thought to inform building codes and housing sector practices; promoting the most energy efficient technologies available. It was also thought the R-2000 program established a competitive advantage for builders who associated energy efficiency with high quality construction. Lastly, the R-2000 program was thought to establish a market niche for supporting technologies that would overtime disrupt current building practices; moving the industry to build increasingly energy efficient homes.

Analytical Approach

Outcome assessments are relatively new to the energy industry. With recent attempts to specify market transformational impacts, the approach has gained some attention along with studies employing the Delphi Method (Gordon 1994). These types of studies have received regulatory support and have led market transformational claims across energy efficiency portfolios.

While the original intent was to build a fully integrated and cohesive study using a Delphi approach to build consensus on the value of the R2000 program over several iterations, the scope of this analysis has been abbreviated significantly to address budgetary constraints. Nevertheless, many of the interactive aspects of this type of 'back-casting' approach have been thoughtfully adopted.

The project consisted of four stages, as well as a series of on-going administrative activities. These administrative activities consisted of conference calls with program and department staff. Among the planned activities was the administration of data and management of document requests related to the R-2000 Standard.

- Phase I consisted of a document review and departmental interviews. Planned activities consisted of the following: a review of the evolving R-2000 Standards, a review of available reports on the R-2000 program, meetings with R-2000 internal stakeholders, a facilitated discussion of anticipated programmatic outcomes, and an exploration of advancements in building technologies, construction practices, and home diagnostics.

- Phase II consisted of focus groups with subject matter experts. Our role was to define the scope of SMEs needed; namely, housing developers, energy advisors, key trades, and related associations. We then defined a sample frame consisting of a broader group SMEs for a survey.

  To prepare documentation and questions for the SMEs, NRCAN's Demand Policy and Analysis Division provided us data on the residential housing sector; namely, energy intensities for Canadian homes, home energy use statistics, trends in technology adoption, a history of building practices/standards, and documentation regarding the evolution of codes along with the R-2000 Standard. The interviews were analyzed and the findings summarized and presented to NRCAN.

- Phase III consisted of an electronic survey distributed to stakeholders with Part 9 housing.

- Phase IV consisted of a report and its presentation to NRCAN.

Expert opinions were solicited in five sequential iterations between February and April, 2013. The participants were highly engaged (every session went over its allotted time and the survey had a participation rate of nearly 50%).

Each interaction was designed to build on ideas presented by the previous cohort. As such, long-tenured internal experts identified programmatic drivers and shared perspectives that were improved upon by external experts and authorities. Focus Groups of home builders and Energy Advisors from across the country fine-tuned several hypotheses, identified key market drivers, and illustrated which R-2000 program mechanisms improved energy efficiency (at least anecdotally).

This input was used to create a chained attribution model (Iverson 2003) to map key drivers of energy efficiency. An electronic survey was created to validate these results and measure key metrics needed in a quantification of historical program benefits.

It should be noted that the responses were solicited from builders and other stakeholders who generally had evidenced a high level of commitment to the R-2000 initiative and/or energy efficiency. Given the scope of the study, this may lead to an unavoidable bias within individual responses.

This was considered an acceptable risk. By involving a range of stakeholders from various perspectives, including tenure with the program, we expect the biases to be self-limiting. Individual perspectives and stakeholder loyalty to the program's principles are expected to balance the feedback offered. The following highlights the stakeholders contacted for the study: internal stakeholder interviews, R-2000 accredited builder focus groups (x2), energy service provider focus groups (x2), and an interview with a training director.

This is consistent with DELPHI approaches that interpret a range of influences and interconnections. These interviews require individuals with extensive knowledge acquired over a protracted period of involvement. Through an iteration of responses, we expect a consensus to form around a conservative consensus estimate.

Constraints and Limitations

NRCAN had both budget and time constraints due to the fiscal year-end and timings related to subsequent reporting, which constrained our investigations. The following paragraphs seek to introduce these constraints and the compromises embedded in our selected approach.

> **Budget Constraint.** The budget allocation of NRCAN required us to be judicious in our selection of research methods to ensure the appropriate number of SMEs could be consulted. The length of the proposed interviews were sufficient to explore the full range of anticipated outcomes and structured to inform survey activities.
>
> **Time Constraint.** Perhaps the single largest time commitment for the assessment was the identification and solicitation of industry experts. Finding time to coordinate schedules with industry professionals can be a challenge. NRCAN helped to secure participation of SMEs in our research effort. Our approach required NRCAN to introduce us to and provide contact information for R-2000 certified builders, codes/standards professionals, energy advisors, and key trades/associations. This was necessary to avoid delays that had the potential to jeopardize the project.
>
> **Scope of Inquiry.** The outcome assessment sought by NRCAN explored the historical impact of R-2000 across several decades. We understood that it would be difficult to find individuals with 30+ years of experience. SMEs contacted through this research effort had to capture both historic and current perspectives related to R-2000. Our approach was to invite respondents who joined R-2000 in differing decades to account appropriately for aspects of the program that evolved over time.

Key Findings from the Study

A feature of the analytical approach is the triangulation of key findings. This is exhibited in the assessment of historic home energy use. We first looked at the evolution of energy intensities of the reference 2000 sq. ft. single family home. A second measure was the estimated improvement of energy efficiency for new dwellings by industry stakeholders. The third measure was to look at observed home energy use as an indicator in the advancement of building practices. By examining the congruency between these independent estimates, an indication of accuracy is provided; even amidst the inherent imprecision of broad market measurements in relation to a specific reference housing type.

Evolution of Energy Intensities by Dwelling Type

Historic energy intensities for residential buildings document the amount of energy utilized per square foot of housing; normalized for weather and climate and segmented by housing type. The values were expressed in GJ/square foot and GJ/square meter.

There was gradual improvement in energy intensities across all housing types; excepting row homes and low rise apartments. The single family homes had an energy intensity of ~.093 GJ/sq. ft. in the 1970s and improves to ~.072 GJ/sq. ft. by the 2000s. Similar trends are seen in the other housing types; however, low rise apartments are an exception. Low rise apartment energy intensities began at ~.47GJ/sq. ft. and rose to ~.051 GJ/sq. ft. These results are shown in TABLE 1 that follows.[1]

TABLE 1: **Energy Intensities by Dwelling Type (GJ/sq. ft.) by Decade**

Year	*Mobile Homes*	*Single Family*	*High Rise Apt*	*Row Home*	*Low Rise Apt*
1970 – 1979	0.114694316	0.093040913	0.046852096	0.072700593	0.047487338
1980 – 1989	0.079408172	0.079542155	0.041273645	0.065108934	0.046595259
1990 – 1999	0.092807455	0.081412176	0.038874376	0.069608136	0.059819605
2000 – 2007	0.069993708	0.072398885	0.039996687	0.065543076	0.051586418
	Percent Change in Energy Intensity				
1970s to 2000s	-39%	-22%	-15%	-10%	9%
1980s to 2000s	-12%	-9%	-3%	1%	11%
1990s to 2000s	-25%	-11%	3%	-6%	-14%
	Annualized Rate of Improvement via a Linear Regression				
Slope (ΔGJ/sq. ft.)	-.00121	-.00060	-.00023	-.00017	-.00026
Slope (Δ%/year)	-1.05%	-0.65%	-0.49%	-0.23%	-0.54%
Slope (ΔGJ/year)	-2.4 GJ/year	-1.2 GJ/year	-0.46 GJ/year	-0.34 GJ/year	-0.52 GJ/year

Using the energy intensities reported for each decade, we were able to regress changes in energy intensities to a linear estimate. The slope of the line represents the annualized improvement in the energy intensity of single family homes; namely -.00060 GJ/sq. ft. per year. Multiplying the slope by the assumed 2000 square feet of our reference home, the annualized improvement is -1.2 GJ/year (highlighted at the bottom of TABLE 1).

Energy Efficiency Improvements for New Dwellings

When industry leaders in new home construction were asked to estimate the energy efficiency of new homes from past decades to current building practices, respondents reported the energy efficiency of a home in the 1980s was 49% less efficient than today's home; the home of the 1990s 37%; and the home of the 2000s 21%. Regressing these three estimates, the annualized improvement in home energy efficiency was 1.46% per year. This data is shown in TABLE 2.

[1] Data was provided by Natural Resources Canada (NRCan) through a custom query ran April 16, 2013 on the Canadian Socioeconmic Database (CANSIM) and Canadian Mortgage and Housing Corporation (CMHC) - Table 027-0009 of 7505.

TABLE 2: Estimates of Energy Efficiencies for New Dwellings

Year	Count	Mode	Average
1980s	27	40%	49%
1990s	27	30%	37%
2000s	28	20%	21%
	Annualized Rate of Improvement via a Linear Regression		
Slope (Δ%/year)			-1.26 %/year
Slope (ΔGJ/year)	2000 * 0.093 * -1.26%		-2.35 GJ/year

This number is higher than the annualized improvement in energy intensities. Energy intensities represent how much energy is used; whereas, energy efficiency is a comparative performance ratio normalized for output.

For example, an addition to an existing home may result in zonal heating units to be installed to condition the additional square footage. These systems will almost certainly add to the amount of energy consumed by the household. The energy intensity would be changed by the incremental energy used divided by the added square footage; while the energy efficiency would be impacted by the amount of energy required to produce the desired level of heating requirements. In this case, the zonal heat may be resistive in nature; thereby, the space heating efficiencies nears 100% vs. 85% efficiency of the central heating unit used for the rest of the house. Despite this efficiency improvement, the energy intensity of the home could rise if the housing addition is heavily used by the occupants and the insulation is such that ratio of energy used to condition the added space is greater than that of the home prior to the renovation.

For clarity, it is worth restating that energy intensities for the reference single family home improved by -0.65 %/year representing -1.2 GJ/year. Energy efficiency on the other hand improved by -1.26 %/year, representing an annualized improvement of -2.35 GJ/year.[2]

Trends in Home Energy Use

Given the anticipated difference between the change energy intensities versus energy efficiency, a third measurement of energy improvement was considered. We asked the same industry leaders about the impact of R-2000 on Canadian building performance standards. An overwhelming consensus formed with 95% of respondents agreeing that R-2000 had a large influence on building practices and 92% of respondents agreeing that R-2000 educated the industry on home energy performance.

The hot2000 software program was indicated as a valuable tool used to inform energy policy; providing legislators and regulators with the means to estimate energy impacts of legislative options for new home construction. When asked about the net impact of hot2000 and derivative modeling tools, respondents suggested that home energy performance was advanced by 21 years. Absent R-2000's hot2000 software, experts implied that Canada would be building homes equivalent in energy performance to homes of the early 1990s.

A literature search was conducted to estimate the energy use of homes from 1990s. The Canadian socioeconomic database from Statistics Canada (CANSIM) indicated an approximate 9.9 million households used 1,193,833 terajoules of energy. This represents an average home energy consumption of 121 GJ/year in the early 1990s.

[2] TABLE 2 has been corrected since the original report was filed with NRCAN to show the fitted annualized growth rate of -1.26% (-2.35 GJ/year) versus the rate of -1.46% (-2.72GJ/year). This was an isolated error in TABLE 2 and did not propagate into the calculation of energy savings reported to Natural Resources Canada.

Compare this with the 2006 CANSIM data that reports 12.4 million households using 1,235,758 terajoules of energy; namely, an average home energy use of 99 GJ/year.[3] The slope between the energy consumption per home in the mid-2000s and mid-1990s is 99 GJ/year minus 121 GJ/year reported as a percentage of the 1990 home. The resulting annualized rate of improvement was -1.14% year. Backcasting this to the 1970s reference home, the annualized rate of improvement becomes -2.12 GJ/year.

TABLE 3: Trends in Home Energy Use

Decade of Interest	Number of Households	Total Energy Consumption (TJ)	Energy Use per Home (GJ/year)
1990s	9.9 million	1,193,833	121
2000s	12.4 million	1,235,758	99
	Annualized Rate of Improvement via a Linear Regression		
Slope (Δ%/year)			-1.14 %/year
Slope (ΔGJ/year)	-1.14% * 0.093 * 2000		-2.12 GJ/year

Market Changes Alter Residential Energy Consumption

Energy consumption per household and energy intensity are not only influenced by energy efficiency, but also by market factors; most notably, fewer persons living in bigger homes with a greater number of electronic devices used by occupants. "Between 1990 and 2009, the population grew 22 percent (6.0 million people) and the number of households increased 36 percent (3.5 million). The rise in the number of households, combined with increased average living space and higher penetration rate of appliances, contributed to the increase of 11 percent, or 140.2 PJ, in residential energy consumption, from 1,282.1 PJ to 1,422.3 PJ."[4]

TABLE 4: Residential Energy Consumption

Year	Number of Households	Total Energy Consumption (PJ)	Energy Use per Home (GJ/year)
1990	9.9 million	1,282.1	130
2009	13.4 million	1,422.3	106
	Annualized Rate of Improvement		
Slope (Δ%/year)			-1.0 %/year
Slope (ΔGJ/year)	-24 / 20		-1.2 GJ/year

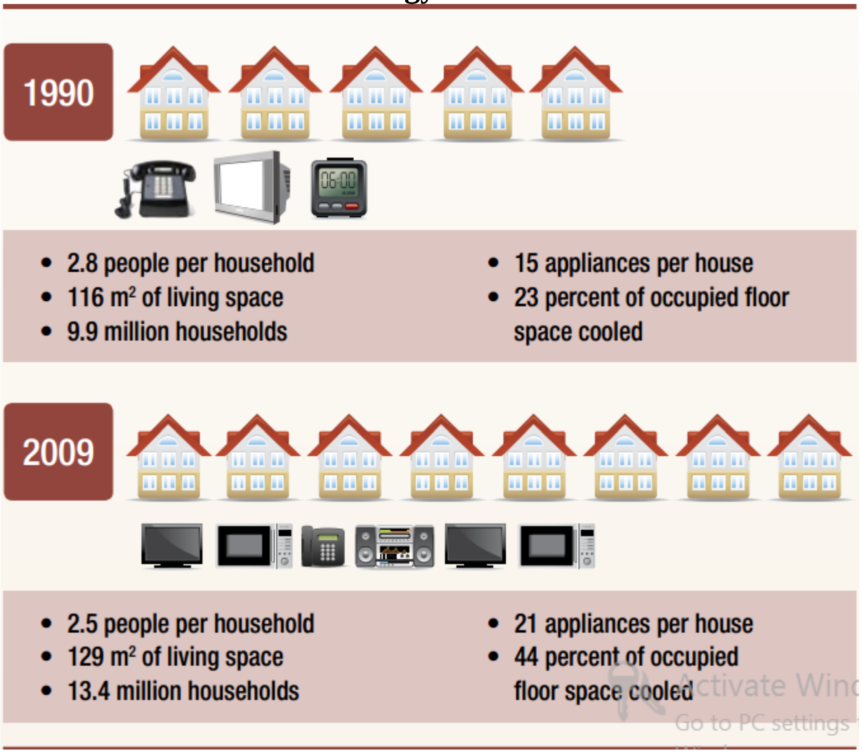
Improvements in residential energy use can be stated as moving from 130 GJ/year in 1990 to 106 GJ/year in 2009; namely, an annualized improvement of -1.2 GJ/year or an annualized improvement of -1.0%/year.

[3] CANSIM - 153-0032 - Energy use, by sector
[4] Official publication of Natural Resources Canada, "Energy Efficiency Trends in Canada 1990 to 2009", Cat. No. M141-1/2009 (Print), December 2009, pages 12-13.

Overview of Results by Method

The slope, -1.2 GJ/year in TABLE 4 is the same as was calculated for our 2000 square foot reference home in TABLE 1. This improvement was seen despite the tendency for Canadians to have fewer occupants with a greater number of electronic appliances living in larger homes with a higher proportion of living space being cooled. This can be contextualized by the following graphic offered by Natural Resources Canada.

FIGURE 1: Residential Energy Indicators 1990 - 2009



NRCan Cat. No. M141-1/2009E-PDF, page 13

Homes of the 1970s would pre-date computers, cordless telephones, and other small appliances common in 1990s. Similarly, the penetration rates of small appliances continued to rise following the 1990s. As such, changes in energy intensity do not represent changes in energy efficiency of homes. While energy intensities changed by 18% between 1990 and 2009, energy efficiency changed by 37% over the same period.[5] This is a ratio of 1:2.

This ratio is used to convert energy intensity improvements to energy efficiency improvements (see TABLE 5). It is important to note that homes of the 1970s and 1980s would have no computer devices; most of these homes would not have a microwave; and only a few would have multiple television sets. As such, using the ratio from the 1990s forward provides for a conservative estimate of improved energy efficiency.

[5] Ibid, page 17.

TABLE 5: Improvement in Energy Efficiency of Canadian Homes

Description	Calculated	Adjustment	Corrected
Energy Intensities of Single Families Homes	-1.2 GJ/year	2x	-2.4 GJ/year
Estimates of Efficiency Improvements for New Dwellings	-2.35 GJ/year	None	-2.35 GJ/year
Trends in Residential Energy Use	-2.1 GJ/year	None[6]	-2.1 GJ/year
	Mean Consensus Estimate		
Rate of Energy Efficiency Improvement(GJ/year)			-2.29 GJ/year

The three estimates of annualized rates of home energy efficiency are similar. While the three differing metrics highlight long-term energy efficiency improvements from varied approaches, they nonetheless offer insight to housing trends and remain comparable.

The first method looked at energy intensities across Canada's housing stock and then normalized to a 2000 square foot single family home. This housing type and size represents Canada's predominant housing archetype. When the energy intensities are corrected by the Delphi Panelists' estimate of overall efficiency improvement, we are able to compare the reported energy efficiency gains in the Canadian housing market by simulating the addition of increasingly energy efficient dwellings to the housing mix across the last three decades.

Because the majority of energy efficiency gains are realized in the single family home (larger efficiency gains in mobile homes and lower efficiency gains in multi-family dwellings is offset by the smaller market presence of these housing types), we are able compare reported energy efficiency gains from the addition of new homes to the housing mix with trends in residential energy use.

This last measure looks at the home as a system; thereby, embedding efficiency improvements in household appliances, HVAC systems, and structural elements of the building. Since deep retrofits to the existing housing structure are relatively rare, the majority of the energy efficiency gains from structural improvements in the building envelop and HVAC systems of new homes. This leaves the incremental efficiency gains of home appliances as the principal component for variance between the three measures of improved efficiency. Since home appliance penetration rates impact both existing and newly constructed homes, when coupled with incremental gains in energy efficiency, the variance between the estimates are manageable.

Understanding that triangulation of market metrics is less of an engineering exercise than a socioeconomic comparison, we are comfortable with the accuracy of the findings despite their inherent imprecision. This gives us confidence that the house as a system demonstrated improved energy efficiencies from the 1980s forward. The estimated annual improvement in home energy use is 2.29 GJ/year per household constructed.

Energy Savings Realized

TABLE 6 seeks to estimate the market savings realized from improved home design and construction practices.

[6] Although annualized rate of improvement uses energy intensities to arrive at -2.1 GJ/year, no adjustment is used because the consensus estimate was in the context of the house as a system; thereby, behavioral and demographic factors were normalized in the responses offered by our experts.

TABLE 6: Market Energy Savings by Decade

Decade of Construction	Average Age of Home	Rate of Improvement	Housing Starts[7]	Additional Savings (PJ)[8]	Realized Savings[9]
1970 – 1979	39	-2.29 GJ/year[10]	2,339,846	-209 PJ	
1980 – 1989	28		1,809,520	-116 PJ	-572 PJ
1990 – 1999	18		1,485,691	-61 PJ	
2000 – 2009	8		2,012,633	-37 PJ	
2010 – 2012	1		598,707	-1 PJ	

For each decade of construction, CANSIS provided the number of housing starts. These housing starts represent the number of homes that could be impacted by advances in building practices. Multiplying the number of housing starts by the average rate of improved energy efficiency by the average age of these homes, the observed market savings is calculated. Summing the market savings for each decade provides the savings realized in the new home construction market over the past 30+ years. Summing market savings from the 1980s through 2012, we arrive at the technical potential for the R-2000 Standard.

During our discussions, we referred to this number (-572 PJ) as 'the size of pie'; namely, the observed efficiency improvement achieved by the entire Canadian housing market. Yet to be calculated was the 'slice of the pie' associated with the R-2000 Standard.

Factors Leading to the Observed Efficiency Improvement

To begin assessing the historical impact of R-2000 in the marketplace, we asked subject matter experts to weight four factors developed through our focus groups. Moreover we asked them to suggest other contributing factors as necessary. The responses were summarized as follows in TABLE 7 which includes, next to the four predefined factors, building/trade advocacy as the primary other factor thought to drive the construction of energy efficient housing.

TABLE 7: (Q4) Factors Contributing to Improved Energy Efficiency

Contributing Factor	*Mode*	Wt. Mean
1. Building Codes and Standards	***25%***	**26%**
2. Federal Labeling Programs	***25%***	**26%**
3. Consumer Concern over Energy Prices	***20%***	**19%**
4. Lower Price for Leading Technologies	***10%***	**15%**
5. Others: Builder/Trade Advocacy	***20%***	**14%**
Totals	***100%***	***100%***

[7] As reported by CANSIM

[8] Market savings is the product of housing starts times annual improvements times the average age of the home. The result is then converted from GJ to PJ; whereby, 1 PJ = 1,000,000 GJ.

[9] This represents the energy efficiency gains observed after R-2000 was introduced to the Canadian housing market plus the energy savings realized from prior years. This does not mean that R-2000 can be attributed the entire observed effect, rather the 572 PJ represents the 'size of the pie'. The remaining sections seek to attribute a portion of the 572 PJ savings effect to the R-2000 program.

[10] Worth mentioning here is that this annualized improvement is an average of three differing methods to estimate the average energy efficiency improvement across all decades. No effort is made in our calculations to estimate the savings for a given decade with that of another decade. The chosen method seeks only to represent the average long-term energy efficiency gains of the entire market.

Respondents were asked a series of questions to which their responses were tabulated. The tabulated results were then summarized and weighted to assess the impact of R-2000 on each of these contributing factors. These weighted contributions are highlighted in TABLE 8.

TABLE 8: Contribution of R-2000 to each Factor

(QID) Survey Result	*Building Codes and Standards*	*Federal Labeling Programs*	*Consumer Concern over Energy Prices*	*Lower Price for Leading Tech-nologies*	*Other Factors: Builder Advocacy*
(Q5) 61% of respondents believe that R-2000 had a significant impact	*.61*				
(Q7) 81% of homes thought to have benefited from the R-2000 program	*.81*			*.81*	*.81*
(Q7) Zero respondents believed there has been no impact to homes beyond those certified under R-2000	*1.0*	*1.0*			*1.0*
(Q8) 72% of respondents credit R-2000 as a place for technical and informational sources regarding new home construction					*.72*
(Q8) 92% confirm that R-2000 catalyzed advances in building science; the program was a great companion to other active areas of building science research. "It tied it all together" -- See Q9 for additional support	*.92*	*.92*		*.92*	
(Q8) 92% confirm that R-2000 standards and training courses have documented many of the lessons learned and offered them to the industry as guides to energy efficient housing construction.		*.92*		*.92*	
(Q8) 64% believe that without R-2000, there would have been no comprehensive and centralized documentation of energy efficient building practices		*.64*			
(Q8) 72% of respondents credit R-2000 as a place for technical and informational sources regarding new home construction					*.72*
(Q8) 33% acknowledge that R-2000 was one of many entities tracking building science advancements; there were plenty of other places to go for similar information			*.33*		
(Q8) 25% Regardless of R-2000, the industry was always active in documenting better and more energy efficient building practices			*.25*		
(Q9) Respondents weight R-2000 with 52% of technological advancements that have since been adopted in home construction nationwide				*.52*	
(Q10) 92% said R-2000 led to better quality and longer-lasting homes		*.92*	*.92*		*.92*
(Q10) 89% say that R-2000 brought innovative technologies to builders -- other responses within Q10 support this statement		*.89*		*.89*	
(Q10) 59% expect that R-2000 lowered prices for emergent technologies				*.59*	
(Q10) 51% believe that it improved the resale value of homes			*.51*		
(Q10) 92% feel that it enabled Canadians to save energy			*.92*		
(Q10) 92% state that R-2000 mechanisms educated the industry on energy performance			*.92*		
(Q10) 59% believe that R-2000 mechanisms embedded energy efficient appliance into new homes		*.59*			
(Q10) 95% credit R-2000 for raising Canadian Performance standards	*.95*				
(Q11) 53% weight given by respondents to factors thought to drive builder adoption of R-2000 standards					*.53*
(Q11) 84% claim that builders adopt R-2000 standards to improve homeowner comfort			*.84*		
(Q11) 65% say that R-2000 reduced energy bills for homeowners			*.65*		
(Q11) 80% feel that R-2000 accreditation raises the visibility of the builder and led to a better quality home		*.80*			

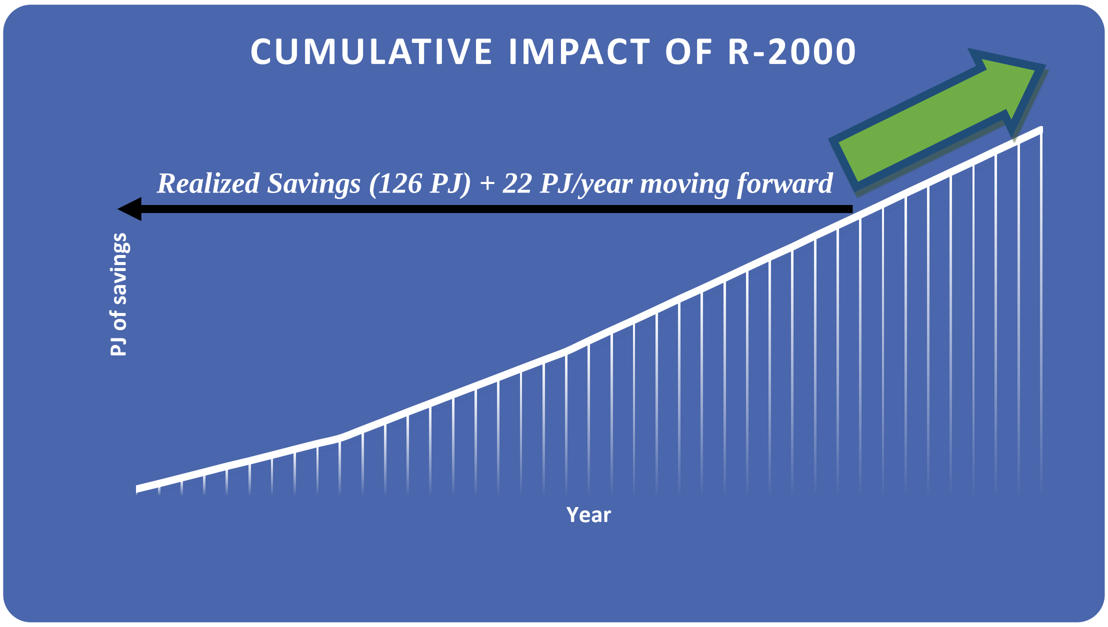
(QID) Survey Result	Building Codes and Standards	Federal Labeling Programs	Consumer Concern over Energy Prices	Lower Price for Leading Tech-nologies	Other Factors: Builder Advocacy
R-2000 Contribution	.43	.21	.02	.19	.20
Factor Weight	.26	.26	.19	.15	.15
R-2000 Factor Weight	.11	.05	.00	.03	.03
R-2000 Weight			.22		

The takeaway from TABLE8 is that R-2000 accounts for 22% of energy efficiency improvements in the new home construction market since the early 1980s. This aligns well with an evaluation of indirect effects by (NRCAN 1996) that said, *"On average, we estimate that about 27% of the energy saved through such improvements to conventional housing [influence on the development of building codes, technologies, and practices] during 1981-1995 can be attributed to this program [R-2000]."*[11]

Market Impact of the R-2000 Standard

The calculation of the overall market impact is a simple calculation, pulling data from TABLE 5 and TABLE 7. The following calculation states the market impact related to R-2000's influence on the housing and construction market; namely, -572 PJ x .22 = -126 PJ across 5.8 million new housing starts over 32 years. The cumulative impact will continue to grow at a rate of 22 PJ/year, plus an additional 0.5 PJ per million of new homes constructed. FIGURE 2 illustrates the cumulative impact realized from R-2000 moving forward from the 1980s through 2012. It also implies, via the green arrow, the perpetual nature of the realized market transformational effect.

FIGURE 2: Cumulative Energy Savings Resulting from R-2000



[11] Audit and Evaluation Branch of Natural Resources Canada, "Evaluation of the R-2000 of Natural Resources Canada", Summary Report PE 220/1996, February 1996, page 5. A report that appears to have been influenced by a detailed investigation commissioned by the Audit and Evaluation Branch in September 1995 conducted by the ARA Consulting Group, Inc.

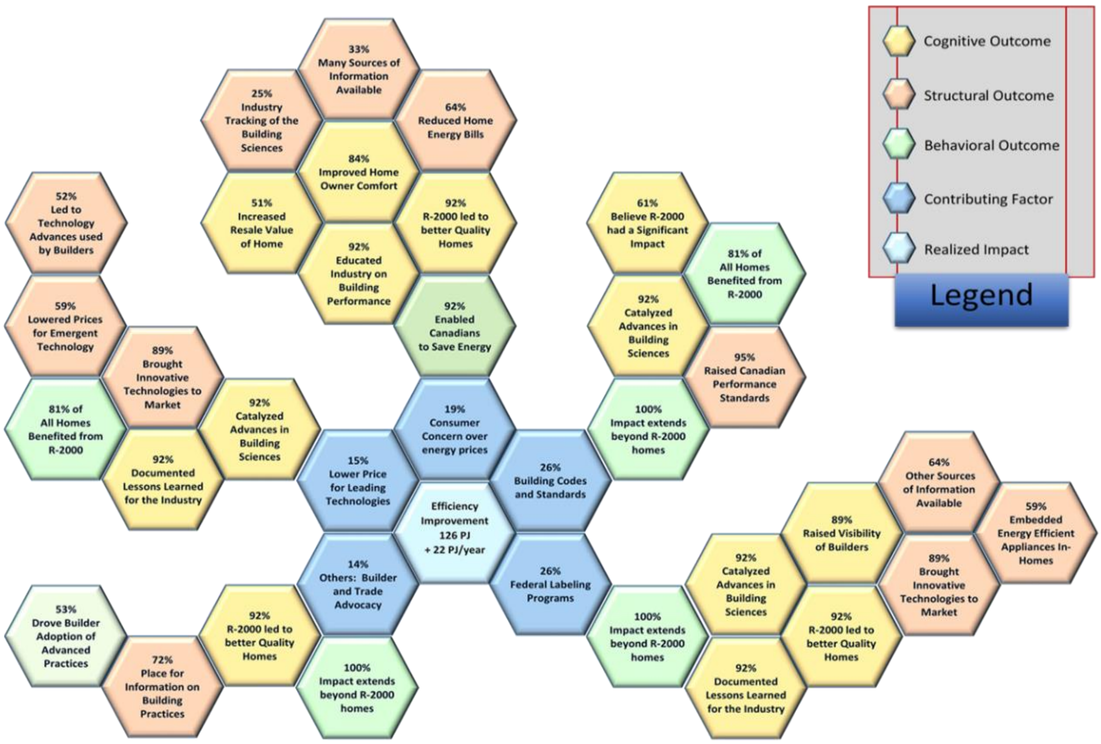
Conclusions about the Methodology

The study of market transformational programming poses many challenges to researchers tasked with quantifying the impact of a single or on-going intervention in the general market. The market has many factors, which can impact individual market actors differently. Noting the cause to any single impact can never yield a precise estimate of the effect; KMDR Research offers this study as evidence that market transformational impacts can be estimated by triangulating the measurement of key market indicators around the impact to be quantified.

Program administrators had a reasonable expectation that their interventions would alter market structure and drive the cognitive processes of key market actors. KMDR Research used the *CSB Construct™* to model how the observed behaviors and realized impacts could be caused by the achievement of anticipated cognitive and structural outcomes.

The attribution pathway was identified using a series interviews with industry subject matter experts. The DELPHI method, whereby a sample of convenient and available individuals with a rare set of competencies are assembled to offer expert opinion, can offer insights into evolution of the new housing market and provide informed estimates on the influence of driving market factors. Once weighted, techniques associated with structural equation modeling can be used to estimate the program impact, even amidst a broad set of market influences. The attribution pathway for the historical impact of the R-2000 program is shown in FIGURE 3.

FIGURE 3: Attribution Pathway for the R-2000 Program



When challenged with this retrospective impact assessment that extended over a 30-year period, we knew experts from each decade (from the 1980s forward) would need to be identified. Luckily, we found program administrators, certified builders, and energy advisors who could speak to the program offer across the entire period of investigation. Furthermore, we anticipated that data for the early years would not be readily available. As such, we relied on averaged rates of change supplied from regression models to 'backcast' historic levels of home energy consumption.

In the end, we were confident in the point estimates resulting from our calculations. We even found quantitative support for program savings in the form of research reports that evaluated program impacts in the mid-1990s. Through a ‘preponderance of evidence’, we are comfortable that the estimated program impact of 126 PJs is useful estimate of the cumulative impact of the R-2000 Program since its introduction in 1982.

For organizations and researchers seeking to quantify market transformational impacts, client concerns over the precision of market-based estimates must be parried. KMDR Research offers a solution in the form of a triangulation of measurement around key market metrics. The DELPHI Method also requires deep experience within the sector and program types under consideration; otherwise, the facilitator of the DELPHI interviews will be unable to probe the technical underpinnings upon which the responses of subject matter experts are formed.

Given market transformational study is gaining prominence in our industry, we offer references the can inform both the administrator and the researcher about the DELPHI Method and its usefulness in causal attribution modeling. Anyone wishing to study market transformation must be able to identify individuals, associations, and organizations with decades of experience in their field. Furthermore, researchers must carefully construct survey instruments and navigate in-depth conversations that draw upon the rich experience base and technical knowledge of panel of experts assembled for the DELPHI method. And lastly, researchers must carefully consider the responses offered by experts (sometimes with divergent interests), which may be confounded by inherent bias formed during the tenure of the expert within his/her role in the marketplace.

Given the complexity of market transformational evaluation, KMDR Research recommends the methods employed in this study be adopted only by those with foundational knowledge in outcome assessment and principal investigators with long commitments to the industry. The following references are offered researchers seeking to better understand the methodologies used in our study of historical impacts associated with NRCAN’s R-2000 program standard.

REFERENCES

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