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November 8, 2010

British Columbia Utilities Commission
Sixth Floor
900 Howe Street
Vancouver, B.C.
V6Z 2N3

Attention: Ms. Erica M. Hamilton, Commission Secretary

Dear Ms. Hamilton:

Re: Terasen Utilities (comprised of Terasen Gas Inc., Terasen Gas (Vancouver Island) Inc. and Terasen Gas (Whistler) Inc.) 2010 Long Term Resource Plan

Response to the British Columbia Utilities Commission ("BCUC" or the "Commission") Information Request ("IR") No. 2

On July 15, 2010, Terasen Gas filed the Application as referenced above. In accordance with Commission Order No. G-146-10 setting out the Amended Regulatory Timetable for the review of the Application, the Terasen Utilities respectfully submit the attached response to BCUC IR No. 2.

If there are any questions regarding the attached, please contact the undersigned or Ken Ross at (604) 576-7343 or ken.ross@terasengas.com for further information.

Yours very truly,

on behalf of the TERASEN UTILITIES

Original signed:

Diane Roy

Attachment

cc (e-mail only): Registered Parties

ACCEPTING 2010 LTRP UNDER SECTION 44.1 OF THE UTILITIES COMMISSION ACT

1.0 Reference: Exhibit B-5, BCUC IR 8.1, IR 1.1

Approval Sought in the 2010 LTRP

"The Terasen Utilities 2010 Long-Term Resource Plan (LTRP) provides a snapshot in time of the Terasen Utilities ongoing resource planning process." BCUC IR 1.1

"The only approval that the Terasen Utilities are seeking in the LTRP is that the Commission accepts the LTRP in accordance with Section 44.1 of the Utilities Commission Act. The Commission's acceptance of the LTRP is not a prerequisite for, and would not constitute approval or prejudgment of, the applications that the Terasen Utilities plan to file." BCUC IR 8.1

1.1 Subsection 44.1(2) of the UCA prescribes what a long-term resource plan should include. Is it because of the nature of this 2010 LTRP, because it is a "snapshot in time", that the Commission's acceptance is not prerequisite of Terasen Utilities' future plans?

Response:

In its response to BCUC IR 1.1.1, the Terasen Utilities stated that the Commission's acceptance is not a prerequisite for the ability of the Terasen Utilities to file future applications. This is because the *Utilities Commission Act* allows a utility to file applications under various sections and there is no provision that states that a utility must first receive acceptance of a plan under section 44.1 before a utility can make an application under any other section.

1.2 Terasen Utilities state that they require the freedom to respond to new events and information and therefore may not proceed with the LTRP as filed. Instead of shelving or not carrying out the 2010 LTRP when circumstances change, would it be more apt for the Terasen Utilities to build on the 2010 LTRP as the Utilities' planning tool to develop strategies and create various portfolios such that the Utilities could adjust readily to new events and information? If so, please describe if there are strategies and portfolios in the making and describe their state of development.

Response:

The Terasen Utilities would first like to clarify their interpretation of the use of portfolios in the resource planning process. The creation of portfolios is a useful resource planning exercise in some cases. The Terasen Utilities have in the past used the development and evaluation of alternative resource portfolios when facing imminent infrastructure constraints for which a number of alternative solutions are possible. Another example of a portfolio exercise is often seen in electricity supply planning where different generation options can be combined with different transmission and demand side management options to create a broad range of portfolios that can be evaluated against a set of criteria. A preferred portfolio can then be selected and implemented over time to meet future demand. The Terasen Utilities also use portfolio analysis and decision making in preparing their Annual Contracting Plans for gas supply, which are a separate submissions from the resource planning process and are discussed in Section 6.2.1 of the 2010 Long Term Resource Plan ("LTRP").

The 2010 LTRP is in part dealing with shifting trends in energy policies, customer needs and other market characteristics for which the "new" solutions (Biogas, NGV and AES) do not readily lend themselves to a range of such traditional portfolio alternatives, and infrastructure projects that are far enough in the future and/or localized such that the creation of portfolios are not warranted at this time. It may be that in the future, when the Terasen Utilities low and no-carbon solutions are sufficiently advanced, such solutions can be examined in a portfolio setting, but at this time the Terasen Utilities believe the strategy and action plan it has identified in the 2010 LTRP provide them with the most adaptable approach to the changing planning environment we are currently operating within.

In the response to BCUC IR 1.1.1, the Terasen Utilities were responding to the suggestion that, if the 2010 LTRP were accepted by the Commission, they would be legally bound to follow the 2010 LTRP and could not change course without further approval from the Commission. While the Terasen Utilities do not believe such a strict requirement is found in the *Utilities Commission Act*, the 2010 LTRP is the Terasen Utilities' plan and the Terasen Utilities are committed to follow the 2010 LTRP if it is accepted by the Commission. The Terasen Utilities were not suggesting and did not state that they would shelve or not carry out the 2010 LTRP whenever circumstances changed. The 2010 LTRP is a long-term and high-level planning document that is updated and typically filed every two years. If circumstances were to change in a significant way, the Terasen Utilities would build on the 2010 LTRP as part of its ordinary planning process and the changes would be reflected in the next LTRP. The two year cycle for preparing the LTRP therefore gives the Terasen Utilities the flexibility to adjust to new events and information in the resource planning process.

1.3 Considering that the Terasen Utilities are at the juncture of moving towards providing alternative energy solutions from a traditional gas distribution utility, would a long-term plan that is supported by portfolios of programs (as opposed to a plan without portfolio) lead a more meaningful regulatory review as to whether to accept or reject the 2010 LTRP?

Response:

Please see the response to BCUC IR 2.1.2. The Terasen Utilities believe that the approach taken, which was the same approach taken in the approved 2008 Resource Plan that first described alternative energy initiatives, remains appropriate for the 2010 LTRP.

TGI already has an approved rate structure in place for alternative energy services, as a product of the approved NSA in the 2010-2011 TGI RRA. TGI is currently preparing an application to the Commission with respect to alternative energy solutions. The future growth of the alternative energy services that will be facilitated by further approvals granted in the anticipated application may allow TGI to develop alternative portfolios of supply and demand side options that include alternative energy services. Similarly, as the Terasen Utilities improve their forecasting methodologies for thermal energy demand and as the alternative energy services mature, it is expected that alternative energy services will become more integrated into the long-term resource plan. However, at the current time, alternative energy services are in a nascent stage and there is insufficient information and data for the long-term resource plan to include such portfolios or complete demand forecasts for alternative energy services.

2.0 Reference: Exhibit B-5, Response to BCUC IR 1.1

Resource Planning Process

“… the Terasen Utilities have already “adopted” the positions recommended in the 2010 LTRP. The Commission’s review of the LTRP under section 44.1 of the Utilities Commission Act provides the Commission with the opportunity to consider the current state of the Terasen Utilities resource planning and opine on whether carrying out the LTRP is in the public interest.”

2.1 Are all of those “positions” recommended in the 2010 LTRP included in the Response to BCUC IR 56.2? If not, please identify what other “positions” have already been “adopted” by Terasen Utilities and include the related estimated spending.

Response:

BCUC IR 1.1.1 asked whether acceptance of the 2010 LTRP would commit the Terasen Utilities “to adopt” the positions in the 2010 LTRP. The response of the Terasen Utilities regarding having already “adopted” the positions appears to have been misunderstood; it was meant to indicate that the 2010 LTRP is developed by and therefore reflects the resource planning of the Terasen Utilities and, for this reason, the 2010 LTRP is not something that the Terasen Utilities need to be compelled by Commission order to adopt. The Terasen Utilities are seeking the Commission’s acceptance of the 2010 LTRP and the Terasen Utilities are committed (although not legally bound) to carrying out the 2010 LTRP if accepted by the Commission. The Terasen Utilities were not suggesting that they would proceed with its resource plans regardless of the Commission’s determination or that they would incur particular expenditures without the necessary approvals from the Commission. The Terasen Utilities confirm that they *will* have regard to the Commission’s determinations on this LTRP, and *will* obtain necessary approvals to incur expenditures.

The response to BCUC IR 1.56.2 provides a list of applications that the Terasen Utilities plan to file in carrying out the Action Plan contained in the LTRP. This is not a list of the positions in the 2010 LTRP.

2.2 Please clarify whether Terasen Utilities will be seeking rates recovery for any capital and O&M expenses for activities “adopted” but not as yet approved by the Commission. If “yes”, please provide details of them and their associated expenses.

Response:

Please see the response to BCUC IR 2.2.1. As is customary, the Terasen Utilities will seek CPCNs where required. As is customary, the Terasen Utilities will also seek approval from the Commission to recover all prudently incurred capital and O&M expenses in revenue requirements applications.

2.3 The Terasen Utilities are of the view that "the *Utilities Commission Act* does not state that the utility is obligated to undertake aspects of the resource plan that are accepted" (Exhibit B-5, pp.1-2), and that the Utilities have the freedom to discontinue or change their resource plan when deemed prudent. Please explain and justify whether the costs invested in stranded assets and abandoned programs should be incurred by ratepayers.

Response:

Please also see the response to BCUC IR 2.1.2.

Cost recovery in rates is determined at the time of a future revenue requirements application. The test for recoverability in the context of a revenue requirements application is the prudence test, not whether or not expenses incurred were tied to a matter outlined in a previously approved resource plan. Thus, the Commission's approval of a LTRP does not represent a determination that costs associated with the items included in the plan are prudent. Similarly, the utility can conceivably incur costs prudently even though they do not directly relate to an item in an approved LTRP. The Terasen Utilities acknowledge that they may be at risk for imprudent expenditures if they were to follow an aspect of a resource plan that has been rejected by the Commission, but also note that they may be at risk of imprudence for following an accepted plan in the face of changed circumstances that make the plan no longer advisable. The Terasen Utilities seek many approvals from the Commission in addition to the long-term resource plan that mitigate the risk of stranded assets or abandoned programs, or any subsequent Commission finding that the Terasen Utilities have acted imprudently. Such filings include the Annual Contracting Plan, gas supply contracts, EEC requests pursuant to section 44.2, CPCN applications and revenue requirement applications. In the absence of specific facts, it is impossible to determine whether costs invested in stranded assets or abandoned programs should be incurred by ratepayers as the factors related to such a determination would be context specific.

3.0 Reference: Exhibit B-5, BCUC IR 56.1; Exhibit B-4 BCSEA IR 11.1

Planning Horizon

"The Terasen Utilities would understand the Commission's acceptance of the 2010 LTRP to be an acceptance of the Terasen Utilities' plan to pursue ongoing and expanded EEC funding, but would not understand such acceptance to be a prejudgment or endorsement of the particular EEC program that the Terasen Utilities will be proposing in their next revenue requirement applications." BCUC IR 56.1

"The planning horizon for the LTRP is 20 years." BCSEA IR 11.1

3.1 A revenue requirements application normally sets rate for one to three test years. The planning horizon for the LTRP is 20 years and the Action Plan has a four year window.

3.1.1 Will the Terasen Utilities file another EEC Application before 2013 to update the 2008 EEC Application? Please explain why or why not.

Response:

Yes.

It is the intention of the Terasen Utilities to consult with the EEC Stakeholder Group to gather input on the next EEC funding approval application, including areas of program activity, the appropriate amount of funding and the appropriate length of the funding period. It is the Terasen Utilities' intention to use this feedback to help formulate the EEC funding request as part of the next Revenue Requirement Application which will be filed with the BCUC in Spring/Summer 2011. The Terasen Utilities are of the belief that a longer EEC funding approval period would create more certainty within the marketplace and therefore market actors would be more prepared to make commitments that support the uptake of efficiency measures by customers. At this time, the Terasen Utilities has not finalized the funding term that will be requested within the Revenue Requirement.

3.1.2 Why is a short-term revenue requirements application the appropriate forum to propose and discuss EEC programs that normally involve long term investments, savings persistence and incur long term amortization costs?

Response:

Please see also the response to BCUC IR 2.3.1.1.

Due to the fact that Commission approval for EEC funding is not in place beyond 2011, a funding request for EEC programs beyond 2011 will need to be made in 2011. The Terasen Utilities believe that the most efficient regulatory process would be to make an EEC funding approval request within the upcoming Revenue Requirement Applications that will be filed with the BCUC in the Spring/Summer of 2011. This is also consistent with the process for the last EEC funding request, which was included in TGI and TVI's 2010 and 2011 Revenue Requirement Applications. The Terasen Utilities are not aware of any concerns expressed by stakeholders relating to examining the EEC programs at the same time as the broader revenue requirements; however, as noted in the response to BCUC IR 2.3.1.1, it is the intent of the Terasen Utilities to gather feedback from the EEC Stakeholder group on the nature of the next EEC funding approval submission.

3.1.3 In the Utilities' opinion, does the UCA subsection 44.1 (2) (b) and (c) require a EEC Plan developed under certain probable scenarios and supported by cost-effective strategies and portfolios of programs? If so, please indicate where they are in the 2010 LTRP.

Response:

It may well make sense for the Terasen Utilities to address EEC funding in future LTRP filings, provided that the planning cycle allows for that to occur in a practical manner (e.g. the necessary studies must have been completed in time for the filing of the Plan). However, the *Utilities Commission Act* does not specify the regulatory mechanism whereby a public utility must seek EEC funding. Rather, subsections 44.1(2)(b) and (c) of the *Utilities Commission Act* require that a resource plan include: a plan of how the public utility intends to reduce demand by taking cost-effective demand-side measures and an estimate of the demand for energy that the public utility expects to serve after it has taken cost-effective demand-side measures. This requirement does not necessarily require an EEC Plan developed under certain probable scenarios and supported by cost-effective strategies and portfolios of programs. In the current circumstances, this was impractical. Please see the response to BCUC IR 2.4.1 for how the Terasen Utilities plan for cost-effective DSM meets the requirements of the *Utilities Commission Act*.

4.0 Reference: Exhibit B-5, Response to BCUC IR 8.1, IR 8.2

Low and No Carbon Initiatives

"However, in this Application, the Terasen Utilities are not seeking approvals for any low or no-carbon initiatives, nor are the Terasen Utilities requesting a determination that its plan to bring forward future applications is in the public interest. The only approval that the Terasen Utilities are seeking in the LTRP is that the Commission accepts the LTRP in accordance with Section 44.1 of the Utilities Commission Act."

4.1 Terasen Utilities state that EEC Funding Scenarios A, B, and C are not to be interpreted as plans, but rather as "illustrations" to indicate that increased funding leads to increased energy savings . Detailed program planning was not prepared in creating the three funding scenarios.

In the absence of a plan, please explain how the Application satisfies Sections 44.1(2)(b), (c), (d) or Sections 44.1(8)(a), (c) and (d) of the *Utilities Commission Act*.

Response:

As explained in the 2010 LTRP and in response to BCUC IR 1.38.1, the necessary analytic and planning work for an EEC funding application has not yet been completed. As such, The Terasen Utilities' plan for EEC funding as contained in the LTRP is to continue to make use of the approved EEC funding for 2010 and 2011 and complete the required analytical and planning work for a full EEC funding request and apply for specific levels of expanded and ongoing EEC funding post 2011, which will include measures for low income housing, rental accommodations and student education.

The following table explains how the 2010 LTRP satisfies Sections 44.1(2)(b), (c), (d) or Sections 44.1(8)(a), (c) and (d) of the *Utilities Commission Act*.

Section of the UCA	2010 LTRP Compliance
44.1(2)(b)	The Terasen Utilities plan of how they intend to reduce the demand by taking cost-effective demand-side measures is to continue to make use of the approved EEC funding for 2010 and 2011 and to complete the required analytical and planning work for a full EEC funding request and apply for specific levels of expanded and ongoing EEC funding post 2011, which will include measures for low income housing, rental accommodations and student education.

Section of the UCA	**2010 LTRP Compliance**
44.1(2)(c)	The energy savings predicted by EEC Scenarios B or C can be subtracted from the demand forecast presented in Section 4 of the 2010 LTRP to calculate an estimate of the demand for energy that the Terasen Utilities expect to serve after it has taken cost-effective demand-side measures. As the Terasen Utilities have not yet completed the necessary analytic and planning work for an EEC funding proposal, the Terasen Utilities have presented Scenarios B and C as illustrations of the range of energy savings that may be realized, from which can be calculated an estimate of the demand that the Terasen Utilities expect to serve after taking EEC measures.
44.1(2)(d)	Section 6.1 examines facilities that the public utility will or may need to construct to serve the estimated demand over the long term while Appendix D describes the facilities that the public utility intends to construct or extend in the short term in order to serve the estimated demand.
44.1(8)(a)	The Terasen Utilities plan for EEC as presented in the LTRP is consistent with the British Columbia energy objectives in the *Clean Energy Act*. This consistency is illustrated by scenario C and is explained in the response to BCUC IR 1.38.1.
44.1(8)(c)	The Terasen Utilities plan for EEC as presented in the LTRP shows that the Terasen Utilities "intend to pursue adequate cost-effective demand-side measures" as required by Section 44.1(8)(c) of the UCA.
44.1(8)(d)	The Terasen Utilities plan for EEC as presented in the LTRP is in the interests of persons in British Columbia who receive or may receive service from the Terasen Utilities because the Terasen Utilities plan to carry out existing approved EEC programs and plan to seek further EEC funding based on analytic and planning work that is expected to show that expanded EEC funding will be cost-effective. The Terasen Utilities believe that it is in the interests of persons in British Columbia who receive or may receive service from the Terasen Utilities for the Terasen Utilities to pursue available cost-effective EEC programs.

4.2 The Utilities have stated that "The Commission's acceptance of the LTRP is not a prerequisite for, and would not constitute approval or prejudgment of, the applications that the Terasen Utilities plan to file." Please explain how the Commission's acceptance or rejection of the 20 year plan would affect the Utilities operational and planning practices over the next 24 months.

Response:

The acceptance by the Commission of the 2010 LTRP would confirm for the Terasen Utilities that their resource planning is acceptable to the Commission and in the public interest. If the Commission were to accept the 2010 LTRP, the Terasen Utilities would undertake the necessary operational and planning practices to carry out the 2010 LTRP as planned.

The rejection by the Commission of the 2010 LTRP could have different effects on the Terasen Utilities operational and planning practices over the next 24 months depending on which aspects of the 2010 LTRP the Commission were to reject and why. If, for example, the Commission were to reject an aspect of the Terasen Utilities plan to acquire resources to meet its forecast demand, the Terasen Utilities anticipate that they might potentially do one or more of the following, depending on the circumstances: (a) seek to address or respond to the Commission’s concerns when the Terasen Utilities file applications for specific initiatives, (b) file a revised resource plan if warranted, or (c) address the concerns in the context of the next LTRP. The specific operational and planning effects of this would be context dependent.

4.3 Please confirm that the list provided in Response to IR 56.2 summarizes the 2010 LTRP initiatives that Terasen Utilities are requesting acceptance. If not, please provide a tabular summary of those initiatives by time period. Please itemize estimated expenses for each initiative for the period F2012 to F2020.

Response:

The response to BCUC IR 1.56.2 contains a list of regulatory filings related to the Action Plan that the Terasen Utilities plan to submit to the Commission. This is not a list of initiatives that the Terasen Utilities are seeking acceptance of. Rather, we have requested acceptance of the 2010 LTRP pursuant to section 44.1 of the Act (with the correction noted in the first paragraph of the response to BCUC IR 1.8.1.1, Exhibit B-5). We are not requesting approval for any spending amounts within the 2010 LTRP.

ALTERNATIVE ENERGY SERVICES AND INTEGRATED ENERGY SERVICES

5.0 Reference: Exhibit B-4, BCSEA IR 2.1, IR 2.2, IR 12.2

Alternative Energy Services

“From 2010 onward, it was agreed and approved as part of the Negotiated Settlement Agreement with respect to the TGI 2010-2011 Revenue Requirement Application that TGI will be developing and delivering alternative energy services. There are no other criteria that distinguish the alternative energy services delivered by Terasen Energy Services from those under development by TGI.” BCSEA IR 2.1

“TGI will be providing alternative energy services throughout the service area of the Terasen Utilities ….. It is not our intention to migrate these services out of TGI and into Terasen Energy services.” BCSEA IR 2.2

5.1 The RRA in question is an application for rate setting for the two years 2010-2011 and appears to deal only with allocation of costs and deferral account mechanism for AES. Would it be more accurate to describe the approval of the NSA of the RRA proceeding as an approval for the alternative energy services “initiative” as opposed to approving an overarching regulatory framework?

Response:

The Terasen Utilities are unclear as to the distinction being drawn between an “initiative” and an “overarching regulatory framework” (which we do not believe were terms that the Terasen Utilities have used in this proceeding). Rather than attempting to define these terms, it is most useful to refer to what was in fact agreed to and approved by the Commission. The Commission approved a New Energy Solutions Deferral Account, an economic test in the form of General Tariff Terms and Conditions Section 12A – Alternative Energy Extensions, and a CPCN threshold of $5 million. The NSA also contemplates that TGI may bring forward specific contracts for approval by the Commission as rates. These are all of the rate structures and approvals required to permit TGI to engage in alternative energy services, and the intention of the parties was that TGI would pursue these initiatives.

5.2 In Exhibit B-1, Chapter 8, p.186, the Terasen Utilities state their intention to seek approval of an overall business and regulatory model and seek CPCN approval of specific projects (emphasis added). Please confirm that this approval being sought is distinct and separate from requests related to alternative energy services that might be included in the next revenue requirements application.

Response:

Confirmed. The reference to seeking approval of "an overall business and regulatory model" was intended to be shorthand for obtaining rate approvals relating to particular projects, public interest approval (as necessary) for capital expenditures required to facilitate providing service, and any proposals for a streamlined regulatory assessment process for future projects and service agreements. These approvals would build on the framework set out in the approved 2010-2011 TGI NSA. The Terasen Utilities currently intend to bring this application separately from the next RRA.

6.0 Reference: Exhibit B-4, Response to BCSEA IR 1.3, IR 1.4

Terasen Energy Services

"If Terasen Energy Services provides any services that fall under the definition of "public utility", it is subject to regulation by the Commission."

6.1 TES has participated in projects that are regulated by the Commission. If TES is a regulated utility and it offers alternative energy services not distinguishable from those offered by Terasen Utilities, why is TES not included in the Terasen Utilities' LTRP or why has it not separately filed its own LTRP?

Response:

TES maintains alternative energy programs that were developed or that went into service prior to the Negotiated Settlement Agreement with respect to the TGI 2010-2011 Revenue Requirement Application, which put in place a framework to permit TGI to pursue alternative energy services.

With the exception of Dockside Green Energy in which TES is a minority partner, TES' alternative energy services have never been actively regulated by the Commission, and TES has been, in effect, treated as an NRB. The Terasen Utilities now believe that some of these assets should actually be subject to regulation. With the approval of the rate structures within TGI, one logical approach would be to transfer ownership of the appropriate assets to TGI. This is being actively considered, but would not occur until the Commission has had the opportunity to consider the matter in the context of an application dealing with the issue.

TES has not filed a long-term resource plan as TES has never been actively regulated. In the case of regulated entities, public utilities file resource plans "in the form and at the time the commission requires". To this point, no such requirement exists and the Terasen Utilities believe that it would make little sense to require a resource plan to be filed for assets of such limited scope and size.

6.2 Please confirm whether TES is a regulated or non-regulated business entity. Please also provide a tabular summary of the products and services that TES currently provides to ratepayers and the wider market.

Response:

Please see the response to BCUC IR 2.6.1 with respect to whether TES is a regulated or non-regulated business entity.

TES provides the following products and services under contract to the Terasen Utilities and building owners:

1. Natural gas distribution system operating services.
2. Propane storage plant access, use, and related distribution system operating services.
3. Geo-exchange loop field system access, use and related operating services.
4. In conjunction with geo-exchange loop field system services, geo-exchange mechanical equipment access, use and related operating services.

In partnership with others, TES also owns the Dockside Green district energy system and provides related utility services.

7.0 Reference: Exhibit B-5, BCUC IR 2.2, IR 9.2

Competition in Integrated Energy Services and TES

"The rejection of the LTRP would not prohibit TGI from making a future application to implement alternative energy services." BCUC IR 2.2

"Yes there are competitors to TGI in the area of integrated energy services. However, competition is a Federal mandate under the Constitution of Canada and not, in and of itself, within the jurisdiction of the BCUC." BCUC IR 9.2

7.1 Please confirm that in the Response to BCUC IR 9.2, Terasen Utilities were referring to the federal law *The Competition Act* whose purpose was, among other things, to prevent anti-competitive practices in the marketplace. Does a natural monopoly currently exist for the integrated energy services market and NGV market? Please explain your answer.

Response:

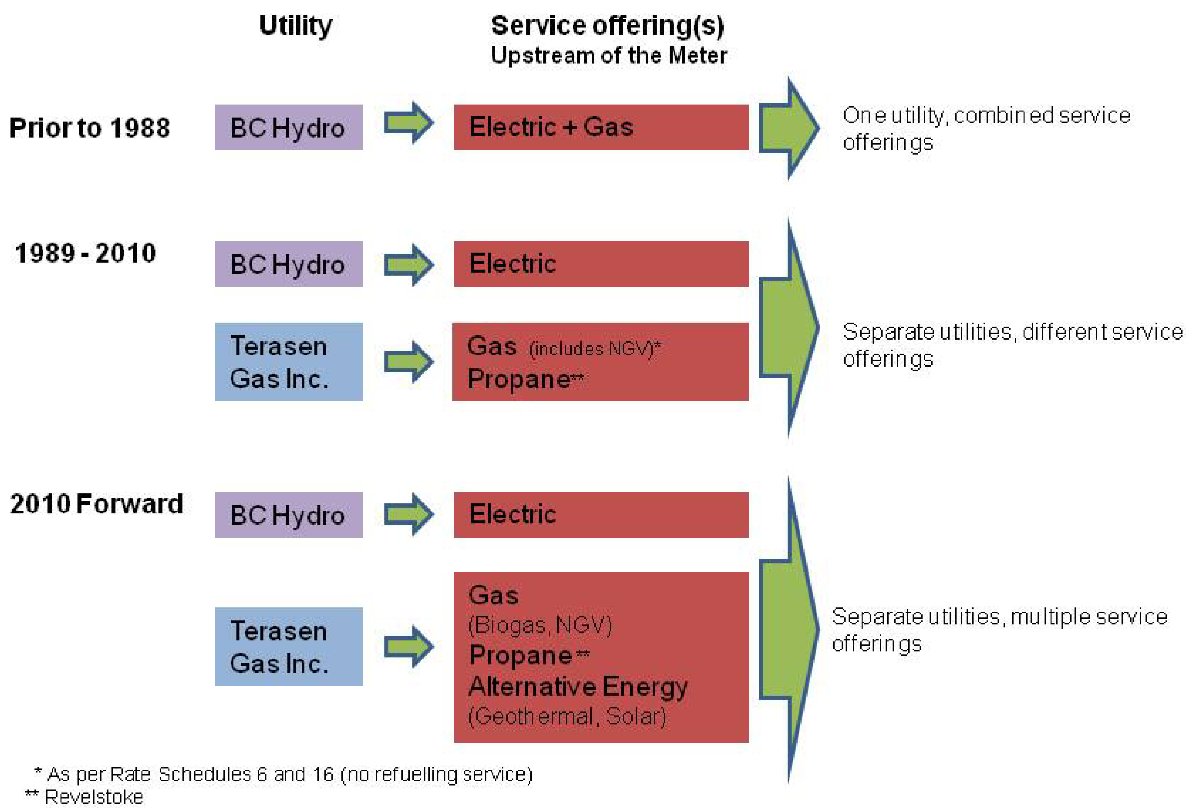
The Terasen Utilities confirm that they were referring to the *Competition Act*. The Commission's jurisdiction extends to entities that meet the definition of "public utility", which will necessarily include, for instance, entities that provide (through a district energy system) thermal energy to the public or a corporation for compensation (unless they meet a specified exception in the definition). As such, even if an entity other than the Terasen Utilities is providing the thermal energy service to the public for compensation through a district energy system, it will still be subject to Commission regulation. Central Heat is an example of a district energy system that has, for many years, provided thermal energy to the public and is subject to Commission regulation.

The existence of natural monopolies, and the efficiencies associated with them, provide a policy and economic rationale for regulation of entities and services that meet the requirements of the Act in the sense that regulators have been given the power to preclude a multiplicity of players from operating in a given area in circumstances where it makes most sense in the public interest for there to only be one player (with one set of power lines or pipes, rather than two parallel sets of the same utility infrastructure). However, another aspect of the policy underlying rate regulation is that once a customer of a utility has invested in and installed appliances that operate off a particular form of energy, the customer is in many respects captive to the utility even if, theoretically, the customer could switch to another fuel source (e.g. use electric heating). It thus becomes important for a utility to have its rates regulated so that this effective monopoly cannot be abused.

A natural monopoly of *all* integrated energy services currently operating in British Columbia does not at this moment in time exist. There are various owners and operators of standalone discrete energy systems such as geo-exchange serving one customer and some BC municipalities have created their own district energy utilities including City of North Vancouver, City of Vancouver, Town of Revelstoke, and Resort Municipality of Whistler. However, a natural monopoly may exist within the service area of each of these district or discrete energy systems. Once a district or discrete system has been built and customers have been attached to the specific systems, it may not be economical for more than one company to put pipes in the street to serve the customer within the same geographic footprint and, because there is a high capital barrier to entry for the utility providing service, customers are effectively captive. This is what the Terasen Utilities were referring to in the response to BCUC IR 1.9.2, where we stated: "The Terasen Utilities also note that it would be incorrect to conclude that the energy service provided to third parties by an owner and operator of geothermal, solar thermal or district energy systems is not monopolistic in nature. With respect to district energy system serving a community, for example, TGI or another provider selected by the consumer would have an effective monopoly over the provision of heat to the customers in the community." This is why the definition of "public utility", which captures such energy systems, aligns with policy.

On a province wide basis, there are benefits associated with the Terasen Utilities being involved in the provision of regulated integrated energy services that have already been pursued by other regulated entities (e.g. Central Heat) for some time. Integrated energy services are capital intensive and economies of scale can be realized by companies that own a number of systems. These economies of scale can also translate to better products and costs for the end user resulting from operation expertise to the spreading of risk across multiple installations. This is similar to the early stages of the gas distribution system in British Columbia, where there were a greater number of utilities providing regulated service to customers across the province (Victoria Light, Columbia Gas, Interior Gas, BC Hydro Gas etc.). Over time there is consolidation resulting in reduced risk to the customer and more stable rates. Regardless of who owns and operates the district energy system assets, the Commission fixes the rates.

There is no legal or regulatory reason why the Terasen Utilities should be precluded from being involved in alternative energy services, for instance, simply because our dominant business has been and remains the provision of natural gas service. There is a long history in this Province of regulated utilities providing more than one type of regulated service, dating back to the time when gas and electricity service was provided by the same utility (as provided in the figure below).



More recently, the Commission's decision with respect to the Gateway Estates CPCN spoke favourably regarding the inclusion of a propane utility within TGI rather than having a proliferation of smaller regulated Terasen Utilities entities. There is no logical distinction between the provision of propane service within TGI and providing regulated thermal energy service.

With respect to the NGV market in BC, it is assumed that this question is directed at the provision of fuelling services for NGVs. Compression and fuelling services can be provided by the utility as a regulated service as evidenced by the provision of such service by Terasen Gas (as approved by the BCUC). The service can also be provided by third parties, as has been the case in BC for a number of years.

Customers, in general, lack the technical experience and capability to be comfortable contracting for the build of NGV stations that involve high pressure gases or cryogenic liquid. Third parties are not developing the BC market as is demonstrated by the lack of fuelling stations being built in the region (In the BC region no new fuelling stations have been installed for almost a decade). Terasen Gas is proposing to provide fuelling services to targeted customers where contracts are possible so that customers can be provided with a complete service option that can deliver fuel to their vehicles. As the market develops the Terasen Utilities expect that some customers and some third parties may elect to participate in the fuelling services market. The participation of the Terasen Utilities in the market will be regulated and the rates being charged for fuelling services will be fair as they will reflect the full cost of service.

7.2 In the Commission Guidelines: Retail Markets Downstream of the Utility Meter (RUMDUM) published in April 1997 (Ref: Exhibit A2-1), The Guidelines quoted staff position paper's conclusion as follows:

> *the Commission's powers include ….. the ability to define the utility's domain, that is to determine which goods and services the utility will provide, …..the Commission has the power to influence the corporate structure under which utility shareholders will participate in the unregulated market*

Do Terasen Utilities agree with the above statements? If no, please explain.

Response:

No, the Terasen Utilities do not agree with the paraphrased statement set out above to the extent that it could be taken to suggest that the Commission has a wide discretion to regulate what goods and services a utility can provide and corporate structure. The full passage from the decision was actually much narrower in scope than the truncated quotation would suggest. Further, the Commission Panel rejected material elements of the Staff's position paper based on legal advice from Commission counsel about the limitations on the Commission's jurisdiction.

This response is organized in three parts:

- The services that TGI is contemplating are core public utility services, not unregulated services provided downstream of the utility meter as were being addressed in the RMDM proceeding.
- The paraphrased wording should be considered in its full context; and
- The Commission Panel's determinations on its jurisdiction in the RMDM process support the position of the Terasen Utilities regarding appropriateness of engaging in alternative energy services.

Core Utility Services vs. Services Downstream of the Utility Meter

The Terasen Utilities have identified in a number of responses why it is that alternative energy services fall within the scope of public utility services. Regardless of what entity provides those services, they will be subject to regulation by the Commission by virtue of the definition of "public utility" in the Act. This is actually supported by the RMDM decision, in that the decision noted the "very broad" scope of the definition of "public utility" (p.2) and accepted the ongoing importance of regulation over what the Commission referred to as "core utility assets (pipes and wires)" (p.3). Alternative energy services involve the generation and delivery infrastructure for thermal energy, which are part and parcel of "core utility assets".

The Paraphrased Passage in Context

The referenced passage appeared on page 5 of the RMDM decision. For ease of reference, it provides in full:

> *"In British Columbia, regulation of natural gas and electricity utilities is undertaken by the British Columbia Utilities Commission ("BCUC", "the Commission") under the authority of the Act. <u>The Commission's powers include oversight of utility rates and the utility expenditures responsible for those rates.</u> The staff position paper concluded that <u>these powers</u> give the Commission the ability to define the utility's domain, that is to determine which goods and services the utility will provide, since the utility would be unlikely to offer services for which it cannot recover the costs. As a result, the paper suggested that the Commission has the power to influence the corporate structure under which utility shareholders will participate in the unregulated market."* [Emphasis added.]

The underlined wording, which was omitted from the paraphrasing, makes it clear that the passage was referring to the jurisdiction of the Commission over utility rates and utility expenditures responsible for those rates. The passage was referring to the suggestion in the Staff paper that rate regulation can *indirectly* influence matters such as what services a public utility would offer and what corporate structure a utility adopted. There is no suggestion in this passage that the Commission has the jurisdiction to *directly* stipulate such matters, as the truncated quotation might be taken to suggest.

The Commission Rejected Key Aspects of Staff Position Paper

The Commission rejected key aspects of the Staff position paper based on legal advice from Commission counsel. The legal opinion provided by Commission counsel is included in Attachment 7.2. The advice, and the Commission's adoption of it in the context of RMDM, supports the position of the Terasen Utilities that the Commission should consider the alternative energy services without reference to whether or not they enhance or detract from the ability of others to participate as providers of alternative energy.

The Commission paraphrased the legal advice from Commission counsel (Boughton and Company) as follows (p.8):

> *"In response to these submissions, the Commission staff sought a legal opinion on the issue of the Commission's jurisdiction with respect to downstream retail markets. In summary, the opinion stated the following:*
>
> *1. The Commission does not have the jurisdiction to directly regulate an NRB unless the NRB is itself a public utility, a common carrier, or a common processor.*
>
> *2. The Commission has the jurisdiction to regulate the relationship between a public utility and an affiliated NRB to the extent that the relationship affects ratepayers. For example, the Commission has the jurisdiction to ensure that an NRB is not 'subsidized' by a public utility to the detriment of ratepayers.*
>
> *3. <u>The Commission does not, however, have the jurisdiction to regulate the relationship between a public utility and an NRB so as to ensure the relationship does not affect the competitive retail market downstream of the meter. The Commission's jurisdiction is limited to consideration of the effects of the relationship on ratepayers</u>.*
>
> *4. <u>The Commission has the jurisdiction to regulate retail market downstream of the utility meter ("RMDM") activities by a public utility, but only to the extent that such activities affect ratepayers. Similarly, the Commission has the jurisdiction to prohibit a public utility from participating in RMDM if prohibition is the only reasonable and effective means by which the Commission can mitigate or alleviate any negative effects on ratepayers</u>.*
>
> *5. Ratepayers do not own a public utility's corporate name. The corporate name is goodwill which is owned by the company. The shareholders have a right to share in the assets of a company, including the corporate name, if the company is dissolved."* [Emphasis added.]

The advice of Commission counsel reflected a notable departure from the position being advocated by Staff. The Commission later stated, for instance, "…it is clear from the submissions received and the legal opinion that certain changes to the specific objectives, criteria and principles initially proposed by staff are needed." A notable departure from the Staff position paper occurred in the context of confining the Commission's jurisdiction to limit the involvement of public utilities in particular non-regulated businesses so as to promote competition.

The relevance of Commission counsel's opinion and the Commission Panel's finding in the RMDM process to the subject matter at hand is that, if the Commission cannot limit a public utility's involvement in non-regulated enterprises with the objective of promoting competition, it logically follows that the Commission could not preclude the involvement of the Terasen Utilities in core utility business (pipes and wires) to make it easier for other parties to compete and fulfil that role instead.

8.0 Reference: Exhibit B-5, Response to BCUC IR 2.1; Exhibit B-3 BCOAPO IR 3.1

Terasen Energy Services ("TES")

"TGI is now pursuing alternative energy services as described in Section 3.1.1 of the LTRP. In the respectful submission of the Terasen Utilities, it is the services being pursued by TGI that are the subject of this proceeding, rather than TES's services."
BCUC IR 2.1

"The Terasen Utilities does not envision any issues with respect to cross-subsidization or affiliate relations with respect to TES going forward." BCOAPO IR 3.1

8.1 Please provide the corporate structure of Terasen Gas that includes all regulated and non-regulated business units. Please discuss the extent to which the relationship between regulated and non-regulated business units are stand-alone and arms length entities or in the alternative share resources such as offices, employees, and other assets.

Response:

The corporate structure of the Terasen Utilities is as described on Page E-1 (Executive Summary) and pages 2 to 3 of the 2010 LTRP. As approved in the 2009 Negotiated Settlement Agreement, Terasen Gas Inc. started to develop alternative energy within Terasen Gas Inc. The development of this business within Terasen Gas Inc. has been kept separate as directed. Terasen Energy Services is a sister company to the Terasen Utilities. The provision of services to TES, such as shared offices, assets or employees, are charged to TES as contemplated under the Transfer Pricing Policy approved by the BCUC.

8.1.1 The Response to BCOAPO IR 3.1 states that Terasen Utilities do not envision any issues with respect to cross-subsidization or affiliate relations with TES going forward. Please provide a description of the nature of TES' relationship with Terasen Utilities including a historical perspective of how assets are shared between the corporate entities.

Response:

As approved in the 2009 Negotiated Settlement Agreement, Terasen Gas Inc. started to develop alternative energy within Terasen Gas Inc. The development of this business within Terasen Gas Inc. has been kept separate from the natural gas business as directed. Terasen Energy Services is a sister company to Terasen Gas Inc. Any provision of services to TES, such as shared offices, assets or employees, are charged to TES as contemplated under the

Transfer Pricing Policy approved by the BCUC. The application of the Transfer Pricing Policy ensures that there is no improper cross-subsidization of TES by the Terasen Utilities.

8.2 The Utilities have stated that the "delivery of alternative energy services to customers is a regulated activity under the *Utilities Commission Act*". Do the Utilities consider that alternative energy services are exclusive to regulated utilities in the Province of British Columbia? If so, please state why.

Response:

Alternative energy services are, by definition, subject to regulation by the Commission where they involve the provision of thermal energy (heat or cold) to the public or a corporation for compensation. This is the test under section 1 of the *Utilities Commission Act,* by virtue of the definition of "public utility". The alternative energy services that will be offered by the Terasen Utilities will all provide thermal energy to the public or a corporation for compensation, and are thus "public utility" services and subject to regulation by the Commission. The same would be true regardless of what entity owned the alternative energy infrastructure used to provide thermal (heat or cold) energy service to the public for compensation. The only instances where an alternative energy service provider will not be regulated are if the entity does not provide thermal energy (heat or cold) to the public or a corporation for compensation (e.g., it is using the thermal energy for its own purposes or is not seeking compensation), if the alternative energy service fits within an exception under the definition of "public utility" (e.g., the entity is owned by a municipality), or if the public utility is exempted under section 22 from the application of Part 3 of the *Act* by Regulation.

9.0 Reference: Exhibit B-5, Response to BCUC IR 2.2; Exhibit B-4 BCSEA IR 12.2

Venture into Alternative Energy Services

"While these activities and plans for future applications are relevant background to the resource plan, the Terasen Utilities are not seeking any approvals in the LTRP to proceed with offering alternative energy services. TGI notes that no advance approval is required for TGI to file applications with the Commission to implement alternative energy services as contemplated by the NSA." BCUC IR 2.2

"In TGI's 2010-2011 RRA, TGI outlined its rationale and strategy for offering alternative energy services and proposed a regulatory model for undertaking these services." BCSEA IR 12.2

9.1 The Application states that the Utilities "anticipate that they would proceed with implementing alternative energy services whether or not the Commission accepts the LTRP". Under such a scenario, please discuss if a regulatory review of the organizational structure of various entities of Terasen Gas should take place. Please discuss if a review of the regulated and unregulated nature of the alternative energy services should take place before the next filings of LTRP, EEC Application or CPCN and funding applications related to the EEC.

Response:

The recent NSA for TGI has already approved tariff provisions which provide an economic test for proceeding with alternative energy services and contemplate that TGI may bring forward particular alternative energy service contracts for approval to the Commission as rates. The Terasen Utilities are not seeking any approvals in the 2010 LTRP related to alternative energy services that would be a precondition to the Companies acting on the Commission's order in the RRA. The implementation of alternative energy solutions in the manner approved and contemplated by TGI's NSA would not trigger any need to review the organizational structure of various entities of Terasen Gas.

The issue of whether alternative energy services are regulated or unregulated was thoroughly canvassed in the TGI's 2010-2011 RRA proceeding, and the Commission has approved rate structures regulating the delivery of alternative energy services. It makes sense that these services are treated as regulated public utility services. It is unequivocal that providing thermal energy to the public or a corporation for compensation is a public utility service under section 1 of the *Utilities Commission Act* (definition of "public utility"), subject to certain exceptions that do not apply in the present circumstances. Well before the TGI RRA, the Commission had already granted CPCNs and approved rates to other utilities for alternative energy services, such as in the case of Dockside Green. Central Heat, a district energy system delivering thermal energy to customers in Vancouver, has been regulated for many years. Therefore, the proper question is not whether alternative energy services are regulated or unregulated, but whether the

Commission believes that it is in the public interest that they be provided in any particular case and the nature of the regulation to be applied. Alternative energy services are strongly supported by the British Columbia's energy objectives in the *Clean Energy Act*, are being requested by customers, and are a growing source of low carbon energy that reduces GHG emissions. The Terasen Utilities therefore believe that these factors speak to Terasen Gas' provision of alternative energy services, generally, being in the public interest. Other factors relevant to the public interest will be project-specific, e.g. cost and rates charged. The Terasen Utilities will be filing an application that seeks approvals specific to alternative energy service projects advanced in 2011. The Terasen Utilities believe that the alternative energy application in 2011 will be the appropriate time for the Commission to consider the public interest issues, but the regulated nature of the services has already been determined on more than one occasion and the legislation is, with respect, beyond doubt.

Issues relating to alternative energy services need not be heard before or in conjunction with an EEC funding request. The provision of alternative energy services requires rate approvals (sections 59 to 61) and, potentially, approvals for the construction and operation of utility infrastructure (section 45). EEC funding is obtained under a different section of the Act, specifically the expenditure schedule provision in section 44.2(1)(a).

9.2 Page 4 of the RUMDUM Guidelines (Exhibit A2-1) depicts those areas as part of the question of determining the proper domain of the utility. Please provide a similar figure depicting products and services related to Innovative Technologies, Alternative Energy Services, and Integrated Energy Services according to the Terasen Utilities' current perception.

Response:

The Terasen Utilities believe that the question of whether or not a service ought to be regulated is dictated by the *Utilities Commission Act*, and in particular the broad definition of "public utility." We have not reproduced the schematic in the RMDM Guidelines, as the Terasen Utilities would characterize all of the identified services as falling within the centre of the circle as "core monopoly products (e.g. pipes and wires)". Our reasons are as follows:

- The Alternative Energy Services (which may also be called Integrated Energy Services) consist of, in general terms, equipment for thermal generation, the delivery infrastructure (pipes), and meters. As discussed in the response to BCUC IR 2.7.1, any such system has characteristics of a monopoly within the geographic footprint it occupies, as there may be inefficiencies associated with duplication of infrastructure and also barriers for customers to leave the system. These factors provide a sound policy rationale for rate and service regulation. The provision of thermal energy to customers, involving generation, distribution and meters, has long been a public utility service by virtue of the definition of "public utility" in the *Act*, and the Commission has regulated such services as public utility services. A good example of a thermal energy utility incorporating both generation (boiler), distribution (pipe), and meters, is Central Heat, which has been regulated by the Commission for many years. Dockside Green is a more recent example of a small alternative energy utility regulated by the Commission.[1]

- The referenced Innovative Technologies is actually an EEC program, not a service offering. EEC programs are "core monopoly products" because they are demand-side management resources that are only cost-effective for the utility to undertake based on the benefits to ratepayers.

RMDM is discussed in additional detail in the response to BCUC IR 2.7.2.

[1] The diagram on p.3 of the Guidelines relegates billing and meters to the middle circle "Debatable/Transitional Products"; however, the Guidelines (p.3, footnote) are clear that these facilities are still the necessary utility infrastructure for the time being: "Some parties argue that the meter/regulator assembly and meter reading information to customers may also become a competitive service. However, in the near term, the utility will require basic meters in its control to verify the quantities of energy transported by the monopoly pipes or wires." The Terasen Utilities have thus included meters within the central "core monopoly products".

10.0 Reference: Exhibit B-5, Response to BCUC IR 9.2

Competition

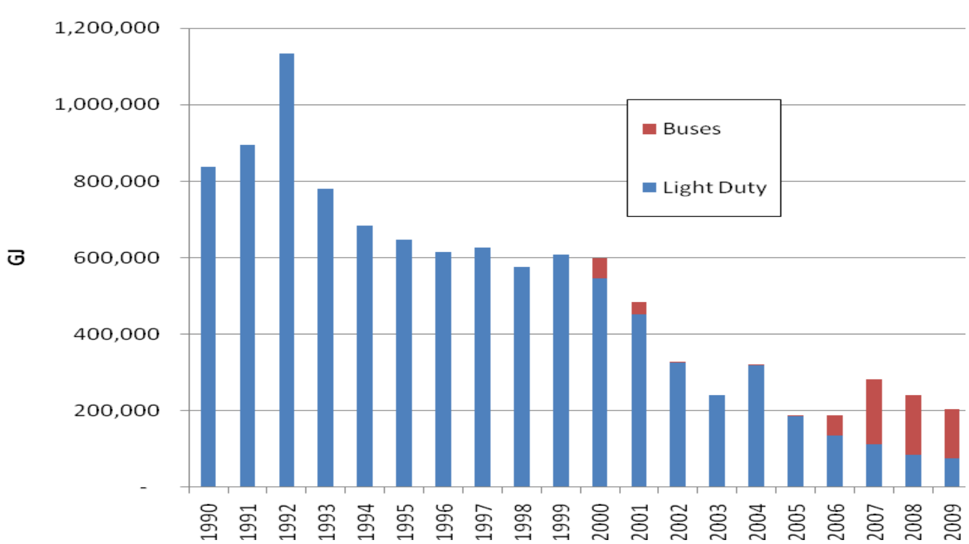
"Yes there are competitors to TGI in the area of integrated energy services. However, competition is a Federal mandate under the Constitution of Canada and not, in and of itself, within the jurisdiction of the BCUC. Neither is the Commission's jurisdiction defined by reference to whether a service is subject to competition."

10.1 Would the pursuit of AES and NGV markets by the Utilities prevent or hinder the development of competitive markets in those sectors of the British Columbian economy? Please discuss how such pursuits might be beneficial or harmful to ratepayers.

Response:

Pursuit of AES and NGV markets by the Terasen Utilities is expected to assist in the development of competitive markets in those sectors. With respect to the NGV market, there is virtually no development activity in the BC market at present and the existing base of business that was previously developed has been on a long steady decline as shown in the chart below. If the Terasen Utilities are successful in re-developing a base of business it would be natural for this economic activity to attract additional competitive entries.

British Columbia NGV Consumption since 1990*



* Data collected from Terasen Gas.

Notes:

- Light Duty – Rate Schedule 6
- Buses – Rate Schedule 25 (2003-2006), and Rate Schedule 3 (2000-2002). Data not available prior to 2000.

If the Terasen Utilities are prevented from participating in such markets the marketplace may not materialize to the benefit of existing customers.

With respect to the broader customer base, development of NGV markets will benefit customers by creating additional load on the system and generating additional delivery revenues; thereby reducing delivery rates for the general customer base as described in more depth in the response to BCUC IR 1.12.1.

With respect to AES, this market is being developed by Terasen Utilities as well as other companies in response to customer demand, and as a result the development of AES is very much in the interest of our customers.

With respect to the impact on natural gas customers, AES costs are to be recovered from AES customers and there is also a contribution to overhead that benefits natural gas customers. The impact on natural gas demand is dependent on the type of AES installed. Where gas is a component of the AES, the overall consumption of natural gas is lower than if a conventional natural gas system were installed. Conversely in a residential condominium building that would have otherwise used electric baseboards for heating, there will be additional gas load. The total impact on natural gas ratepayers is dependent on the type of systems introduced, the type of systems displaced, and the rate at which AES solutions displace natural gas overtime.

CURRENT AND EXPECTED REGULATIONS, UNCERTAINTIES AND RISKS

11.0 Reference: Exhibit B-5, BCUC IR 3.1, IR 3.2, IR 7.1, IR 11.3, IR 12.2

Uncertainties and Risks

11.1 In the Response to BCUC IR 3.1, the Terasen Utilities state that they are unable to speculate on potential impacts on EEC programs due to lack of details of the regulations of the Greenhouse Gas Reduction (Cap and Trade) Act. Have the Terasen Utilities developed scenarios for its EEC program implementation to plan for different possible outcomes related to capped emissions regulations?

Response:

There has not been enough detail to date to productively determine scenarios related to capped emission regulations for the Terasen Utilities EEC programs due to the lack of information and wide range of scenario possibilities. There have been discussions implying that the Terasen Utilities might be responsible for customer emissions under a Cap and Trade scenario, but the most recent information available is that customer emissions would not be subject to Cap and Trade due to the implementation of the Carbon Tax in BC.

The Terasen Utilities are working to understand and assess upcoming *Greenhouse Gas Reduction (Cap and Trade) Act* implications and will continue to review proposed policy and framework and impacts on all aspects of our business including EEC activity.

Please also refer to BCUC IR 2.11.2.

11.2 In the Response to BCUC IR 3.2, the Terasen Utilities state they are still resolving how offsets could be apportioned if they were part of a compliance portfolio. Have the Terasen Utilities developed different portfolios of programs to adjust to the possible outcomes regarding whether EEC initiatives qualify as offsets?

Response:

The Terasen Utilities first need to undertake the exercise to determine whether theTerasen Utilities EEC programs even qualify as offsets. The terms and conditions for each of the Terasen Utilities’ EEC programs, except NGV at this time, all currently contain language to the effect that the Terasen Utilities retain the rights to the GHG reductions as a result of the funds distributed under the EEC program for implementation of the technology. However, there are other factors which go into determining offset qualification such as additionality, protocols, ownership of GHG emissions reductions when more than one party contributes to the cost of creating that GHG emissions reduction, and the appropriate apportionment of GHG emissions reductions in these cases. The Terasen Utilities then could consider whether there is an economic case to proceed with using some of all of the Terasen Utilities EEC programs to create offsets and how they may be used as a compliance tool under Cap and Trade.

The Terasen Utilities are working to resolve some of these issues, however they do not expect to come to a determination on this matter until 2011, once the WCI and other carbon regulations become more defined. It is anticipated that as a result of this exercise, the Terasen Utilities would be prepared to analyse possible scenarios for portfolios of programs that may qualify as offsets.

11.3 In the Responses to BCUC IR 7.1 and 7.4, the Terasen Utilities have applied a carbon tax amount of $30/tonne to the cost of gas beyond 2012 in the absence of information on carbon tax beyond 2012. Given that the Application quoted some reports that indicate carbon taxes may need to go up to $300 per tonne in order to have a meaningful impact on consumer behavior and therefore reduce GHG emissions, would developing various carbon tax scenarios as inputs be useful in providing better insights on EEC cost-benefit analysis and load forecasts?

Response:

Yes, it would, and it is the Terasen Utilities' intent to explore impacts on EEC activity and energy savings from different carbon tax levels, and to present those findings in the next EEC funding application.

11.4 The Terasen Utilities' intention is to move forward with the NGV programs as they have long-term benefits. Ownership of potential carbon offsets has not been considered. Would the impact on the cost-benefit analysis be significant under 'with' and 'without' carbon offsets ownership scenarios?

Response:

The impact on the cost/benefit analysis of potential carbon offsets depends on the price that is assumed for the offsets. For a typical customer considering a switch to NGVs, the value of the potential carbon offset is generally not a major economic driver. The incremental cost of a natural gas garbage truck compared to a conventional diesel garbage truck is approximately $40,000 - $50,000.

Using the Natural Resources Canada "GH Genius" model[2] and fleet operating data, the carbon reduction is estimated at 10.7 tonnes per truck per year[3]. If we assume that this could be monetized at a rate of $25/te (based on estimates from Pacific Carbon Trust), each truck would earn about $267.50/year in offsets before costs of validation and verification. By comparison, the expected fuel cost reduction for this vehicle is approximately $10,000 per year[4]. Hence the value of the carbon offset is not a significant driver in the economic decision.

11.4.1 On page 116 of the 2009 EEC Annual Report, Terasen Utilities suggested that the Companies may seek the Commission's approval allowing a weighted average TRC of less than 1.0 in future filings for Innovative Technologies. Is this because the Terasen Utilities are not sure about the attributes that they could count as benefits?

Response:

Innovative Technologies represent an important component of the Terasen Utilities' overall commitment to EEC activities. Since Innovative Technologies have very little market penetration within British Columbia, the costs for encouraging adoption may be high. These costs include expenditures on such activities as customer and installer education, marketing, monitoring, measurement, system equipment and installation costs. Even though these technologies may offer energy savings and reduce GHG emissions, their higher costs may increase the likelihood of them from not passing the cost-benefit test which negatively affects the portfolio weighted TRC and limits future program opportunities.

As noted in the response to BCUC IR 1.32.1 and 1.32.2, the Terasen Utilities are finding that the TRC test may not be appropriate in all cases and Innovative Technologies may be one such case. Counting other attributes as benefits in the Societal Test approach is challenging as other attributes may be subjective and difficult to measure.

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2 NRCAN, http://oee.nrcan.gc.ca/transportation/tools/greenhouse-gas-info.cfm

3 Model has been run assuming 31,200 kms per year as activity level. Diesel fuel displacement of 46,800 litres per year.

4 Fuel savings based on diesel price of $0.94/litre including all taxes except GST (flow through cost). NG pricing estimated based on Rate 25 delivery with commodity at $4.27/GJ, fueling station charge of $5.60/GJ and carbon tax of $0.99/GJ.

11.4.2 In the Response to IR 11.1, Terasen Utilities state that the NGV programs for municipal fleets will be subject to the same threshold as other DSM programs of having to pass the TRC test, which means that overall benefits from the NGV programs will exceed the costs. Does this assertion contradict the suggestion on page 116 of the 2009 EEC Annual Report?

Response:

On page 116 of the 2009 EEC Annual Report, the TGI and TGVI state:

> *"While the Commission and the Companies agree the Innovative Technologies Portfolio will have a weighted average TRC of 1.0 or greater for 2010 and 2011, the Companies may seek the Commission's approval allowing a weighted average TRC of less than 1.0 in future filings. By their nature, Innovative Technologies are new and costs for encouraging adoption may be high, but early experience is necessary to develop knowledge and encourage market uptake."*

The TRC threshold for NGV programs implemented within the currently approved tranche of EEC funding will be consistent with other elements of the EEC program and will not contradict the statement on page 116 of the 2009 EEC Annual Report. The Terasen Utilities may still seek Commission approval for the allowance of a weighted average TRC of less than 1.0 for its Innovative Technologies Portfolio in future EEC filings for funding approval beyond 2011.

TGI anticipates its future portfolio of NGV programs will maintain a weighted average TRC of at least 1.0. However on an NGV project-by-project basis TGI may proceed with a TRC less than 1.0, as long as the Innovative Technologies Portfolio maintains a weighted average TRC of at least 1.0 for 2010 and 2011.

To date, TGI has not evaluated or sought approval of any NGV programs with a weighted average TRC of less than 1.0.

11.5 In the Response to BCUC IR 12.2, Terasen Utilities concluded that the Whistler fuel cell bus purchase was part of an effort to showcase fuel cell technology under development in B.C. In the LTRP, have the Terasen Utilities considered scenarios to accommodate changes in provincial government policy such as the promotion of fuel cell bus or electric bus over NGV bus?

Response:

Yes, the Terasen Utilities have considered scenarios to accommodate change in provincial government policy.

Potential change in government policy is one of many factors that will determine the ultimate rate of adoption of NGV's in BC. At present, government policy is supportive of NGV adoption as evidenced in regulations such as the Low Carbon Fuel Requirement Regulation, which mandates a 10% reduction in the carbon intensity of transportation fuels by 2020.

In the 2010 LTRP, the Terasen Utilities provided three potential scenarios for adoption. The Low NGV Demand Growth scenario outlined in Section 4.3.3.3 (page 108) of the LTRP specifically contemplates an environment where "Public policy measures to encourage the use of natural gas as a transportation fuel is less aggressively pursued." This scenario encompasses the situation where provincial government policy might favour promotion of fuel cell bus or electric bus technology.

11.6 In Response to BCUC IR 1.1, the Terasen Utilities state that they have already "adopted" the positions recommended in the 2010 LTRP. Please comment on the risks inherent in these adopted positions given the uncertainties described in the IRs above.

Response:

Please see the response to BCUC IR 2.2.1. The use of the term "adopted" was meant to indicate that the 2010 LTRP reflects the Terasen Utilities current plans and was not intended to suggest that the Terasen Utilities would proceed with any particular position regardless of the Commission determinations.

12.0 Reference: Exhibit B-5, Response to BCUC IR 10.1

NGV Refueling Market

"TGI acknowledges that there is capital risk associated with our plans to enter the NGV refueling market; however, we believe the data shows that the expected benefits to all customers significantly outweigh those risks. TGI does not expect that this prudent investment will negatively impact our risk profile."

12.1 What are the data referred to by TGI in the above quote? To the extent possible, please file a copy of the data as an exhibit to the Application.

Response:

The data referred to in the above quote relates to an economic analysis of the benefits to customers from the addition of the target of 30PJ of incremental load from the NGV market.

TGI has used the projected increases in natural gas system load for three scenarios (Reference Case, Low Growth, and Reference Case plus Passenger) to calculate the impact to revenue requirement and the corresponding impact to TGI delivery rates under each scenario. The revenue requirement benefit represents the increase in delivery margin from the incremental volumes associated with the Transportation Fuelling service and is offset by the cost of service of the forecast EEC innovative technologies funding attributable to the Transportation Fuelling Service.

This issue will be addressed in depth as part of the Transportation Fuelling Service Application that will be submitted by the end of 2010; however, the main findings are presented below:

All Customers Benefit from Increased Throughput[5]

Impact to Existing Natural Gas Customers: NGV Refuelling Service	2012	2015	2020	2025	2030
Forecast Revenue Requirement Reduction (Increase), $000's					
Reference Case	384	2,285	12,501	39,829	82,451
Low Growth	308	730	5,059	15,865	33,377
Plus Passenger	421	2,650	17,973	50,773	104,339
Approximate Annual Delivery Rate (Decrease) Increase, %					
Reference Case	-0.07%	-0.42%	-2.31%	-7.36%	-15.24%
Low Growth	-0.06%	-0.14%	-0.94%	-2.93%	-6.17%
Plus Passenger	-0.08%	-0.49%	-3.32%	-9.38%	-19.29%
Volume (TJs)					
Reference Case	264	1,236	6,024	15,764	29,549
Low Growth	225	556	2,588	6,543	12,403
Plus Passenger	274	1,336	7,524	18,764	35,549

The results are consistent in all three demand forecast scenarios: increased throughput from the Transportation Refuelling Service results in a favourable reduction in delivery rates for TGI existing natural gas customers. Under the Reference Case, existing natural gas customers benefit with a significant 15.2% reduction, or $82.5 million, in delivery rates in 2030. In today's dollars, this is an approximate revenue requirement reduction of $22.0 million.

As discussed in response to CEC IR 2.5.7, the addition of load under Rate Schedule 16, (LNG) is expected to require additional investment in LNG production and storage facilities in the 2015 – 2020 time frame. The load addition benefits referenced above are expected to provide the basic economic justification for this investment. The economic business case will be developed as TGI gains more experience and confidence in the load projections as the initial market develops. Application for capacity expansion assets would be dealt with in a CPCN once it becomes clear that the capacity additions are required.

Overall, the development of a larger NGV market in B.C. offers the opportunity to offset natural gas demand declines in other customer segments such as the residential and commercial sectors. Increasing NGV load also offers benefits to the natural gas system as NGV load tends to be more year-round in nature than low load factor space heating, which is the dominant contributor to demand in the residential and commercial customer segments.

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5 In the upcoming Transportation Fuelling Service Application, TGI has created three scenarios which mirror the projections in the 2010 LTRP. The "Reference Case" refers to the "Favourable NGV Environment Scenario" as described in the 2010 LTRP. The other scenarios have the same names across both Applications.

13.0 Reference: Exhibit B-5, Response to BCUC IR 11.2, pp. 23-25

NGV Cost Effectiveness

13.1 How many NGV (LNG and CNG) would be required to be introduced annually in British Columbia in order to replace the existing vehicles in Terasen Utilities'' target market for fuel switching (e.g., buses, long haul trucks, vocational trucks, taxis, etc.) which are currently in operation. Please assume a 20 year period.

Response:

Based on the 20-year NGV demand forecast provided in the 2010 LTRP, TGI expects to capture 6.5% of the target transportation market by 2030.[6] Under favourable market conditions, TGI believes this is a reasonable estimation. Given this background, therefore, we interpret the question above to be asking how many vehicle additions per year would be required to replace and exceed the current number of NGVs operating in BC. We have provided a response below based on the NGV demand forecast.

Since the current number of NGVs in BC would be replaced by 2014, the table below only shows a summary of the first five years of the 20-year demand forecast.

Total Cumulative Number of NGVs under the Favourable NGV Environment Scenario

Category	2010 Actual	2011	2012	2013	2014	2015
Light Duty Trucks	550	550	650	750	850	1,000
Medium Duty Trucks	30	30	40	65	80	100
Heavy Vocational Trucks	-	25	50	100	150	200
Heavy Duty Trucks	-	9	41	73	105	200
Buses	50	75	100	150	200	250
Marine Vessels	-	-	-	-	-	1
Total Cumulative Vehicles:	630	689	881	1,138	1,385	1,751
Incremental Vehicle Additions:	-	59	192	257	247	366

We estimate that the current number of vehicles fuelled by the Terasen Utilities is approximately 630.[7] The cumulative number of NGVs by 2014 is 1,385. This calculates to 755 incremental new vehicle additions by the end of 2014. Therefore, TGI estimates additions would exceed the 630 NGVs currently in operation sometime during 2014.

6 Please see page 109 the 2010 LTRP for the Favourable NGV Environment Scenario.

7 Please see page 106 of the 2010 LTRP for the list of assumptions.

13.2 Automobile and truck manufactures are continually improving the fuel efficiency and emission standards for the vehicles that they manufacture to meet increasingly stringent environmental standards and regulations. Please provide a comparison of tailpipe emissions per kilometer for the "best" diesel, gasoline, and NGV vehicles available to the Canadian market at present.

Response:

TGI has developed its GHG emissions estimates on a per kilometer basis using emission factors from Natural Resources Canada's GHGenius model.[8] This model calculates a "wells-to-wheels" lifecycle assessment of transportation fuels. The GHGenius model is a widely accepted source for calculating vehicle emissions. In 2009, the Province of British Columbia incorporated lifecycle emissions with explicit reference to GHGenius in the development of its Low Carbon Fuel Requirements Regulation.[9]

In the 2010 LTRP, TGI used GHGenius version 3.17, which was released in February of 2010. Since then, updated versions have been released in June 2010 (3.18) and August 2010 (3.19). The results in the model change frequently to reflect a variety of changes in the real world, including changing electric power mix, increasing quantities of bitumen sourced crude oil, and engine technology improvements. Thus, these results represent the "best' vehicles available to the Canadian market at present.

The emissions factors from vehicle operation ("tailpipe") are summarized in the table below.

	GHGenius "Tailpipe" Emission Factor (g/km)			
	Gasoline	Diesel	CNG	LNG
Light Duty Vehicle[10]	216	N/A	185	N/A
Heavy Duty Vehicle/Bus[11]	N/A	1,078	941	808

Source: GHGenius 3.18, BC region[12]

[8] Software available from Natural Resources Canada at www.ghgenius.com.
[9] http://www.cngva.org/en/home/environment--safety/lifecycle-emissions-benefits.aspx
[10] Refers to passenger cars, light duty trucks, and medium duty trucks
[11] Refers to heavy duty trucks, vocational trucks, and buses.
[12] GHG Version 3.18 is used in this IR as this response has been developed using more recent data from the upcoming Transportation Fueling Service Application. Version 3.17 was the latest version available when the LTRP was submitted. The differences with respect to this calculation are not material.

TGI believes that total lifecycle emissions are a more accurate indicator of GHG impact than simply tailpipe emissions from vehicle operations. The "wells-to-wheels" lifecycle assessment includes:

- fuel extraction;
- fuel processing;
- fuel storage, transport and delivery;
- vehicle operation;
- vehicle assembly transport, and materials.

Based on GHGenius 3.18, GHG emissions reductions on a lifecycle basis are:

- Passenger Cars / Light Duty Trucks / Medium Duty Trucks:
  - Gasoline to CNG is a 25.6% reduction in CO_2e
- Heavy Duty Trucks / Vocational Trucks / Buses:
  - Diesel to CNG is a 23.2% reduction in CO_2e
  - Diesel to LNG is a 26.8% reduction in CO_2e

In summary, the Terasen Utilities believe the conversion of gasoline or diesel vehicles to NGVs can significantly reduce GHG emissions in the BC transportation sector.

13.2.1 If all of the fleet vehicles which are currently operating in British Columbia were replaced by the most fuel efficient diesel and gasoline vehicles which are currently available in the market, what annual impact would that have on the reduction fuel consumption and GHGs? If this were considered the base-case for NGVs, what incremental savings in GHGs would be achieved through the introduction of NGV. Please provide a comparison with the savings used in the 2010 LTRP with the above calculation.

Response:

The GHG assessment contained in the LTRP is developed based on current diesel and gasoline fleet vehicles. The assessments are based on Natural Resource Canada's GHGenius model version 3.17.[13] This model is constantly being updated to reflect the latest generations of technology affecting GHG emissions. For a further discussion please see the response to BCUC IR 2.13.2.

Thus, the base case for fuel consumption and GHG emissions reflects the reality of a fleet owner's options when considering how to retire or replace a vehicle at the end of its useful life. We have not considered the emissions of a 10 year old vehicle. Rather we have considered the emissions of a new vehicle equipped with a natural gas engine versus a new vehicle equipped with a diesel engine (for heavy duty applications) or a new vehicle equipped with a gasoline engine (for certain light duty applications).

In general, compared to current (i.e. most recent) generation diesel technology, CNG spark ignited engines deliver a 23% GHG emissions reduction and LNG diesel cycle engines deliver a 27% GHG emissions reduction . Diesel engines are the standard comparison for heavy duty market segments that are the primary targets for NGVs.

With respect to light duty segments, the comparison is a spark ignited CNG engine versus a gasoline engine. In this case the GHGenius model indicates the most recent generation of gasoline engine technology generates 25% more GHG emissions than a spark ignited light duty CNG engine.

[13] Software available from Natural Resources Canada at www.ghgenius.com

14.0 Reference: Exhibit B-5, Response to BCUC IR 38.1

Government Objectives CEA s. 2(h)

"The Terasen Utilities believe that of the three scenarios, Scenario C is the most consistent with the objectives of the CEA and UCA since it presents the implementation of an increase in cost effective DSM programs." BCUC IR 38.1

14.1 Please discuss the risks to Terasen Utilities NGV initiatives if: (a) the gap between CNG/LNG engines and diesel and gasoline engines continued to narrow in future in terms of tailpipe emissions and the hydrocarbons of NGV continues to worsen compared to diesel engines; and (b) the provincial and federal policies continue to favour fuel cell and electric vehicles (ref: BCUC IR 12.2).

Response:

The Terasen Utilities do not accept the stated position that provincial and federal policies favour fuel cell and electric vehicles. Provincial Government policy as implemented in the provincial Low Carbon Fuel Requirement Regulation is technology neutral. Federal policy is also supportive of NGV initiatives as evidenced by NRCan's leadership of the recent NGV Commercialization Roadmap initiative[14].

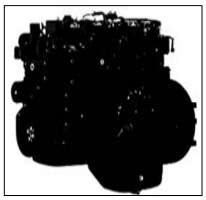
The recent improvements that have been achieved with respect to diesel engine emissions are the result of post combustion scrubbing technologies, such as particulate traps and nitrogen oxides (NOx) scrubbers. These improvements to diesel technology have closed the emissions advantages of natural gas engines but only with respect to oxides of nitrogen and particulates. Natural gas engines continue to hold an advantage over diesel engines with respect to tailpipe and lifecycle CO2 emissions. Further, the addition of after treatment scrubbing technology results in a decline in fuel efficiency[15] which increases GHG emissions. The main drivers of the NGV initiative are fuel cost advantages and GHG advantages; therefore TGI does not believe there is significant risk to the NGV initiatives from the addition of scrubbers to improve the environmental performance of diesel engines.

Improvements in basic combustion technology achieved regarding internal combustion engines should also be applicable to natural gas engines as well as gasoline and diesel. As more market share is developed for natural gas engines additional research is being devoted to this technology, resulting in improvements in performance. See the two figures below provided by Cummins - Westport:

[14] http://www.cngva.org/en/home/canadas-industry/natural-gas-for-transportation-deployment-roadmap.aspx
[15] http://www.epa.gov/otaq/retrofit/tech-summary.htm

Four Generations of Natural Gas Engines

1990 | 1998 | 2001 | 2007



L 10

- Introduced in 1990
- 10 litre Lean burn SI Mechanical
- Based on Industrial NG engine

C8.3G Mechanical

- Introduced in 1998
- Major improvement over 1st generation CNG L10 Series
- Over 4000 still in service
- Improved Reliability

C Gas Plus

- Introduced in 2001
- State of the art “PLUS” spark ignition/control system
- **First engine 2004 EPA Certified**
- Six fold reliability Increase vs C8.3G Mechanical

ISL G

- Introduced in June 2007
- Stoichiometric EGR combustion
- Wastegate Turbo
- Three Way Catalyst
- **First HD engine certified 2010 NOx and PM levels**

Key Characteristics-Diesel vs. NG

Just Like Cell Phones, Natural Gas Engines have Continued to Improve

	L 10 G	C 8.3	C Plus	’07 ISL G
Emissions	Better	Better	Better	Better
Reliability	Worse	Worse	Similar	Similar
Fuel Cost/Mile	Worse	Worse	Similar	Better*
Durability	Worse	Worse	Similar	Similar
LCC	Worse	Worse	Worse	Better*
Timeline	1989	1996	2001	2007

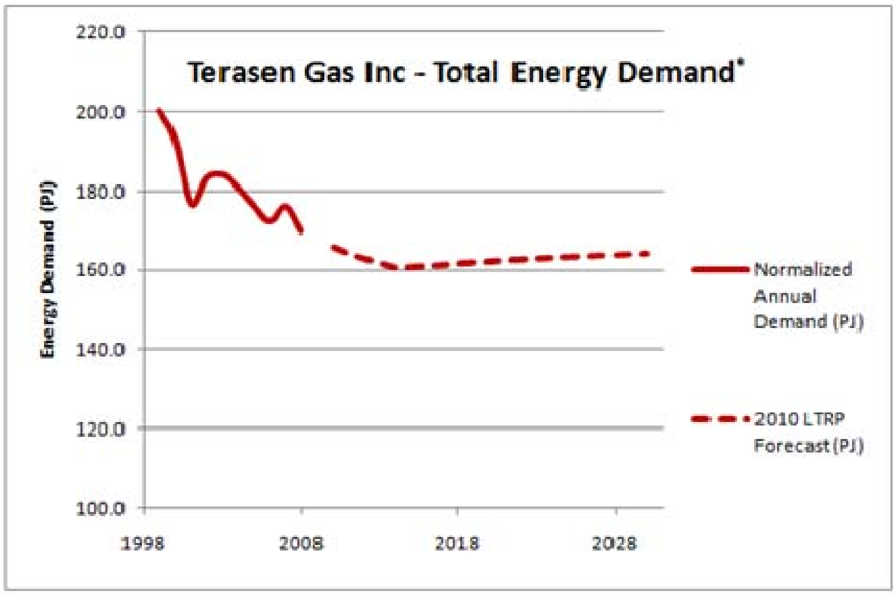
*Must Have Fuel Price Differential to be lower

EEC FUNDING SCENARIOS

15.0 Reference: Exhibit B-5, Response to BCUC IR 15.1, p. 35 and Response to BCUC IR 26.1.1, p. 58

Demand Forecast Tables

15.1 Appendix B-2, Exhibit B-5 of the Utilities 2010 LTRPI contains a forecast of energy demand for the period 2010 to 2030. In order to include a historical perspective, the following graph was prepared. Please confirm whether the graph is accurate. If not, please provide an updated version.



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Normalized Annual Demand (PJ)	200.1	192.5	176.8	183.2	184.1	180.8	176.4	172.4	176.2	170.0

* Prepared by Commission Staff. Normalized Annual Demand data from TGI 2010-2011 Revenue Requirement Application, Exhibit B-4, Response to IR 4.3, p. 9 2010 LTRP Forecast data is the aggregated TGI Coastal and TGI Interior forecasts from 2010 LTRP, Exhibit B-5, Appendix B-2

<u>**Response:**</u>

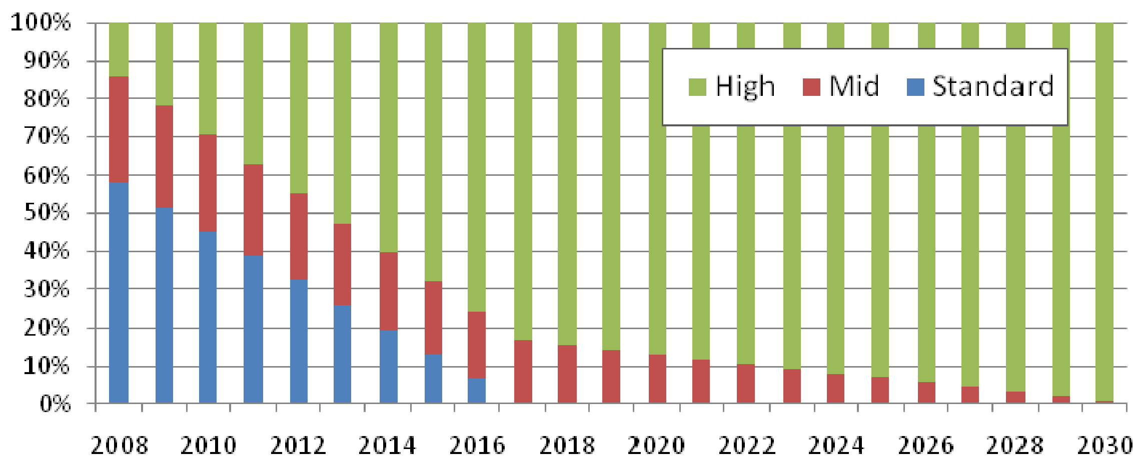
The Terasen Utilities confirm the graph is accurate based on Normalized Annual Demand data from TGI's 2010-2011 Revenue Requirement Application and 2010 LTRP forecast data.

15.1.1 There seems to be a leveling out of energy demand starting sometime around 2016. Please explain the critical factors and assumptions used in modeling this forecast.

Response:

The levelling out seen in approximately 2016 is primarily due to the anticipated retrofitting of all standard efficiency furnaces by that time. The retrofitting of standard efficiency heating equipment with units of higher efficiency ratings has the most significant impact on residential average use per customer. Given that, once all standard efficiency furnaces are replaced with those of higher efficiency ratings, the Terasen Utilities anticipate future annual demand for residential customers will stabilize. As presented in Figure 4-2 p.79 in the LTRP, the Terasen Utilities estimates that standard efficiency furnaces will be completely phased out from its existing customer base sometime between 2017 and 2020 depending on the region.

This analysis is based on results from 2008 REUS survey and the assumption that most people will replace their furnaces once they reach the end of their expected service life. Going forward, the Terasen Utilities will monitor the adoption of high efficiency appliances in our customer base and refine our model assumptions accordingly.



15.2 Historical data provided in response to BCUC IR 26.1.1 do not agree with historical data provided by Terasen Gas Inc. in response to IR 4.3., Exhibit B-4 of the 2010-2011 Revenue Requirement Application previously filed with Commission. The following table summarizes variances. Please reconcile the differences.

Historical Actual Energy (PJ)	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Ref.
2010-2011 Revenue Requirement	198.9	196.7	178.5	186.5	176.6	171.6	175.7	170.1	182.6	183.4	1
2010 Long Term Resource Plan	210.1	208.5	190.0	198.2	188.5	183.2	188.0	182.6	195.7	196.8	2
Variance	11.2	11.8	11.5	11.7	11.9	11.6	12.3	12.5	13.1	13.4	Line 2-1

1 Data source: TGI 2010-2011 Revenue Requirement Application, Exhibit B-4, p.9

2 Data source: 2010 LTRP, Exhibit B-5, Response to IR 26.1.1, p. 58

Response:

The differences presented in 2010-2011 Revenue Requirement and 2010 LTRP as illustrated in the table above are due to the level of data aggregation.

The 2010-2011 Revenue Requirement table includes only TGI while the LTRP includes all the companies (TGI, TGVI, and TGW). The historical data Terasen Utilities provided in response to BCUC IR 1.26.1.1 was consistent with the historical data previously filed in the 2010-2011 Revenue Requirement Application.

16.0 Reference: Exhibit B-5, BCUC IR 19.1, IR 8.2

Three EEC Funding Scenarios

The three funding scenarios are intended to be high level and for illustrative purposes. The level of detailed program planning such as that which was completed for the TGI/TGVI 2008 EEC application was not undertaken in creating the three scenarios. The savings presented in the three EEC Scenarios were derived from variations in the assumptions of EEC funding.

16.1 Please confirm that when creating the three scenarios, assumptions to correspond each scenario to uncertainties in the planning environment (e.g., change to government policy or cost to supply of natural gas) were not explicitly or implicitly made.

Response:

That is correct. The scenarios were developed by taking the energy savings associated with the currently approved funding envelope, and varying them proportionally based on the assumed funding level. The Terasen Utilities will be preparing an EEC program plan based on the findings of the 2010 CPR, incorporating externalities such as government policy and the avoided cost of natural gas for submission in support of the next EEC funding approval request.

16.2 Since the three funding scenarios were created without reference to composition of strategies and/or program, would it be difficult to assess if the program costs and associated savings are realistic?

Response:

The funding scenarios are intended to be very high level and are based upon energy savings and associated costs for previously approved EEC activity. Based upon that previously approved EEC activity, funding levels and energy savings were developed "from the ground up," i.e. program by program. Therefore, although high-level estimates only, the Terasen Utilities believe that the Scenarios were developed based on the best available information at the time and should be considered realistic given that they are based on the real costs and savings of the existing EEC programs. No approvals for EEC funding based upon the scenarios presented are being sought in this LTRP. It is the intent of the Terasen Utilities to prepare an EEC program plan based upon the findings of the 2010 CPR in support of the next EEC funding approval request. That plan will provide information about program assumptions on both the cost and savings side, and it should be possible to assess whether those assumptions in support of the next EEC funding request are reasonable, as was done in the EEC proceeding in 2008/2009.

17.0 Reference: Exhibit B-4, BCUC IR 51.5 Attachment; Exhibit B-3, BCOAPO IR 1.4

EEC Expenditure Analysis

Under Option B, the mid-year deferral accounts for TGI and TGVI for the year 2013 will reach \$79,132,000 (\$65.118 m + \$14.014 m). Under Option C, the midyear deferral accounts for TGI and TGVI for the year 2013 will reach \$137,471,000 (\$104.268 + \$33.203).

17.1 Please explain how such deferral accounts will be financed.

Response:

Assuming that the existing treatment of the EEC deferral accounts continues, the accounts will be part of the Terasen Utilities' Rate Base, which is financed according to the capital structure approved by the Commission. As currently approved, the composition of financing the Rate Base would be 40% with Common Equity, approximately 50% - 55% with Long Term Debt and the balance with Unfunded Debt.

17.2 Please confirm if such large increase in deferral accounts over a long-term period would increase the operational risk for the Terasen Utilities.

Response:

As previously discussed, the development and presentation of the EEC Scenarios in the 2010 LTRP was for illustrative and discussion purposes only.

Although the impact to rate base of the deferred expenditures is large in the early years, once the balances in the deferral accounts reach the half way (5 year) point of their current amortization schedule, the increases to rate base begin to decline, and, at the 10 year point, there is no incremental impact on rate base due to ongoing expenditures.

In general, the Terasen Utilities do not expect that an increase in the deferral accounts over a long-term period would increase the operational risk for the Terasen Utilities unless it resulted in uncompetitive rates. Deferral accounts such as the EEC deferral account are intended to allocate the costs of the EEC programs to the customers that benefit from them by attempting to match the recovery period to the periods of reduced consumption that result from the programs. The reduced consumption results in savings to the related customers and mitigates the rate pressure. As long as the deferral accounts continue to be approved for recovery from customers and the impact to on customers' rates is not significant (see Attachment 51.5 as provided in the response to BCUC IR 1.51.1 for illustrative rate impacts), there should be little impact on the risk profile of the Terasen Utilities resulting from the deferral accounts.

17.3 Please comment how these large balances affect Terasen Utilities' credit rating.

Response:

It is not anticipated that these balances would cause a downgrade to Terasen Utilities' existing credit ratings as long as it continues to be financed consistent with the rest of the utility rate base and there is an expectation that the amounts deferred will be recovered in customer rates over a reasonable time frame.

17.4 In the Response to BCOAPO IR 1.4, Terasen Utilities state that TGI has not yet established the final methodology or time period for recovery of the deferral account balance. When will it take place?

Response:

The Terasen Utilities expects to file an application with the Commission in the first quarter of 2011 to deal with the business model and rates for alternative energy service offerings (e.g. geothermal). This application will discuss the proposed treatment of the New Energy Solutions deferral account and how it would be recovered from customers.

17.4.1 The Response to BCOAPO IR 1.4 refers to a future Commission review on the New Energy Solutions Deferral Account balance. Is this part of the four-year Action Plan of the 2010 LTRP?

Response:

Yes. The Commission review of the New Energy Solutions deferral account is part of Action Item 4 on page 188 of the LTRP where it is indicated that the Terasen Utilities will be seeking approval of the overall business and regulatory model for the new energy solutions line of business.

18.0 Reference: Exhibit B-2, Response to BC Hydro IR 2.1; Exhibit B-4, Response to BCSEA 16.3

Market Share for NGV in B.C.

In describing the three potential scenarios for adoption of NGV's in the LTRP, the Terasen Utilities will monitor the actual rates of adoption and may need to adjust forecast of adoption rates (either up or down) in subsequent Resource Plans.

18.1 Please comment if adjustment of adoption rates should also be reflected in future EEC Annual Reports.

Response:

It is Terasen Utilities plan to track the rates of NGV adoption and to make any necessary adjustments in subsequent Resource Plans. Rates of adoption will also affect EEC incentives paid and information about rates of adoption and incentives paid will also be included in future EEC Annual Reports.

18.2 In the Response to BCSEA IR 16.3, Terasen Utilities indicate that no specific collaboration with BC Hydro has taken place to date on low emission vehicle programs. Could a lack of coordination result in the risk of both sides making more optimistic projections, electric vehicles for BC Hydro and NGV for Terasen Utilities?

Response:

In the response to BCSEA IR 1.16.3, the Terasen Utilities indicated that efforts to establish collaboration with BC Hydro are planned.

At this point in time it is not possible to speculate on where such collaboration discussions will lead, although it is TGI's view that electric vehicle solutions are best targeted on low mileage range passenger commuter vehicle applications. This view is supported by the City of Vancouver, which has released a number of requirements to support the use of electric vehicles for residential service.[16]

The NGV program being pursued by Terasen Gas is focused on commercial, return-to-base, heavy duty trucking fleet applications where fuel consumption is high. Hence it is unlikely that there is a significant risk of double counting penetration estimates.

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[16] The City of Vancouver, Sustainability, http://vancouver.ca/sustainability/electric_vehicles.htm

The electric and natural gas development plans do not have significant shared target markets in any segment other than transit buses. Therefore, any share gains will come at the expense of conventionally fuelled vehicles.

19.0 Reference: Exhibit B-2, Response to BCUC IR 8.2

New EEC Funding Scenarios and Programs

"The level of detailed program planning such as that which was completed for the TGI/TGVI 2008 EEC Application was not undertaken in creating the three scenarios."

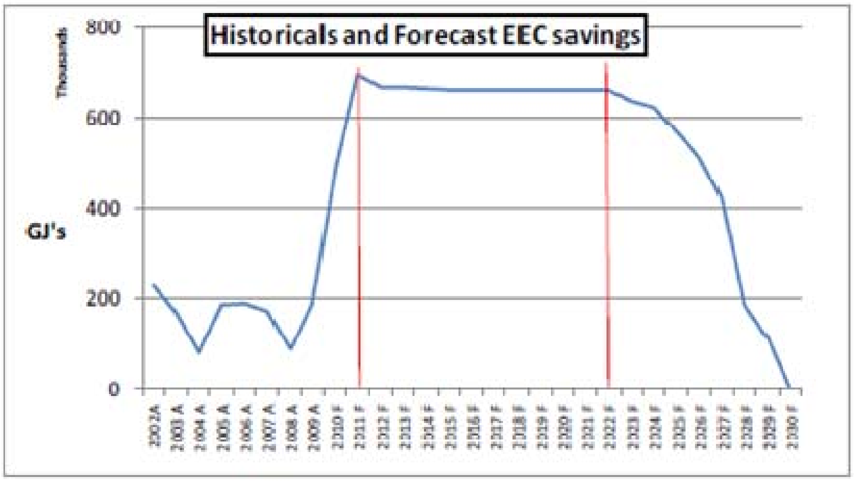
19.1 What is the relationship between the EEC Annual Report and the EEC portion of the LTRP? For example, do the analyses and study results on current EEC activities and commitment to undertake activities in the Annual Report get fed into the long-term plan?

Response:

The EEC Annual Report looks backward at the previous year's EEC activity, and forward to the EEC activity planned for the upcoming year. The EEC portion of the 2010 LTRP presented 3 scenarios that are based on the work that was done to support the 2008 EEC Application in that the energy savings used in the scenarios are those associated with the EEC funding level approved in the EEC Proceeding. The EEC Annual Report is detailed and presents such information as expenditure, participation and resultant energy savings in specific programs. This information has not been fed into the EEC scenarios presented in the 2010 LTRP because there has not yet been any program planning done to support an EEC funding approval request beyond currently approved levels.

20.0 Reference: Exhibit B-5, Response to BCUC IR 43.1 p. 112-113

Impact on Energy Savings Funding Scenario A



20.1 The above graph was supplied by the Utilities in response to IR 43.1. For illustrative purposes, Commission staff have highlighted the 10-year period 2011F to 2022F by superimposing demarcations for those years. Despite EEC funding ceasing at the end of 2011, the graph seems to suggest that EEC savings will not be materially impacted for a subsequent 10 year period. Please confirm whether this is correct. If “yes”, please explain the underlying assumptions which support this level of EEC program persistence.

Response:

The Terasen Utilities confirm that the EEC savings will remain constant over the 10 year period from 2011 to 2022. In Scenario A, the Terasen Utilities assume that once funding expires at end of 2011, the existing number of participants, acquired through that funding, will continue to accumulate savings until the end of the measure life at which point the savings begin to cease and decline. The Terasen Utilities also assume that the measures being considered under the current planned programs are not discarded or replaced before the end of their expected measure life, since natural gas equipment such as furnaces, boilers and water heaters is difficult to remove.

20.1.1 Based on the data summarized in the above graph, please calculate the cumulative energy savings from 2009 to 2030. Please reconcile this amount with the energy savings for Funding Scenario A as illustrated in Figure 5.1, Exhibit B-1, p. 122.

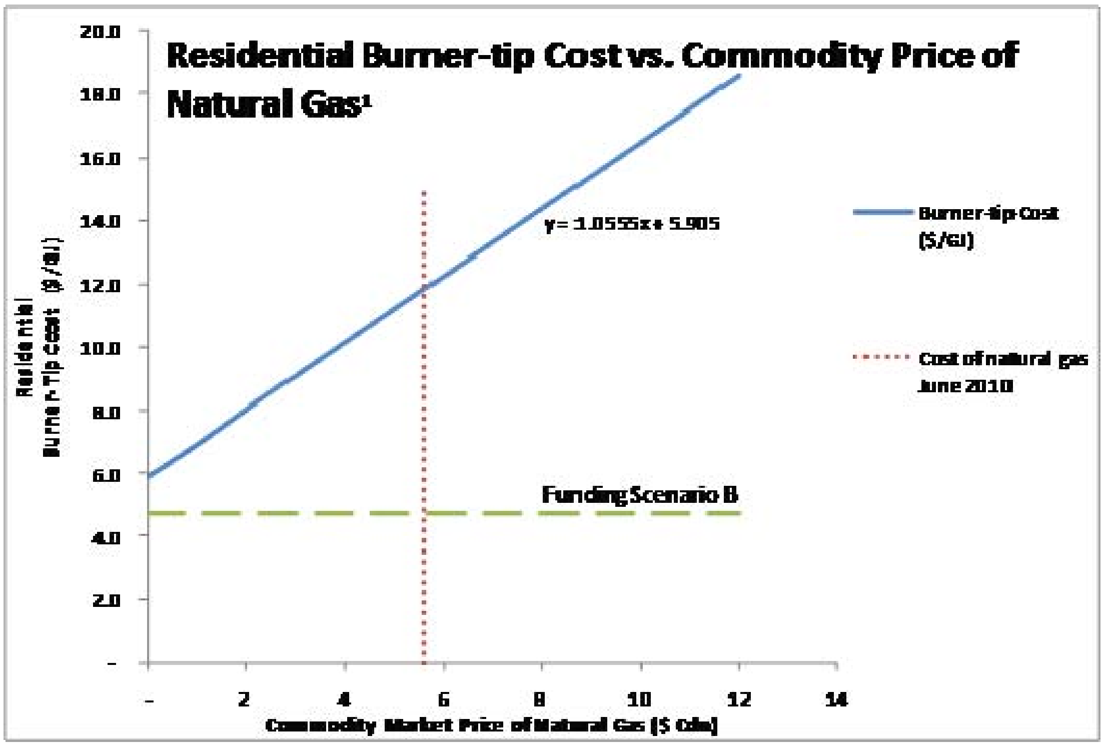
Response:

The cumulative energy savings from 2009 until 2030 from the above graph is 11,751,561 GJ's or 12 PJ's when rounded. The energy savings for funding scenario A as illustrated in Figure 5.1, Exhibit B-1 when rounded is also 12 PJ's.

21.0 Reference: Exhibit B-5, Response to BCUC IR 41.1.3 p. 111

Impact of Commodity Prices on EEC Funding Scenarios

21.1 Based on the rate structure of residential customers (June 2010), a summary of the relationship between the market price of natural gas and end user cost is summarized the table and graph below. Please confirm whether the data are correct. If not, please provide an updated version.



June 2010 Residential Rate Structure		Cost of Natural Gas ($/GJ)				
		-	1.00	4.00	8.00	12.00
Basic Charge ($)	11.84	0.00	0.00	0.00	0.00	0.00
Delivery Charge ($/GJ)	3.145	3.15	3.15	3.15	3.15	3.15
Midstream Charge ($/GJ)	1.725	1.73	1.73	1.73	1.73	1.73
Carbon Tax ($/GJ)	0.7449	0.74	0.74	0.74	0.74	0.74
Clean Energy Levy (%)	0.4	0.02	0.03	0.04	0.05	0.07
GST (%)	5	0.28	0.33	0.48	0.68	0.88
Burner-tip Cost[2] ($/GJ)		5.92	6.97	10.13	14.35	18.57

1 Prepared by Commission Staff

2 Excluding basic monthly charge of $11.84

Response:

The Terasen Utilities concurs with the residential rate structure table as prepared in the IR and presented above. However, we do not agree with the addition of the line representing funding Scenario B in the above chart. Please see the response to BCUC IR 2.21.1.1 for an explanation.

21.1.1 The above data seem to suggest that even if the commodity price ($/GJ) of natural gas fell to zero, it would remain economically beneficial for residential customers to support Terasen Utilities implementation of EEC Funding Scenario B. Stated slightly differently, there seems to be no commodity price of natural gas at which Terasen Utilities EEC Funding Scenario B is not financially economic. Please confirm whether this approximation is correct. If not, please provide an updated analysis and explanation.

Response:

The Terasen Utilities do not agree that scenario B leads to $5/GJ as illustrated in the chart and analysis above. Simply dividing the total projected expenditure by savings over time is not an appropriate mechanism to determine the cost-effectiveness of the portfolio as there are other inputs that go into the TRC calculation, such as cost of gas and discount rates that are missing from this analysis. Even If the commodity were to go to $0/GJ, there would be programs that would not pass the TRC cost benefit test as the overall costs would outweigh the benefits. Hence, it is challenging to determine the commodity price below which EEC programs would no longer economic, as detailed program planning for scenarios B and C has not been done. As stated in BCUC IR 1.42.1.3, scenarios B and C would offer a mix of programs at different cost effectiveness levels as defined by the currently-approved portfolio level TRC to as wide a range of customers as possible to satisfy the EEC program principle of universality and yet meet the current cost benefit guidelines.

The Terasen Utilities understand the analysis that the IR is trying to point out from the graph illustrated above, but, in the absence of portfolio-level cost-effectiveness calculations for scenarios B and C, it is too early to state unequivocally the commodity price below which EEC programs would not be financially economic.

21.1.2 Please confirm at what commodity price ($/GJ) Funding Scenario C is no longer economic.

Response:

Please see the response to BCUC IR 2.21.1.1. As program planning has not yet been completed, the Terasen Utilities are unwilling to speculate as to the commodity price at which Scenario C is no longer economic.

COST-EFFECTIVENESS OF EEC PROGRAMS

22.0 Reference: Exhibit B-5, Response to BCUC IR 33.1, pp. 72-73

Annual Demand Forecast

"In general, the more funds there are for EEC programs and activities the greater the energy savings."

22.1 Funding Scenarios A, B, and C each have significantly different costs and forecasted EEC impacts. It is generally observed in all production systems that there is a point beyond which the addition of more resources results in progressively decreasing marginal benefits. If the law of diminishing returns does not apply to the EEC in the 2010 LTRP, please explain why and provide supporting evidence.

Response:

No EEC program planning was conducted to support the Scenarios; however, as noted on page 121 of Exhibit B-1 in relation to Scenario C:

> *"Terasen Utilities recognize that the success of its initiatives will help transform the market throughout the planning period, and the scenario assumes that funding levels and associated savings begin to taper off by $5 million annually starting in 2022."*

So, at a high level, funding levels in Scenario C have been adjusted to reflect the fact that after a certain period of time, the "low-hanging fruit" in energy savings will have been captured by the Companies' EEC activity. The Terasen Utilities have not conducted any research as to whether the law of diminishing returns applies to DSM activity in general or more specifically at the spending levels captured in scenarios A, B and C, so we are unable to either confirm or refute this.

In preparation for the next EEC funding approval request, program planning will be conducted and any program risks such as diminishing returns will be identified at that time.

22.1.1 Please provide an analysis and supporting calculations of the marginal benefit associated with incremental spending for each of the proposed Funding Scenarios A, B, and C. Please clearly identify the assumptions implicit in the calculations.

Response:

The quoted statement in the preamble to the IR is a general statement; it is intuitive that, generally speaking, the more funds there are for EEC activity, the greater the energy savings will be as more funds means more programs, and more program participants installing efficiency measures that result in energy savings. The Scenarios are high level, for illustrative purposes only. No program planning has been conducted thus the Terasen Utilities have not conducted an analysis of the marginal benefit associated with increased spending. In actuality, marginal benefits will vary depending upon the mix of programs that constitute an EEC plan.

22.1.2 If a marginal analysis has not yet been performed, do the Utilities intend to perform such an analysis in conjunction with future Commission filings?

Response:

The Terasen Utilities will be putting forward a program plan in support of the next EEC funding approval request. The Terasen Utilities do not currently intend to perform a marginal analysis. However, insomuch as the next EEC funding approval submission varies from currently approved funding levels, activities and resultant energy savings, a marginal analysis could be performed. This topic and others will be discussed at the March 2011 EEC workgroup workshop that will discuss the request for EEC funding for 2012 and beyond.

23.0 Reference: Attachment: News Release and Media Reports

District Energy Systems in Kelowna, Conversion to CNV Vehicles by Waste Management Inc, and Geoexchange System in Okanagan School District

Attached are three articles from News Releases and Press Report relating to (1) Agreement to develop two renewable energy systems in Kelowna using Terasen-owned and operated district energy systems; (2) Terasen funding Waste Management Inc. to offset the incremental cost of the CNG trucks; and (3) a deal to retrofit and operate a geoexchange system in Central Okanagan School District.

News Release

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FOR IMMEDIATE RELEASE

September 30, 2010

Terasen Gas to develop renewable energy projects in Kelowna worth $38-million

City expected to save energy costs and produce fewer greenhouse gases

SURREY, B.C. – Terasen Gas and the City of Kelowna have entered into an agreement in principle to develop two unique renewable energy systems in Kelowna valued at $22-million and $16-million respectively. Using Terasen-owned and operated district energy systems, the Kelowna City Centre Energy System and Kelowna South Pandosy Energy System will help the City reduce its energy use and lower greenhouse gas emissions.

"This is an important, innovative collaboration that will help to reduce our carbon footprint," said City of Kelowna Mayor Sharon Shepherd. "District energy can significantly reduce greenhouse gas emissions while ensuring businesses and residences have a secure source of energy. This is one more step towards our goal to build a safe, vibrant and sustainable city."

"An integrated energy solution, such as a district energy system, allows us to incorporate alternative energy sources, in this case waste heat and water, to help ensure British Columbia meets its energy and environmental goals," said Doug Stout, Vice President, Energy Solutions and External Relations, Terasen Gas and FortisBC. "The systems will provide many benefits, including energy savings, affordable cost for customers, and proven reliability."

The two district energy systems will use waste heat and water from the City's wastewater treatment plant and from Sun-Rype Products Ltd., with other project collaborators providing energy to heat or cool a number of buildings in Kelowna. The new infrastructure will be put in place over the next decade. According to the City of Kelowna's January 2010 pre-feasibility study, both projects combined could also have the potential to save 16,300 tonnes of CO_2 per year – equivalent to removing approximately over 3,500 cars from the road annually.

"Sun-Rype is very pleased to collaborate in this important environmental initiative in Kelowna, and we look forward to working with Terasen and the City of Kelowna to make this project a success," said Dave McAnerney, CEO, Sun-Rype Products Ltd.

Before building the two district energy systems, Terasen Gas and the City of Kelowna will work to negotiate and conclude definitive agreements. With the successful conclusion of these agreements and the engineering work, approval from the British Columbia Utilities Commission will be required to proceed with the projects.

In October 2009, the City of Kelowna began exploring the possibility of district energy systems with local businesses. The pre-feasibility study identified a potential for district energy systems in four key areas of Kelowna: City Centre, South Pandosy, Orchard Park / Highway Centre and Rutland Centre.

Terasen Gas builds, owns and operates district energy systems for large-scale developments and existing communities. Buildings connected to district energy systems have lower capital costs for their energy equipment as they can eliminate conventional boilers, chillers or air conditioners, saving valuable upfront dollars that can be invested elsewhere.

For more information on Terasen Gas' integrated energy solutions, please visit terasengas.com.

For more information on the district energy pre-feasibility study, see the energy management section at kelowna.ca/environment.

Terasen Gas is mainly composed of the operations of Terasen Gas Inc. and Terasen Gas (Vancouver Island) Inc., both indirect wholly owned subsidiaries of Fortis Inc. Fortis Inc., the largest investor-owned distribution utility in Canada, serves approximately 2,100,000 gas and electric customers and has total assets exceeding $12 billion. Its regulated holdings include Terasen Gas and electric utilities in five Canadian provinces and three Caribbean countries. Fortis Inc. owns non-regulated hydroelectric generation assets across Canada and in Belize and upper New York State. It also owns hotels and commercial real estate in Canada. Fortis Inc. shares are listed on the Toronto Stock Exchange and trade under the symbol FTS. Additional information can be accessed at www.fortisinc.com or www.sedar.com

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NOTE TO NEWS EDITORS: Mayor Sharon Shepherd is in attendance at the Union of British Columbia Municipalities (UBCM) convention in Whistler. Those wishing phone interviews, please contact Tom Wilson at 250-469-8663 to make arrangements.

Media Contacts:

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Waste Management converting garbage trucks from diesel to natural gas

BY JEFF LEE, VANCOUVER SUN SEPTEMBER 28, 2010

Waste Management of Canada is converting its diesel garbage trucks to compressed natural gas.
Photograph by: Debra Brash, Postmedia News Files

WHISTLER - Waste Management Inc. will begin conversion of its diesel trash-hauling fleet in Vancouver later this year to compressed natural gas.

On Monday North America's largest commercial waste company announced a deal with Terasen Gas to supply fuel for 20 new CNG trucks the company will put in operation by the end of 2010.

The companies made the deal public at the Union of B.C. Municipalities, where Terasen is attempting to broaden its utility business with municipal governments. Rob Sherman, Waste Management's B.C. director of operations, said the company has 100 trucks in Metro Vancouver working on commercial contracts with apartment buildings and businesses.

He said the company will eventually convert all of its fleet to CNG as the trucks are replaced. Switching to natural gas will save the company 35-45 per cent in fuel costs, but Sherman said it's also good for business.

"We're all about clean air. This is a huge investment for us because we have clients that want us to associate with us if we undertake these kinds of green initiatives. It's a competitive differentiator for us."

Under the deal, Terasen gave Waste Management a grant from its Energy Efficiency and Conservation Fund to help with the purchase of the trucks. Neither company would reveal the size of the contribution, but Vito Triggiano, Terasen's manager of natural gas vehicles sales, said it was enough to be an incentive for Waste Management to begin the conversion.

Sherman said Waste Management already has 930 natural gas trucks in its North American fleet of more than 20,000 vehicles, and is aggressively moving to put more in place as conventional diesel trucks are retired.

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News Release

FOR IMMEDIATE RELEASE

October 12, 2010

Central Okanagan School District to save energy and money with new Terasen Gas geoexchange system

SURREY, B.C. –Terasen Gas and School District 23 Central Okanagan, have signed a deal to retrofit and operate a $650,000 geoexchange system, expected to be operational in 2010, at Helen Gorman Elementary School in West Kelowna. The geoexchange system will help the school manage its energy costs and reduce its carbon footprint.

"As one of the first utility companies in Canada to include alternative energy solutions as part of its regulated energy service offerings, our deal with the Central Okanagan School District will help them use energy efficiently and benefit the environment," said Doug Stout, Vice President, Energy Solutions and External Relations at Terasen Gas and FortisBC.

Once the geoexchange system is operational, Terasen Gas estimates that Helen Gorman Elementary School will save approximately 84 tonnes of greenhouse gas emissions (GHG) and 1,400 gigajoules of net energy per year. The geoexchange system will also enable Terasen Gas to determine how geoexchange systems can be used in other school districts to reduce schools' energy usage and GHGs.

"This upgrade and the operational savings it brings will result in more money being directed to the classroom while providing a more comfortable and sustainable learning space," said Ben Stewart, MLA for Westside-Kelowna on behalf of Education Minister Margaret MacDiarmid. "This project between the Province, the Central Okanagan School District and Terasen Gas is a model for the kind of partnership needed to aggressively pursue critical environmental goals."

Terasen Gas directly invested $225,000 into the retrofit and contributed an additional $100,000 through an Energy Efficiency and Conservation incentive to help fund the overall cost of the project, with the school district funding the balance.

"We are excited about this innovative and sustainable energy project and look forward to making significant progress in reducing our carbon footprint," said Hugh Gloster, Central Okanagan School District Superintendant. "With Helen Gorman Elementary School as an example, we hope many other schools will be encouraged to follow our lead to become as energy efficient as possible."

Geoexchange systems are one of Terasen Gas' principal alternative energy solutions that can be implemented in both new construction and retrofits. They transport heat from where it is generated to where it is needed by capturing heat from the earth, water or waste heat sources. Geoexchange systems also provide many benefits for developers, building owners and end-users, ranging from indoor comfort, to protecting the environment, to stable rates which provide financial certainty regarding the price of energy.

For more information on Terasen Gas' integrated energy solutions, please visit terasengas.com.

Terasen Gas is mainly composed of the operations of Terasen Gas Inc. and Terasen Gas (Vancouver Island) Inc., both indirect wholly owned subsidiaries of Fortis Inc. Fortis Inc., the largest investor-owned

23.1 For each of the three activities, please describe the following:

(a) What is the relevance, if any, of these activities to the 2010 LTRP? Since Terasen Utilities will not be asking for approval in this LTRP to proceed with these projects, please describe if these initiatives offer any insight to the Commission with regards to accepting the 2010 LTRP.

(b) Whether there were competing candidates for the funding and the criteria used in the selection of these recipients.

(c) How will these initiatives be tracked, measured, verified and reported? Will the TRC be used to assess the program and will the UC and RIM tests be carried out and reported? What will be the tests, in particular, the measurement for GHG emissions reductions?

(d) For the funding of the CNG trucks, will do the data for the calculations of GHG emissions reductions come from? Are the new CHC emissions compared to the old vehicle's emissions being replaced or to the current diesel or gasoline engine's GHG emissions?

(e) How will the results of these EEC initiatives inform demand forecasting for conventional natural gas usage and renewable energy usage?

Response:

This answer is structured in a manner to address each of the questions for each news release.

(1) Agreement to develop two renewable energy systems in Kelowna using Terasen-owned and operated district energy systems;

A. This project is an example of how Terasen Utilities is working towards the Province's goal of GHG emissions reduction targets and developing new products that meet the growing demand for alternative energy systems. Inclusion in the LTRP illustrates how the introduction of an increasing amount of alternative energy systems can impact the demand forecasts. This type of DES project is subject to Commission approval. TGI will be filing an alternative energy service application with the Commission early in 2011 and is not asking for approval in the LTRP to proceed with this project.

B. This is not an EEC initiative. As the Kelowna DES is still in the early design phase, whether or not the project or related activities will be evaluated for a contribution from TGI's EEC programs is yet to be determined.

C. As noted in (1)B, this project has not yet been evaluated for a contribution from TGI’s EEC programs.

D. not applicable

E. As noted in (1)B, this project has not yet been evaluated for a contribution from TGI’s EEC programs.

(2) Terasen funding Waste Management Inc. to offset the incremental cost of the CNG trucks;

A. The Waste Management NGV project is an example of how Terasen Utilities is working with fleet operators to develop NGV markets in heavy duty trucking operations that consume large quantities of diesel fuel. The LTRP includes demand from NGV markets. The WM project is an example of the type of load that is to be added and demonstrates that there is customer demand for NGV services. The project supports the Province’s goal of GHG emissions reductions, while adding beneficial load to Terasen Utilities’ system. The arrangements with WM for Terasen Utilities to provide compression and dispensing services is subject to BCUC approval. The Terasen Utilities will be submitting a separate application the BCUC for approval to provide such transportation related fueling services in by the end of 2010.

B. The Terasen Utilities has identified several market segments where NGVs have a strong value proposition. Segments of interest include high fuel consuming fleet vehicles such as garbage trucks, transit buses and heavy duty tractors. Within each segment of interest, the Terasen Utilities is identifying early adopter candidates that can help lead market transformation. Within the garbage truck segment the Terasen Utilities identified several leading companies that operate large fleets within the TGI service territory. Target companies were made aware of the incentive program and asked to provide an application outlining why their fleet would make the best choice for an NGV program. Waste Management Inc. submitted an application under this program. The program was subjected to a business case evaluation including a TRC test and was selected as a suitable candidate for the incentive program. A strong factor in the evaluation was the company’s expressed desire to expand from 20 initial NGV trucks to 100 NGV trucks (entire fleet) over time.

C. The agreements for NGV projects have specific take or pay requirements with respect to CNG consumption. Each of these agreements will be monitored through the billing process to ensure that consumption tracks contractual commitments. Each project will have a dedicated meter set established within the fuelling station to provide the consumption information that will be used to track usage and to feed into the GHG emissions reduction calculations. In addition, the agreement contains a specific provision for sharing of information regarding the performance of the vehicles.

Similar to conventional EEC programs, any EEC incentive funding provided for integrated and alternative energy services and natural gas vehicles would be subject to the same cost benefit analysis approved in the Commission's decisions on the 2008 EEC application and 2009 RRA. The TRC test is used to assess the cost effectiveness of the EEC portfolio as a whole, while the other ratios are given consideration during program planning and implementation stages. The Terasen Utilities report on all EEC activities including any funding provided to integrated and alternative energy systems and NGV in the EEC Annual Report. UC, RIM and TRC results for all programs were included in the 2009 Annual Report as Appendix J.

D. For natural gas vehicles, the Terasen Utilities developed its GHG emission estimates on a 'grams per kilometre' basis using emission factors from Natural Resources Canada's GHGenius model[17]. This model incorporates complete lifecycle emissions including materials, production, transportation, and vehicle operation. The 'grams per kilometre' approach is consistent with industry associations such as the Canadian Natural Gas Vehicle Alliance[18]. The Terasen Utilities have used data provided by the customer regarding the number of kms each vehicle typical travels in a year. This data has been compared to and verified against data developed from research into average distance traveled per year for each vehicle category that was used in the LTRP estimates.

The GHG emissions are compared to the current diesel/gasoline engine's GHG emissions baseline standard as described in the above paragraph – not to the emissions from the vehicles being replaced. Please also see response to BCUC IR 2.13.2 for more details.

E. Implementing renewable thermal energy alternatives, enhanced energy efficiency and conservation programs, and low carbon transportation fuel solutions will have an impact over time on conventional natural gas and renewable usage. The Terasen Utilities are currently in the process of developing methodologies for forecasting demand for renewable thermal and natural gas as a transportation fuel. Section 4.3 of the 2010 LTRP provides a conceptual demonstration of our approach by using specific examples and their impact on demand. While initially the scale of development of these alternative energy systems and natural gas vehicles will be slow compared to the Terasen Utilities core natural gas business, we expect the focus on developing these services today will result in growing market penetration in future years. Therefore, the impact of implementing these solutions on natural gas demand will be limited in the initial years.

17 Based on estimates from GHGenius software available from Natural Resources Canada(www.ghgenius.com)
18 http://www.cngva.org/en/home/environment--safety/lifecycle-emissions-benefits.aspx

Going forward the Terasen Utilities will be monitoring the adoption and growth of the new initiatives and acquiring additional data, research and tools that are needed to fully develop and implement these forecasting approaches. All of this new work will need to be done alongside our ongoing traditional forecasting processes as these will remain the primary input into our natural gas system and supply planning activities for the foreseeable future.

(3) Retrofit and operate a geoexchange system in Central Okanagan School District.

A. As noted above for the Kelowna DES (in 1(A)), the geoexchange system for the Central Okanagan School District is another example of how Terasen is working towards the Province's goal of GHG emissions reduction targets and developing new products that meet the growing demand for alternative energy systems. Inclusion in the LTRP illustrates how the introduction of an increasing amount of alternative energy systems can impact the demand forecasts.

B. The Okanagan School District retrofit opportunity came about via our regular customer interactions. An aging boiler was in need of replacement and the school district had determined they would like to install a geo-exchange system. They viewed the Terasen Utilities as an important part of the installation and ongoing operation due to our expertise in thermal energy systems. The Terasen Utilities' business offering related to alternative energy is available to all customers, but only some customers decide to proceed. In addition to the significant capital investments into the system by both the Terasen Utilities and the school district, providing an EEC component to this project was determined based on the initiative exhibited by the school district to implement this system and provide an opportunity for a pilot project that would enable the Terasen Utilities to assess the operating results for geoexchange in a school building.

C. The answer to 2(C) above details the application of TRC, UC, and RIM. The development of measurement tools for GHG savings will be done as this project is implemented if required.

D. not applicable

E. As noted in 3(B) this EEC initiative will provide access to operating results. This information can be utilized in the future to more accurately estimate the natural gas component and renewable component of alternative energy installations in the Terasen Utilities' demand forecasts.

24.0 Reference: Exhibit B-5, Response to BCUC IR 10.1, p.17

Transportation Fuel Service Offerings - NGV

24.1 Based on Terasen's historical experience with NGV programs (for example with Blacktop Cabs), please discuss the key problems and successes experienced by the Utilities in developing that line of business. If some customers have abandoned NGV programs, please explain why. Is it known whether they were substituted with competitive technology?

Response:

Historically, NGV programs in B.C. were focused on the passenger vehicle market through the development of public fueling stations. The BC NGV market has declined from a peak of 1.1 million GJ of consumption in 1992 to 200,000 GJ in 2009. TGI believes the decline in consumption from passenger and light duty vehicles over the past ten years is due to a number of reasons:

- In the period from 2001 to 2003 the price advantage of natural gas versus conventional fuels narrowed to the point where there was insufficient economic incentive to switch fuels given the differential in capital cost between the two options.[19]
- Passenger cars and light duty OEM suppliers such as Ford and General Motors withdrew their natural gas vehicle offerings of pickup trucks and vans from the market around 2004.[20]
- Cost of engine conversions for light duty vehicles increased from around $3,000 in the early 1990s to approximately $7,000 - $10,000 at present day.[21] As a result, the increased incremental cost of conversion made the adoption of light duty NGVs less attractive in terms of economic payback.
- BC refueling infrastructure was not supported by an 'anchor-tenant' model which has been successful in other jurisdictions. As a result of loss in load, NGV station closures resulted in a decline in customer confidence and convenience for refueling. In recent years, five stations closed in 2007 and eight stations closed in 2010. No new stations have been built since 2002.[22]
- Government incentive programs such as the Natural Resources Canada matching grant program discontinued in 2006.[23] As a result, customers who considered converting

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[19] See page 21 of the 2010 LTRP.
USA Today, July 5, 2007 http://www.usatoday.com/money/autos/2007-05-08-natural-gas-usat_N.htm
[21] Based on conversations with conversion specialist Excel Fuels Installations. Prices do not include incentive funding, grants, or subsidies.
[22] Based on Rate Schedule 6 customer history, no new accounts have been added since 2002.
[23] NGV Annual Report 2007, Order No. G-98-99

NGVs were faced with an increased incremental vehicle cost, making the switch to NGVs less attractive.

- There were also early generation technology issues with NGVs that have now been resolved.

One known customer, Black Top Cabs ("Black Top"), abandoned its NGV program which began in 1983 and peaked with around 160 taxis in 1995.[24] TGI believes one of the primary reasons Black Top abandoned its NGV program was due to the narrow price advantage of natural gas over gasoline in the early 2000s. In 2007, Black Top began its adoption of electric hybrid taxis with the help of government rebates and tax exemptions in the amount of $4,000 per vehicle.[25]

TGI is not presently focused on developing the passenger vehicle market and is targeting commercial, return-to-base fleet operators in the heavy duty truck and bus categories.

TGI believes that with a revised business model and a phased approach in implementation, the present market conditions are favourable to revitalize the NGV market for the following reasons:

- The economic advantage of natural gas over conventional fuels is large and growing and natural gas market fundamentals support the continuation of this economic advantage;
- The volatility of natural gas pricing under Rate Schedule 6 is less than gasoline or diesel pricing;[26]
- Reliable OEM natural gas vehicles are now available, particularly with respect to the heavy duty truck and bus market segments (e.g., Cummins-Westport powered buses and garbage trucks);
- As a secondary market, OEM's for light duty vehicles are now producing vehicles designed to be converted to natural gas fuel. (e.g., GM and Ford "NGV Ready" trucks and vans) and could leverage off of refuelling stations built for return-to-home fleets; and
- Environmental and regulatory policy initiatives have been initiated to favour adoption of low carbon footprint fuels (e.g., BC's Low Carbon Fuels Requirement Regulation).

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24 Fuelsense Newsletter, BC Gas, July 1995

25 The Province, June 24, 2007, http://www.canada.com/theprovince/news/story.html?id=9cd3797a-ce1c-459e-a7ac-71ebb128fd14&k=44379

26 Please see Figure 2-7, page 21 of the 2010 LTRP

24.2 Segmented by year, please provide a list of companies that Terasen has provided NGV programs and services to over the past 10 years. For each company, please provide time series data of the number of vehicles in use and the annual consumption of natural gas. Please also indicate the type and quantity of financial subsidy that has been provided to each company.

Response:

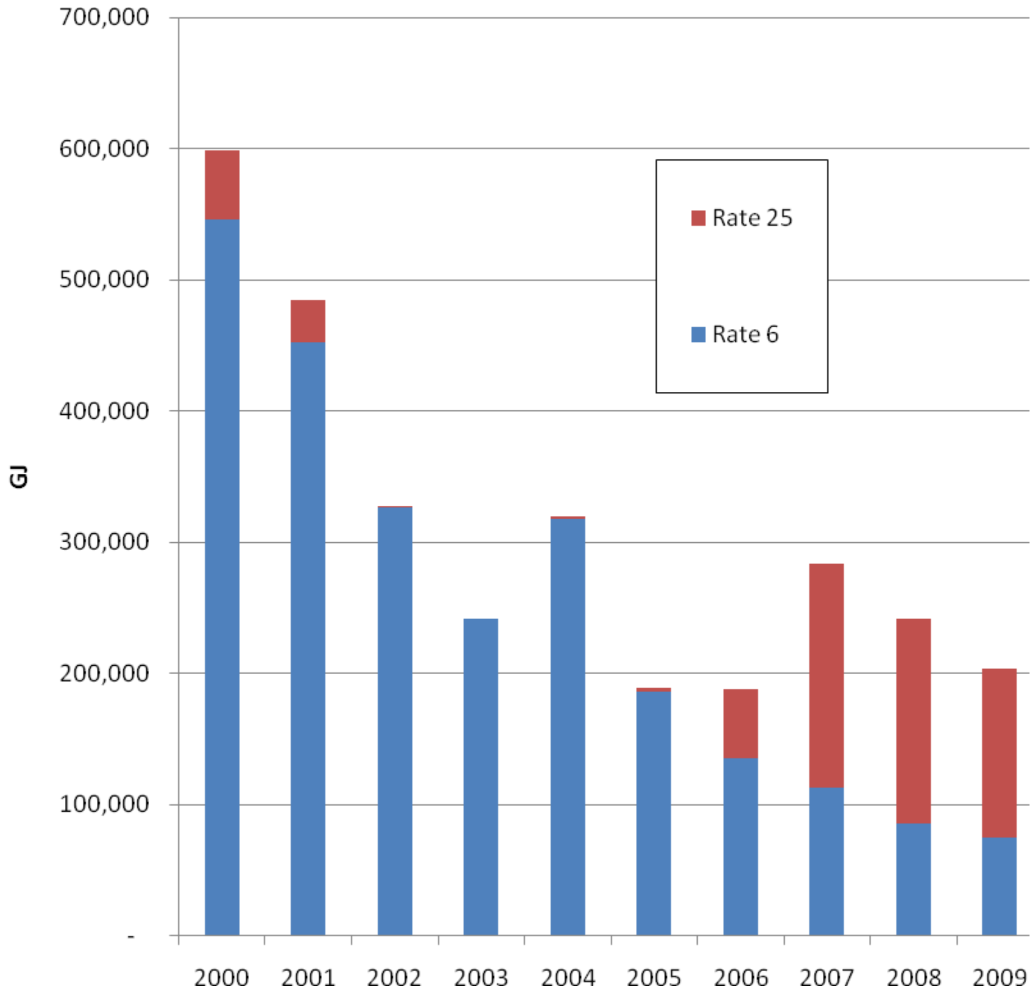
TGI provides NGV service under a number of different Rate Schedules, but only Rate Schedules 6 and 25 have consumption over the past 10 years. Rate Schedule 6 includes a variety of passenger and light duty vehicle customers who consume gas to operate NGVs, but do not receive fuelling service from TGI. In addition to serving vehicles in the general public, Rate 6 serves companies such as Viking Logistics, Euro Asia Transload, and Lordco Autoparts. Many of these companies, including TGI's own fleet, have historically received compression and dispensing service from Clean Energy Fuels Corp.

TGI has provided NGV incentive funding through its Rate Schedule 6 Grant program. Over the past ten years, three commerical customers have received grants. The table below summarizes TGI's NGV customers, their grants, and their approximate number of vehicles in 2000 and in 2010. The table also includes Coast Mountain Bus Company, the only customer under Rate Schedule 25.

Customer	Rate Schedule	Estimated Number of Vehicles[27]		Rate 6 Grant	Year (s) of Grant
		2000	2010		
Euro Asia Transload Inc	6	0	70	$100,000	2008
Kelowna School District	6	0	2	$40,000	2009, 2010
Lordco Autoparts	6	40	45	$3,000	2003
Coast Mountain Bus Company	25	50	50	$0	-

TGI serves multiple customers under Rate Schedule 6 and cannot isolate specific accounts over a time series.[28] Therefore consumption data from all Rate Schedule 6 customers is provided. Annual consumption from 2000 to 2009 under Rate 6 and 25 is summarized in the figure below.

[27] TGI does not have a complete database from which to provide a time series of the annual number of vehicles.
[28] This is due to software system constraints.



Please see the response to BCUC IR 2.24.3 for a time series data summary of these Rate Schedules.

24.3 Please provide a historical graph of Rate 6, 6A and 26 for the period 2000 to 2010 in graphical and tabular data in electronic format. Please note any observable trends and discuss the underlying reasons for them.

Response:

TGI did not have any consumption under Rate 6A and Rate 26 for the period 2000 to 2010. TGI does have NGV consumption under Rate 25, General Firm Transportation Service, Commission Order No. G-89-03. Coast Mountain Bus Company is the only NGV customer under Rate 25.

Please refer to Attachment 24.3 for graphical and tabular data for Rate 6 and Rate 25.

TGI has detailed the reasons for decline in Rate 6 consumption in its response to BCUC IR 2.24.1.

Coast Mountain Bus Company purchases natural gas for its fleet of buses under Rate Schedule 25. The history for natural gas buses in BC is summarized chronologically below:[29]

- 1991 – Three CNG buses enter test service in Lower Mainland. These were conversions of conventional diesel powered buses.
- 1995 – 25 CNG buses purchased for regular operations. These were first generation OEM buses supplied by New Flyer. The buses were equipped with Detroit Diesel 50 Series Natural Gas engines.[30]
- 1998 – Further 25 buses purchased. These were also equipped with the Detroit Diesel 50 series engine coupled with Voith 3 speed transmissions. This particular bus proved very problematic from an operating reliability perspective.
- 2001 – As a result of a spike in natural gas pricing and continuing operability issues associated with the first generation buses, all 50 natural gas buses were parked.
- 2004 – 25 of the 50 parked buses were re-powered with diesel engines and returned to service.
- 2006 - 50 second generation OEM natural gas buses entered into regular service (New Flyer buses equipped with Cummins C-Gas Plus engines).
- 2006 – Approximately 25 of the remaining first generation Detroit Diesel engine buses were also brought back into service.

Operational issues with the Detroit Diesel engines included lower power and high maintenance costs. OEM vendor sources have also indicated that the engine and transmission specifications on these vehicles were not properly matched resulting in non-optimal performance. The second generation of buses powered by the C+ class Cummins engines are reported to have had much

[29] From interviews with BC Transit and Cummins Westport staff

[30] The results from the program are summarized in an April 1997 report developed by Sypher-Mueller International Inc. http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/335500/fuelchoice.pdf

better performance and reliability. Since the initial pilot in 1994 to 2010 there have been many advances in NGV technology.

24.3.1 In the Canadian context, please provide recent examples of other jurisdictions which have made decisions to operate NGV programs in the form of a regulated monopoly.

Response:

Several Canadian utilities have modest NGV support programs. In general these programs provide incentives to partially assist NGV customers offset the capital cost premium associated with NGVs. The Terasen Utilities are not aware of any recent Canadian decisions affecting the operation of NGV programs by Canadian utilities.

In jurisdictions outside of Canada, such as Utah, there is recent success expanding NGV programs under a regulated utility model that is not implemented as a monopoly in the sense that the utility is not the only entity that can provide NGV services.[31] Similarly, TGI's Transportation Fuelling Service Application that will be submitted by the end of 2010 will propose that TGI be allowed to provide Fuelling Services to customers that request fueling services. Customers will also have the alternative to provide such fueling services themselves, or to seek out third parties willing to provide such services.

[31] http://www.questargas.com/FuelingSystems/NGV/RonJibsonsNGVstoryinAmericanGasMagazine.pdf

25.0 Reference: Exhibit B-5, Response to BCUC IR 11.2, p.22

NGV Pilot Program

	Number of Vehicles		Total Incremental Cost	
	2010	2011	2010	2011
Vocational Trucks (@ $41,000 per)	7	22	$ 287,000	$ 902,000
Heavy Duty Trucks (@ $78,000 per)	9	10	$ 702,000	$ 780,000
Total Heavy Duty Trucks:	16	32	$ 989,000	$ 1,682,000

25.1 In addition to the incremental cost related to the purchase of vehicles, please state what incremental costs must be incurred by customers that adopt NGV programs. Please include all capital and O&M costs including fueling stations, additional labor, maintenance, etc.

Response:

NGV customers who operate large commercial, return-to-base heavy duty trucking fleets may incur the following incremental vehicle costs:

- **Upgrades and shop improvements for "gas safe" facilities.** A typical large fleet operator could expect to pay a one-time cost of approximately $150,000 in shop improvements to facilitate an on-site fuelling station.[32] Examples of safety modifications may include the addition of methane detectors and increased ventilation.

- **Ongoing vehicle operations and maintenance.** It is arguable whether or not the conversion to natural gas results in a significant incremental increase in maintenance costs over diesel vehicles. A long term study of a bus fleet in Pierce County (near Seattle) found that its CNG bus fleet had nearly identical maintenance costs to its diesel buses.[33]

No incremental labour additions are anticipated with the conversion from diesel vehicles to NGVs.[34]

TGI will be seeking approval of its Transportation Fuelling Service Application by the end of 2010. This application will include a model that captures the full cost of service of the station capital through a 'user pay' fuelling service charge. This fuelling service charge will depend on a variety of inputs, including vehicle and infrastructure asset life, station capital cost, fuel consumption, and property taxes. In general, large fleet operators could expect to pay around $5 per gigajoule ("GJ") over the term of the contract. The fuelling service charge is one element

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32 Based on TGI's preliminary conversations with large fleet operators.

33 BC Transit Fuel Choice Study 1997, Sypher-Mueller International Inc. http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/335500/fuelchoice.pdf

34 Based on TGI's preliminary conversations with large fleet operators.

of the overall fuel cost delivered to the vehicle. Commodity cost, delivery charges and applicable taxes are other components of the cost of delivering a useful fuel to the vehicle. At present market pricing, the full delivered cost of natural gas is well below the cost of delivering diesel to the vehicle. For example:

Rate Schedule 6 Commodity and Delivery	$9.046/GJ
Fueling Service Charge	$5.00/GJ
Carbon Tax	$0.99/GJ
HST	$1.68/GJ
Total	$16.72/GJ

On a diesel litre equivalent ("DLE") basis this equates to $0.645/DLE providing a substantial advantage opposite diesel pricing which presently ranges from approximately $0.95 to $1.15 depending on local taxes, size of account and delivery point.

The fuelling station charge is not an incremental cost to the end user as it is rolled into the delivered price of the fuel. This complete service offering is important in allowing customers to directly compare the costs of NGV operation versus the costs of conventional fuelled vehicle operation.

25.1.1 Based on the Utilities' experience with the NGV pilot program, please update the above table to reflect the full cost incurred by customers to implement a typical NGV program.

Response:

In its response to BCUC IR 2.25.1, the Terasen Utilities described the incremental costs incurred by NGV customers. Based on this response, an NGV customer could expect to pay an incremental $150,000 for shop improvements, as well as their calculated fuelling service charge.

As indicated in the response to BCUC IR 2.25.1, the fuelling station charge is one element of the cost of delivering fuel to the vehicle. The net cost of delivering fuel to the vehicle is well below the cost of delivering diesel to the vehicle so the fuelling station costs are already factored into the analysis.

Since the Terasen Utilities have not yet implemented any NGV programs or installed any fuelling stations, the Terasen Utilities are not in a position to detail the actual costs incurred for NGV fuelling stations. Within the upcoming NGV application, Terasen Gas will have costs estimates for refuelling stations that will be contained within the application.

25.2 Have Terasen Utilities developed a model to assess the breakeven point of the number of miles per fleet? If "yes", please provide a copy of that assessment. If "no", does Terasen plan to conduct such an assessment?

Response:

The Terasen Utilities have developed a basic model to calculate the fuel savings of natural gas versus diesel (or gasoline) based on estimated gas consumption. This is included in Attachment 25.2. The model includes:

- An assessment of diesel or gasoline (plus associated costs) against CNG (plus associated costs).
- Key inputs such as number of vehicles, daily diesel fuel consumption, annual days of vehicle operation, CNG engine efficiency, and a predetermined fuelling service charge.[35]
- An option for Rate Schedule selection (6 or 25) based on anticipated monthly volumes.

Key measureable outputs – fuel cost per diesel litre equivalent and net fuel savings per year.

For example, a typical fleet of 20 trucks, consuming 100 litres of diesel per day per vehicle, could save $263,230 per year by switching to CNG when purchasing gas under Rate Schedule 25.

Assuming an incremental vehicle cost of $40,000 per truck (or total fleet cost of $800,000), the customer could achieve breakeven in approximately three years.

The addition of $150,000 for a gas safe maintenance facility would extend the payback period to 3.6 years.

As discussed in the response to BCUC IR 2.25.1, the costs associated with fuelling infrastructure are built into the analysis and there are no other significant costs to the customer.

[35] This is fuelling charge is calculated through a cost of service model which recovers the station capital cost through a user-pay agreement. A complete working model will be submitted in TGI's Transportation Fuelling Service Application later in 2010.

25.3 The pilot NGV program conducted by Terasen Utilities indicates that from 2010 to 2011 vocational trucks were subsidized in the amount of $1.2 million to achieve 328 tonnes of CO2 savings. Heavy-duty trucks were subsided in the amount of $1.5 million to achieve 2,268 tonnes of CO2 savings. From these data, it appears that CO2 savings associated with heavy-duty trucks have a cost-benefit ratio that is more than 500% more effective than that of vocational trucks. Please confirm whether this interpretation is correct, and if not, please provide a revised interpretation.

	Tonnes of CO_2e	
	2010	**2011**
Vocational Trucks (@ 40,000 km per year)		
Tonnes of CO_2e from Diesel	401	1,261
Tonnes of CO_2e from CNG	322	1,012
Tonnes of CO_2e reduced	79	249
Heavy Duty Trucks (@ 300,000 km per year)		
Tonnes of CO_2e from Diesel	3,869	4,299
Tonnes of CO_2e from LNG	2,795	3,105
Tonnes of CO_2e reduced	1,074	1,194
Total Tonnes of CO_2e reduced:	1,154	1,443

Response:

TGI would like to clarify its response to BCUC IR 1.11.2.

Firstly, since heavy duty trucks such as Class 8 highway tractors operate long-haul distances, they are expected to achieve greater GHG emissions reductions. TGI has developed its GHG emissions estimates on a 'grams per kilometre' basis using emission factors from Natural Resources Canada's GHGenius model.[36] While the actual emissions reductions of heavy duty trucks running on LNG (27%) are not significantly different than vocational trucks running on CNG (23%), the average distance travelled does vary significantly (300,000 kms versus 40,000 kms per year).

Secondly, while $989,000 and $1,682,000 could fund 16 and 32 trucks respectively, the resultant GHG emissions reductions were only listed for the years 2010 and 2011. Since these vehicles are expected to operate over a longer period, the actual GHG emissions reductions will be much larger than the values listed for 2010 and 2011. On average, vocational trucks could

[36] Software available from Natural Resources Canada at www.ghgenius.com, version 3.17

operate for ten years and heavy duty trucks for five years. Using 2010 as an example, cumulative GHG emissions reductions for vocational trucks would be 790 tonnes[37] and GHG emissions reductions for heavy duty trucks would be 5,370 tonnes.[38]

Therefore, the assertion that heavy duty trucks "have a cost-benefit ratio that is more than 500% more effective than that of vocational trucks" does not hold true. On a net basis, the cost-benefit for heavy duty trucks over vocational trucks is less than 300%. However, on a per kilometre basis, the advantage is negligible.

TGI intends to offer fuelling service to both of these market segments in response to customer demand. The entire trucking segment, nearly 66 PJ,[39] represents a very large opportunity for TGI to convert diesel vehicles to natural gas and provides an economical solution for customers with significant GHG emissions reduction benefits.

25.3.1 Please explain the selection criteria Terasen Utilities applied during its pilot program to determine what firms to offer NGV subsidies and the level of subsidies to be provided to each of them.

Response:

Please refer to the response to BCUC IR 2.23.1 (2 B) for a discussion on the selection criteria used to determine candidates for the EEC incentive funding.

25.3.2 Terasen Utilities NGV pilot program is based on an up-front subsidy to cover 100% of the incremental cost of purchasing a NGV vehicle. Have the Utilities considered offering NGV subsidies which are not front-end loaded? For example, has a fuel subsidy been considered which rewards customers for substituting higher carbon fuels for natural gas? Please discuss all of the options that have been considered by Utilities.

Response:

The Terasen Utilities considered a number of options with respect to subsidies for the NGV Pilot Program.

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[37] Calculation 79 x 10 = 790

[38] Calculation 1,074 x 5 = 5,370

[39] Please see page 62 of the 2010 LTRP

Through extensive discussions with stakeholders the Terasen Utilities identified that the higher upfront capital cost of NGVs was a major barrier preventing development of NGV markets in the service territory. In general, NGVs being offered for Terasen's target markets cost 15 – 50% more than vehicles equipped with diesel or gasoline engines. The operator must recoup this investment in the form of fuel cost savings over the life of the vehicle. Therefore, a decision to proceed with an NGV purchase involves risk that the savings will continue to be realized. Additionally, the customer must also be able to finance the incremental cost which is a challenge for many transportation operations where access to capital is constrained. Finally, the accepted practice in the industry is to purchase diesel or gasoline vehicles, so choosing NGVs may be viewed as a non-conventional decision.

At the present time, the fuel cost advantage of natural gas over diesel is approximately 40%. It was felt that subsidizing a larger fuel cost advantage was not going to help transform the market as it does not deal with the fundamental issue of upfront capital cost.

Subsidizing the fuelling infrastructure was another potential alternative. This option was rejected as it would not be consistent with fair competition for fuelling services.

A further option of developing incentive contributions provided by provincial and federal governments is still under development.

25.3.3 For the period 2010 to 2011 Terasen Utilities NGV pilot program realized a total of 2,597 tonnes of CO2 savings (1,154 tonnes in 2010 and 1,443 tonnes in 2011) at an average cost to ratepayers of $1,028 per tonne of CO2 ($2.67 million ÷ 2,597 tonnes of CO2). The cost to ratepayers for CO2 savings provided by Terasen Utilities is approximately 3,400% higher than the Utilities estimated market value of C02 (based on $30/tonne). From an economic perspective, please discuss whether it is in ratepayers' best interest to pay this premium on CO2 savings.

<u>Response:</u>

TGI would like to clarify its response to BCUC IR 1.11.2. Since NGVs are expected to operate over a period longer than one year, the actual GHG emissions reductions will be much larger than the values listed for 2010 and 2011. Using 2010 as an example, cumulative GHG emissions reductions for vocational trucks over 10 years would be 790 tonnes[40] and GHG emissions reductions for heavy duty trucks over 5 years would be 5,370 tonnes.[41] On a dollars

[40] Calculation: 79 tonnes in 2010 x 10 years = 790 tonnes

[41] Calculation: 1,074 tonnes in 2010 x 5 years = 5,370 tonnes

per tonne basis, this calculates to $363 per tonne for vocational trucks, and $130 per tonne for heavy duty trucks.[42] These values are significantly less than $1,000 per tonne as stated in the question. However, this value per tonne is not the only factor when determining the overall economic case for NGVs.

Aside from GHG emissions reductions, the NGV program would also provide significant benefits to all TGI system customers through impact on customer delivery rates. The potential impact on customer delivery rates is discussed in the response to BCUC IR 2.12.1.

25.3.3.1 Aside from the NGV pilot program, have the Utilities considered EEC options which might reduce GNG emissions more economically? If so, please discuss.

Response:

The Terasen Utilities are not entirely clear on what is meant by "EEC options". If EEC options is taken to mean different EEC programs, the Terasen Utilities have not conducted an analysis on the EEC programs and their resultant cost/tonne for GHG emissions reductions, as the Terasen Utilities have been focussed instead on the TRC, which is the approved metric for program analysis. The Terasen Utilities have a variety of EEC programs, some of which may provide a reduction in GHG emissions at lower cost per unit than NGV pilot program.

The Terasen Utilities note that the transportation market provides one of the largest opportunities for GHG emissions reductions in the Province with total consumption of petroleum energy equal to roughly the size of the gas and electricity markets combined. The combination of GHG emissions reduction and the benefits to gas ratepayers of higher utilization of the existing system make the NGV market one of the key opportunities for meaningful GHG emissions reductions on a sustainable basis.

[42] Calculation: $287,000 / 790 = $363 / tonne, and $702,000 / 5,370 = $130 / tonne

26.0 Reference: Exhibit B-5, Response to BCUC IR 12.2, pp. 27-29 and BCUC IR 38.2, pp. 97-98

NGV Target Markets

"Section 2(g) of the Clean Energy Act is one of the British Columbia energy objectives that must be considered by the Commission in determining whether to accept a long-term resource plan pursuant to section 44.1 of the Utilities Commission Act. It does not impose on the Terasen Utilities an obligation to meet certain GHG emissions reduction targets." (Ref. Exhibit B-5, p. 97)

26.1 Terasen Utilities has stated that it is not obliged to meet GHG reduction targets which have been outlined in Section 2(g) of the *Clean Energy Act*, but that Utilities are nevertheless pursuing EEC programs which contribute to GHG reduction (Ref. Exhibit B-5, p. 97). As it specifically pertains to the Application, please identify GHG targets for the period 2012 to 2016 and from 2017 to 2020, and describe those plans (NGV and others) the Utilities have in place to achieve those targets.

Response:

As discussed in Section 2.2.3.3 of the 2010 LTRP, the B.C. government has set GHG emissions reduction targets for total emissions in the Province, as set out in the *Greenhouse Gas Reductions Targets Act*:

- 6% below 2007 levels by 2012,
- 16% below the 2007 levels by 2016,
- 33% below 2007 level by 2020, and
- 80% below 2007 level by 2050

However, as mentioned in the response to CEC IR 1.2.1, the government has not prescribed how such reductions are to take place.

The Terasen Utilities do not have any regulatory compliance obligations as of yet to reduce natural gas throughput to meet the government GHG emissions reduction targets for our own emissions and our customer emissions. However, we strive to reduce our own operating emissions and bring forth solutions for customers that help them support the energy and climate change goals of the province, while helping customers manage their energy costs. We continue to help our customers reduce their GHG emissions in the province through EEC programs and by offering them an integrated approach to low carbon energy consumption through potential service offerings such as biogas, geothermal, district energy system and NGV solutions. These new service offerings and alternative energy solutions will help customers meet their climate change goals and may help achieve GHG emissions reductions in a more economic way than other alternatives.

27.0 Reference: Exhibit B-5, Response to BCUC IR 20.1, p. 44

Residential Use Trends and Furnace Efficiency Assumption

27.1 Please provide a copy of the Conditional Demand Analysis and input assumptions used in determining that standard furnaces consume 17 GJ to 20 GJ more energy per year than higher efficiency furnaces.

Response:

A copy of the conditional demand analysis ("CDA") report is provided in Attachment 27.1. The calculation is based on the results of the Conditional Demand Analysis ("CDA") portion of the 2008 Residential End Use Study ("REUS"). The CDA assigns Unit Energy Consumption ("UEC") values for various natural gas end uses by housing type and region through mathematical modeling and billing analysis. The CDA estimates for primary heating represent an aggregate of consumption by all furnaces irrespective of efficiency levels. The allocation of consumption by furnace efficiency is based on the UEC values for furnaces from the CDA, the percentage of each type of furnace installed in the residences participating in the REUS, and the overall efficiency level of each furnace type.

For example, in the Lower Mainland region, space heating for a single family home ("SFD") is estimated to be 64.6 GJ's as illustrated in the table below.

Exhibit 13.9: Primary Gas Space Heating UECs by Dwelling Type (GJ/year)

Dwelling Type	LM	INT	TGVI	TGW	FN	2008 TG Average
SFD	64.6	52.3	43.9	77.7	113.4	59.5
VSD	5.7	13.9	**	-	-	7.1
MFD	34.4	33	21	33.4*	-	33.5
Average	**62**	**51.6**	**43**	**66.9**	**113.4**	**57.8**

* Small sample size (less than 30 households with end use present).

From the 2008 REUS survey responses, the distribution of natural gas furnaces among the respondents by efficiency level is 58.1% for low efficiency, 27.7% for mid-efficiency and 14.1% for high efficiency. The overall efficiency rating for each furnace type is assumed to be 67% for low, 80% for mid and 93% for high efficiency furnace. These efficiency ratings are within established industry norms. The Terasen Utilities estimated the average SFD furnace efficiency of 74.3% from the above inputs. By using the input assumption of 64.6 GJ's for a SFD from the table above and 74.3% as an average efficiency level for a SFD, the Terasen Utilities estimated end use consumption by efficiency level by multiplying with the overall efficiency levels for each furnace type. The results are 72 GJ for low efficiency, 60 GJ for mid-efficiency and 52 GJ for high efficiency furnace for a SFD in the Lower Mainland region. The difference in end use consumption between Low and High efficiency furnaces is 20 GJ per year. The same methodology was applied to the Interior region to derive the overall difference in end use consumption of 17 GJ per year between low and high efficiency furnace.

28.0 Reference: Exhibit B-5, Response to BCUC IR 23.1, p. 54

Commercial Use Rate

Utilities customers are segmented into residential, commercial and industrial categories based on a combination of factors that include customer end-use and annual consumption. Figure 4-1, Exhibit B-1, p. 76 provides a summary of Terasen Utilities customers and annual demand.

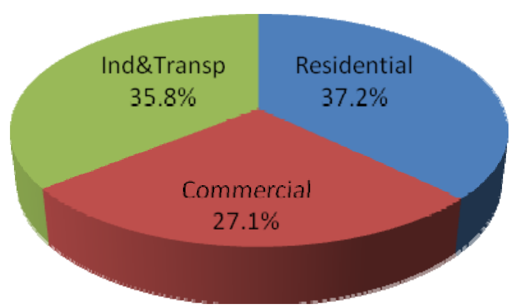
28.1 Please verify the time period represented in the data illustrated in Figure 4.1 by stating the start date and end date of the underlying data.

Response:

The customer data represented in Figure 4.1 is as of 31 December 2009, while the demand chart illustrates the annual demand expected in 2010 (with actual included for January and February 2010).

The figure below illustrates the Annual Demand for 2009.

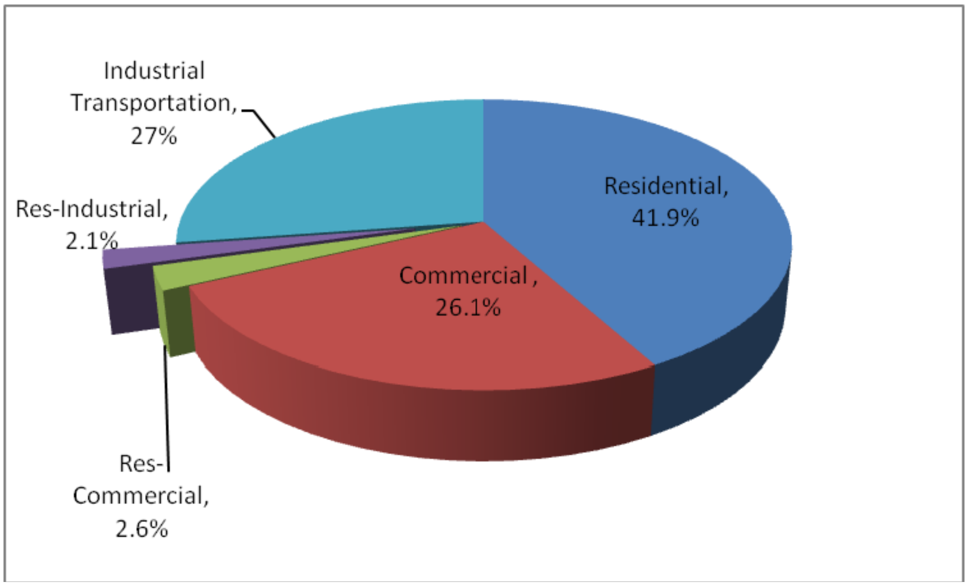
Annual Demand By Customer Type 2009



28.2 Some multi-unit residential complexes such as condominiums are not metered separately. Terasen Utilities allocate what is traditionally considered a residential end-use customers to either a commercial or industrial segment based on the aggregated demand recorded on a single meter. Please provide an alternative version of Figure 4.1 based on the allocation of residential customers by end-use irrespective of the volume of natural gas recorded at the meter.

Response:

The following figure illustrates the portion of residential customers that have been identified (through industry sector codes) in both the Commercial and Industrial customer classes. Please note that for both TGVI and TGW, industry sector codes are not available and therefore only TGI is represented in this analysis. The "Res-Industrial" represents those customers identified as industrial customers who are in the Apartment/Condo sector, while the "Res-Commercial" represents those customers identified as commercial customers who are in the Apartment/Condo sector.



29.0 Reference: Exhibit B-5, Response to BCUC IR 34.1, p. 75; IR 34.3, pp. 77-78

Risk Profile of Innovative Technologies

"The Innovative Technologies funding itself will not have a material impact on the Terasen Utilities risk profile." BCUC IR 34.1, p. 75

"It is to be noted that technologies in the portfolio are subject to change depending on market conditions, introduction of new technologies and obtaining further data." BCUC IR 34.3, p. 77

29.1 Assuming that the Innovative Technologies program applied for and received approval from the Commission, please elaborate on the strategies, beyond offering customers incentives, Terasen Utilities will employ to successfully overcome the barriers and market failures outlined in response to IR 34.3.

Response:

As outlined in response to BCUC IR 1.34.3, the most common market barriers for Innovative Technologies are the limited availability of experienced installers, the lack of infrastructure ensuring high professional standards and capacity, and the low public awareness of the practicality of these technologies. The Terasen Utilities believes that those market barriers will be reduced with implementing additional market support activities within the Innovative Technology program design. These measures would add another layer of system enforcement, measurement and awareness beyond offering customers incentives. Since Innovative Technologies programs are currently being designed such measures haven't been fully constructed.

The Terasen Utilities believes that limiting program participant eligibility to installations by contractors that meet specific certifications would reduce the overall risk of poor system installations that can negatively affect the energy and general performance of the measure as well as cause potential safety issues. The Terasen Utilities also believe that such a requirement would encourage more installers to become educated ensuring high professional standards in order to meet the increased demand requirements. Such installation certifications are already in place through Canadian Solar Industries Association ("CanSIA") and Canadian GeoExchange Coalition.

The Terasen Utilities are also recognized as a credible voice in the energy industry that can communicate and educate the public as to the practicality of these technologies whether through our website, community events, customer call center or other marketing media. The Terasen Utilities also have connections with industry associations, trade allies, local, provincial and federal governments, manufactures, distributors, contractors, consultants, retailers and other utilities. Relationships with these partners can be used to increase public and industry awareness, add another layer of system enforcement, help qualify system data and performance and work towards the development and administration of joint incentive programs.

30.0 Reference: Exhibit B-5, Response to BCUC IR 34.5, p. 81 and IR 55.1 Attachment

Risk Profile of Innovative Technologies

"At this time, the Terasen Utilities does not have good data on the appropriate level of financial incentives necessary to make Innovative Technologies attractive to customers. There is therefore a need to conduct pilot programs to test the effect that differing levels of incentives have on adoption rates, such as the pilot programs currently underway for solar thermal and NGV."

30.1 The Utilities submitted a forecast of the impact that Funding Scenarios will have on rates and rate base in IR 55.1. Please explain what assumptions were made in these forecasts in the absence of "good data on the appropriate level of financial incentives". To the extent possible, please provide a confidence level for Terasen Utilities 20 year forecast.

Response:

The Terasen Utilities believe that the correct reference in BCUC IR 2.30.1 is to the response to BCUC IR 1.51.5 rather than IR 1.55.1.

The response to BCUC IR 1.34.5 discusses the need to conduct pilot programs for Innovative Technologies to test the effect that different levels of incentives have on adoption rates, while the response to BCUC IR 1.51.5 illustrates at a high level the impact on rates from each of the Scenarios. The Scenarios were developed at a high level for illustrative and discussion purposes and do not include analysis of spending by different program areas as the program planning has not been done. The assumptions used in developing the impact on rates and rate base as illustrated in Attachment 51.5 as provided to response to BCUC IR 1.51.5 are discussed in the response to BCUC IR 1.33.1.

The Terasen Utilities believe that the question is referring to the confidence level of the 20 year impact on rates and rate base. As discussed above, the scenarios are developed for illustrative purposes and as such no confidence level has been developed.

31.0 Reference: Exhibit B-5, Response to BCUC IR 36.1 p. 84

Conservation Potential Review (CPR)

"The CPR study itself will not incorporate Commission determinations as it is intended to provide the Terasen Utilities with an "unfettered" view of the amount of cost-effective conservation available in its service territories."

31.1 Please confirm if the Utilities still intend to incorporate the CPR results to update the three funding scenarios.

Response:

It is the Terasen Utilities' intent to use the CPR results to support their next EEC funding approval request for funding for the period 2012 and beyond. The CPR results will not be used to update the three funding scenarios in support of the next EEC funding approval request, but rather will be used to develop an EEC program plan in support of the next EEC funding approval request.

32.0 Reference: Exhibit B-5, Response to BCUC IR 39.2 p. 105

Rate Affordability and Diminishing Returns

"The Terasen Utilities can report that in 2009, TGI expended $5.743 million on EEC activity, and that calculated NPV energy savings were 1,223,550 GJ, as per the 2009 EEC Annual Report filed to the Commission on March 31, 2010."

32.1 Please restate the above statement by converting NPV energy saving of 1,223,550 GJ into a dollar amount representing the avoided costs. Please state the assumptions used and the resulting cost-benefit ratio.

<u>Response:</u>

The NPV energy savings of 1,223,550 GJ's corresponds to $7,928,604 approximately based on the avoided cost of energy of $6.48/GJ. The avoided cost of energy includes the 2009 commodity, midstream and a marginal system improvement charge. The resulting cost benefit ratio is 1.38.

33.0 Reference: Exhibit B-5, Response to BCUC IR 41.2 p. 108

Acceleration of GHG Reduction

"The Terasen Utilities do not anticipate that there will be free riders for EEC NGV grants for medium and heavy duty return to home fleets for the foreseeable future for the reasons outlined in the response to BCUC IR 1.41.1."

33.1 To better understand the market demand for NGV technology and the underlying business case, please provide examples, if any, of market interventions undertaken by other Canadian jurisdictions to materially change customers' willingness to adopt NGV technology.

Response:

One example of market interventions undertaken by another Canadian jurisdiction to change customers' willingness to adopt NGV technology comes from Eastern Canada. Robert Trucking has recently made a decision to purchase and operate 180 Peterbilt Heavy Duty Tractors[43] powered by natural gas engines in the trucking corridor from Quebec City, Quebec to Mississauga, Ontario. A key factor enabling this decision was a provincial government incentive in the form of accelerated depreciation rates for LNG powered vehicles to help offset the higher capital cost of the vehicles.

[43] http://www.prnewswire.com/news-releases/westport-announces-robert-transport-order-for-180-peterbilt-lng-trucks-powered-by-westport-hd-systems-105996703.html

34.0 Reference: Exhibit B-5, Response to BCUC IR 46.4 pp. 127-130

EEC Energy Savings Persistence

"The Terasen Utilities do not have data on the persistence of their EEC programs over the past 10 years."

34.1 Are tracking systems now being put in place for all programs? Given the absence of data for those earlier initiatives? Is it correct to assume that currently, persistence for all EEC programs last 10 years, i.e., over the amortized period? If "no", please clarify. Are there EEC programs with persistence savings of less than 10 years? If "yes", please provide details.

Response:

The Terasen Utilities contacted the Commission staff to seek clarification of this question. The Commission staff responded with the following re-wording of the question:

34.1 Are tracking systems now being put in place for all programs, given the absence of data for those earlier initiatives? Is it correct to assume that currently, persistence for all EEC programs lasts for a period of 10 years, i.e., over the amortized period? If "no", please clarify. Are there EEC programs with persistence savings of less than 10 years? If "yes", please provide details.

Historically the Terasen Utilities had used a series of Microsoft Excel spreadsheets to track program participation. This was adequate when the Terasen Utilities annual approved expenditure was around $4 million. With the EEC and RRA approvals, and the consequent increase in approved expenditure levels, the Terasen Utilities identified the need for a stable, robust tracking system that allowed for better reporting. Thus, the Terasen Utilities are in the process of implementing a web-based program tracking system called TrakSmart in order to better manage and analyze EEC activity overall. The TrakSmart system was discussed at the last EEC Stakeholder meeting held in December 2009.

The Ontario Energy Board defines persistence as follows:

"Persistence is a measure of how long a DSM measure is kept in place by the customer. Persistence is important for all energy efficiency programs as a lack of persistence can have very significant effects on overall net program savings estimates. For example, if an energy efficient measure with a 15-year lifetime is removed after only two years, most of the savings expected to result from that installation will not materialize."[44]

It is the view of the Terasen Utilities that for the most part, the gas measures being installed in the Terasen Utilities' current suite of EEC activities – furnaces, boilers and water heaters – will

[44] Source: http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/DSM_Guidelines_Staff_Paper_appendixA_20090126.pdf

remain in place for their useful life, as they are difficult and expensive to remove. The energy savings streams used to calculate the present value of the currently approved EEC activity are accumulated over the measure life, which in many cases is longer than 10 years.

Theoretically, there are natural gas EEC programs with persistence savings of less than 10 years – one such program would be a furnace maintenance program such as the "Furnace TLC" program the Terasen Utilities are currently running. This program offers a $25 incentive to customers to get their furnaces serviced in preparation for the upcoming heating season. The Terasen Utilities are currently conducting some research to determine the energy savings attributable to such programs. This research consists of a survey of other utilities' practices and is not complete, therefore the Terasen Utilities have not to date attributed any energy savings to this program. However, the Terasen Utilities would expect that any savings attributable to a furnace servicing program would have a persistence of less than one year.

Persistence is a complex and challenging issue. As noted in the 1995 paper attached as Attachment 34.1, "Measuring Persistence: A Literature Review Focusing on Methodological Issues",

> *"The past decade has marked the development of the concept of persistence and a growing recognition that the long-term impacts of demand-side management (DSM) programs warrant careful assessment. Although increasing attention has been paid to the topic of persistence, no clear consensus has emerged either about its definition or about the methods most appropriate for its measurement and analysis."*

The paper further notes that:

> *"The literature review revealed that the term "persistence" is defined in numerous different and sometimes conflicting ways. Most often, persistence refers to the long-term temporal pattern of energy savings and load reductions from DSM investments. This is the definition that we emphasize. However, persistence also is often defined as the operational life of an energy conservation measure, or the degree of retention of measures. Other definitions refer to the time-line of energy savings relative to expectations or the degradation of energy savings over time."*

Given this complexity, the Terasen Utilities will be seeking to develop a clear definition and approach to persistence and to the evaluation and application of persistence in conjunction with the other BC utilities, and with the Terasen Utilities' EEC Stakeholder group.

34.2 Would the introduction of Innovative Technologies programs which are relatively new to the market provide a compelling rationale for tracking persistence? Please explain.

Response:

The Terasen Utilities cannot state unequivocally that the Innovative Technologies programs would in and of themselves provide a compelling rationale for tracking persistence. The Innovative Technologies that are currently the subject of Innovative Technologies program development and piloting are Solar Thermal, GeoExchange and NGV. In the case of Solar Thermal and Geoexchange, these technologies are difficult to remove. Although it is conceivable that a program participant may cease to use the solar or geoexchange portion of a system and instead resort to using the natural gas backup equipment fulltime, the Terasen Utilities have not encountered any data that would suggest that customers will actually do this. Given the relatively high cost of installing solar and geoexchange systems, the participant is more likely to use it in order to "get their money's worth". As noted in the response to BCUC IR 2.34.1, the Terasen Utilities would seek to develop an approach to persistence in collaboration with the other BC utilities and with the EEC Stakeholder Group.

34.3 In the absence of persistence data, please explain the methodology employed by the Utilities to develop the 20 year forecasts provided in its Application.

Response:

The Terasen Utilities assume that the 20 year forecast referenced in the question relates to the three scenarios for EEC activity described in the 2010 LTRP. The Scenarios are developed for illustrative purposes and provide a range of savings proportional to the level of funding available based on the currently approved EEC program portfolio. The savings for the current conventional EEC programs have been estimated on a program by program basis by multiplying the number of expected participants with the estimated savings and the measure life, with an adjustment to create a net to gross ratio. While developing the Scenarios, the Terasen Utilities assumed that the measures being considered under the current planned programs are not discarded or replaced before the end of their expected measure life. The Terasen Utilities believe this is not unreasonable to assume for the development of the scenarios as the gas measures being installed in the current suite of EEC activities – furnaces, boilers and water heaters – will remain in place for their useful life, as they are difficult and expensive to remove. However, going forward, as additional data becomes available through ongoing research and evaluation, measurement and verification activities, the Terasen Utilities may refine input assumptions for future program planning should there be a material change in measure persistence.

Attachment 7.2

Boughton Peterson Yang Anderson

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REPLY ATTENTION OF: Gordon A. Fulton
FILE NO: 45026.6

March 10, 1997

B.C. Utilities Commission
6th Floor
900 Howe Street
Vancouver, B.C.
V6Z 2N3

Attention: Ms. Deborah Emes, Manager, Strategic Services

Dear Ms. Emes:

Re: Retail Markets Downstream of the Meter

You have requested our opinion on the Commission's jurisdiction with respect to participation by a public utility or an affiliated non-regulated business ("NRB") in the unregulated retail markets downstream of the meter ("RMDM"). More specifically, you have asked whether the Commission can prevent a public utility or an NRB from participating in RMDM. You have also asked whether the Commission can prevent a public utility from providing services to an NRB or whether the Commission is limited to looking at cross-charges. Finally, you have requested our opinion as to whether the ratepayers or shareholders own a public utility's name.

Background

The Commission is considering the issue of participation by public utilities and NRBs in RMDM. The Commission is also considering guidelines or terms and conditions if public utilities or NRBs participate in RMDM.

The crux of the issue is whether public utilities or NRBs should be allowed to provide services and products "down-stream" of the meter. Historically, public utilities focused on markets up-stream of the meter, namely production and delivery of gas or electricity. Services and products down-stream of the meter are provided by contractors and businesses in a competitive market-place. Public utilities have not traditionally been involved in RMDM.

The Commission staff prepared and distributed a position paper entitled "Retail Markets Downstream of the Utility Meter", dated December 4, 1996 (the "Staff Paper") and invited comments from interested parties. A number of participants made submissions and reply submissions to the Commission. Some raised concerns about the Commission's jurisdiction to regulate participation by public utilities and NRBs in RMDM.

In arriving at our opinion, we have considered the *Utilities Commission Act*, S.B.C. 1980, c. 60 and amendments thereto (the "Act"), certain texts on public utility regulation, and the relevant caselaw. In addition, we have considered the submissions made by various parties in response to the Staff Paper.

Summary of Opinion

The following is a summary of our opinion:

1. The Commission does not have the jurisdiction to directly regulate an NRB unless the NRB is itself a public utility, a common carrier, or a common processor.

2. The Commission has the jurisdiction to regulate the relationship between a public utility and an affiliated NRB to the extent that the relationship affects ratepayers. For example, the Commission has the jurisdiction to ensure that an NRB is not "subsidized" by a public utility to the detriment of ratepayers.

3. The Commission does not, however, have the jurisdiction to regulate the relationship between a public utility and an NRB so as to ensure the relationship does not affect the competitive retail market down-stream of the meter. The Commission's jurisdiction is limited to consideration of the effects of the relationship on ratepayers.

4. The Commission has the jurisdiction to regulate RMDM activities by a public utility, but only to the extent that such activities affect ratepayers. Similarly, the Commission has the jurisdiction to prohibit a public utility from participating in RMDM if prohibition is the only reasonable and effective means by which the Commission can mitigate or alleviate any negative effects on ratepayers.

5. Ratepayers do not own a public utility's corporate name. The corporate name is goodwill which is owned by the company. The shareholders have a right to share in the assets of a company, including the corporate name, if the company is dissolved.

<u>Discussion</u>:

The Commission's Jurisdiction - Legal Principles

The questions on which we were asked to express an opinion are questions regarding the Commission's jurisdiction and, as such, it is helpful to summarize some of the key principles described in the recent B.C. Court of Appeal decision in *British Columbia Hydro & Power Authority v. British Columbia (Utilities Commission)* (1996), 20 B.C.L.R. (3d) 106 (C.A.) (the "*B.C. Hydro* Decision"):

1. The starting point for an analysis of the Commission's jurisdiction is the Act;

2. The Act is detailed legislation which amply delineates the Commission's jurisdiction by express terms. There is no need to imply terms; and

3. The specific provisions of the Act conferring jurisdiction on the Commission should be examined in light of the <u>purpose</u> of the Act, the reason for the Commission's existence, the area of expertise of the commissioners, and the nature of the problem before the Commission. The purpose of the Act and the reason for the Commission's existence is defined by looking at the historical purpose of the Act and reason for the Commission's existence.

Commission's Jurisdiction to <u>Directly</u> Regulate NRBs

The Commission clearly has jurisdiction over a "public utility", which is defined in s. 1 of the Act to mean:

> "...a person, or his lessee, trustee, receiver or liquidator, who owns or operates in the Province, equipment or facilities for
>
> (a) the production, generation, storage, transmission, sale, delivery or furnishing of electricity, natural gas, steam or any other agent for the production of light, heat, cold or power to or for the public or a corporation for compensation, or
>
> (b) the conveyance or transmission of information, messages or communications by guided or unguided electromagnetic waves, including systems of cable, microwave, optical fibre or radiocommunications where that service is offered to the public for compensation,
>
> but "public utility" does not include
>
> (c) a municipality or regional district in respect of services furnished by the municipality or regional district within its own boundaries,
>
> (d) a person not otherwise a public utility who furnishes the service or commodity only to himself, his employees or tenants, where the service or commodity is not resold to or used by others,

(e) a person not otherwise a public utility who is engaged in the petroleum industry or in the wellhead production of oil, natural gas or other natural petroleum substances, or

(f) a person not otherwise a public utility who is engaged in the production of a geothermal resource, as defined in the *Geothermal Resources Act*."

If an NRB is itself a public utility as defined in the Act, the Commission has jurisdiction over the NRB. The Commission also has jurisdiction over common processors and carriers under Part 5 of the Act. Certain provisions of the Act deal with municipalities and regional districts.

Nowhere does the Act specifically confer on the Commission the jurisdiction to regulate NRBs or any other person, which is not itself a public utility. In our opinion, the Commission does not have the jurisdiction to directly regulate NRBs that are not themselves public utilities, common carriers, or common processors.

Commission's Jurisdiction to Regulate the Relationship Between a Public Utility and an NRB

Our opinion that the Commission does not have the jurisdiction to directly regulate an NRB that is not itself a public utility does not preclude the Commission's jurisdiction to regulate the relationship between a public utility and an NRB.

Enron submits that the Commission has the jurisdiction to regulate all aspects of the relationship between a public utility and an NRB. In summary, Enron submits the basis for the jurisdiction is the general supervisory powers under s. 28 of the Act and the "contractual" relationship between a public utility and an NRB. Enron is also clearly of the view that the Commission has the jurisdiction to regulate the relationship to protect competition in RMDM.

BC Gas agrees the Commission has the jurisdiction to regulate the relationship between a public utility and an affiliated NRB, but only in so far as is necessary to ensure ratepayers are not negatively affected by the relationship. In other words, the Commission has the jurisdiction to ensure there is no "cross-subsidization". However, BC Gas submits the Commission does not have the jurisdiction to prevent the flow of benefits from the public utility to the NRB, provided there is no cross-subsidization. In B.C. Gas' view, competition is a matter within the jurisdiction of other regulatory agencies.

B.C. Hydro takes the view that s. 28 is not so broad a provision as to confer blanket authority on the Commission to regulate all utility activities. B.C. Hydro cites the Court of Appeal decision in *B.C. Hydro, supra*. B.C. Hydro is of the view the Commission does not have the jurisdiction to regulate competition in RMDM.

Other interested parties, such as the independent heating, cooling, gas and ventilating contractors are clearly of the view the Commission has the jurisdiction to regulate the relationship between NRBs and public utilities to ensure there is no cross-subsidization and unfair competitive advantages.

Section 28 of the Act provides:

> "(1) The commission has general supervision of all public utilities and may make orders about equipment, appliances, safety devices, extension of works or systems, filing of rate schedules, reporting and other matters it considers necessary or advisable for the safety, convenience or service of the public or for the proper carrying out of this Act or of a contract, charter or franchise involving use of public property or rights.
>
> (2) Subject to this Act, the commission may make regulations requiring a public utility to conduct its operations in a way that does not unnecessarily interfere with, or cause unnecessary damage or inconvenience to, the public"

Section 28 is often referred to as the Commission's general supervisory power over public utilities. It is worded rather broadly but, in light of the *B.C. Hydro* decision, it must be read in the context of the Act as a whole and the historical purpose of the Commission.

At p 117 of the *B.C. Hydro* Decision, the Court of Appeal summarized the purpose of the Commission:

> "In this light the Utilities Act is a current example of the means adopted in North America, firstly in the United States, to achieve a balance in the public interest between monopoly, where monopoly is accepted as necessary, and protection to the consumer provided by competition. The grant of monopoly through certification of public convenience and necessity accompanied by the correlative burden on the monopoly of providing service at approved rates to all within the area from which competition was excluded." (emphasis added)

In its submission, Enron refers to the Court of appeal decision in *B.C. Gas Utility Ltd. v. B.C. Hydro et al.* (May 31, 1995) CA017981 (B.C.C.A.) ("the *BC Gas* Decision"). In that decision, the Commission amended the language of an agreement between B.C. Gas and B.C. Hydro to give effect to the intent of the parties in light of certain changed circumstances. The Court comments on a number of occasions about the "broad powers" of the Commission to regulate B.C. Gas and B.C. Hydro.

At page 10 of the *BC Gas* Decision, the Court of Appeal stated:

> "The regulatory power of the Commission in these matters is necessarily broad in order that it be able to discharge its duty to ensure that the monopoly undertakings under its supervision operate according to the best interests of the consuming public, under established principles of utility regulation."

The "matters" referred to by the Court of Appeal related to sections 30, 31, 36, 64(1) and (2), 65(1), 70(1) and (2), 103(1) and 114(1). The Court of Appeal in the *BC Gas* Decision was specifically dealing with the Commission's jurisdiction to regulate existing contracts between public utilities where the contracts directly affected the current rates paid by ratepayers. The *BC Gas* Decision did not specifically deal with the Commission's general supervisory powers under s. 28 of the Act. Rather, it dealt with numerous other provisions of the Act. Finally, the *BC Hydro* Decision is more recent and, in our view, provides a narrower interpretation of the Commission's general jurisdiction over public utilities.

In both decisions, however, the Court of Appeal refers to "consumers" or the "consuming public". In our opinion, "consumers" and the "consuming public" means consumers of the products and services of a public utility. More specifically, consumers are ratepayers. It follows the purpose of the Act and the Commission is to balance the right of the monopoly to receive fair compensation with the need to protect ratepayers from the abuse of a public utility's monopoly powers.

As a result and bearing in mind the purpose of the Commission, it is also our opinion that section 28 confers upon the Commission the jurisdiction to regulate the relationship between a public utility and an NRB to the extent the relationship impacts ratepayers. For example, if the NRB uses the assets, systems or services of the public utility, ratepayers are effectively subsidizing the NRB and, as such, the Commission has the jurisdiction to regulate the cross-subsidization. It is further our opinion that the Commission has the jurisdiction to ensure that the NRB's activities do not impose additional business or financial risks on the public utility.

It is important to emphasize that the Commission's jurisdiction to regulate the relationship between a public utility and an NRB arises because the public utility and its ratepayers are affected by the relationship. The Commission, as a result, has the jurisdiction over the public utility to regulate its activities to minimize or eliminate the effect on ratepayers. The Commission does not, however, have the jurisdiction to directly regulate the NRB because the relationship affects ratepayers (unless the NRB is a public utility). Of course, the indirect result is that the Commission affects aspects of the NRB's business and operations by regulating the relationship between it and the public utility.

Competition in RMDM

The issue of protecting or fostering competition in unregulated markets is a more difficult issue.

Enron included a number of authorities in support of its submission. Most of the authorities are American state tribunal decisions that adopt FERC Order 497, which is an Order regulating the relationship between interstate pipelines and their marketing affiliates. In each of the American authorities, the Court or tribunal considers, amongst other factors, the effect of the pipeline-affiliate relationship on other non-affiliated marketers.

We wish to make two comments about the American authorities cited by Enron. First, neither FERC Order 497 nor any of the court or tribunal decisions deal with services or products downstream of the meter. Second, American tribunals operate within a different legislative and legal framework than the BCUC. In British Columbia, the Commission must exercise its powers under the Act with regard to the principles set out in the *BC Hydro* Decision.

Therefore, it is our view that the American authorities cited by Enron are not determinative of this issue.

Enron also included a decision of the Manitoba Public Utilities Board, Order No. 110/96, dated November 4, 1996. In that case, the Board considered guidelines for acceptable conduct between Centra Gas Manitoba Inc. and its affiliated companies in respect of, amongst other things, markets downstream of the meter. At p. 21 of the Decision, the Board ordered Centra Gas to form a working committee to consider a code of conduct, stating:

> "The purpose of this code of conduct should be to ensure that Centra treats its affiliates as it would any third party in order to allow for fair compensation for all participants in the competitive elements of the natural gas market or related services."

At p. 23 of the Decision, the Board ordered the Code of Conduct between the utility and its affiliates to include the following:

> "The shared service must not result in undue disadvantage to any competitors in the market."

The Manitoba Public Utility Board was obviously of the view it has the jurisdiction to consider the effect of the relationship between a public utility and its affiliate on unregulated, competitive markets. Unfortunately, the Board did not specifically state in its decision which provision of its Act conferred such jurisdiction on the Board.

We have reviewed the *Manitoba Public Utilities Act*, R.S.M. 1987, c. P280, as amended. There is no provision of the Act that specifically confers jurisdiction on the Board to regulate or consider the effect of public utilities or NRBs on competitive markets. Section 74 of the Act is similar to s. 28 of the B.C. Act. We reviewed caselaw in which s. 74 was considered. None of the judicial decisions were helpful to us in arriving at our present opinion. Nor were we able to find a discussion of this issue in the authorities we reviewed. In *Bonbright et al* (1993) at 553, the authors compare "regulation" and anti-trust laws. In so doing, they seem to differentiate between the two forms of regulation, stating that the "aims and motives" are different. Finally, we were also unable to find a B.C. case that specifically dealt with this issue.

In our view, and in light of the *B.C. Hydro* Decision, the question as to the Commission's jurisdiction to regulate anti-competitive practises in non-regulated markets requires the following analysis:

> Is there a specific statutory provision in the Act which confers jurisdiction on the Commission to regulate anti-competitive practises in non-regulated markets? In answering this question, it is important to keep in mind the purpose of public utility tribunals.

We have concluded, after considering the purpose of the Commission and the Act, that the Commission's general supervisory powers under s. 28 do not confer jurisdiction on the Commission to regulate anti-competitive practises by a public utility in RMDM.

The only other provision of the Act that might be applicable is s. 65 which states that a public utility cannot demand a rate for a service furnished in the Province that is "unduly discriminatory". Again, s. 65 must be interpreted in light of the purpose of the Commission and the Act. In our view, s. 65 confers on the Commission the jurisdiction to ensure that a public utility does not unduly discriminate as between ratepayers so as to give an unduly preferential rate to a specific business, person, or rate class.

As was the case with our consideration of the Commission's jurisdiction to regulate affiliates of public utilities, we cannot find a specific provision of the Act that confers on the Commission the jurisdiction to regulate anti-competitive behaviour by public utilities or NRBs in non-regulated RMDM.

In our view, the historical purpose of public utility tribunals was to protect the ratepayer from the market power of the monopoly public utility by setting prices and conditions of service. In fact, and as noted in the *B.C. Hydro* Decision and the Staff Paper, monopolies were often accepted as necessary. The introduction of competition into areas such as gas marketing and sales is a recent development. Competition in production is also a recent development, particularly electricity production. The Commission, like many public utility tribunals, is grappling with ways of fostering fair competition in markets that were historically considered part of a "natural" monopoly, while at the same time protecting the interests of ratepayers. As noted in the Staff Paper, the interest by some public utilities in RMDM is itself a recent development.

In our view, RMDM and competition in those markets were not historical concerns of public utility tribunals. Therefore, it is our opinion that the Commission does not have the jurisdiction under the Act to regulate, or consider, the effects of public utility or NRB participation on un-regulated RMDM.

In arriving at our opinion, we acknowledge that it differs from the American authorities cited by Enron, and the Manitoba Public Utilities Board Decision. Our opinion also conflicts with the 1993 B.C. Gas Furnace Repair Plan Decision. However, we would note the following:

(a) For the reasons cited above, the American authorities are not determinative of this issue;

(b) There was no discussion in the B.C. Gas Furnace Repair Plan Decision about the source of the Commission's jurisdiction to regulate or consider the effects of public utility or NRB participation in RMDM. Further, the *B.C. Hydro* Decision was released after the B.C. Gas Furnace Repair Plan Decision;

(c) The Manitoba Public Utilities Board did not consider the *B.C. Hydro* Decision in its 1996 Centra Decision; and

(d) Our opinion also seems to be consistent with the submissions made by participants who participate in BCUC proceedings on a regular basis.

Commission's Jurisdiction to Regulate RMDM

As noted above, the Commission has jurisdiction over public utilities, as defined in s. 1 of the Act. The extent of the Commission's jurisdiction is determined by the Act, bearing in mind the purpose of the Act and public utility tribunals in general.

In the Manitoba Public Utilities Board Decision, Centra Gas referred to the decision of the Manitoba Court of Appeal in *Greater Winnipeg Cablevision Limited v. The Public Utilities Board and Manitoba Telephone System*, [1979] 2 WWR 822 (Man. C.A.). In that case, the Court considered whether the Manitoba Public Utilities Board had the jurisdiction to regulate the amount of rent charged for coaxial cables by public utilities. The Court of Appeal stated at 87:

> "It is common ground that MTS is a public utility within the definition, with respect to its telephone and telegraph services...<u>It does not necessarily follow that everything done by the MTS is subject to the regulatory supervision of the board.</u> It is possible for an undertaking to be a public utility as defined in the Act for some purposes and not for others." (emphasis added)

The Manitoba Court of Appeal went on to consider the specific provisions of the Act and concluded the Act did not give the Board the jurisdiction to regulate coaxial cables.

This decision is important for two reasons. First, the Court concluded a tribunal does not have jurisdiction over everything a public utility does simply because it is a public utility as defined by the Act. Second, the Court will look to the relevant statute to determine the scope of the tribunal's jurisdiction over a public utility. In our view, the Manitoba Court of Appeal decision is consistent with the principles enunciated in the *B.C. Hydro* Decision.

Various provisions of the Act give the Commission jurisdiction to regulate service, operations, property, rates or systems of a public utility. "Service" is defined in s. 1 of the Act to include:

> "the use and accommodation provided, and a product or commodity furnished, by a public utility and also includes the plant, equipment, apparatus, appliances, property and facilities employed by or in connection with a public utility in providing service or in furnishing a product or commodity for the purposes in which the public utility is engaged and for the use and accommodation of the public."

The definition of "service", "operations", "property", and "systems" could be interpreted broadly to include RMDM activities. However, the various provisions of the Act must be interpreted in light of the purpose of the Commission, namely the protection of the ratepayer against the monopoly power of the utility. Further, the intention of the Legislature when the Act was enacted is important. As noted above, it seems unlikely the Legislature reasonably contemplated the participation of public utilities in RMDM when the Act came into force in 1980. In our opinion, it is far more likely the Legislature had in mind the traditional services, operations, property and systems of a public utility, namely production and delivery of natural gas and electricity. This view is supported by the definition of public utility in s. 1 which clearly focuses on production and delivery. In light of the Court of Appeal decision in *B.C. Hydro supra.*, we are of the view the Court would probably apply a narrow interpretation to these terms.

Regardless, and for the reasons stated above, we are of the view the Commission has the jurisdiction under s. 28 of the Act to ensure a public utility's participation in RMDM does not affect ratepayers. We are also of the view the Commission could prohibit a public utility from participating in RMDM if the public utility's participation in RMDM affected ratepayers and prohibition was the only reasonable method to mitigate or alleviate the negative impacts on ratepayers.

Is the Corporate Name of a Public Utility Owned by the Shareholders or the Ratepayers?

It seems to be a settled principle of law that the name of a business forms part of the goodwill of the business. Goodwill, in turn, is an asset of the business which is owned by the owners of the business. (*Bugden v. Voisey* (1955), 2 D.L.R. (2d) 427 (Nfld. T.D.) at 433). In the case of a corporation, the shareholders own a right to share in the assets of the corporation upon dissolution.

Most utilities within the jurisdiction of the Commission are companies incorporated pursuant to the *Companies Act* R.S.B.C. 1979 c. 59 as amended. Section 21(1) of the *Companies Act* specifically states that a company has the full legal capacity of a natural person. A company, therefore, has the right to own assets, including goodwill and trademarks. B.C. Hydro is incorporated under the *Hydro and Power Authority Act* R.S.B.C. 1979 c. 188 as amended. Section 12(e) and (g) of that Act gives B.C. Hydro the right to own and dispose of property including, amongst other things, trademarks.

In our opinion, regulated public utilities in B.C. have the right to own goodwill and their corporate name unless there is a specific legislative rule to the contrary. Furthermore, the shareholders of the public utility own a share of those assets, subject to legislation to the contrary. We considered the provisions of the *Company Act*, the *Utilities Commission Act*, and the *B.C. Hydro and Power Authority Act*. There are no provisions in any of the three statutes that specifically state that a public utility does not own its goodwill and corporate name, nor are there any provisions that affect the principle that shareholders own a right to share in the goodwill of a public utility upon dissolution.

There is also some issue as to whether the Commission can regulate how a public utility uses its corporate or business name. West Kootenay Power refers to two decisions in its submission. The first is the decision of the Supreme Court of the State of Minnesota in *Minnegasco v. Minnesota Public Utilities Commission* (June 13, 1996). This decision is also referred to by Centra Gas in the decision of the Manitoba Public Utilities Tribunal. In *Minnegasco*, the Court held that goodwill is an asset of a utility which is not paid for by ratepayers. Therefore, in that case, the Court concluded the tribunal did not have the jurisdiction to impute revenue to a public utility if an affiliate did not pay to use the company name. The second decision referred to by West Kootenay Power is the decision of the California Public Utilities Commission in *Southern Eddison Co.*, (1988), Cal. PUC. In that case the Public Utilities Commission concluded that goodwill is not an asset which is paid for by the ratepayers. Neither the *Minnegasco* nor the *Southern Eddison Co.* decision conclude that goodwill is not property of a public utility.

The Manitoba Public Utilities Board concluded that it did in fact have jurisdiction over the corporate or business name of a public utility. However, the Board went on to decide that it would not restrict the use of the public utility's name by affiliates. In so deciding, the Board considered statutory provisions which are similar to sections 28 and 59 of the *Utilities Commission Act*. Section 59 states:

> 59. (1) Except for a disposition of its property in the ordinary course of business, a public utility shall not, without first obtaining the commission's approval, <u>dispose of or encumber</u> the whole or part of its property, franchises, licences, permits, concessions, privileges or rights, or by any means, direct or indirect, merge, amalgamate or consolidate in whole or in part its property, franchises, licences, permits, concessions, privileges or rights with those of another person.
>
> (2) The commission may give its approval under this section subject to conditions and requirements considered necessary or desirable in the public interest. (emphasis added)

Section 59 confers upon the commission the jurisdiction to control dispositions and encumbrances of property of a public utility. In our opinion, the property referred to in s. 59 includes goodwill and any trade mark rights in a corporate name. This is consistent with the Manitoba Public Utilities Tribunal decision.

The term "dispose" is defined in the *Interpretation Act*, s. 29, as follows:

> "dispose" means to transfer by any method and includes assign, give, sell, grant, charge, convey, bequeath, devise, lease, divest, release and agree to do any of these things;

This definition suggests that more than a mere licence of the use of property is needed. There must be an actual "transfer" of a proprietary interest.

The definition of "dispose" in the Black's Law Dictionary is:

> "**Dispose of** To alienate or direct ownership of property;. . .to pass into the control of someone else; to alienate, relinquish, part with or get rid of; to put out of the way; to finish with; to bargain away.

Again, this definition suggests a transfer of a proprietary interest.

Boughton Peterson Yang Anderson

The term "encumber" is not defined in Black's Law Dictionary. The caselaw we reviewed in which the term has been considered was not helpful to us in reaching our opinion.

"Encumbrances" against property include charges, liens, and mortgages. It is questionable, in our view, whether licences are encumbrances against property. A license is only a right to use property for a specific purpose in return for a license fee and may be revoked at any time. A breach of a license subjects the party in breach to damages.

It is our view that s. 59 of the Act is intended to prohibit a public utility from doing anything with its property, including goodwill, that might put the property outside of the jurisdiction of the Commission, or that might interfere with the Commission's ability to protect ratepayers. Thus, a public utility cannot sell or assign its name without Commission approval. A public utility probably can, however, licence its name without Commission approval.

This then is our opinion. If we can amplify matters in any way, please feel free to contact us.

Yours very truly,

BOUGHTON PETERSON YANG ANDERSON

Gordon A. Fulton
GAF/KMD/rw

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Attachment 24.3

REFER TO LIVE SPREADSHEET

Provided in electronic format only

(accessible by opening the Attachments Tab in Adobe)

Attachment 25.2

REFER TO LIVE SPREADSHEET

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(accessible by opening the Attachments Tab in Adobe)

Attachment 27.1

SAMPSON
RESEARCH
Consulting

CONDITIONAL DEMAND ANALYSIS OF RESIDENTIAL ENERGY CONSUMPTION

2008 RESIDENTIAL END USE STUDY

Prepared by:

Inter*VISTAS* Consulting Inc

for

Sampson Research Inc.
& Terasen Gas

April 16, 2009

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Table of Contents

List of Exhibits

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1 INTRODUCTION

Terasen Gas uses information on end-use energy consumption for power system planning, load forecasting, marketing and demand side management. End-use consumption refers to the consumption of space heating, water heating, cooking and other specific uses as opposed to total consumption. The Unit Energy Consumption (UEC) for an end-use is defined as the quantity of energy consumed by that end-use in a given period of time.

The purpose of this report is to present the methodology and results of a residential end-use study for Terasen Gas' service territory. The study used Conditional Demand Analysis (CDA) to estimate UEC values for several residential end-uses. CDA is a multivariate regression technique which combines utility billing data with weather information and customer survey data.

The remainder of this report is structured as follows: Section 2 gives the study objectives, Section 3 describes the model employed, Section 4 discusses the data used, Section 5 provides the key results and Section 6 offers some concluding remarks.

2 OBJECTIVES

The objectives of this study are to:

- estimate weather-normalized UEC values for 10 residential end-uses, including: space heating, water heating, cooking and other specific uses (
- Exhibit 1);
- estimate UEC values for each of the following regions: Lower Mainland, Interior, Vancouver Island, Whistler and Fort Nelson; and
- disaggregate UECs for key end-uses by the following dwelling types: single family dwelling, vertical subdivisions and other multi-family dwellings.

Exhibit 1: Residential End-uses Modelled

Primary Space Heating	Secondary Space Heating
Water Heating	Decorative Fireplace
Heater Type Fireplace	Gas Range, Cook Top & Oven
Piped Gas BBQ	Gas Dryer
Swimming Pool	Hot Tub

3 APPROACH

Conditional Demand Analysis (CDA) was used to disaggregate total household consumption into UECs for several residential end-uses. CDA is based on the notion that total household consumption is directly related to the stock of end-uses present in the dwelling and the energy consumption levels associated with these end-uses (UECs). The basic conditional demand model can be represented as:

$$HEC_{ht} = \sum_{all\ a} UEC_{aht} S_{ah}$$

where HEC_{ht} is the total energy consumption by household *h* in month *t*, UEC_{aht} is the energy consumption through end-use *a* by household *h* in month *t*, and S_{ah} is the presence or absence of end use *a* in household *h*.
The UECs for these end-uses are modelled as functions of appropriate exogenous variables, such as end-use features, dwelling characteristics and household utilization patterns. In the remainder of this section, we describe the functional forms for each end-use.

3.1 Primary Gas Space Heating

The primary gas space heating usage for household *h* in month *t* is based on a balance equation:

$$UEC_{gheat,ht} = \frac{HEATLOSS_{ht} - SECHT_{ht}}{EFFH_{h}}$$

where $HEATLOSS_{ht}$ is the net heat loss, $SECHT_{ht}$ is the heat loss replaced by non-gas secondary heating systems, and $EFFH_{h}$ is the system efficiency.

3.1.1 Net Heat Loss

The net heat loss of a structure can be expressed as:

$$HEATLOSS_{ht} = SURFLOSS_{ht} - SOLGAIN_{ht} - INTGAIN_{ht}$$

where $SURFLOSS_{ht}$ is the heat loss through envelope surfaces, $SOLGAIN_{ht}$ is the solar gain through all surfaces during heating periods, and $INTGAIN_{ht}$ is the internal gains during heating periods.

3.1.2 Heat Loss through Envelope

The heat loss through envelope surfaces is given by:

$$SURFLOSS_{h} = \alpha_1 U_{h} AREA_{h} TDIFF_{ht}$$

where U_h is the overall conductivity of the shell, $AREA_h$ is the total surface area, and $TDIFF_{ht}$ is the differential between inside and outside temperature levels.

Overall Model

3.1.3 Shell Conductivity

The conductivity of the shell is assumed to depend on residence type, the percentage of windows and doors that are insulated, and the level of basement insulation[1]:

$$U_h = \alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h + \alpha_4 WINDBL_h + \alpha_5 WINBEST_h + \alpha_6 DOORS_h + \alpha_7 BASEPRES_h BASEINSUL_h$$

where MFD_h equals one if the household dwelling is a multi-family dwelling, VS_h equals one if the dwelling is a vertical subdivision (apartment), $WINDBL_h$ is the percentage windows with double pane glass, and $WINBEST_h$ is the percentage of windows with more insulation than double pane (double pane low-E or triple pane, regular or low-E), $DOORS_h$ is the proportion of exterior doors that are insulated (aluminium storm doors or insulated exterior doors), $BASEPRES_h$ equals one if a basement is present, and $BASEINSUL_h$ equals one if the basement has average or better insulation (R > 6).

3.1.4 Surface Area

The surface area of the structure is modelled as a function of the total floor area:

$$AREA_h = \alpha_1 SQFT_h^{\beta}$$

where $SQFT_h$ is the square footage of the household and β is the elasticity of surface area with respect to square footage. We assumed that β equals 0.5 (i.e. the square root) because the surface area of the building shell increases less than proportionately with floor area for standard shaped buildings.

3.1.5 Temperature Differential

The differential between inside and outside temperature levels is modelled as a function of heating degree days and household heating behaviour (frequency of turning down the temperature at night or during the day when no one is home, and frequency of using window coverings to reduce heat loss in winter)[2]:

$$TDIFF_{ht} = HDD_{ht}\left(\alpha_1 + \alpha_2 TDNIGHT_h + \alpha_3 TDDAY_h + \alpha_4 WINTER_t WINCVR_h\right)$$

where HDD_{ht} is heating degree days, $TDNIGHT_h$ is the frequency of using a programmable thermostat or manual setback at night, $TDDAY_h$ is the frequency of using a programmable thermostat or manual setback during the day when no one is home, and $WINCVR_{ht}$ is the frequency of using window covers during winter.

3.1.6 Solar Gain

The solar gain through all surfaces during heating periods is modelled as a function of the surface area of the home and minutes of sunlight:

$$SOLGAIN_{ht} = \alpha_1 AREA_h WINTER_t HRSUN_{ht}$$

where $HRSUN_{ht}$ is hours of sunlight and $WINTER_t$ equals one if t is a winter month (December, January or February).

[1] An attempt was made to include variables involving wall and ceiling insulation levels. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[2] An attempt was made to include a variable representing the frequency of opening windows during the winter to let in fresh air. This variable was not retained in the final model because it was not statistically significant.

3.1.7 Internal Gain

The internal gain during heating periods is modelled as a function of the surface area of the home:

$$INTGAIN_{ht} = \alpha_1 AREA_h WINTER_t$$

3.1.8 Non-gas Secondary Heating System

The heat loss replaced by a non-gas secondary heating system, given that a primary gas heating system is present, can be expressed as:

$$SECHT_{ht} = \alpha_1 NONGASHEAT_h HDD_{ht} AREA_h$$

where $NONGASHEAT_h$ equals one if non-gas secondary heat is present (e.g. non-gas fireplace, woodstove, electric baseboards, etc.)

3.1.9 System Efficiency

System efficiencies are modelled indirectly in terms of the efficiency level of the boiler or furnace[3]:

$$1/EFFH_h = \alpha_1 + \alpha_2 MIDEFF_h + \alpha_3 HIGHEFF_h$$

where $MIDEFF_h$ equals one if a mid efficiency furnace is in use, and $HIGHEFF_h$ equals one if a high efficiency boiler or furnace is in use.

3.1.10 Overall Primary Gas Space Heating Model

Combining the preceding equations gives the overall model of primary gas space heating usage:

$$UEC_{gheat,ht} = \begin{cases} HDD_{ht} AREA_h (\alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h + \alpha_4 WINDBL_h + \alpha_5 WINBEST_h \\ + \alpha_6 DOORS_h + \alpha_7 BASEPRES_h BASEIN + \alpha_8 TDNIGHT_h + \alpha_9 TDDAY_h \\ + \alpha_{10} WINTER_t WINCVR_h + \alpha_{11} MIDEFF_h + \alpha_{12} HIGHEFF_h + \alpha_{13} NONGASHEAT_h) \\ + \alpha_{14} AREA_h WINTER_t HRSUN_{ht} + \alpha_{15} AREA_h WINTER_t \end{cases}$$

In the specification above, most of the interaction terms are not shown because they were not statistically significant or produced unreasonable results.

3.2 Secondary Gas Space Heating

Secondary gas space heating includes any additional or supplementary use of gas to heat the residence (e.g., furnaces, gas wall heaters, gas heater stoves, etc.) The use of gas fireplaces is modelled separately.

The secondary gas space heating usage is modelled simply as a function of heating degree days, total surface area and dwelling type:

$$UEC_{secght,ht} = HDD_{ht} AREA_h (\alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h)$$

[3] An attempt was made to include a variable for whether or not the furnace pilot light is turned off during the year. This variable was not retained in the final model because it was not statistically significant.

3.3 Fireplaces

The energy usage by gas fireplaces (decorative and heater type) is assumed to depend on the number of fireplaces in use[4]:

$$UEC_{decgasfire,ht} = \alpha_1 DECGASFIRE_h$$
$$UEC_{heatgasfie,ht} = \alpha_1 HEATGASFIRE_h$$

where $DECGASFIRE_h$ is the number of declarative fire places and $HEATGASFIRE_h$ is the number of heater type gas fire places.

3.4 Water Heating

Gas water heating energy usage can be expressed as:

$$UEC_{gwheat,ht} = \frac{WHLOSS_{ht} + VUSE_{ht}}{EFFWH_h}$$

where $WHLOSS_{ht}$ is the heat losses associated with standby losses from the heating unit, $VUSE_{ht}$ is the heat losses tied to water usage, and $EFFWH_h$ is the efficiency of the unit.

3.4.1 Standby Losses

The heat losses associated with standby losses is assumed to depend on the temperature differential between the tank temperature and the inlet temperature[5]:

$$WHLOSS_{ht} = \alpha_1 WHTDIFF_{ht}$$

where $WHTDIFF_{ht}$ is the differential between the tank temperature and the inlet temperature. The differential between tank temperature and inlet temperature is modelled simply as a function of heating degree days:

$$WHTDIFF_{ht} = \alpha_1 HDD_{ht}$$

3.4.2 Water Usage

The heat losses tied to water usage is assumed to depend on the average number of baths and showers taken, the proportion of low-flow showerheads, and whether or not a front loading clothes washer is present[6]:

$$VUSE_{ht} = \alpha_1 + \alpha_2 BATHS_h + \alpha_3 SHWRS_h + \alpha_4 LOWFLPROP_h + \alpha_5 CWFLD_h$$

[4] An attempt was made to include variables representing if the fireplaces are used primarily for heating, ambiance or both. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[5] An attempt was made to include variables involving the dwelling type, number of household members (a proxy for tank size), and the presence or absence of water heater blankets. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[6] An attempt was made to include variables involving household size, as well as the average number of dishwasher loads and washing machine loads. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

where $BATHS_h$ is the number of baths taken per week, $SHWRS_h$ is the number of showers taken per week, $LOWFLPROP_h$ is the proportion of low-flow showerheads, and $CWFLD_h$ equals one if a front loading clothes washer is used.

3.4.3 System Efficiency

An attempt was made to model system efficiencies in terms of the age of the water heater, however, the results were not statistically significant. Therefore, we assumed that $EFFWH_h$ is constant across households.

3.4.4 Overall Gas Water Heating Model

Combining the preceding equations gives the overall model for gas water heating energy usage:

$$UEC_{gwheat,ht} = \alpha_1 HDD_{ht} + \alpha_2 BATHS_h + \alpha_3 SHWRS_h + \alpha_4 LOWFLPROP_h + \alpha_5 CWFLD_h$$

3.5 Gas Ranges, Cook Tops and Ovens

Energy consumption of gas ranges, cook tops and ovens is assumed to depend on the number of these appliances in use[7]:

$$UEC_{gasrange,ht} = \alpha_1 GASRANGE_h$$

where $GASRANGE_h$ is the number of gas ranges, cook tops and ovens in use.

3.6 Gas BBQs

Energy consumption of gas BBQs is modelled as a function of the number in use[8]:

$$UEC_{BBQ,ht} = \alpha_1 GASBBQ_h$$

where $GASBBQ_h$ is the number of gas barbeques in use.

3.7 Gas Dryers

Energy consumption of gas dryers is modelled as a function of the number in use[9]:

$$UEC_{Dryer,ht} = \alpha_1 GASDRYER_h$$

where $GASDRYER_h$ is the number of gas dryers in use.

[7] An attempt was made to include variables involving household size, income and the presence of a microwave. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[8] An attempt was made to include a variable involving household size. This variable was not retained in the final model because it was not statistically significant.

[9] An attempt was made to include a variable involving household size and the number of washing machine loads. These variables were not retained in the final model because they were not statistically significant.

3.8 Swimming Pools

Energy consumption through the operation of swimming pools is assumed to be constant for those households with gas-heated swimming pools[10]:

$$UEC_{Swimpoolgas,ht} = \alpha_1$$

3.9 Hot Tubs

Energy consumption through the operation of hot tubs is assumed to be constant for those households with gas-heated hot tubs[11]:

$$UEC_{hottubgas,ht} = \alpha_1$$

3.10 Regional Analysis

Regional variations in the CDA were explored by fitting separate models for each of the five key regions: Lower Mainland, Interior, Vancouver Island, Whistler and Fort Nelson. However, small sample sizes for many of the regions, combined with low penetration rates for many of the end uses, led to large variation and uncertainty in the UEC estimates across regions. To ensure more stable and robust results, it was decided to incorporate regional terms into a single overall model instead of using separate regional models. With this approach, the model was able to capture regional variation in UECs for key end uses like space heating, but assumed constant UEC specifications for most other end uses.

[10] An attempt was made to include variables for whether or not the pool is covered when not in use and whether or not solar supplementary heating is used. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[11] An attempt was made to include a variable for whether or not the hot tub is covered when not in use. This variable was not retained in the final model because it was not statistically significant.

4 DATA AND SAMPLE

The sample used for the Conditional Demand Analysis consisted of 2,077 households in Terasen's service territory who participated in the 2008 Residential End-use Study (Exhibit 2). The survey data from these customers was used in combination with two years worth of monthly billing data for each customer and weather data for the same period. The two-year period used was July 2006 to June 2008. Customers with incomplete or irregular billing data were screened out from the sample.

Exhibit 2: Sample used in Conditional Demand Analysis

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Total
Single Family Dwelling	294	370	435	93	137	1,329
Multi Family Dwelling	170	190	173	34	1	568
Vertical Subdivision	114	4	62	-	-	180
Total	**578**	**564**	**670**	**127**	**138**	**2,077**

5 RESULTS

The conditional demand model was estimated using ordinary least squares. Overall, the model performed well. Most regression coefficients had the correct sign and were significant at the five percent level or better (see Appendix A). The value of the adjusted R-squared value was 0.864 and the F statistic was 8,236.

The regression coefficients were used to calculate Unit Energy Consumption (UEC) values for major residential end-uses. UECs were calculated for each household possessing the end-use by substituting household variables into the end-use equations. Normal heating degree days and hours of sunlight were substituted to generate weather-normalized UECs for space heating and water heating. Weighted average UECs were then calculated across all households possessing the end-use and across the various household subgroups.

5.1 Unit Energy Consumption

The weighted average UECs are shown in Exhibit 3. As expected, the largest end-uses are primary space heating at 57.8 GJ per year and secondary space heating at 23.2 GJ per year. Other major end-uses are water heating (19.8 GJ per year), decorative fireplaces (20.9 GJ per year) and heater type fireplaces (17.4 GJ per year). Pools and hot tubs are also heavy users of natural gas, but they have lower penetration rates than other major end-uses.

Exhibit 3: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	1,720	0.91	57.8	52.6	61%	67.8
Secondary Space Heating	268	0.07	23.2	1.5	2%	n/a
Water Heating	1,624	0.84	19.8	16.6	19%	20.8
Decorative Fireplace	354	0.18	20.9	3.8	4%	16.8^
Heater Fireplace	932	0.42	17.4	7.3	8%	15.8^^
Range, Cook Top, Oven	550	0.23	5.4	1.3	1%	8.5
BBQ	402	0.15	8.1	1.2	1%	3.1
Dryer	148	0.06	3.9	.2	<1%	4.0
Pool	28	0.02	38.5*	.9*	1%	53.5
Hot Tub	31	0.02	19.5	.4	<1%	17.9
Household Consumption						
Estimated				**85.8**		**96.1**
Actual				**98.9**		**104.9**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

The average energy consumption per household (HEC) is calculated by multiplying each end use's UEC by its penetration rate and summing across end uses. The HEC is a measure of the average consumption of a household in Terasen's service territory. The weather-normalized, weighted HEC was estimated to be 85.8 GJ per year. In comparison, the actual weighted average consumption for the sample was 98.9 GJ per year. Part of the reason that estimated, weather-normalized consumption is lower than actual consumption levels is because normal weather conditions were warmer than during the two-year period from July 2006 to June 2008. However, it is still common in Conditional Demand Analysis to underestimate actual consumption levels. [12]

Exhibit 3 also shows a comparison between these UEC estimates and those produced in a previous study of 2002 data.[13] The most significant change observed is the drop in primary space heating gas consumption. This may be explained by improvements in heating efficiency over the time period. However, some of this decline may also be due to methodological differences between the two studies. Notably, the 2002 study did not attempt to incorporate regional differences in its model formation, which appears to have led to an over-estimation of the space heating UEC for the Interior region. As a final point, the service territory analyzed in the 2002 study excluded Vancouver Island and Whistler. Vancouver Island now forms a sizable portion of Terasen's service territory, but has lower space heating consumption than the Lower Mainland or the Interior.

The UECs for many of the other end uses are relatively consistent between studies, with the exception of some of the lower penetration end uses. Note that the UEC for BBQs appears to be over-estimated in the current study. This may be due to small sample sizes or a confounding effect with other end-uses, e.g., gas range. A review of other studies found UEC estimates for BBQs of about 2-3 GJ/year.

5.2 UECs by Region

Regional terms were incorporated into the CDA model for space heating to disaggregate by the five geographic regions. The results are presented in the following sections.

5.2.1 Lower Mainland

Exhibit 4 shows weighted average UECs for the Lower Mainland region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 92.1 GJ per year. In comparison, the actual weighted average consumption for the sample was 108.9 GJ per year.

Exhibit 4: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	494	0.94	62.0	58.0	63%	65.3
Secondary Space Heating	62	0.05	18.1	0.9	1%	-
Water Heating	426	0.84	20.4	17.2	19%	21.0
Decorative Fireplace	129	0.20	21.4	4.2	5%	16.2^
Heater Fireplace	274	0.42	18.3	7.8	8%	14.9^^
Range, Cook Top, Oven	196	0.26	5.6	1.4	2%	8.6
BBQ	66	0.12	8.1	1.0	1%	3.4
Dryer	24	0.05	4.2*	0.2*	<1%	4.0
Pool	10	0.03	38.5*	1.0*	1%	53.6
Hot Tub	11	0.03	19.5*	0.5*	<1%	17.8
Household Consumption						
Estimated				**92.1**		**93.8**
Actual				**108.9**		**109.0**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

[12] In CDA, the model's intercept term is forced to be zero to ensure it does not capture the effects of the individual end uses. However, forcing the intercept to zero often results in underestimated total household consumption because non-modelled end uses (e.g. patio heaters) and behaviours (e.g. heating use in the summer) are not captured.
[13] *BC Gas Residential End Use Survey Results*, prepared by Habart & Associates, December, 2003.

5.2.2 Interior

Exhibit 5 shows weighted average UECs for the Interior region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 78.5 GJ per year. In comparison, the actual weighted average consumption for the sample was 86.7 GJ per year.

Exhibit 5: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	617	0.93	51.6	48.0	61%	74.1
Secondary Space Heating	37	0.05	39.3	2.0	3%	-
Water Heating	574	0.86	18.8	16.0	20%	20.3
Decorative Fireplace	111	0.16	19.8	3.2	4%	18.6^
Heater Fireplace	251	0.35	15.9	5.5	7%	18.3^^
Range, Cook Top, Oven	96	0.16	5.1	0.8	1%	7.8
BBQ	124	0.20	8.1	1.6	2%	2.8
Dryer	35	0.06	3.6	0.2	<1%	4.0
Pool	10	0.02	38.5*	0.9*	1%	53.3
Hot Tub	8	0.01	19.5*	0.3*	<1%	17.9
Household Consumption						
Estimated				**78.5**		**101.7**
Actual				**86.7**		**96.7**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

5.2.3 Vancouver Island

Exhibit 6 shows weighted average UECs for the Vancouver Island region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 64.8 GJ per year. In comparison, the actual weighted average consumption for the sample was 67.2 GJ per year.

Exhibit 6: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	377	0.71	43.0	30.4	47%
Secondary Space Heating	149	0.23	19.9	4.5	7%
Water Heating	420	0.76	18.8	14.4	22%
Decorative Fireplace	72	0.12	19.7	2.5	4%
Heater Fireplace	337	0.56	16.1	9.1	14%
Range, Cook Top, Oven	162	0.28	4.7	1.3	2%
BBQ	136	0.24	8.1	1.9	3%
Dryer	67	0.13	3.4	0.5	1%
Pool	3	0.01	38.5*	0.3*	<1%
Hot Tub	1	0.00	19.5*	0.1*	<1%
Household Consumption					
Estimated				**64.8**	
Actual				**67.2**	

* Small sample size (Less than 30 households with end-use present)

5.2.4 Whistler

Exhibit 7 shows weighted average UECs for the Whistler region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 92.6 GJ per year. In comparison, the actual weighted average consumption for the sample was 96.6 GJ per year.

Exhibit 7: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	101	0.80	66.9	53.2	57%
Secondary Space Heating	18	0.14	33.6*	4.7*	5%
Water Heating	88	0.69	18.5	12.8	14%
Decorative Fireplace	36	0.28	22.2	6.3	7%
Heater Fireplace	49	0.38	15.8	6.1	7%
Range, Cook Top, Oven	67	0.53	4.8	2.6	3%
BBQ	59	0.47	7.9	3.7	4%
Dryer	10	0.08	3.3*	0.3*	<1%
Pool	4	0.03	**	**	**
Hot Tub	11	0.09	19.5*	1.7*	2%
Household Consumption					
Estimated				**92.6**	
Actual				**96.6**	

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.2.5 Fort Nelson

Exhibit 8 shows weighted average UECs for the Fort Nelson region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 130.2 GJ per year. In comparison, the actual weighted average consumption for the sample was 150.4 GJ per year.

Exhibit 8: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	131	0.94	113.4	106.0	81%
Secondary Space Heating	2	0.01	**	**	**
Water Heating	116	0.83	22.7	18.8	14%
Decorative Fireplace	6	0.04	19.3*	0.8*	1%
Heater Fireplace	21	0.15	14.7*	2.2*	2%
Range, Cook Top, Oven	29	0.21	5.3*	1.1*	1%
BBQ	17	0.12	7.9*	1.0*	1%
Dryer	12	0.09	3.3*	0.3*	<1%
Pool	1	0.01	**	**	**
Hot Tub	-	0.00	**	**	**
Household Consumption					
Estimated				**130.2**	
Actual				**150.4**	

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3 UECs by Dwelling Type

Exogenous variables were incorporated into the CDA models for space heating (primary and secondary) and water heating to disaggregate by the following dwelling types: single family dwelling, vertical subdivisions and other multi-family dwellings.

5.3.1 Primary Space Heating

Exhibit 9 shows estimated primary gas space heating unit energy consumption by geographic region and housing type.

Exhibit 9: Primary Gas Space Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	64.6	43.9	52.3	77.7	113.4	59.5
Multi Family Dwelling	34.4	21.0	33.0	33.4*	-	33.5
Vertical Subdivision	5.7	**	13.9	-	-	7.1
Average	**62.0**	**43.0**	**51.6**	**66.9**	**113.4**	**57.8**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3.2 Secondary Space Heating

Secondary gas space heating unit energy consumption also varies between region and housing type as shown in Exhibit 10.

Exhibit 10: Secondary Gas Space Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	20.1*	20.7	40.0*	42.6*	**	26.0
Multi Family Dwelling	9.7*	10.0	21.3*	**	-	10.7
Vertical Subdivision	2.7*	-	**	-	-	2.6
Average	**18.1**	**19.9**	**39.3**	**33.6**	**	**23.2**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3.3 Water Heating

A similar pattern occurs for gas water heating UECs as shown in Exhibit 11.

Exhibit 11: Gas Water Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	20.6	19.0	18.9	19.8	22.7	20.0
Multi Family Dwelling	18.3	14.7	16.0	14.0*	-	17.7
Vertical Subdivision	17.4	**	13.2	-	-	16.5
Average	**20.4**	**18.8**	**18.8**	**18.5**	**22.7**	**19.8**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

6 CONCLUSIONS

This report presented the methodology and results of a residential end-use study for Terasen Gas' service territory. Conditional Demand Analysis (CDA) was used to estimate UEC values for 10 residential end-uses. The study found considerable variation in UECs across end-uses. It also revealed that space heating and water heating consumption varied significantly across geographic area and housing type. These results provide valuable information on end-use energy consumption which can be used for power system planning, load forecasting, marketing and demand side management.

6.1 Limitations

The results of this study should be interpreted with some caution due to several important limitations:

Limitation #1. The estimated consumption levels of high-penetration end-uses may mask the effects of other end-uses and/or partially capture the base consumption load of a household.

Limitation #2. The effects of low-penetration end-uses (e.g. gas dryers or BBQs) are difficult to estimate because of small sample sizes.

Limitation #3. Consumption values could not be accurately estimated for some regions and dwelling types due to small sample sizes.

Limitation #4. Some information collected through the self-reported customer surveys may be unreliable.

Limitation #5. The rich model specifications originally developed for some end-uses had to be simplified because of unreasonable regression results.

Appendix A

Regression Analysis

APPENDIX A: REGRESSION ANALYSIS

Exhibit 12: Regression Output

	Coefficient	SE	t-value	P-value
LM x AREA x HDD x S_{gheat}	0.001300	0.000009	152.4	0.000
VI x AREA x HDD x S_{gheat}	0.001035	0.000012	86.1	0.000
IN x AREA x HDD x S_{gheat}	0.000819	0.000009	93.2	0.000
WH x AREA x HDD x S_{gheat}	0.000958	0.000041	23.3	0.000
FN x AREA x HDD x S_{gheat}	0.000870	0.000017	50.7	0.000
LM x MFD x AREA x HDD x S_{gheat}	-0.000414	0.000012	-34.0	0.000
LM x VS x AREA x HDD x S_{gheat}	-0.000899	0.000063	-14.2	0.000
VI x MFD x AREA x HDD x S_{gheat}	-0.000354	0.000049	-7.2	0.000
IN x MFD x AREA x HDD x S_{gheat}	-0.000152	0.000016	-9.4	0.000
IN x VS x AREA x HDD x S_{gheat}	-0.000412	0.000094	-4.4	0.000
WH x MFD x AREA x HDD x S_{gheat}	-0.000321	0.000093	-3.5	0.001
AREA x HDD x TDNIGHT x S_{gheat}	-0.000044	0.000007	-6.4	0.000
AREA x HDD x TDDAY x S_{gheat}	-0.000116	0.000006	-18.9	0.000
AREA x HDD x WINTER x WINCVR x S_{gheat}	-0.000006	0.000006	-1.0	0.317
AREA x HDD x MIDEFF x S_{gheat}	-0.000045	0.000004	-10.1	0.000
AREA x HDD x HIGHEFF x S_{gheat}	-0.000152	0.000005	-29.3	0.000
AREA x HDD x WINDBL x S_{gheat}	-0.000086	0.000005	-15.7	0.000
AREA x HDD x WINBEST x S_{gheat}	-0.000115	0.000007	-16.7	0.000
AREA x HDD x DOORS x S_{gheat}	-0.000086	0.000005	-16.2	0.000
AREA x HDD x BASEPRES x BASEINSUL x S_{gheat}	-0.000041	0.000004	-10.7	0.000
AREA x WINTER x HRSUN x S_{gheat}	-0.000449	0.000044	-10.1	0.000
AREA x WINTER x S_{gheat}	0.026443	0.002614	10.1	0.000
HDD x AREA x NONGASHEAT x S_{gheat}	-0.000065	0.000004	-17.6	0.000
HDD x AREA x S_{secght}	0.000338	0.000008	43.6	0.000
HDD x AREA x MFD x S_{secght}	-0.000150	0.000030	-5.0	0.000
HDD x AREA x VS x S_{secght}	-0.000280	0.000083	-3.4	0.001
DECGASFIRE x $S_{decgasfire}$	1.381636	0.032368	42.7	0.000
HEATGASFIRE x $S_{heatgasfire}$	1.071822	0.022930	46.7	0.000
HDD x S_{gwheat}	0.000577	0.000232	2.5	0.013
BATHS x S_{gwheat}	0.211052	0.005681	37.1	0.000
SHWRS x S_{gwheat}	0.110918	0.002027	54.7	0.000
LOWFLPROP x S_{gwheat}	-0.019552	0.038940	-0.5	0.616
CWFLD x S_{gwheat}	-0.459419	0.042375	-10.8	0.000
GASRANGE x $S_{gasrange}$	0.310153	0.025780	12.0	0.000
GASBBQ x S_{bbq}	0.659416	0.047388	13.9	0.000
GASDRYER x S_{dryer}	0.278914	0.060137	4.6	0.000
$S_{swimpool}$	3.212457	0.115210	27.9	0.000
$S_{hottubgas}$	1.628916	0.123136	13.2	0.000

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CONDITIONAL DEMAND ANALYSIS OF RESIDENTIAL ENERGY CONSUMPTION

2008 RESIDENTIAL END USE STUDY

Prepared by:

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for

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1 INTRODUCTION

Terasen Gas uses information on end-use energy consumption for power system planning, load forecasting, marketing and demand side management. End-use consumption refers to the consumption of space heating, water heating, cooking and other specific uses as opposed to total consumption. The Unit Energy Consumption (UEC) for an end-use is defined as the quantity of energy consumed by that end-use in a given period of time.

The purpose of this report is to present the methodology and results of a residential end-use study for Terasen Gas' service territory. The study used Conditional Demand Analysis (CDA) to estimate UEC values for several residential end-uses. CDA is a multivariate regression technique which combines utility billing data with weather information and customer survey data.

The remainder of this report is structured as follows: Section 2 gives the study objectives, Section 3 describes the model employed, Section 4 discusses the data used, Section 5 provides the key results and Section 6 offers some concluding remarks.

2 OBJECTIVES

The objectives of this study are to:

- estimate weather-normalized UEC values for 10 residential end-uses, including: space heating, water heating, cooking and other specific uses (
- Exhibit 1);
- estimate UEC values for each of the following regions: Lower Mainland, Interior, Vancouver Island, Whistler and Fort Nelson; and
- disaggregate UECs for key end-uses by the following dwelling types: single family dwelling, vertical subdivisions and other multi-family dwellings.

Exhibit 1: Residential End-uses Modelled

Primary Space Heating	Secondary Space Heating
Water Heating	Decorative Fireplace
Heater Type Fireplace	Gas Range, Cook Top & Oven
Piped Gas BBQ	Gas Dryer
Swimming Pool	Hot Tub

3 APPROACH

Conditional Demand Analysis (CDA) was used to disaggregate total household consumption into UECs for several residential end-uses. CDA is based on the notion that total household consumption is directly related to the stock of end-uses present in the dwelling and the energy consumption levels associated with these end-uses (UECs). The basic conditional demand model can be represented as:

$$HEC_{ht} = \sum_{all\ a} UEC_{aht} S_{ah}$$

where HEC_{ht} is the total energy consumption by household *h* in month *t*, UEC_{aht} is the energy consumption through end-use *a* by household *h* in month *t*, and S_{ah} is the presence or absence of end use *a* in household *h*.

The UECs for these end-uses are modelled as functions of appropriate exogenous variables, such as end-use features, dwelling characteristics and household utilization patterns. In the remainder of this section, we describe the functional forms for each end-use.

3.1 Primary Gas Space Heating

The primary gas space heating usage for household *h* in month *t* is based on a balance equation:

$$UEC_{gheat,ht} = \frac{HEATLOSS_{ht} - SECHT_{ht}}{EFFH_h}$$

where $HEATLOSS_{ht}$ is the net heat loss, $SECHT_{ht}$ is the heat loss replaced by non-gas secondary heating systems, and $EFFH_h$ is the system efficiency.

3.1.1 Net Heat Loss

The net heat loss of a structure can be expressed as:

$$HEATLOSS_{ht} = SURFLOSS_{ht} - SOLGAIN_{ht} - INTGAIN_{ht}$$

where $SURFLOSS_{ht}$ is the heat loss through envelope surfaces, $SOLGAIN_{ht}$ is the solar gain through all surfaces during heating periods, and $INTGAIN_{ht}$ is the internal gains during heating periods.

3.1.2 Heat Loss through Envelope

The heat loss through envelope surfaces is given by:

$$SURFLOSS_h = \alpha_1 U_h AREA_h TDIFF_{ht}$$

where U_h is the overall conductivity of the shell, $AREA_h$ is the total surface area, and $TDIFF_{ht}$ is the differential between inside and outside temperature levels.

3.1.3 Shell Conductivity

The conductivity of the shell is assumed to depend on residence type, the percentage of windows and doors that are insulated, and the level of basement insulation[1]:

$$U_h = \alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h + \alpha_4 WINDBL_h + \alpha_5 WINBEST_h + \alpha_6 DOORS_h + \alpha_7 BASEPRES_h BASEINSUL_h$$

where MFD_h equals one if the household dwelling is a multi-family dwelling, VS_h equals one if the dwelling is a vertical subdivision (apartment), $WINDBL_h$ is the percentage windows with double pane glass, and $WINBEST_h$ is the percentage of windows with more insulation than double pane (double pane low-E or triple pane, regular or low-E), $DOORS_h$ is the proportion of exterior doors that are insulated (aluminium storm doors or insulated exterior doors), $BASEPRES_h$ equals one if a basement is present, and $BASEINSUL_h$ equals one if the basement has average or better insulation (R > 6).

3.1.4 Surface Area

The surface area of the structure is modelled as a function of the total floor area:

$$AREA_h = \alpha_1 SQFT_h^{\beta}$$

where $SQFT_h$ is the square footage of the household and β is the elasticity of surface area with respect to square footage. We assumed that β equals 0.5 (i.e. the square root) because the surface area of the building shell increases less than proportionately with floor area for standard shaped buildings.

3.1.5 Temperature Differential

The differential between inside and outside temperature levels is modelled as a function of heating degree days and household heating behaviour (frequency of turning down the temperature at night or during the day when no one is home, and frequency of using window coverings to reduce heat loss in winter)[2]:

$$TDIFF_{ht} = HDD_{ht}\left(\alpha_1 + \alpha_2 TDNIGHT_h + \alpha_3 TDDAY_h + \alpha_4 WINTER_t WINCVR_h\right)$$

where HDD_{ht} is heating degree days, $TDNIGHT_h$ is the frequency of using a programmable thermostat or manual setback at night, $TDDAY_h$ is the frequency of using a programmable thermostat or manual setback during the day when no one is home, and $WINCVR_{ht}$ is the frequency of using window covers during winter.

3.1.6 Solar Gain

The solar gain through all surfaces during heating periods is modelled as a function of the surface area of the home and minutes of sunlight:

$$SOLGAIN_{ht} = \alpha_1 AREA_h WINTER_t HRSUN_{ht}$$

where $HRSUN_{ht}$ is hours of sunlight and $WINTER_t$ equals one if t is a winter month (December, January or February).

[1] An attempt was made to include variables involving wall and ceiling insulation levels. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[2] An attempt was made to include a variable representing the frequency of opening windows during the winter to let in fresh air. This variable was not retained in the final model because it was not statistically significant.

3.1.7 Internal Gain

The internal gain during heating periods is modelled as a function of the surface area of the home:

$$INTGAIN_{ht} = \alpha_1 AREA_h WINTER_t$$

3.1.8 Non-gas Secondary Heating System

The heat loss replaced by a non-gas secondary heating system, given that a primary gas heating system is present, can be expressed as:

$$SECHT_{ht} = \alpha_1 NONGASHEAT_h HDD_{ht} AREA_h$$

where $NONGASHEAT_h$ equals one if non-gas secondary heat is present (e.g. non-gas fireplace, woodstove, electric baseboards, etc.)

3.1.9 System Efficiency

System efficiencies are modelled indirectly in terms of the efficiency level of the boiler or furnace[3]:

$$1/EFFH_h = \alpha_1 + \alpha_2 MIDEFF_h + \alpha_3 HIGHEFF_h$$

where $MIDEFF_h$ equals one if a mid efficiency furnace is in use, and $HIGHEFF_h$ equals one if a high efficiency boiler or furnace is in use.

3.1.10 Overall Primary Gas Space Heating Model

Combining the preceding equations gives the overall model of primary gas space heating usage:

$$UEC_{gheat,ht} = \begin{cases} HDD_{ht} AREA_h (\alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h + \alpha_4 WINDBL_h + \alpha_5 WINBEST_h \\ + \alpha_6 DOORS_h + \alpha_7 BASEPRES_h BASEIN + \alpha_8 TDNIGHT_h + \alpha_9 TDDAY_h \\ + \alpha_{10} WINTER_t WINCVR_h + \alpha_{11} MIDEFF_h + \alpha_{12} HIGHEFF_h + \alpha_{13} NONGASHEAT_h) \\ + \alpha_{14} AREA_h WINTER_t HRSUN_{ht} + \alpha_{15} AREA_h WINTER_t \end{cases}$$

In the specification above, most of the interaction terms are not shown because they were not statistically significant or produced unreasonable results.

3.2 Secondary Gas Space Heating

Secondary gas space heating includes any additional or supplementary use of gas to heat the residence (e.g., furnaces, gas wall heaters, gas heater stoves, etc.) The use of gas fireplaces is modelled separately.

The secondary gas space heating usage is modelled simply as a function of heating degree days, total surface area and dwelling type:

$$UEC_{secght,ht} = HDD_{ht} AREA_h (\alpha_1 + \alpha_2 MFD_h + \alpha_3 VS_h)$$

[3] An attempt was made to include a variable for whether or not the furnace pilot light is turned off during the year. This variable was not retained in the final model because it was not statistically significant.

3.3 Fireplaces

The energy usage by gas fireplaces (decorative and heater type) is assumed to depend on the number of fireplaces in use[4]:

$$UEC_{decgasfire,ht} = \alpha_1 DECGASFIRE_h$$
$$UEC_{heatgasfire,ht} = \alpha_1 HEATGASFIRE_h$$

where $DECGASFIRE_h$ is the number of declarative fire places and $HEATGASFIRE_h$ is the number of heater type gas fire places.

3.4 Water Heating

Gas water heating energy usage can be expressed as:

$$UEC_{gwheat,ht} = \frac{WHLOSS_{ht} + VUSE_{ht}}{EFFWH_h}$$

where $WHLOSS_{ht}$ is the heat losses associated with standby losses from the heating unit, $VUSE_{ht}$ is the heat losses tied to water usage, and $EFFWH_h$ is the efficiency of the unit.

3.4.1 Standby Losses

The heat losses associated with standby losses is assumed to depend on the temperature differential between the tank temperature and the inlet temperature[5]:

$$WHLOSS_{ht} = \alpha_1 WHTDIFF_{ht}$$

where $WHTDIFF_{ht}$ is the differential between the tank temperature and the inlet temperature. The differential between tank temperature and inlet temperature is modelled simply as a function of heating degree days:

$$WHTDIFF_{ht} = \alpha_1 HDD_{ht}$$

3.4.2 Water Usage

The heat losses tied to water usage is assumed to depend on the average number of baths and showers taken, the proportion of low-flow showerheads, and whether or not a front loading clothes washer is present[6]:

$$VUSE_{ht} = \alpha_1 + \alpha_2 BATHS_h + \alpha_3 SHWRS_h + \alpha_4 LOWFLPROP_h + \alpha_5 CWFLD_h$$

[4] An attempt was made to include variables representing if the fireplaces are used primarily for heating, ambiance or both. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[5] An attempt was made to include variables involving the dwelling type, number of household members (a proxy for tank size), and the presence or absence of water heater blankets. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[6] An attempt was made to include variables involving household size, as well as the average number of dishwasher loads and washing machine loads. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

where $BATHS_h$ is the number of baths taken per week, $SHWRS_h$ is the number of showers taken per week, $LOWFLPROP_h$ is the proportion of low-flow showerheads, and $CWFLD_h$ equals one if a front loading clothes washer is used.

3.4.3 System Efficiency

An attempt was made to model system efficiencies in terms of the age of the water heater, however, the results were not statistically significant. Therefore, we assumed that $EFFWH_h$ is constant across households.

3.4.4 Overall Gas Water Heating Model

Combining the preceding equations gives the overall model for gas water heating energy usage:

$$UEC_{gwheat,ht} = \alpha_1 HDD_{ht} + \alpha_2 BATHS_h + \alpha_3 SHWRS_h + \alpha_4 LOWFLPROP_h + \alpha_5 CWFLD_h$$

3.5 Gas Ranges, Cook Tops and Ovens

Energy consumption of gas ranges, cook tops and ovens is assumed to depend on the number of these appliances in use[7]:

$$UEC_{gasrange,ht} = \alpha_1 GASRANGE_h$$

where $GASRANGE_h$ is the number of gas ranges, cook tops and ovens in use.

3.6 Gas BBQs

Energy consumption of gas BBQs is modelled as a function of the number in use[8]:

$$UEC_{BBQ,ht} = \alpha_1 GASBBQ_h$$

where $GASBBQ_h$ is the number of gas barbeques in use.

3.7 Gas Dryers

Energy consumption of gas dryers is modelled as a function of the number in use[9]:

$$UEC_{Dryer,ht} = \alpha_1 GASDRYER_h$$

where $GASDRYER_h$ is the number of gas dryers in use.

[7] An attempt was made to include variables involving household size, income and the presence of a microwave. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[8] An attempt was made to include a variable involving household size. This variable was not retained in the final model because it was not statistically significant.

[9] An attempt was made to include a variable involving household size and the number of washing machine loads. These variables were not retained in the final model because they were not statistically significant.

3.8 Swimming Pools

Energy consumption through the operation of swimming pools is assumed to be constant for those households with gas-heated swimming pools[10]:

$$UEC_{Swimpoolgas,ht} = \alpha_1$$

3.9 Hot Tubs

Energy consumption through the operation of hot tubs is assumed to be constant for those households with gas-heated hot tubs[11]:

$$UEC_{hottubgas,ht} = \alpha_1$$

3.10 Regional Analysis

Regional variations in the CDA were explored by fitting separate models for each of the five key regions: Lower Mainland, Interior, Vancouver Island, Whistler and Fort Nelson. However, small sample sizes for many of the regions, combined with low penetration rates for many of the end uses, led to large variation and uncertainty in the UEC estimates across regions. To ensure more stable and robust results, it was decided to incorporate regional terms into a single overall model instead of using separate regional models. With this approach, the model was able to capture regional variation in UECs for key end uses like space heating, but assumed constant UEC specifications for most other end uses.

[10] An attempt was made to include variables for whether or not the pool is covered when not in use and whether or not solar supplementary heating is used. These variables were not retained in the final model because they were not statistically significant or produced unreasonable results.

[11] An attempt was made to include a variable for whether or not the hot tub is covered when not in use. This variable was not retained in the final model because it was not statistically significant.

4 DATA AND SAMPLE

The sample used for the Conditional Demand Analysis consisted of 2,077 households in Terasen's service territory who participated in the 2008 Residential End-use Study (Exhibit 2). The survey data from these customers was used in combination with two years worth of monthly billing data for each customer and weather data for the same period. The two-year period used was July 2006 to June 2008. Customers with incomplete or irregular billing data were screened out from the sample.

Exhibit 2: Sample used in Conditional Demand Analysis

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Total
Single Family Dwelling	294	370	435	93	137	1,329
Multi Family Dwelling	170	190	173	34	1	568
Vertical Subdivision	114	4	62	-	-	180
Total	**578**	**564**	**670**	**127**	**138**	**2,077**

5 RESULTS

The conditional demand model was estimated using ordinary least squares. Overall, the model performed well. Most regression coefficients had the correct sign and were significant at the five percent level or better (see Appendix A). The value of the adjusted R-squared value was 0.864 and the F statistic was 8,236.

The regression coefficients were used to calculate Unit Energy Consumption (UEC) values for major residential end-uses. UECs were calculated for each household possessing the end-use by substituting household variables into the end-use equations. Normal heating degree days and hours of sunlight were substituted to generate weather-normalized UECs for space heating and water heating. Weighted average UECs were then calculated across all households possessing the end-use and across the various household subgroups.

5.1 Unit Energy Consumption

The weighted average UECs are shown in Exhibit 3. As expected, the largest end-uses are primary space heating at 57.8 GJ per year and secondary space heating at 23.2 GJ per year. Other major end-uses are water heating (19.8 GJ per year), decorative fireplaces (20.9 GJ per year) and heater type fireplaces (17.4 GJ per year). Pools and hot tubs are also heavy users of natural gas, but they have lower penetration rates than other major end-uses.

Exhibit 3: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	1,720	0.91	57.8	52.6	61%	67.8
Secondary Space Heating	268	0.07	23.2	1.5	2%	n/a
Water Heating	1,624	0.84	19.8	16.6	19%	20.8
Decorative Fireplace	354	0.18	20.9	3.8	4%	16.8^
Heater Fireplace	932	0.42	17.4	7.3	8%	15.8^^
Range, Cook Top, Oven	550	0.23	5.4	1.3	1%	8.5
BBQ	402	0.15	8.1	1.2	1%	3.1
Dryer	148	0.06	3.9	.2	<1%	4.0
Pool	28	0.02	38.5*	.9*	1%	53.5
Hot Tub	31	0.02	19.5	.4	<1%	17.9
Household Consumption						
Estimated				**85.8**		**96.1**
Actual				**98.9**		**104.9**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

The average energy consumption per household (HEC) is calculated by multiplying each end use's UEC by its penetration rate and summing across end uses. The HEC is a measure of the average consumption of a household in Terasen's service territory. The weather-normalized, weighted HEC was estimated to be 85.8 GJ per year. In comparison, the actual weighted average consumption for the sample was 98.9 GJ per year. Part of the reason that estimated, weather-normalized consumption is lower than actual consumption levels is because normal weather conditions were warmer than during the two-year period from July 2006 to June 2008. However, it is still common in Conditional Demand Analysis to underestimate actual consumption levels. [12]

Exhibit 3 also shows a comparison between these UEC estimates and those produced in a previous study of 2002 data.[13] The most significant change observed is the drop in primary space heating gas consumption. This may be explained by improvements in heating efficiency over the time period. However, some of this decline may also be due to methodological differences between the two studies. Notably, the 2002 study did not attempt to incorporate regional differences in its model formation, which appears to have led to an over-estimation of the space heating UEC for the Interior region. As a final point, the service territory analyzed in the 2002 study excluded Vancouver Island and Whistler. Vancouver Island now forms a sizable portion of Terasen's service territory, but has lower space heating consumption than the Lower Mainland or the Interior.

The UECs for many of the other end uses are relatively consistent between studies, with the exception of some of the lower penetration end uses. Note that the UEC for BBQs appears to be over-estimated in the current study. This may be due to small sample sizes or a confounding effect with other end-uses, e.g., gas range. A review of other studies found UEC estimates for BBQs of about 2-3 GJ/year.

5.2 UECs by Region

Regional terms were incorporated into the CDA model for space heating to disaggregate by the five geographic regions. The results are presented in the following sections.

5.2.1 Lower Mainland

Exhibit 4 shows weighted average UECs for the Lower Mainland region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 92.1 GJ per year. In comparison, the actual weighted average consumption for the sample was 108.9 GJ per year.

Exhibit 4: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	494	0.94	62.0	58.0	63%	65.3
Secondary Space Heating	62	0.05	18.1	0.9	1%	-
Water Heating	426	0.84	20.4	17.2	19%	21.0
Decorative Fireplace	129	0.20	21.4	4.2	5%	16.2^
Heater Fireplace	274	0.42	18.3	7.8	8%	14.9^^
Range, Cook Top, Oven	196	0.26	5.6	1.4	2%	8.6
BBQ	66	0.12	8.1	1.0	1%	3.4
Dryer	24	0.05	4.2*	0.2*	<1%	4.0
Pool	10	0.03	38.5*	1.0*	1%	53.6
Hot Tub	11	0.03	19.5*	0.5*	<1%	17.8
Household Consumption						
Estimated				**92.1**		**93.8**
Actual				**108.9**		**109.0**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

[12] In CDA, the model's intercept term is forced to be zero to ensure it does not capture the effects of the individual end uses. However, forcing the intercept to zero often results in underestimated total household consumption because non-modelled end uses (e.g. patio heaters) and behaviours (e.g. heating use in the summer) are not captured.
[13] *BC Gas Residential End Use Survey Results*, prepared by Habart & Associates, December, 2003.

5.2.2 Interior

Exhibit 5 shows weighted average UECs for the Interior region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 78.5 GJ per year. In comparison, the actual weighted average consumption for the sample was 86.7 GJ per year.

Exhibit 5: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)		UECs in 2002 (GJ/year)
Primary Space Heating	617	0.93	51.6	48.0	61%	74.1
Secondary Space Heating	37	0.05	39.3	2.0	3%	-
Water Heating	574	0.86	18.8	16.0	20%	20.3
Decorative Fireplace	111	0.16	19.8	3.2	4%	18.6^
Heater Fireplace	251	0.35	15.9	5.5	7%	18.3^^
Range, Cook Top, Oven	96	0.16	5.1	0.8	1%	7.8
BBQ	124	0.20	8.1	1.6	2%	2.8
Dryer	35	0.06	3.6	0.2	<1%	4.0
Pool	10	0.02	38.5*	0.9*	1%	53.3
Hot Tub	8	0.01	19.5*	0.3*	<1%	17.9
Household Consumption						
Estimated				**78.5**		**101.7**
Actual				**86.7**		**96.7**

* Small sample size (Less than 30 households with end-use present)
^ 2002 data represents log fireplaces
^^ 2002 data represents inserts

5.2.3 Vancouver Island

Exhibit 6 shows weighted average UECs for the Vancouver Island region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 64.8 GJ per year. In comparison, the actual weighted average consumption for the sample was 67.2 GJ per year.

Exhibit 6: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	377	0.71	43.0	30.4	47%
Secondary Space Heating	149	0.23	19.9	4.5	7%
Water Heating	420	0.76	18.8	14.4	22%
Decorative Fireplace	72	0.12	19.7	2.5	4%
Heater Fireplace	337	0.56	16.1	9.1	14%
Range, Cook Top, Oven	162	0.28	4.7	1.3	2%
BBQ	136	0.24	8.1	1.9	3%
Dryer	67	0.13	3.4	0.5	1%
Pool	3	0.01	38.5*	0.3*	<1%
Hot Tub	1	0.00	19.5*	0.1*	<1%
Household Consumption					
Estimated				**64.8**	
Actual				**67.2**	

* Small sample size (Less than 30 households with end-use present)

5.2.4 Whistler

Exhibit 7 shows weighted average UECs for the Whistler region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 92.6 GJ per year. In comparison, the actual weighted average consumption for the sample was 96.6 GJ per year.

Exhibit 7: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	101	0.80	66.9	53.2	57%
Secondary Space Heating	18	0.14	33.6*	4.7*	5%
Water Heating	88	0.69	18.5	12.8	14%
Decorative Fireplace	36	0.28	22.2	6.3	7%
Heater Fireplace	49	0.38	15.8	6.1	7%
Range, Cook Top, Oven	67	0.53	4.8	2.6	3%
BBQ	59	0.47	7.9	3.7	4%
Dryer	10	0.08	3.3*	0.3*	<1%
Pool	4	0.03	**	**	**
Hot Tub	11	0.09	19.5*	1.7*	2%
Household Consumption					
Estimated				**92.6**	
Actual				**96.6**	

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.2.5 Fort Nelson

Exhibit 8 shows weighted average UECs for the Fort Nelson region. The weather-normalized, weighted average annual energy consumption per household (HEC) was estimated to be 130.2 GJ per year. In comparison, the actual weighted average consumption for the sample was 150.4 GJ per year.

Exhibit 8: Penetration Rates and Unit Energy Consumption by End-use

	Sample Size (unweighted)	Penetration (% presence)	Unit Energy Consumption (GJ/year)	Average Consumption per Household (GJ/year)	
Primary Space Heating	131	0.94	113.4	106.0	81%
Secondary Space Heating	2	0.01	**	**	**
Water Heating	116	0.83	22.7	18.8	14%
Decorative Fireplace	6	0.04	19.3*	0.8*	1%
Heater Fireplace	21	0.15	14.7*	2.2*	2%
Range, Cook Top, Oven	29	0.21	5.3*	1.1*	1%
BBQ	17	0.12	7.9*	1.0*	1%
Dryer	12	0.09	3.3*	0.3*	<1%
Pool	1	0.01	**	**	**
Hot Tub	-	0.00	**	**	**
Household Consumption					
Estimated				**130.2**	
Actual				**150.4**	

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3 UECs by Dwelling Type

Exogenous variables were incorporated into the CDA models for space heating (primary and secondary) and water heating to disaggregate by the following dwelling types: single family dwelling, vertical subdivisions and other multi-family dwellings.

5.3.1 Primary Space Heating

Exhibit 9 shows estimated primary gas space heating unit energy consumption by geographic region and housing type.

Exhibit 9: Primary Gas Space Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	64.6	43.9	52.3	77.7	113.4	59.5
Multi Family Dwelling	34.4	21.0	33.0	33.4*	-	33.5
Vertical Subdivision	5.7	**	13.9	-	-	7.1
Average	**62.0**	**43.0**	**51.6**	**66.9**	**113.4**	**57.8**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3.2 Secondary Space Heating

Secondary gas space heating unit energy consumption also varies between region and housing type as shown in Exhibit 10.

Exhibit 10: Secondary Gas Space Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	20.1*	20.7	40.0*	42.6*	**	26.0
Multi Family Dwelling	9.7*	10.0	21.3*	**	-	10.7
Vertical Subdivision	2.7*	-	**	-	-	2.6
Average	**18.1**	**19.9**	**39.3**	**33.6**	**	**23.2**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

5.3.3 Water Heating

A similar pattern occurs for gas water heating UECs as shown in Exhibit 11.

Exhibit 11: Gas Water Heating UECs (GJ/year)

	Lower Mainland	Vancouver Island	Interior	Whistler	Fort Nelson	Average
Single Family Dwelling	20.6	19.0	18.9	19.8	22.7	20.0
Multi Family Dwelling	18.3	14.7	16.0	14.0*	-	17.7
Vertical Subdivision	17.4	**	13.2	-	-	16.5
Average	**20.4**	**18.8**	**18.8**	**18.5**	**22.7**	**19.8**

* Small sample size (Less than 30 households with end-use present)
** Insufficient sample size (Less than 5 households with end-use present)

6 CONCLUSIONS

This report presented the methodology and results of a residential end-use study for Terasen Gas' service territory. Conditional Demand Analysis (CDA) was used to estimate UEC values for 10 residential end-uses. The study found considerable variation in UECs across end-uses. It also revealed that space heating and water heating consumption varied significantly across geographic area and housing type. These results provide valuable information on end-use energy consumption which can be used for power system planning, load forecasting, marketing and demand side management.

6.1 Limitations

The results of this study should be interpreted with some caution due to several important limitations:

Limitation #1. The estimated consumption levels of high-penetration end-uses may mask the effects of other end-uses and/or partially capture the base consumption load of a household.

Limitation #2. The effects of low-penetration end-uses (e.g. gas dryers or BBQs) are difficult to estimate because of small sample sizes.

Limitation #3. Consumption values could not be accurately estimated for some regions and dwelling types due to small sample sizes.

Limitation #4. Some information collected through the self-reported customer surveys may be unreliable.

Limitation #5. The rich model specifications originally developed for some end-uses had to be simplified because of unreasonable regression results.

Appendix A

Regression Analysis

APPENDIX A: REGRESSION ANALYSIS

Exhibit 12: Regression Output

	Coefficient	SE	t-value	P-value
LM x AREA x HDD x S_{gheat}	0.001300	0.000009	152.4	0.000
VI x AREA x HDD x S_{gheat}	0.001035	0.000012	86.1	0.000
IN x AREA x HDD x S_{gheat}	0.000819	0.000009	93.2	0.000
WH x AREA x HDD x S_{gheat}	0.000958	0.000041	23.3	0.000
FN x AREA x HDD x S_{gheat}	0.000870	0.000017	50.7	0.000
LM x MFD x AREA x HDD x S_{gheat}	-0.000414	0.000012	-34.0	0.000
LM x VS x AREA x HDD x S_{gheat}	-0.000899	0.000063	-14.2	0.000
VI x MFD x AREA x HDD x S_{gheat}	-0.000354	0.000049	-7.2	0.000
IN x MFD x AREA x HDD x S_{gheat}	-0.000152	0.000016	-9.4	0.000
IN x VS x AREA x HDD x S_{gheat}	-0.000412	0.000094	-4.4	0.000
WH x MFD x AREA x HDD x S_{gheat}	-0.000321	0.000093	-3.5	0.001
AREA x HDD x TDNIGHT x S_{gheat}	-0.000044	0.000007	-6.4	0.000
AREA x HDD x TDDAY x S_{gheat}	-0.000116	0.000006	-18.9	0.000
AREA x HDD x WINTER x WINCVR x S_{gheat}	-0.000006	0.000006	-1.0	0.317
AREA x HDD x MIDEFF x S_{gheat}	-0.000045	0.000004	-10.1	0.000
AREA x HDD x HIGHEFF x S_{gheat}	-0.000152	0.000005	-29.3	0.000
AREA x HDD x WINDBL x S_{gheat}	-0.000086	0.000005	-15.7	0.000
AREA x HDD x WINBEST x S_{gheat}	-0.000115	0.000007	-16.7	0.000
AREA x HDD x DOORS x S_{gheat}	-0.000086	0.000005	-16.2	0.000
AREA x HDD x BASEPRES x BASEINSUL x S_{gheat}	-0.000041	0.000004	-10.7	0.000
AREA x WINTER x HRSUN x S_{gheat}	-0.000449	0.000044	-10.1	0.000
AREA x WINTER x S_{gheat}	0.026443	0.002614	10.1	0.000
HDD x AREA x NONGASHEAT x S_{gheat}	-0.000065	0.000004	-17.6	0.000
HDD x AREA x S_{secght}	0.000338	0.000008	43.6	0.000
HDD x AREA x MFD x S_{secght}	-0.000150	0.000030	-5.0	0.000
HDD x AREA x VS x S_{secght}	-0.000280	0.000083	-3.4	0.001
DECGASFIRE x $S_{decgasfire}$	1.381636	0.032368	42.7	0.000
HEATGASFIRE x $S_{heatgasfire}$	1.071822	0.022930	46.7	0.000
HDD x S_{gwheat}	0.000577	0.000232	2.5	0.013
BATHS x S_{gwheat}	0.211052	0.005681	37.1	0.000
SHWRS x S_{gwheat}	0.110918	0.002027	54.7	0.000
LOWFLPROP x S_{gwheat}	-0.019552	0.038940	-0.5	0.616
CWFLD x S_{gwheat}	-0.459419	0.042375	-10.8	0.000
GASRANGE x $S_{gasrange}$	0.310153	0.025780	12.0	0.000
GASBBQ x S_{bbq}	0.659416	0.047388	13.9	0.000
GASDRYER x S_{dryer}	0.278914	0.060137	4.6	0.000
$S_{swimpool}$	3.212457	0.115210	27.9	0.000
$S_{hottubgas}$	1.628916	0.123136	13.2	0.000

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Attachment 34.1

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MEASURING PERSISTENCE: A LITERATURE REVIEW FOCUSING ON METHODOLOGICAL ISSUES

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DISCLAIMER

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EXECUTIVE SUMMARY

This literature review was conducted as part of a larger project to produce a handbook on the measurement of persistence. The past decade has marked the development of the concept of persistence and a growing recognition that the long-term impacts of demand-side management (DSM) programs warrant careful assessment. Although increasing attention has been paid to the topic of persistence, no clear consensus has emerged either about its definition or about the methods most appropriate for its measurement and analysis. This project strives to fill that gap by reviewing the goals, terminology, and methods of past persistence studies. It was conducted from the perspective of a utility that seeks to acquire demand-side resources and is interested in their long-term durability; it was not conducted from the perspective of the individual consumer.

Over 30 persistence studies, articles, and protocols were examined for this report. The review begins by discussing the underpinnings of persistence studies: namely, the definitions of persistence and the purposes of persistence studies. Then, it describes issues relevant to both the collection and analysis of data on the persistence of energy and demand savings. Findings from persistence studies also are summarized. Throughout the review, four studies are used repeatedly to illustrate different methodological and analytical approaches to persistence so that readers can track the data collection, data analysis, and findings of a set of comprehensive studies that represent alternative approaches.

DEFINITIONS, PURPOSES, AND SCALES OF ANALYSIS

The literature review revealed that the term "persistence" is defined in numerous different and sometimes conflicting ways. Most often, persistence refers to the long-term temporal pattern of energy savings and load reductions from DSM investments. This is the definition that we emphasize. However, persistence also is often defined as the operational life of an energy conservation measure, or the degree of retention of measures. Other definitions refer to the time-line of energy savings relative to expectations or the degradation of energy savings over time.

Persistence studies are conducted for many different purposes. Although planning and evaluation are the two overarching purposes, these broad goals can be refined further to distinguish the following purposes: resource planning, load forecasting, annual program planning, program evaluation, lost revenue recovery, shareholder incentive calculations, and the determination of performance contracting payments. The methods used to satisfy each of these purposes varies. For instance, univariate or multivariate regression analysis of billing data may be sufficient for determining shareholder incentives and performance contract payments. On the other hand, equipment surveys and on-site inspections, in conjunction with multivariate analysis, may be necessary for program evaluation because they can offer insights into the causes of any degradation or increase in savings over time. Another kind of goal for persistence studies is to discover methods for improving programs by changing procedures that appear to lead to premature measure removal or by altering the program to delete specific types of equipment that tend to be removed or become dysfunctional.

The array of purposes for persistence studies and different approaches taken in such studies. is influenced by the diversity of factors that can impair the persistence of measures and energy savings. These factors include the technical life of a measure, which is influenced by technical degradation under optimal conditions; market factors such as remodeling and occupant turnover: and operational life, which can be affected by how the measure actually is installed, sized, operated, and maintained.

To enhance the understanding of persistence, three scales of analysis were delineated. Each of the scales, described below, encompasses different time frames and scopes of investigation:

- **measure** – used in studies that predict the pattern of year-to-year savings from the installation of a particular DSM measure by a single cohort of participants in a DSM program;
- **cohort** – used in studies that predict the pattern of year-to-year savings from the installation of a collection of DSM measures by a single cohort of participants in a DSM program; and
- **program** – used in studies that predict the pattern of net program savings from packages of measures for all years (across multiple cohorts) of program participants in a DSM program.

The *measure* scale addresses the energy savings associated with a particular measure during its lifetime and usually focuses on a single cohort of participants. Studies at this scale, which constitute a significant proportion of persistence work to date, frequently seek to determine the technological and behavioral reasons why particular measures achieve certain levels of savings over time. In contrast, studies falling within the *cohort* scale tend to emphasize program persistence and not the savings associated with particular measures. The *program* scale is the least common, perhaps because it requires the longest time frame and, possibly, the largest financial investment to track net savings over multiple participant cohorts. Many factors can influence the trajectory of a program's energy savings, such as changing program features and operations, changing baseline efficiencies, and the effects of participant self-selection on savings over time.

THE DESIGN OF PERSISTENCE STUDIES

The various definitions of persistence, goals of studies, and the scales of analysis summarized above affect the selection of methods for collecting and analyzing persistence data, as do other factors such as project budgets and regulatory influences. Control group decisions provide an illustration of this point. If the focus is on the persistence of gross energy savings from installed energy conservation measures, control groups are unnecessary. Control groups, however, are required to ascertain net savings over time because it is critical in these cases to distinguish program effects from other effects. The options identified in the literature review include control groups consisting of non-participants and control groups consisting of later participants. Establishing and maintaining adequate control groups is particularly challenging for persistence studies, for the following reasons:

- the need for control group members to remain unaffected by a program over an extended period;
- the cost of selecting an appropriate control group and obtaining data from such a group;
- changes in programs over time;
- market transformation;
- sample attrition due to mobility and other changes to the end user;
- changes in the composition of participants over time (e.g., from a group of people or buildings with great potential for saving energy to those with significantly lower potential savings); and
- changing economic conditions including energy prices that can influence patterns of energy consumption.

Persistence studies can adopt a retrospective or prospective research design. The vast majority of studies are retrospective, using data from past participants and selecting analytical methods to interpret existing data. Another possibility is prospective studies, which use data from current and future participants and which allow desired analyses to determine what data are collected.

DATA COLLECTION METHODS

Four primary data collection methods are used in persistence studies. These methods are telephone and mail surveys, on-site inspections, billing histories, and metering or monitoring. Metering refers to the collection of whole-building or end-use energy consumption data and monitoring denotes the collection of relevant, non-energy consumption data (e.g., temperature, humidity, and duty cycle). The kinds and quality of data the four main data collection methods can provide vary, as do their costs. Method selection entails trade-offs between the costs of obtaining high-quality data and the potential benefits to the utility.

Telephone and mail surveys are often used to study measure persistence. They also may be used for eliciting background information about customers, their attitudes, needs, and behaviors to shape studies, to acquire information to help explain or confirm the findings obtained via other methods, or to elicit the customers' degree of satisfaction over time with particular energy conservation measures. Although they are relatively inexpensive to administer and can be cost effective, the main limitations of these methods are that they may produce flawed data because of their reliance on the expertise, knowledge, and biases of respondents.

On-site inspections may be the method most appropriate for evaluating and verifying the physical persistence of energy-conservation measures, the factors influencing the lack of such persistence, and the operating performance of energy conservation measures. They have been used primarily to determine measure retention rather than measure performance. If measure retention is the persistence goal, on-site inspections offer several advantages. First, inspections may be the only means of acquiring reliable information about whether or not measures remain in place and operational, and about where measures are located. Second, inspections are conducive to conducting face-to-face surveys with on-site personnel. Finally, high-quality measure retention information obtained through on-site inspections is useful in conditional demand studies conducted for the purpose of estimating the persistence of savings.

However, site inspections tend to be costly, although their costs depend upon the amount of information collected and the degree of data precision sought. Beyond their high costs, disadvantages of using on-site inspections include their reliance on the expertise of on-site auditors; consistency among auditors; access limitations both to equipment and to some locations within facilities; their limitations in documenting historical and behavioral characteristics; and the possibility of a large non-response bias.

Information collected from telephone or mail surveys, and from on-site inspections, may serve to increase the accuracy of engineering estimates by providing data on the numbers of measures in place and (for on-site inspections) operating as anticipated. Surveys (mail, telephone, or on-site) also help to explain why measures may not achieve the manufacturers' estimates of savings by ascertaining information about behavior. Particularly for on-site surveys, DSM professionals should evaluate the extent to which field work is necessary to provide information that may increase the accuracy of estimates, given that field work tends to be costly.

Billing data typically are used to evaluate the net energy (electric and/or gas) savings attributable to energy conservation programs rather than particular energy conservation measures. They are amenable, therefore, to cohort- and program-scale analyses. In this context, the main advantages of billing analyses are that they use large amounts of readily available data; that they provide information at an aggregate level; and that they tend to be cost-effective. Billing analyses generally rely on assumptions about the physical presence of installed energy conservation measures; involve the use of comparison groups; and include some form of weather normalization so as to determine the persistence of net energy savings. A limitation of billing analyses is sample attrition over time, due to data quality problems that often reduce the size of the sample available for analysis and other factors that reduce the sample size (e.g., changes in participant and non-participant populations). Also, billing analyses generally are inadequate for distinguishing the savings achieved from individual energy conservation measures.

Metering or monitoring may be used to provide detailed information about the energy and load effects of specific measures at specific premises, over time. They also are a good means for acquiring data about non-energy consumption characteristics, such as those related to weather or the times and manner of equipment use, that are important for distinguishing program or equipment effects from other effects and for understanding why certain levels of energy savings are achieved. Such insights may lead to increased persistence through changes in program design or delivery. Nevertheless, these measurements can produce biased estimates of energy consumption because of the limited duration of many metering projects and the inability of short-term metering to characterize changes over time. It also is difficult to generalize to a larger population when small samples are used for metering or monitoring. Further, metering and monitoring tend to be equipment- and cost-intensive; they probably constitute the most expensive of the four categories of data collection methods.

DATA ANALYSIS METHODS

Methods used to estimate the persistence of savings range from engineering methods based on equipment surveys, to univariate and multivariate analysis of energy consumption data.

Equipment survey/engineering methods estimate gross savings and, although they focus on individual measures, often aggregate measures when calculating savings. These methods may be used for different persistence study goals, such as program evaluation or determining shareholder payments. The most comprehensive of these methods considers both survival energy savings (which is the gross energy savings from measures installed by the program) and stimulated energy savings (which reflects any savings due to installations of additional high-efficiency measures by participants or non-participants as the result of the program but without further program incentives). These kinds of surveys usually are used to collect data only once or twice from any single cohort of participants.

Univariate analyses of energy consumption, frequently conducted for the purpose of determining shareholder payments, typically rely solely on weather normalization to analyze the savings from energy conservation programs. Once weather-normalization data adjustments are made, analyses simply highlight any energy consumption differences.

In addition to adjusting for weather, multivariate analyses of the energy savings from DSM programs strive to include additional factors. These factors include electricity prices, pre-participation consumption, sample selection bias, building square feet, the use of alternative energy sources such as wood, and long-run average heating degree days. Multivariate analyses of this type can test hypotheses about the causes of savings persistence, enhancement, or degradation, which can lead to improvements in program design. Therefore, these methods more often are used for the purpose of program evaluation than to determine shareholder payments.

A major difference in the use of uni- and multivariate analyses is in their relative dependence on control groups in determining net energy savings. Both types of approaches are highly dependent on control groups, but multivariate analyses also can make statistical adjustments for differences between control and participant groups. However, because multivariate analyses require more data than do univariate analyses, they are more costly to perform.

FINDINGS OF PERSISTENCE STUDIES

Results of persistence studies, taken as a group, are inconclusive and in some cases inconsistent. Measure persistence studies generally have found that the *ex-post* estimates of year-to-year savings associated with measures were less than the *ex-ante* engineering estimates, although this is not always the case. For instance, when stimulated energy savings (i.e., market transformation) is considered, *ex-post* estimates have exceeded *ex-ante* estimates. Further, significant variability has been observed in the persistence of savings associated with different measures and different sectors.

Persistence studies that focus on the cohort scale, which generally have evaluated residential DSM programs, also have produced varying results. The results of these studies range from a decline in savings to a net increase in savings over time within cohorts of participants. These studies often fail to report confidence intervals or levels of precision, so it is not possible to determine whether the differences are significant.

The one example of an analysis of persistence at the program scale indicated that savings can decrease more precipitously across successive years of participants than across the years following program participation for a single cohort of participants. The importance of this finding underscores the need to conduct persistence studies that analyze the full lifecycle of program impacts.

In part because of the inconclusiveness of findings from persistence studies, one recommendation is to use methods that will provide a basis for statistically strong results. Along these lines, it is important to report levels of precision and variability along with the point estimates of savings over time. At the same time, costs must be considered. Increasingly, utilities are looking for relatively inexpensive and straightforward methods for evaluating their DSM programs. Finally, no single method best meets the variety of users' information needs while remaining within their budgetary constraints.

Beyond these methodological considerations, the future may present a different type of challenge to the conduct of persistence studies. We do not know how utilities will address persistence as they adapt to a competitive world. On the one hand, accurate information about persistence or how to improve persistence may enhance a utility's competitive edge. On the other hand, expensive persistence studies may be an unaffordable luxury. Competition also may result in multiple utilities cooperating to conduct persistence studies.

LIST OF ACRONYMS

ANOVA	Analysis of variance
CCIG	California Conservation Inventory Group
DNAC	Change in normalized annual consumption
DSM	Demand-side management
ESCO	Energy service company
HE	High efficiency
HRCP	Hood River Conservation Project
HVAC	Heating, ventilation. and cooling
IRP	Integrated resource planning
LILCO	Long Island Lighting Company
NAC	Normalized annual consumption
NEPSCO	New England Power Service Company
ORNL	Oak Ridge National Laboratory
PRISM	Princeton Scorekeeping Method
SRC	Synergic Resources Corporation

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1. BACKGROUND AND PURPOSE

The durability or persistence of savings from demand-side management (DSM) investments is an issue of importance to many stakeholders, including: DSM program managers and evaluators, resource planners, load forecasters, DSM forecasters, utility regulators, public interest groups, and customers. Inaccurate assumptions about the persistence of savings can bias estimates of program benefits. These biased estimates may in turn lead to suboptimal program design decisions and to cost-ineffective DSM investments. In addition, they may cause utilities to receive inappropriate net lost revenue adjustments, or energy service companies (ESCOs) may receive performance-based payments that do not reflect actual DSM benefits. Ultimately, utilities may invest in unnecessary supply options or fail to plan for necessary future energy resources if forecasted DSM impacts are inaccurate.

The purpose of this literature review is to provide a framework for developing a handbook on persistence methods. To this end, the review discusses the concept of persistence, describes the methods used to measure it, and briefly summarizes the findings of past persistence studies. The review focuses on measurement issues because it is believed that the use of improved and more consistent methods will help stakeholders make better-informed decisions about DSM programs and future resource requirements. This review was conducted from the perspective of a utility that seeks to acquire DSM resources and is interested in their long-term durability; it was not conducted from the perspective of the individual consumer. It also focuses on net, rather than gross, savings of energy conservation programs.

The past decade has produced conflicting information about the operational lifetimes of individual DSM measures, the trajectory of savings from DSM installations, and the ability of programs to generate sustained savings over extended periods of operation. Some of this confusion has resulted from the use of different operational definitions of persistence and the application of different measurement methods.

Currently, there is no consensus either on how best to measure persistence or on how frequently it should be measured (e.g., Braithwait *et al.* 1994). There are several possible reasons for this lack of agreement. One reason may be the relative newness of the persistence concept and of serious attempts to measure it. Another reason is that persistence has been defined and analyzed at many different scales. Three different scales are described below, each covering a unique time frame and level of DSM investment:

- **measure** – this scale is used in studies that predict the trajectory of year-to-year savings from the installation of a particular DSM measure by a single cohort of participants in a DSM program;
- **cohort** – this scale is used in studies that predict the trajectory of year-to-year savings from the installation of a collection of DSM measures by a single cohort of participants in a DSM program; and

- **program** – this scale is used in studies that predict the trajectory of net program savings from packages of measures for all years (multiple cohorts) of program participants in a DSM program.

The *measure* scale is the least comprehensive and the one that is used most often in persistence studies. At the other extreme, the *program* scale is the most comprehensive and the one that is examined least often. Different measurement methods tend to be used for each of these scales of analysis, although methods are not entirely consistent even within each scale.

Differences in methodology also occur because persistence is measured for many different purposes. In particular, there are two overarching reasons why persistence studies would be undertaken: to serve as a basis for DSM or integrated resource planning (IRP) or to evaluate (e.g., determine what savings are achieved and why) or validate (i.e., assess performance relative to a specified goal) the savings from DSM measures or programs. Throughout this review we identify instances where different scales of analysis and different study purposes require different measurement methods.

This review is organized into eight chapters. Chapter 2 discusses the variety of definitions of persistence and the various reasons for measuring it. Chapter 3 discusses research design and measurement issues, including the use of control groups, units of measure, sampling, sample attrition, and data collection methods. Chapter 4 discusses alternative data analysis approaches for equipment surveys or engineering studies and univariate and multivariate energy consumption analyses used to estimate current and future savings. The review ends with a brief summary of persistence study findings (Chapter 5), a concluding discussion (Chapter 6), a glossary (Chapter 7) and a list of references (Chapter 8).

2. ISSUES FUNDAMENTAL TO PERSISTENCE AND ITS MEASUREMENT

Two conclusions are clear from a review of the literature; namely, that persistence is an issue of growing concern and that the term "persistence" has been used in many different ways. The combination of these two observations creates conditions for considerable ambiguity and mis-communication among stakeholders. It also complicates the task of developing a methods handbook. Therefore, this section seeks to identify the multiple dimensions of persistence so as to lay the foundation for later discussions of current methods and for the handbook itself.

2.1 DEFINITIONS AND SCALES OF ANALYSIS

Persistence in this report is defined as the long-term temporal pattern of energy savings and load reductions from DSM investments. The savings of concern may involve a single energy conservation measure or a package of measures installed in a DSM program.

Questions about the durability of DSM savings first were raised seriously about a decade ago (e.g., Hirst, White, and Goeltz 1984, and 1985). Since then, persistence has been defined in many different ways. At one extreme, the term "persistence" has been referred to as "subsequent-year savings" and "long-term savings," emphasizing the positive; at the other extreme, terms such as "degradation" or "decay" have been used, emphasizing the negative (e.g., Jeppesen and King 1993; Violette *et al.* 1991; White and Brown 1992). An insightful analogy is provided by Braithwait *et al.* (1994), who liken persistence studies to economic studies of the depreciation of investment goods.

Table 2.1 illustrates the range of definitions of persistence used to date. For instance, persistence is often defined as the operational life of an energy conservation measure or the degree of retention of measures. Alternatively, definitions have referred to persistence as the time-line of energy savings relative to expectations.

Table 2.1 also identifies in bold-face type the four persistence studies that are used repeatedly throughout this literature review to illustrate measurement options. They were chosen because they span a wide array of different scales and sectors, and because they provide detailed descriptions of alternative data collection and analysis methods.

Conceptually and in practice, persistence is considered at many different scales, as illustrated in Table 2.1. These scales add another layer of complexity to the discourse about persistence, for a number of reasons described below.

First, studies at each of the scales would focus on different factors to explain the persistence of energy savings. The *measure* scale may focus on the technological and behavioral factors that influence the operation and use of energy conservation measures. For *cohorts*, the emphasis is on large-scale factors that influence energy consumption (e.g., weather), on the consumption of energy,

Table 2.1 Definitions of Persistence[a]

Authors	Definition	Motivation: Planning (P) Eval. (E)	Focus: Program (P) Measure (M)	Sector: Res. (R) Comm. (C) Ind. (I)	End-Use: Multiple or Specific
Braithwait, Maniaci, Blyer, and Attenberger 1994	"The term persistence refers to the extent that the energy savings and the energy efficiency measures that are promoted by utility DSM programs are maintained over time. A distinction is usually made between the persistence of energy savings (both total and net) and the persistence of the energy efficiency measures...themselves..." (p. 3). Distinguish "three distinct but related concepts or elements of persistence" : measure retention (effective measure life); measure performance; and persistence of net energy savings.	E	P, M	multiple	multiple
Brown, Berry, Balzer, and Faby 1993	Discuss savings over lifetime of weatherization measures, which is assumed to be 20 years; an appendix discusses weighted estimates of measure lifetime; no discussion or definition of "persistence" per se.	E	P, M	R	multiple
Brown and White 1992	**No definition. Report discusses the decay in program energy savings over time, by multiple cohorts of participants.**	**E**	**P**	**R**	**multiple**
Coates 1992	No explicit definition; paper deals with 1st-, 2nd-, and 3rd-year energy savings of a program.	E	P	C	multiple
Delaware Office of the Public Advocate and Delmarva Power & Light Company 1993	"Persistence measures whether energy savings continue as expected over a conservation technology's useful life" (p. 29).	E	P	multiple	multiple
Eto, Vine, Shown, Sonnenblick, and Payne 1994	No explicit definition. Distinguish short- medium- and long-term persistence. Also consider economic life of savings.	E	P	C	lighting
Guyant, Hopkins, and Reid 1989	Focused on "longevity," long-term benefits, enduring high levels of efficiency	E	M	R	oil heat systems
Hickman and Brandis 1992	Looked at "measure retention," focusing mainly on premature measure removal.	E	P, M	C	multiple
Hirst, White, and Goeltz 1985	No definition; looked at durability of energy savings one-, two-, and three-years after program. May be "first study to closely examine actual (measured) energy savings due to a conservation program over such a long time span" (p. 2).	E	P	R	multiple
Hirst and Sabo 1991	No definition of "persistence," but define: "lifetime of the programmatic energy effects" as "the median length of time (in years) that a DSM program produces energy effects; it is a function of both the lifetimes of the measures installed and operating practices" (p. 70).	E	P, M	n/a	n/a
Jacobson, Miller, Granda, Conant, Wright, and Landsberg, 1992	No explicit definition; compared engineering estimates with measured savings.	E	P	multiple	multiple
Jeppesen and King 1993	**Use definition from 1990 *Report on (California) Statewide Collaborative Process* (p. A-27 of that report): "Persistence (and decay) refers to any decline in energy-saving effectiveness that may take place over a measure's useful life" (p. II-2).**	**E**	**M, but look at measures as part of programs**	**C**	**multiple**

[a] Bold-faced items are those documents that are highlighted as examples throughout the remainder of this report.

Table 2.1 Definitions of Persistence (cont.)

Authors	Definition	Motivation Planning (P) Eval. (E)	Focus Program (P) Measure (M)	Sector Res. (R) Comm. (C) Ind. (I)	End-Use Multiple or Specific
Keating 1991	"Defined at the utility level, persistence is equivalent to the long-term temporal changes in net program impacts; defined at the societal level, it is equivalent to the long-term temporal changes in total impacts. Note that the persistence of both total and net impacts includes technical and operating characteristics" (pp. 89-90). Also discusses two dimension of measure persistence: lifetimes of DSM measures installed and ways measures operated.	P, E	P, M	multiple	multiple
Massachusetts Department of Public Utilities 1993	No overt mention of persistence, but tables include lifetime savings—their present value of measures and the MWh (kW-Year) savings of programs	E	P, M	multiple	multiple
Miller, Blake, Dagher, Schutte, and Wright 1992	No definition; looked at short-term persistence of measures.	E	M	small C/I	lighting
Minnesota DSM Evaluation Consortium Working Document 1993	Persistence is the "[r]ate of energy-savings effectiveness that takes place over a measure's useful life" (p. 3).	E	P	n/a	n/a
Misuriello and Hopkins 1992	No definition: discuss "the availability of DSM savings over the life of the measure" (p 20)	E	M	multiple	multiple
Narum, Pigg, and Schlegel 1992	**"There are two main ways in which persistence can be defined, and, in turn, evaluated: 1) at the measure-specific level (measure retention, measure lifetimes, and measure performance considerations); and 2) at the program level (total and net impacts)" (p. 2).**	**E**	**P**	**R***	**multiple**
New Jersey Board of Regulatory Commissioners 1993	States that utilities must specify procedures to allow for, or to verify, persistence, but provides no definition of persistence.	E	M	multiple	multiple
Pacific Gas & Electric *et al.* 1993	A persistence study is defined as "A study to assess changes in net program load impacts over time" (p. A-8).	E (verification)	P*	multiple	multiple
Parker 1993	**Defined in terms of the technical persistence of operational life (the percent of originally rebated measures installed and operating, or replaced with other equipment at the end of its operating life) and the persistence of efficient technology (the actual inventory of efficient equipment installed and operating, whether the equipment was installed directly by the program, replaced in kind, or added by the customer without a rebate) (see pp. 28-29).**	**E**	**M**	**C&I**	**multiple**
Pennsylvania Public Utility Commission 1992	Discuss persistence of net savings as long-term effects of program measure. "This is referred to as the 'snap-back', 'rebound', or 'take-back' effect" (p. 16), which can be caused by behavioral responses or equipment degradation.	E	P, M	multiple	multiple
PSCW ca. 1992	Persistence is "the extent to which achieved first-year savings last as long as anticipated" (p. 2)	E	M, P	n/a	n/a
Robinson 1992	No definition. In part this study reports on an effort to help assure the persistence of savings via direct bulb installation.	E	P, M	R	lighting

* Unlike most studies reported in this table, this study focused on gas-utility programs rather than on electric-utility programs.

Table 2.1 Definitions of Persistence (cont.)

Authors	Definition	Motivation Planning (P) Eval. (E)	Focus Program (P) Measure (M)	Sector Res. (R) Comm. (C) Ind. (I)	End-Use Multiple or Specific
U.S. EPA 1993a	"Subsequent-year energy savings: The energy savings occurring in the annual periods following the first year" (p. 21).	E (verification)	M	multiple (utility focus)	multiple
U.S. EPA 1993b	No definition. May claim savings throughout useful life of measure(s). Useful life is the median number of years that a measure produces energy savings.	E (verification)	M, P	multiple	multiple
Vine 1992	Measure persistence: the number of years a measure is installed and its level of efficiency. Program persistence: continuation of participants' energy savings over time. Look at gross and net savings. [No explicit definition given; above definitions based on Vine's recommendations for persistence assessments]	P, E	P, M	multiple	multiple
Violette, D., M. Ozog, M. Keneipp, F. Stern, and P. Hanser 1991	"Refers to any decline in energy-savings effectiveness that may take place over a conservation measure's life. This is a function of both consumer behavior and equipment degradation" (p. C-6).	E	M	multiple	multiple
White and Brown 1990	Report focuses on an impact evaluation three years after weatherization, looking at measures installed and actual electricity saved. No mention of term "persistence."	E	P	R	multiple
White and Brown 1992	No definition; looked at consistency or decay of energy savings over time.	E	P	R	multiple
White, Stovall, and Tonn 1992	**No definition, but interested in "durability or persistence of program benefits, especially load savings..." (p. 25) one-, two-, and three-years after weatherization.**	**E**	**P**	**R**	**multiple**

and on participant/non-participant differences in energy actions. *Program*-scale persistence can encompass the factors relevant to the other scales, and adds the element of cross-cohort comparison to distinguish year-by-year, cohort-by-cohort effects.

Second, the scales extend the distinction between the two dimensions of persistence typically mentioned in the literature, program and measure persistence (e.g., Braithwait *et al.* 1994; Keating 1991;[1] Narum, Pigg, and Schlegel 1992; Vine 1992). "Program persistence" has been used to refer to the durability of net energy savings (those savings attributable directly to the program) of energy conservation programs. The three scales proposed in this review disaggregate the conception of program persistence reported in the literature into cohort-year analyses and analyses over the lifetime of programs. "Measure persistence" has consisted of the long-term gross energy savings associated with specific energy conservation measures. Distinctions between program and measure persistence sometimes have been fuzzy in practice. For example, program persistence may be gauged simply by summing or combining the persistence of separate energy conservation measures. In other cases, because a relatively small group of similar measures constitute a program (e.g., some lighting

[1] Keating distinguishes the persistence of program measures from what he calls "the overall definition of persistence" (p. 89) that can be viewed from either a utility or societal perspective. The utility perspective focuses on the long-term temporal changes in net program impacts" (p. 89) and the societal perspective focuses on "the long-term temporal changes in total impacts" (p. 90). However, in this text, the studies that fall under the "total-impact perspective" are those that are concerned with measure lifetime and the studies that he labels the "net-impact perspective" are equivalent to those labeled in this literature review and by Vine (1992), e.g., as program persistence.

programs), the persistence of the program may be determined by focusing on one energy conservation measure (e.g., high-performance light bulbs in Robinson 1992).

Third, the scales tend to distinguish between net and gross savings; this distinction has tremendous implications for the methods for studying persistence and for analytical results. Because net savings are those savings attributable to the program in question, evaluating the persistence of those savings requires methodological rigor (thus, relatively high financial costs). In particular, they require control groups, so that it is possible to detect the differences between what happened because of the program and what would have happened in its absence. As will be discussed later in this report, establishing control groups for persistence studies is made particularly difficult because elements of the program, participants' energy conservation needs, the pool of appropriate comparison groups (e.g., non-participants who can be "matched" with participant groups), and economic conditions (e.g., the price of electricity) change over time. These kinds of shifts make it difficult to track groups, measures, and savings over time in ways that allow evaluators to state with confidence that the effects they see are attributable to energy conservation measures or programs. In contrast, ascertaining gross energy savings generally requires different and simpler methods from studies of net savings, ranging from engineering estimates to on-site surveys to submetering. Results from gross energy savings studies, however, are of limited value in evaluating the persistence of a program's energy savings. Measure-life studies tend to fall into the category of gross savings. While cohort-scale studies generally aim to ascertain net savings, the control-group constraints sometimes are so limiting that only estimates of gross savings result. Program-scale analyses aim to provide estimates of the persistence of net energy savings.

Measure Persistence. The measure scale focuses on the energy savings associated with a particular measure during its lifetime for a particular cohort year of participants. As noted earlier, studies of the persistence of energy conservation measures are more prevalent than studies of program persistence.

The lifetime savings for an energy conservation measure for a single cohort year of participants is illustrated in Fig. 2.1. The figure shows the net energy savings for a single measure as a function of two kinds of energy savings. First, net energy savings is influenced by "survival energy savings," which is the gross energy savings from measures installed by the program. The second influence is "stimulated energy savings," which reflects possible additional savings due to actions taken both by participants and non-participants, such as installing or replacing more measures as the result of the program but without further program incentives.[2] The stimulated energy savings recognize a program's ability to transform markets for DSM measures. These "market transformation" effects are sometimes called market progression, surge, or free drivership, depending on whether they involve participants or non-participants. In general, they refer to a program's ability

[2] The literature considers "stimulated energy savings" to mean the addition of measures by program participants. We are expanding and enhancing that definition to include the installation of measures by both participants and non-participants.

to accelerate market trends toward increasing energy efficiency, above and beyond the investments that are caused by the program's incentive payments. Market transformation is particularly relevant to evaluations of the net savings of energy conservation programs, which is the primary focus of this review.

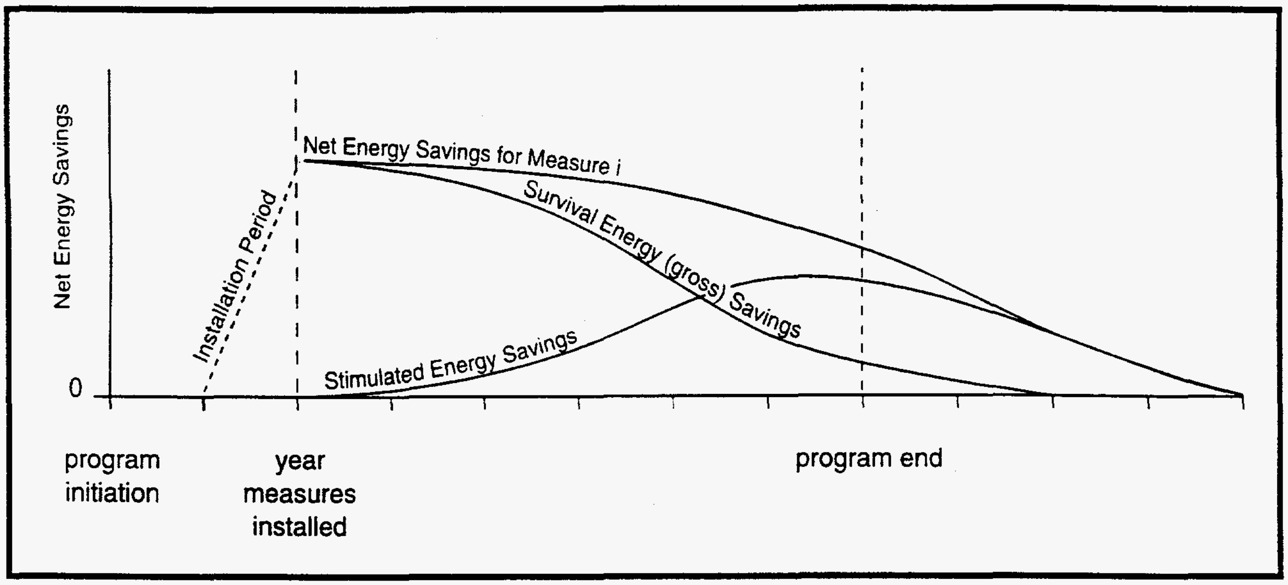

Fig. 2.1 Persistence of Savings from a Single DSM Measure: The Measure Scale

Both survival and stimulated energy savings depend upon measure life and measure performance or efficiency over that life. Measure life is "the time during which the measure is installed and is accruing energy efficiency benefits" (Jeppesen and Rudman 1993, p. 521). It is a function of the measure's technical life, market factors (e.g., remodeling, occupancy or residence changes, behavior), and operational life factors (e.g., installation and sizing, operation, maintenance). In contrast, measure efficiency or performance is "the actual energy efficiency performance of the measure" (Jeppesen and Rudman 1993, p. 521). It is a function of the technical degradation of the measure (including wear-related factors) and behavioral factors (such as operation and maintenance activities).

The following is a more complete list of the many factors that can reduce measure life and impair measure performance:[3]

- improper energy conservation measure installation;
- inadequate maintenance of installed measures;

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[3] The literature on persistence contains varied and sometimes conflicting use of terms. For instance, the LILCO study (Parker 1993) distinguishes "measure lifetime" (or "operating life") from "measure life" (or "technical life"). Measure lifetime, which refers to the field longevity of energy conservation measures, is comprised of a combination of technical endurance (or degradation) and behavior. The concept of measure life, as used in the LILCO study, refers to engineering or manufacturers' projections and does not include behavioral elements.

- technological problems with installed measures (e.g., bad lightbulbs);
- premature removal of the energy conservation measure;
- replacement of energy conservation measures with less efficient measures;
- patterns of energy conservation measure usage that adversely affect measure life;
- surge effects (i.e., "the tendency for some consumers to react to the savings realized by the initial conservation measure installation by expanding their adoption to other conservation measures" [Jeppesen and King 1993, p. II-6;][4] and
- building renovation or turnover (Braithwait *et al.* 1994; Parker 1993).

Cohort Persistence. This scale specifies the lifetime energy savings for all measures installed in a particular cohort year. The scale is illustrated in Fig. 2.2.

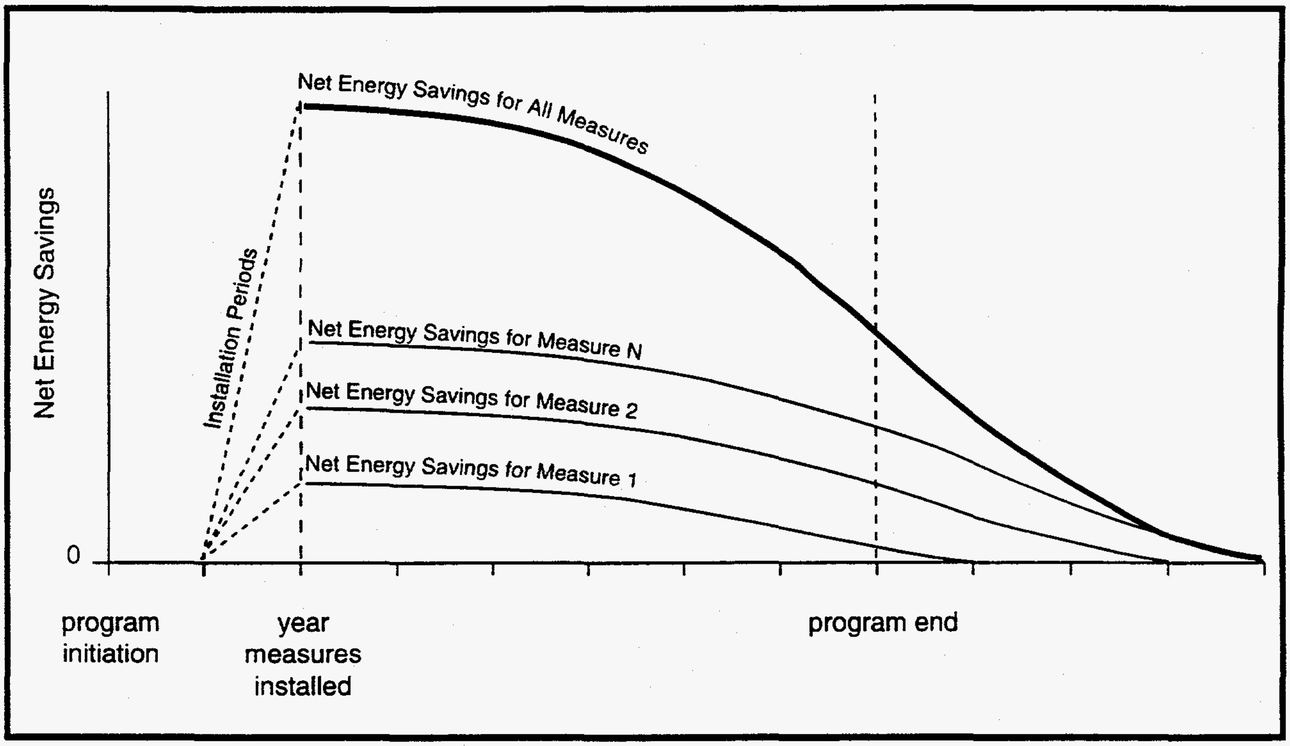

Fig. 2.2 Persistence of Savings from a Package of DSM Measures: The Cohort Scale

Many studies of program persistence are performed at the cohort scale. Some program persistence studies concentrate on the consistency of savings over time, by comparing later-year savings with first-year savings (Vine 1992). However, others (e.g., White and Brown 1990; Narum,

[4] Surge effects refer to behaviors adopted by individual program participants; free-driver effects refer to the behavior of non-participants (Jeppesen and King 1993).

Pigg, and Schlegel 1992) evaluate savings among successive cohorts of program participants. Where these evaluations of multiple cohorts have focused on the persistence of savings across cohorts as well as on the year-to-year savings of individual cohorts (as in Brown and White 1992), they are considered to address the "program" scale.

Persistence at the cohort scale usually is assessed at an aggregate level, without attempting to estimate the energy savings from individual measures. An example of this aggregate approach is provided by White and Brown (1990) in their evaluation of the Bonneville Power Administration's Residential Weatherization Program. They calculated net electricity savings from billing records (weather-normalized) and did not estimate the impacts of different weatherization measures.

Authors of these kinds of program studies tend to take one of two approaches to the factors contributing to a degradation in energy savings over time. One approach is to discuss only generally the kinds of factors that affect persistence, perhaps distinguishing factors that influence measure lifetime and measure performance from those that affect the market.

Another approach is to investigate specifically the contribution of one or more of these factors to program persistence. This approach may overlap considerably with studies that focus on energy conservation measures. Further, the two approaches may call for different kinds of data analysis; descriptive statistics may be adequate for the former, while multivariate inferential statistics may be more appropriate in the latter case.

Program Persistence. This scale refers to the net savings for all measures installed throughout a program's lifecycle. It is represented in Fig. 2.3. Program assessment may be the most important persistence question for forecasting and planning.

The program scale has received little attention in the persistence literature, perhaps because relatively few programs have gone through their entire lifecycles and because of the significant cost associated with tracking net savings over multiple cohorts of program participants. This scale also includes net savings that may extend beyond the operational life of a program. Even though a particular program's activities may be completed, the measures installed in earlier years still may be operating or performing as "high-efficiency" measures. In addition, replacement energy savings (see Fig. 2.1) still may be accruing as the market for DSM measures is transformed.

As with the cohort scale, evaluators can assess specific factors that might affect energy savings over the lifecycle of a program, or they may simply postulate possible causes by analyzing the aggregate patterns. Along with the many factors that affect measure lifetime and measure performance, there are additional factors to consider at this scale that may cause changes in the nature of participants and the DSM measures they adopt. These factors include any changes in local energy prices that may influence the demand for DSM measures, changing economic conditions thatmight affect the ability of a utility's customers to purchase DSM measures, changes in efficiency standards (that may influence baseline measures), changing demographic characteristics, program ramp-up, and the effects of participant self-selection on savings over time. In the case of Brown and

White (1992), for instance, the Residential Weatherization Program attracted very different participants over its ten-year lifecycle. During its first few years of operation, the program attracted intensive energy users with great potential for cost-effective energy savings. During its later years, the program attracted participants with lower utility bills and less saving potential.

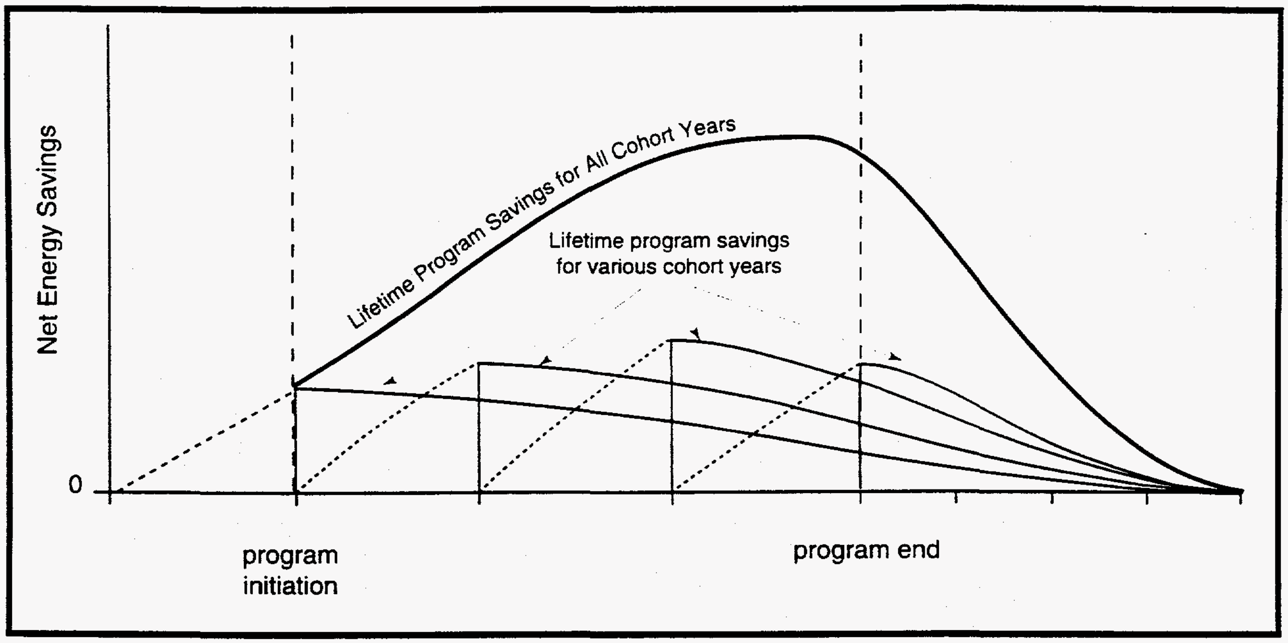

Fig. 2.3 Persistence of Savings Over the Lifetime of a DSM Program: The Program Scale

2.2 PURPOSE OF STUDIES

There are two overarching reasons why persistence studies would be undertaken, to serve as a basis for DSM or integrated resource planning (IRP) or to evaluate or verify the savings from DSM measures or programs. These two general rationales for studying persistence can be refined further, as in Table 2.2. Note that this table reflects a utility perspective and not a customer perspective. Further, the table does not address another possible goal of persistence studies, to discover methods for improving program design and delivery. Program design improvements could involve altering procedures that lead to premature measure removal; program delivery could be improved by avoiding equipment brands that tend to be removed (Oswald 1995).

The methods required to satisfy planning and evaluation — particularly validation — activities are somewhat different from one another. Estimates of predicted measure or program persistence are key for planning purposes, while actual performance over time is central to evaluation. Planning and evaluation may be intertwined in that (a) the accuracy of prediction may be improved by evaluation results (though new data or modeling errors, or new variables may contribute to forecasting errors), (b) the process of evaluating often entails making estimates, particularly since many conservation programs have not been in place long enough to allow truly long-term persistence studies (e.g., Eto *et al.* 1994; Keating 1991; Vine 1992), and (c) evaluations can contribute to an understanding of why predictions and forecasts differ (Baxter 1995). Planners also may benefit from acquiring information from evaluators to help them design programs that maximize persistence (e.g., Braithwait *et al.* 1994; Keating 1991; Vine 1992). Nevertheless, the distinction between planning and evaluation is important for persistence in cases when the information or activities needed for each endeavor differs.

Table 2.2 Purposes for Studying the Persistence of Savings

1. DSM Planning or IRP:
• **resource planning** (i.e., to assess the most cost-effective means of meeting future energy and loan requirements),   • **load forecasting** (i.e., to estimate future load requirements, based on alternative DSM investments with varying levels and trajectories of savings), and   • **annual program planning** (i.e., to allocate resources to next year's portfolio of DSM programs).
2. Program Evaluation:
• **program evaluation** (i.e., to assess the cost-effectiveness of a program based on measured savings over time and to understand factors influencing program impacts),   • **lost revenue recovery** (i.e., to compensate utilities for the loss of revenues from lower electricity sales due to DSM programs),   • **shareholder incentives calculations** (i.e., to determine utility incentive payments that reflect the magnitude and longevity of DSM savings), and   • **performance contracting payments** (i.e., to determine payments to ESCOs that reflect the magnitude and longevity of DSM savings).

Compare, for example, utilities' needs when planning their resource acquisition relative to their needs when validating conservation program or measure effectiveness. For a specific energy conservation measure, planners could use an equation that combines engineering estimates of technical measure life with foreseeable behavioral factors such as maintenance activities or building renovations to project the measure's performance over its life.

Evaluation generally requires evidence of actual measure performance (with performance being a function of technology and behavior), particularly when public utility commissions specifically state that they do not want utilities to rely on engineering estimates. For example, the Massachusetts Department of Public Utilities issued an order that would allow utilities to earn financial incentives for its conservation and load management programs so long as the utility can measure program savings and not rely on engineering estimates (Jacobson *et al.* 1992). The billing analyses and site visits that typically are associated with evaluation exercises easily could be absent from planning activities. The results of billing analyses and site visits could provide useful and much-desired information for planners, but are not generally considered necessary for planning.

While planning and evaluation activities are integral to utilities, attention to persistence currently is not. The general awareness that engineering estimates of energy conservation measures typically overstate both energy savings and measure durability seems to have led to a number of studies evaluating actual savings and durability. Table 2.1 shows that investigations focus predominantly on evaluation. While several documents state that persistence is important to planning activities or to provide information that could be incorporated by planners (e.g., Braithwait *et al.* 1994; Keating 1991; Vine 1992), they do not provide measurement guidelines. A key conclusion from this review of persistence is that the methods handbook should recognize the different purposes for studying persistence and should discuss methods appropriate for each purpose.

3. RESEARCH DESIGN AND DATA COLLECTION ISSUES

A variety of methods are used to collect data on persistence, including surveys, billing data analyses, on-site inspections, and metering and monitoring. Multiple methods often are used in single studies; these methods also may be combined with engineering estimates to produce an evaluation. Other methods for acquiring information to determine persistence include using engineering assumptions and various parameters from previous studies (Braithwait *et al.* 1994; Jeppesen and King 1993). The choice of method is influenced by the study objective(s).

This section describes the main data collection methods currently in use. First, however, some fundamental research design and data collection issues are discussed. These issues are relevant to virtually all persistence studies, though their particulars may vary according to the type of study undertaken, its purpose, etc.

3.1 ASSUMPTIONS AND CONTROL GROUP OPTIONS

The assumptions underlying studies may strongly influence both research design and results. Stated in the extreme, there would be no perceived need for persistence studies if the past assumptions guiding the use of engineering estimates in determining measure life and energy savings remained unquestioned today. Although persistence studies are a recent phenomenon, it is clear that results based solely on engineering estimates may differ considerably from results based on "field" performance (e.g., Braithwait *et al.* 1994; Eto *et al.* 1994; Hirst, White, and Goeltz 1985; Jeppesen and King 1993; Keating 1991; Skumatz *et al.* 1991).

This section focuses on the working assumptions that researchers make, specifically on the assumptions (or choices) that influence research design and data collection. There are two caveats to this discussion. First, the phrase "working assumptions" is used to emphasize that these assumptions deliberately may be used to facilitate the completion of a project, regardless of whether they are accurate. For example, Brown *et al.* (1993) assumed a 20-year lifetime of all installed weatherization measures for the purpose of evaluating savings over that period of time though they specifically stated that some weatherization measures have a much shorter expected lifetime and discussed estimated measure lifetimes in an appendix. Second, financial constraints may force some utilities to make assumptions (e.g., about the physical presence of measures at sites or about the accuracy of survey results in determining the physical presence of measures) instead of measuring persistence.

Assumptions and choices about control groups are extremely important in studies that aim to estimate net energy saving, because of the necessity of attributing savings to a particular program (e.g., Keating 1991; Vine 1992). This attribution depends, in part, on the determination of how program participants would have behaved in the absence of a program. Free drivership (non-participants adopting program measures either consciously due to the program or because of changes in the market [Saxonis 1991]) is among the confounding variables in distinguishing the participant study group from a control group. "The potential implications of this difficulty are that efforts to measure net program savings will be costly, and may provide results that are not sufficiently robust to significantly improve the existing uncertainty" (Braithwait *et al.* 1994, p. 16). In addition, the long timeframe of persistence studies complicates the size and composition of control or comparison groups (see ***Attrition*** in Section 3.4).

Various control group options have been used in previous persistence studies. Table 3.1 describes the approaches used by the four persistence studies highlighted by this literature review. These options mirror those available in non-persistence studies. However, the time dimension of persistence studies challenges the integrity of control groups.

Table 3.1 Examples of Control Group Options

- **no controls:** Long Island Lighting Company (Parker 1993) — gross savings estimated, based on counts of installed equipment in commercial facilities
- **no controls:** Hood River Conservation Project (White, Stovall, and Tonn 1992) — estimated gross savings, based on differences between pre- and post-weatherization load consumption, normalized for long-term weather conditions and by comparing consumption during peak days
- **control group of non-participants:** Bonneville's Residential Weatherization Assistance Program (Brown and White 1992) — estimated net savings, based on comparisons of participants and non-participants; the non-participant sample was weighted to match the geographic distribution of participating households
- **control group of later participants:** Wisconsin low-income residential weatherization program (Narum, Pigg, and Schlegel 1992) — estimated net savings, based on year-to-year comparisons of early and later program participants, where later program participants are the control group for earlier program participants

When comparing participants with non-participants, it is typical to specify that non-participants be matched in some way with participants to provide a reasonable indication of what program participants might have done (or how buildings or conventional equipment might have performed) in the absence of a program. Therefore, billing-data analyses may use eligible non-participants as comparison groups to enable researchers to distinguish program-related changes in energy consumption from non-program-related factors (e.g., White and Brown 1990). Using eligible non-participants has been thought to control for free-ridership effects (participating in programs even though program-sponsored energy conservation measures would have been adopted in the absence of the program) by providing a basis for estimating what participants might have done in the absence of a program (Keating 1991). In some cases, however, this assumption may not be valid. Participation in voluntary programs may distinguish participants from non-participants in ways that influence their energy use, undermining the notion "that non-participants behaved the way participants would have behaved without the program" (Train 1994, p. 426).

Narum, Pigg, and Schlegel (1992) used a variation of the above themes in their study of the persistence of energy savings in low-income Wisconsin residences. They used as their comparison group "a similar group of untreated buildings (composed of later participants), with the assumption that the untreated buildings' energy usage patterns is [sic] a reasonable representation of what the treated buildings would have done had they not participated in the program" (p. 3).

In some cases, no control groups are used and comparisons are made pre- and post-program implementation. This method is known as the time-series approach (Violette 1991). The rationale given for a study of the persistence of load reductions due to the Hood River Conservation Project's residential retrofit demonstration project was that the use of a control group "would have interfered with the maximum possible penetration goal of the [Hood River Conservation Project]" (White, Stovall, and Tonn 1992, p. 1). There were so many participants in the program that the pool of non-participants was too small for meaningful comparisons. The main advantage of the time-series approach is that dwelling and demographic factors are unlikely to change over a few-year timeframe. However, the approach cannot account for such factors as market progression, and typically does not address the impacts of weather (the White, Stovall, and Tonn 1992 study is an exception) or electricity prices (Violette 1991).

Studies focusing on measure performance also entail comparisons, but in these cases the comparisons are with conventional equipment or measures. The LILCO commercial/industrial persistence study (Parker 1993) is an example in which these kinds of comparisons are made. Gross energy savings were estimated on the basis of assumed energy savings associated with the equipment that was in place. As Keating (1991, p. 94) states, "Measuring persistence without a comparison group implicitly assumes that standard equipment experiences no deterioration in performance over time."

Control group considerations are applicable to any evaluation that seeks to determine net energy savings. Persistence studies pose particular challenges to establishing and maintaining adequate control groups, for the following reasons:

- the need for control group members to remain unaffected by a program for an extended period;
- the cost of selecting a control group and obtaining data from such a group;
- changes in programs over time;
- market transformation;
- sample attrition over time;
- changes in the composition of participant cohort groups over time (with different potentials for energy savings); and
- changing economic conditions that can influence patterns of energy consumption.

3.2 RETROSPECTIVE VERSUS PROSPECTIVE DESIGNS

By whatever definition, persistence deals with time. There are four related aspects of time that have particular relevance to research design and measurement. These aspects are the timespan addressed by a study, whether study designs are retrospective or prospective, the frequency with which persistence studies ought to be performed, and the timing of persistence studies relative to measure or program implementation.

Retrospective studies look at past events and use existing information to estimate persistence. The majority of published studies are retrospective (e.g., Brown and White 1992; Hirst, White, and Goeltz 1985; Jacobson *et al.* 1993; Narum, Pigg, and Schlegel 1992; Parker 1993; Skumatz *et al.* 1991; White and Brown 1990; White, Stovall, and Tonn 1992). In contrast, prospective studies are designed to estimate persistence by following participants over time. The research design is established at the beginning of, or early in, a program's life and data are collected in subsequent years. There are advantages and disadvantages to both kinds of study. Retrospective studies, for instance, are limited by the quality, kinds, and completeness of data available; the vagaries of recollection; and fallible reports of current behaviors. The major advantage of retrospective studies is the relative accessibility of certain kinds of data such as maintenance records, test measure life estimates, building permits and utility service records, and billing data. Prospective studies' main advantages are their ability to provide better quality, more detailed, and more timely data for utilities than can retrospective studies. Because prospective studies are designed before data are collected, they may be better able to collect the data most appropriate to answer research questions.[1] Although sampling issues are important for retrospective and prospective studies, prospective studies may provide researchers with more options. For instance, researchers may choose to follow measures that may be moved from one site to another (Vine 1992). Retrospective studies do not track the location of removed measures, presumably due to the difficulty, time, and expense involved in re-creating those migration patterns.

The California Conservation Inventory Group (CCIG) measure life study (Jeppesen and King 1993; Jeppesen and Rudman 1993) explored options for, and components of, prospective research designs to evaluate measure life for a group of extant program participants that would be followed longitudinally in future years. CCIG's attention to prospective research design issues is rare in the literature currently available. Although the extensive discussion cannot be summarized here adequately, an attempt is made to sketch many of the salient points.

Prospective study goals, according to the CCIG study, would be to produce reliable and defensible estimates of DSM measure energy savings over time; the estimates would contribute to DSM evaluations, forecasting, and shareholder earnings. In part because of the expense involved in

[1] Braithwait *et al.* (1994) point out that prospective studies eventually require information about past programs, much like retrospective studies. However, because plans for collecting such data already will be in place, the chances of collecting accurate and appropriate data may be better with prospective than with retrospective studies.

conducting long-term studies, CCIG members compiled a list of the 10 highest priority measures for both commercial and residential sectors. These measures were judged likely to be important to future DSM efforts and their effective measure lives were deemed relatively uncertain. Study authors envisioned a five-year study and recommended using single- (univariate) or multiple-parameter (generally, multivariate) survival functions to estimate a measure's overall mean effective life or the differential effects of causes of failure on a measure's overall mean effective life, respectively. In addition to the typical data requirements for measure persistence studies (measure presence or cause for removal, installation and sizing, remodeling, changes in occupancy or residency, measure operation, measure maintenance, additional failure data, and information on customer behavior), the study adds population characteristics for residences, businesses, and industries as well as tracking data on measure migration. Several data collection methods are suggested: (a) on-site inspection to check measure replacement, measure performance, and to provide consistent data during the course of study; (b) supplemental telephone or mail surveys to follow-up site inspections; and (c) monitoring energy and patterns of equipment use to gauge the operation of appropriate measures. No comparison groups are recommended because the entire focus is on the effective measure life of high-efficiency measures. The authors do not suggest trying to replace those customers who withdraw from the study because replacement is likely to be cost-ineffective and because they prefer direct observation to respondent recollection. Nevertheless, the authors suggest incorporating an oversampling strategy in the research design and to promote the retention of an adequate sample size (with the sampling unit typically consisting of a location at which measures are installed rather than facility occupants).

3.3 FREQUENCY AND TIMING OF DATA COLLECTION

The timespan addressed by a study influences the selection of research methods. Because a number of measures and programs whose expected durability is considerable have only relatively recently been in effect, insufficient time has elapsed to measure actual long-term persistence. As Eto *et al.* (1994) point out, the persistence literature currently consists primarily of short-term studies (first few years after installation), not medium- or long-term studies. This situation translates into evaluation studies that combine measurement with estimation. The total period of study (or, of anticipated program or measure lifetimes) also may constitute an important factor when considering how much to invest in that study. The financial costs of purchasing, installing, and operating monitoring equipment, for instance, may be viewed quite differently for a two-year effort than for a twenty-year effort.

There apparently is no consensus about the frequency with which persistence studies should be conducted. Protocols such as those adopted by the California Public Utilities Commission may prescribe study frequencies (Pacific Gas & Electric *et. al* 1993). As an example, these protocols (p. 17) indicate that Pacific Gas & Electric's, San Diego Gas & Electric's, and Southern California

Edison's new construction programs have a 10-year measurement period during which there are four scheduled persistence studies. The persistence studies are as follows: (a) fourth year, load impact study ("an analysis of the net program impacts in the designated load impact year" [p. 17]); (b) fourth and ninth years, retention studies (collecting "data on the fraction of measures or practice[s] (sic) remaining in a given year that will be used to provide a revised estimate of its effective useful life" [p.17]); and (c) fourth year, performance study ("a time series analysis of the relative change in the performance/efficiency of high efficiency equipment or high performance shell measures over time" [p.17]). These studies are required for the utilities' earning claims. Table 3.2 displays the frequency of required persistence studies.

The author of the LILCO persistence study (Parker 1993) suggests performing measure persistence studies every two or three years. Reasons for this recommendation are to avoid customer irritation with annual surveys focusing on the same item, to allow time for economic conditions to change, and to avoid allocating substantial financial resources to efforts whose results likely will be only marginally different.

Braithwait *et al.* (1994) discuss the timing and frequency of persistence studies in terms of the tradeoffs between the costs incurred and the value of the information obtained.[2] So, for instance, a short-term persistence study would provide valuable information in cases where impacts are quite uncertain. Persistence studies could be initiated somewhat later when there is good information about installed measures and their effects are predicted to be stable for several years. Another alternative is to time persistence studies so as to be most appropriate for the types of equipment installed.

3.4 SAMPLING AND ATTRITION

Sampling choices should be driven by the study goals, the desired units of measure, the duration of the study, data availability, budget, time, and personnel constraints, etc. For persistence studies, changes that occur over time also influence sampling. These changes may involve such items as program modifications, evolving participation in multi-year conservation programs (new program participants over time, people or organizations dropping out of programs), energy-related behaviors (surge effects, takeback, market progression, maintenance and replacement habits, etc.), and otheractivities (e.g., building vacancies, turnover, renovation, or demolition; people relocating). These dynamic conditions make sample identification and sample retention particularly challenging.

Attrition. Sample attrition is a fact of life in energy savings studies. However, its effects are amplified in persistence studies because increasing numbers of participants drop out over time. A variety of factors contribute to sample attrition during the course of data collection. Some of these factors have the effect of reducing the sampling frame (the total set from which a sample can be drawn) rather than of causing the attrition of an already-selected sample.

[2] The LILCO study (Parker 1993) makes a similar point, but in terms of economics rather than in terms of the timing of persistence studies.

Table 3.2 Example From California Protocol

Persistence Studies Required For An Earnings Claim For Pacific Gas & Electric, San Diego Gas & Electric, and Southern California Edison

Program	Required Persistence Studies: Measurement Period	Required Persistence Studies: Measurement Schedule
Residential, Weatherization Retrofit Incentives, and Appliance Efficiency Incentives—Space Conditioning	10 years	1. 4th year load impact study 2. 4th and 9th year retention 3. 4th year performance
Residential and Appliance Efficiency Incentives—Lighting and Refrigeration	To be determined by statewide studies	To be determined by statewide studies
Commercial Energy Efficiency Incentives	10 years	1. 4th year load impact study 2. 4th and 9th year retention 3. 4th year performance
Industrial and Agricultural Energy Efficiency Incentives	7 years	1. 3rd year load impact study 2. 3rd and 6th year retention 3. 3rd year performance
New Construction	10 years	1. 4th year load impact study 2. 4th and 9th year retention 3. 4th year performance
Miscellaneous	10 years	1. 1st, 4th and 9th years retention
Residential Direct Assistance	10 years	1. 1st and 9th year retention
Residential Energy Management Services	7 years	1. 4th year practice retention 2. 6th year practice retention
Commercial and Industrial Energy Management Services	10 years	1. 4th year practice retention 2. 9th year practice retention
Agricultural Energy Management Services	7 years	1. 4th year practice retention 2. 6th year practice retention

Source: Pacific Gas & Electric *et al.* 1993

Among the factors that may contribute to sample attrition are the following:

- incomplete billing or consumption history, if the study is a billing analysis (e.g., Keating 1991; Narum, Pigg, and Schlegel 1992; White and Brown 1990);

- participation in other energy conservation programs, either before or after program in question, if such participation affects related equipment (e.g., Narum, Pigg, and Schlegel 1992);
- earlier participation in the same energy conservation program (e.g., Narum, Pigg, and Schlegel 1992);
- non-participants electing to participate in the program (e.g., Keating 1991);
- insufficient or anomalous data that prevent researchers from assigning buildings, customers, or energy conservation measures to appropriate groups (e.g., Narum, Pigg, and Schlegel 1992);
- building vacancies, remodeling, turnover, or demolition (e.g., Jacobson *et al.* 1993; Parker 1993); and
- participants or energy conservation measures moving (e.g., Jeppesen and King 1993).

Responses to sample attrition fall into three broad categories. First, the research design deliberately can include initial oversampling in anticipation that there will be sample attrition. This fix can be simple, as long as the attrition occurs without bias across sample subgroups. Second, attempts can be made to replace the losses. Replacements may have to be identified to match the composition of the cases lost, if attrition bias is found to exist. Finally, researchers simply can perform analyses with fewer data points. If this approach is taken, analysts should test to determine whether or not attrition bias exists, and then apply weightings to correct for any bias present. An example of this weighting is provided by Brown and White (1992), who corrected for differential rates of attrition among the homes served by the eight utilities that participated in Bonneville's data gathering project.

3.5 DATA COLLECTION METHODS

Four principal methods are used to acquire information about persistence—telephone and mail surveys, billing analyses, on-site inspections, and metering or monitoring. The kinds and quality of data these methods can provide vary, as do their costs. In some cases, regulators provide guidance about the methods that should be used. For instance, the California PUC protocol states that for a load impact study beyond the first load impact year, the "study should make every effort to include an analysis of the billing data from both the comparison and participant groups that were used in the first year impact study (even though some sample attrition is expected)" (Pacific Gas & Electric *et al.* 1993, p. 18). The choice of methods also is influenced by the goals of persistence studies.

Several authors are sensitive to the relative financial costs of implementing data collection methods (e.g., Parker 1993; SRC 1992; Violette *et al.* 1991). However, Braithwait *et al.* (1994) go further to frame method selection in the context not only of the value to the utility of the information likely to be obtained, but also in the context of the risks to the utility of uncertainty about the persistence of energy savings. These authors categorize such risks in terms of (a) the value of DSM as a resource, (b) the prudence of utilities' expenditures and the size of their incentive payments, and (c) the costs associated with not improving programs. So, for example, where planned resource acquisition is limited, persistence information for resource acquisition has relatively little value. The risks of uncertainty with regard to utilities' expenditures and incentive payments vary according to a combination of the following three factors, according to these authors: the direction of bias (e.g., overestimates versus conservative estimates) and uncertainty of persistence information used in DSM planning and evaluation; the magnitude and nature of participants' rebate payments (e.g., large rebate on energy conservation measures paid by utilities versus primary financial burden on participants); and the characteristics of utilities' incentive payment agreements (e.g., based on estimates versus evaluations or verification).

Clearly, choices about which method(s) to adopt must take into account the trade-offs between data quality and costs of obtaining those data relative to the potential benefit to the utility. Nevertheless, it is important to recognize that "in nearly all cases, energy savings resulting from the installation of [energy efficiency measures] can only be *estimated* by combinations of engineering analysis and econometric analysis of changes in energy consumption, while controlling for other factors. Furthermore, attributing the appropriate portion of those savings to the program (i.e., net savings) requires inferences from analysis of customer surveys" (Braithwait *et al.* 1994, p. 12).

3.5.1 Telephone and Mail Surveys

Telephone and mail surveys are basic tools used to conduct many persistence studies, particularly those whose aim is to study measure persistence or total impacts (Braithwait *et al.* 1994; Keating 1991). As Vine (1992) states, they are proven methods that are relatively inexpensive to administer, cost-effective, accurate for certain kinds of data, and can be used to elicit a variety of data. Their limitations are in their relative lack of depth and their reliance on self-reported data, which can be erroneous or biased. Vine (1992) supports the use of such surveys in the following cases (clearly evaluation-oriented, not planning-oriented):

> (1) certain kinds of measures—e.g., residential measures, inexpensive and low risk measures, and measures with good program tracking data, (2) particular programs—programs that are one-measure oriented (non-customized), (3) presence of equipment—rather than the condition or efficacy, and (4) attitudinal and behavioral questions—e.g., customer's experience and satisfaction with the measure. (p. 1078)

Keating (1991) also suggests using surveys to identify free riders and free drivers, although he recognizes that surveys may not be particularly good tools for eliciting motivations for adopting energy-efficiency measures or behaviors.

There is some evidence that data about the third item in Vine's list, presence of equipment, may not be ascertained accurately from telephone or mail surveys. Results of the LILCO persistence study of Commercial Audit and Dollars and Sense Programs (Parker 1993; Velcenbach and Parker 1993; Parker 1994) indicate that mail or telephone surveys may not provide accurate information about the presence of measures, instead suggesting a walk-through of the entire facility (including store-rooms). Nevertheless, telephone and mail surveys are popular tools for tracking and verifying the presence and proper operation of energy efficiency measures (e.g., Jeppesen and King 1993).

Example case: California Conservation Inventory Group measure life study (Jeppesen and King 1993)

- **focus:** effective measure life
- **goal:** part of larger effort; this part tested "the feasibility of using a *retrospective* research approach to the study of effective measure life" (p. III-1)
- **sector:** residential and commercial/industrial
- **target population:** energy efficiency program participants (4 utilities)
- **comparison/control group:** none (non-statistical sampling; study focused on methods)
- **data sources:** utility records on customers and measures installed; telephone survey; on-site inspections
- **time span of study:** study conducted ca. 1992; retrospective portion focused on four time spans — 1976-1980, 1981-1985, 1986-1989, 1990-1991
- **sample size and attrition:** residential — 100 completed interviews ("sample points"), available sample of 1,149; commercial — 56 completed interviews ("sample points"), available sample of 120.

The overall study sought "to obtain recommendations on future research and methods for estimating effective measure life" (p. I-2). Study components consisted of a literature review, a feasibility study of the effectiveness of retrospective measure life research, and recommended research designs for future measure life studies. Telephone surveys were part of the retrospective facet of the research, "designed to be an evaluation of the research processes required for a retrospective research approach" (p. III-1). Three particular items were investigated: sampling, focusing on data availability and quality; the ability of program data to identify both customers and the measures installed; and the adequacy of retrospective data collection methods such as telephone- and on-site surveys. Secondarily, although non-statistical sampling methods were employed, researchers collected substantive data from participants on selected, high-priority conservation measures.

The authors suggested a two-step sampling process in which program data were scanned before drawing the sample. They also discovered that respondents were more likely to be willing to provide information over the telephone than to agree to on-site surveys.

These tools may be used in conjunction with other methods such as site inspections (e.g., Skumatz *et al.* 1991). Telephone surveys may be sufficient for residential sector measures or when, in the future, data on programs improve. However, such surveys may be inadequate as the sole source of information about commercial and industrial programs. In such cases, an effective combination may be to collect data from a small on-site inspection sample and a larger, overlapping telephone survey sample (Braithwait *et al.* 1994).

Another use of telephone interviews is to acquire background information that helps shape subsequent research. As an example, Skumatz *et al.* (1992) used telephone surveys in the first phase of research, specifically "to obtain a better understanding of commercial renovation, remodeling, and turnover rates, and the resultant effects, if any, upon energy-using equipment lifetimes" (p. I-3). Telephone interviews were conducted with a total of 106 knowledgeable respondents such as "contractors, architects, property management firms, government agencies, large private firms, and chain operators" (p. I-3). These interviews elicited information about the types of building changes (renovation, hard-, and soft-remodels) that had occurred; business segment turnover; percentage of buildings retaining same business segment after turnover; building changes typically accompanying turnover; the disposition of equipment removed during renovation or remodel; factors influencing equipment replacement decisions; energy-efficient equipment availability; and experiences regarding equipment operation and maintenance.

3.5.2 On-Site Inspections

On-site inspections are most appropriate to evaluate and verify the physical persistence (presence) of energy conservation measures and the factors influencing the lack of such persistence. The information they may provide about physical persistence is more detailed and accurate than information provided by other methods. Inspections (and metering and monitoring) also may be the only means of ascertaining information about measure performance (Braithwait *et al.* 1994). Jacobson *et al.* (1993) suggest that on-site inspections of non-lighting measures may be particularly fruitful since inspectors may determine where along a continuum of performance those measures may fall. Lighting measure performance, in contrast, may be judged dichotomously — as either working or not working. The amount of information collected and the degree of data precision affect the duration of site visits and their costs; information about measure performance therefore takes more time and costs more money than simply verifying the presence of measures (Braithwait *et al.* 1994). These practical considerations may explain why on-site inspections have been used primarily to determine measure retention rather than measure performance.

A particularly well-developed set of inspection forms was developed for LILCO (see example case). Based in part on a review of several persistence studies, the researchers concentrated on the status of rebated, recommended, or in-place equipment. A lengthy data collection form was used. This form contained, as an example, a site verification sheet to provide a mechanism for collecting data in an organized and replicable way, and for developing tables based on a variety of scenarios (all equipment inspected, equipment prematurely replaced — and the reasons for replacement, equipment not identifiable as rebate equipment, etc.). The form included the following categories: code, device/measure, number rebated or percentage installed, number or percentage verified, status (still operating, never installed, etc.), disposition (where equipment is located, including "unknown"), replacement (if replaced, or with what kind of equipment and rebate, if any), and comments. The "replacement" category allowed researchers to quantify free drivers.

Inspectors were provided with a set of assumptions to help them fill out the site verification form. The format of these assumptions was if-then scenarios that described, as 'ifs', rebate documentation, on-site inspection findings, and qualifiers (e.g., customer contact cannot provide adequate information). The assumptions constituted the 'thens'. Apparently, auditors sometimes found it difficult to match the measures inspected with the measures that had been recommended for rebate. (Jacobson *et al.* 1993 and Jeppesen and Rudman [1993] reported a similar findings for commercial lighting measures.)

Example case: Long Island Lighting Company (Parker 1993)

- **focus:** physical measure persistence
- **goal:** "to estimate the lost savings due to premature replacement" (p. 8) for Dollars & Sense and Audit programs
- **sector:** commercial and industrial
- **target population:** customers receiving rebates or for whom audits were completed in 1988, 1989, and 1990
- **comparison/control group:** none
- **data sources:** utility facility, rebate, audit, energy savings, and account turnover data; on-site inspection data; and face-to-face interviews with facility managers
- **time span of study:** study conducted in 1992; records used from 1987 through 1991
- **sample size and attrition:** over 600 site surveys; no attrition figures

Research design consisted of two major parts, preliminary database work and inspections. Preliminary database compilation and manipulation was performed for the following purposes: to determine the sample frame; to define what information was sought; and to establish how to obtain the desired information. Three databases ultimately were created — Audit, Rebate, and Overlap. The Audit database, consisting of customers who received audits and recommendations, included information about the facility and the audit. Facility information contained facility name and address, contact person, telephone number, and peak demand. Audit information comprised audit number, date, recommended measures, reported percent of installation, kW saved, annual energy savings, and data from the original audit (XENCAP audit) describing the base case, energy-efficiency measure, and quantities and locations of equipment. The Rebate database also included the rebate amount, both kW and dollars and the quantities of rebated equipment, in terms of installed tonnage (e.g., central air conditioners and chillers), BTU output capacity (e.g., room air conditioners), or kW (e.g., non-electric cooling, thermal energy storage, custom rebates). As its title indicates, the Overlap database consisted of those facilities that received both audits and rebates.

Information about account turnovers was added to each of the databases. Identifiers were placed on facilities in the databases that experienced account turnovers from 1987 through 1992. (The utility tracks account turnover data.) Account turnovers indicate meter installation in new or existing buildings, changes in meter or billing names or filing for bankruptcy protection. Account turnovers are not necessarily equivalent to ownership or tenant changes.

The second aspect of the LILCO study consisted primarily of on-site inspections. Researchers tried" to inspect 100% of the facility and rebated or audited measures" (p. 14). When equipment was not accessible (e.g., ballasts), the goal was to inspect about 10% of the quantity rebated through a random selection process that relied on the facility manager's cooperation. When only visual inspection was possible, researchers had to rely on information from the facility's staff.

In addition to inspections, in-person interviews were scheduled with facility managers, particularly the people responsible for the facility's energy use. Ideally, these interviews were conducted at the time of the site inspection.

Vine (1992, p. 1078) listed the following advantages of on-site inspections:

- verifying independently (objectively) measure installation and the quality of installation;
- determining whether measures were applied appropriately;
- determining whether measures are sized appropriately and whether they are operating;
- identifying the energy systems affected by measures;
- determining the maintenance level of a particular measure (e.g., its cleanliness);
- examining measures' efficiency levels and their performance degradation or failure; and
- ascertaining measure-specific information (model numbers, temperatures, and lighting levels).

Braithwait *et al.* (1994) added two items to these advantages. First, on-site inspections have the capability of providing information about opportunities for additional energy conservation measures. Second, and as the LILCO study discussed (Parker 1993), they allow for face-to-face interviews with people who can explain observed conditions.

Disadvantages include varying levels of expertise among on-site auditors; limited access to equipment and measures (e.g., insulation, ballasts); limited or no access to certain locations within a facility (e.g., laboratories, operating rooms, buildings containing hazardous waste, clean rooms, locations where security clearances are required); the inability of inspection alone to document historical and behavioral characteristics; the possibility of a large non-response bias; and high costs relative to billing analyses and telephone or mail surveys (Parker 1993; Vine 1992). Vine promotes the use of on-site inspections for "high priority" measures, such as: "measures with complicated installation (e.g., HVAC systems and energy-intensive industrial process measures); measures with high savings, high costs, or high risk; measures needing high maintenance; and measures with poor program tracking data" (p. 1078).

3.5.3 Billing Data

The use of billing or consumption data is associated primarily with program persistence studies that aim to evaluate net impacts. Studies of electricity savings from Bonneville Power Administration's Weatherization Program are prominent examples of reliance on billing-data analyses (e.g., Hirst, White, and Goeltz 1985; White and Brown 1990).

Sample attrition due to lost or incomplete billing records, participants moving, or non-participants electing to participate can be a serious problem for billing analyses. Attrition rates can be very high. Other problems with billing data methods may be the confounding effects of free-ridership, free-drivership, and self-selection bias — a systematic difference between control and participant groups in which participants' generally greater awareness of conservation issues would influence them to use less energy and to adopt more energy conservation measures than control groups, even in the absence of a DSM program (Violette *et al.* 1991).

Keating (1991) cautions that billing analyses may be unsuitable for large commercial and industrial facilities because of the absence of appropriate comparison groups. Therefore, it is possible that only an estimate of savings can be obtained.

Beyond these items, it is particularly difficult to distinguish research design and measurement elements from data analysis elements for billing analyses. A considerable amount of data processing is necessary, for instance, to determine which observations are usable for analysis (e.g., Violette *et al.* 1991). While these data processing procedures arguably are more appropriate to discuss in terms of data analysis than data collection, they are discussed here because they also are inherent to research design.

In an early evaluation of Bonneville's Residential Weatherization Program, White and Brown (1990) used a number of screens that, together with weather normalization procedures, reduced their participant sample from 513 to 252 and their non-participant sample from 1,339 to 688. (Another element that was important in reducing the sample size was that the screening criteria had to apply for three years, so that the authors could determine third year post-retrofit savings.) Screens that reduced the number of participants' worksheets obtained (1,502) to the number included in the study sample (513) included (1) removal of households that were not single-family, non-low-income customers; (2) removal of households that previously participated in other programs or that previously had been excluded from Bonneville's residential weatherization program samples; and (3) removal of households that were weatherized under the 1986 Long-Term Residential Weatherization Program either early or late in the year. Other screens were the following: (1) removal of households that moved during the study period; (2) removal of households with anomalous billing records; and (3) removal of households that were unsuitable for the weather-normalization model, PRISM. (See chapter 4 for a more detailed discussion of weather normalization). PRISM analyses removed households for the following reasons: (1) less than the minimum of two years' worth of billing history; (2) under 3,000 kWh whole-house electricity use in any single year; (3) PRISM electric space heating estimates of zero or less; (4) failure to have 240 consecutive days of billing history in each year; (5) households whose energy-use patterns were not in alignment with typical all-electric households' energy use patterns.

The later Bonneville study (Brown and White 1992) used similar screening procedures as the 1990 study. However, the latter study also employed less restrictive sample selection criteria, resulting in expanded sample sizes. The 1992 study included households with low covariances of normalized annual consumption (NAC), meaning that such households' consumption of electricity did not change significantly with heating degree days. Using households with low NAC covariances increased sample sizes, particularly for non-participants. In 1988, the participant sample grew from 324 to 356 and the non-participant sample grew from 1,009 to 1,170. The situation in 1989 was similar in that the participant sample increased from 383 to 433 and the non-participant sample increased from 1,238 to 1,466.

Example case: Bonneville's Residential Weatherization Program
(Brown and White 1992)

- **focus:** program savings
- **goal:** "to provide an impact evaluation of Bonneville's 1988 and 1989 long-term Residential Weatherization Program" (p. 1.1)
- **sector:** residential, single-family homes
- **target population:** utilities (6 in 1988 and 9 in 1989) and participating households
- **comparison/control group:** control group — eligible non-participating households; comparisons also made pre- and post-installation
- **data sources:** billing records, National Oceanic and Atmospheric Administration
- **time span of study:** 1 year before through 2 years after installation
- **sample size and attrition:** For 1988, participants — originally 356, ultimately 315; non-participants — originally 1,170, ultimately 1,084. For 1989, participants — 433; non-participants — 1,466.

This study represents one of a series of studies evaluating Bonneville Power Administration's long-term Residential Weatherization Program. The focus of this study was on single-family, non-low-income households. Data were collected from two primary sources; participating utilities provided billing records and the National Oceanic and Atmospheric Administration provided weather data (average daily temperature) for the same time period for which billing data were obtained. The pattern of electricity consumption of a sample of participants was compared with that of a sample of non-participants.

Example case: Wisconsin's Low-Income Weatherization Assistance Program
(Narum, Pigg, and Schlegel 1992)

- **focus:** program savings
- **goal:** to determine the persistence of energy savings in large groups of customers at a program-wide level
- **sector:** residential; low-income, gas-heated buildings (single- and multi-unit buildings)
- **target population:** low-income, gas-heated buildings participating in Utility Weatherization Assistance Program
- **comparison/control group:** control — untreated buildings (later participants); compared treated and untreated buildings year-to-year
- **data sources:** 2 utilities' weatherization program databases, fuel consumption information
- **time span of study:** up to 8 years post-installation
- **sample size and attrition:** for Wisconsin Gas Company — 9,956 buildings in weatherization database, consumption data matched for 7,259 buildings, final sample 5,129; Madison Gas & Electric Company — 2,969 buildings in weatherization database, consumption data matched for 2,270 buildings, final sample 1,553 buildings

This study is similar to the evaluation of the Bonneville Power Administration's long-term residential weatherization program in its focus on overall program savings from packages of weatherization measures. The primary methodological difference between the two studies is in the use of control groups. The Bonneville Power Administration study used two kinds of comparisons — pre- and post-participants as well as participants versus non-participants. The Wisconsin study, in contrast, compared participants and non-participants in any particular year with the preceding year such that energy use was assessed from year to year.

3.5.4 Metering/monitoring

Metering or monitoring may be used to provide detailed, direct information about load effects or about measure performance (Braithwait *et al.* 1994; White, Stovall, and Tonn 1992). Metering entails the use of meters to collect whole-building or facility energy consumption data. Monitoring refers to the collection of non-energy consumption data such as temperature, humidity, and duty cycle at particular premises (Pacific Gas & Electric *et al.* 1993). Although they may be the best available methods for actually measuring energy consumption, results still may have to be stated as estimates for four reasons (Braithwait *et al.* 1994; Vine 1995). First, because direct information is available only for the duration of the metering or monitoring, analysts must make assumptions when generalizing the results from a short period of time (e.g., a few weeks) to an entire year. Second, unless there is long-term metering or monitoring, those methods do not provide information about changes over time. Third, generalizing the results of metering and monitoring a small segment of the population to the larger population requires assumptions to be made. Fourth, when considering net savings, analysts still must consider what portion of the measured savings to attribute to the program.

Example case: Hood River Conservation Project (HRCP)
(White, Stovall, and Tonn 1992)

- **focus:** persistence of program benefits, particularly load savings
- **goal:** to determine the persistence of typical and peak load savings of retrofit demonstration project three years after measures installed
- **sector:** residential
- **target population:** electrically heated houses participating in project
- **comparison/control group:** no control group; comparisons made pre- and post-weatherization
- **data sources:** metering data collected every 15 minutes; three weather stations
- **time span of study:** 1 year before through 3 years after installation
- **sample size and attrition:** originally 320 homes; ultimately 220 homes

The HRCP was intended "to install as many cost-effective retrofit measures in as many electrically heated homes as possible in the community of Hood River, Oregon" (p. 1). This study reported findings from a sample of 320 homes whose end-use loads were submetered for one year before the measures were installed and for three years after installation. It used a time-series approach to focus on "the electric load profiles, load savings, persistence of savings, and fuel switching for [those homes]" (p. 4). Every 15 minutes, submetered data were collected on interior temperature and on electric space heating, electric water heating, and wood fuel space heating end-use loads. Extensive weather data also were collected at 15-minute intervals from three weather stations; these data were averaged. These field data were collected by Pacific Power & Light Company and transmitted to Oak Ridge National Laboratory for compilation into a database. In addition to these data, the database contained audit and weatherization information as well as data collected during four occupant surveys of the submetered houses. The database was submitted to rigorous quality assurance measures.

The original study sample consisted of 320 participating homes, each of which was to be submetered. These homes were selected to represent a cross-section of the community. Sample attrition over a four-year timespan resulted in 220 homes being available for analysis.

3.6 SECTOR AND END USE

This section discusses the relationship between customer sectors (residential, commercial, and industrial) or energy end uses (e.g., lighting and space heating) and persistence. In this context, the main question is, what influence does, or should, sector and end use have on the methods used to evaluate persistence? With regard to sector, forms of the four major categories of methods (surveys, billing analyses, on-site inspections, and metering and monitoring) have been used for residential and commercial/industrial sectors. The literature occasionally addresses the role of sector on the selection of study methods. For example, billing-data methods may be inappropriate for large commercial and industrial sectors because of the difficulty in designating control groups (Keating 1991). Keating also indicated that sample attrition and attrition bias may be particularly strong in the commercial sector.

Sector may influence how measure persistence studies are conducted. Some researchers recognize that evaluating the physical persistence of measures in commercial and industrial facilities, particularly via site visits, may simultaneously provide opportunities to promote measure persistence (e.g., Keating 1991; Parker 1993). Inspectors can check to see if the equipment is in place, running properly, etc. as well as provide facility managers with appropriate educational information.

Table 2.1 shows that, among the studies that specify a sector, all sectors are represented. Most commercial or commercial/industrial sector studies focus on measure persistence (e.g., Parker 1993), although some studies emphasize whole-building energy savings. In contrast, the residential sector studies tend to be less measure- or end-use-specific, instead focusing on whole-building energy savings. A number of residential-sector persistence studies evaluated weatherization programs (e.g., Brown and White 1992; Hirst, White, and Goeltz 1985; Narum, Pigg, and Schlegel 1992; White and Brown 1990 and 1992).

Like sector, end use seems to play a limited role with regard to the methods for ascertaining persistence. It is not surprising that persistence-related studies tend to focus on particular end uses more often when they emphasize measure life or lifetimes than when their goals are to evaluate programs (exceptions include end-use-specific programs). Billing and consumption data typically are not used to evaluate measure lifetimes. Therefore, to the extent that studies specifying end use aim to evaluate physical measure persistence and not net energy savings, such studies tend to use methods other than billing analysis.

The practical problems posed by verifying the existence, proper operation, and energy savings of measures associated with different end uses also may influence the selection of methods and the degree of confidence placed in the results obtained through those methods. As an example, it is quite difficult to verify commercial lighting measures. Survey respondents may not provide accurate information about the installation and operation of those devices, perhaps because of their reliance on assumptions about the facility in question instead of on an intimate knowledge of the particulars of lighting in that facility. On-site inspections therefore may provide information superior to that obtained through telephone or mail surveys. However, field inspectors report their difficulties in determining whether the commercial lighting measures observed during on-site inspections actually are the program-supported measures (e.g., Jacobson *et al.* 1993; Jeppesen and Rudman [1993]; Parker 1993). The methods handbook will grapple with the tradeoffs among methods in terms of their financial costs, time, personnel, and data reliability.

4. DATA ANALYSIS ISSUES

There is considerable overlap between the issues relevant to research design and implementation and the issues relating particularly to data analysis. Since data analysis methods are often planned in conjunction with the research design, many of the issues are identical. For example, data analysis methods are influenced by study objectives; different methods are suitable for different study goals.

All the studies considered in this review of persistence studies may be identified either as Equipment Survey/Engineering or Consumption Evaluation studies. The Equipment Survey/ Engineering studies obtain gross savings estimates by combining survey data on installed and operating equipment with engineering estimates of their unit savings. Equipment Survey/Engineering survey studies tend to focus either on individual measures or packages of measures. To date, they have not been employed to address program life-cycle issues by examining cross-cohort differences. Such an effort would require multiple surveys to track different cohort groups over the installed measure's life. In contrast, Consumption Evaluation studies tend to use pre- and post-retrofit consumption data to estimate a net savings effect. They typically are based on utility bills, although submetering is occasionally used; thus, they generally are limited to whole-building savings effects, which are associated with a package-of-measures scale of analysis. Consumption Evaluation studies also have been the approach used in the few program life-cycle studies completed to date.

A major difference between these two types of studies is the way in which persistence estimates typically are benchmarked. Equipment Survey/Engineering studies usually are benchmarked by pre-retrofit audit information. On the other hand, Consumption Evaluation studies generally use a pre-retrofit year of consumption data to benchmark savings.

Both types of studies can be used to examine program lifecycle performance in terms of persistence within and across cohorts of participants. Equipment Survey/Engineering studies are usually based on an initial audit or equipment survey and at least one follow-up survey to assess persistence. Although Consumption Evaluation studies covering multiple cohort groups from several post-retrofit years can estimate both within- and across-cohort effects, few studies have considered across-cohort effects. In some cases, different cohort groups are assumed to be the same to have a sufficient number of observations with several years of post-retrofit experience.

The issue of gross versus net persistence also is a defining feature of the two types of studies. Equipment Survey/Engineering studies often do not include any explicit net calculations to account for what individuals would have done in the absence of the program. However, these studies implicitly may make net adjustments by the way in which equipment replacement is handled. Consumption Evaluation studies typically include a non-participant group, which may be either a matched "control" group or a group of later participants.

This section focuses on the two basic data analysis issues of estimating program effects and projecting program savings. The estimation issue is the problem of determining the mean and variance of the parameters denoting program savings. The projection issue is the problem of how those parameter estimates are used to determine overall or future program savings.[1] The section is divided into two parts: the first deals with Equipment Survey/Engineering studies and the second with Consumption Evaluation studies.

4.1 EQUIPMENT SURVEY/ENGINEERING STUDIES

Studies based on Equipment Survey/Engineering estimates can be an economical alternative to those based on consumption histories, depending on the level of survey and analysis effort. At a minimum, a telephone survey of "representative" cases with a simple tabulation of results is likely to be relatively inexpensive. On the other hand, an in-depth site survey covering a large number of participants is likely be one of the most expensive options. The resulting saving estimates are, of course, highly dependent on the underlying assumptions of a measure's life and unit savings, which in turn depend on assumptions regarding usage and the performance of alternative measures.

Algorithms used to provide engineering estimates span a range of complexity. Some account for interactions across end uses, while others do not. Some address time-of-use issues and can estimate demand reductions, while others cannot. Engineering estimates also may be calibrated to known measurements from billing or metering data, using statistically adjusted engineering methods. For example, in auditing window film retrofits for the New England Power Service Company, the HEC Inc. used a building energy simulation program, "TRACE 600" by the Trane company (Fleming Group 1994; HEC Inc. 1993 and 1994). This model used field-verified data instead of assumed benchmark estimates, which were used in the initial energy audit. Although Equipment Survey/Engineering studies may use statistical methods, they are distinguished by their use of engineering assumptions as inputs.

The LILCO commercial/industrial persistence study provides a good example of this type of study (Parker 1993; Velcenbach and Parker 1993). The portion of this study that presented findings in terms of energy savings may be categorized as using an engineering approach calibrated to audit information obtained through on-site inspections. The same measures of carryforward were used to provide estimates in terms of both energy and unit counts. On-site calculations were conducted by auditors completing the persistence data collection forms following guidelines described in Chapter 3. This information was used to produce percentage estimates of carryforward which then were used to project cohort-year program savings.

The Jacobson *et al.* (1993) study also relied on on-site inspections to determine measure persistence in the commercial and industrial sector. Similar to the LILCO study, these authors used both engineering calculations and measure counts to estimate energy savings.

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[1] For example, due to data attrition, a subset of program participants may be examined to estimate average household savings. In this case, the estimation problem is a single parameter one. The program savings then may be projected by applying the average household savings for the estimation subset to the entire population of program participants. The

The literature reviewed in this report may under-represent the amount of work utilities are doing to assess the persistence of energy efficiency measures. For example, Niagara Mohawk Power Corporation's (1994) *Annual Evaluation Report: 1993 Demand-Side Management Program* refers to a presistence study of a few energy efficiency measures. Neither these kinds of documents nor filings or hearings before Public Utility Commissions were reviewed for this report, however.

4.1.1 Assessing a Measure's Physical Persistence

Perhaps the most comprehensive measures of physical persistence were developed in the LILCO study (see sidebar). Its four measures take into account a variety of factors including the normal replacement of high-efficiency equipment for similar types of equipment and the premature replacement of high-efficiency equipment for less efficient equipment. It also differentiates between high-efficiency equipment installed with or without a rebate.

Persistence Statistics Used in the LILCO Study

$$\text{Technical Persistence of Measures' Operational Life} = 1 - \left[\frac{\text{Premature Replacement}}{\text{Number Inspected}}\right]$$

$$\text{Persistence of Efficient Technology} = 1 - \left[\frac{\text{Additional HE Equip.}}{\text{Number Inspected}}\right] - \left[\frac{(\text{Premature Replacement}) + (\text{Normal Replacement by Non - HE Equip.})}{\text{Number Inspected}}\right]$$

Where:

Number Inspected = Program measures surveyed less those that could not be identified or inspected or excluded for other survey reasons.

Premature Replacement = High-efficiency equipment prematurely replaced by less efficient equipment, which reduces the persistence of energy savings by reducing operational life.

Normal Replacement by Non-HE Equipment = Number of measures replaced after normal operating life, but not with high-efficiency (HE) equipment.

Additional HE Equipment = Additional high-efficiency equipment obtained without a rebate.

Two units of measure are used, percentages and kWh.

Source: Parker (1993)

In the final analysis, the LILCO study only used the carryforward equation to project program savings. By definition, carryforward cannot exceed 100%. The definition also means that

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variance estimate may be used to test whether program savings are significant for a given confidence level and may also be used to determine overall program confidence levels.

the utility takes credit for the savings associated with a particular piece of equipment even after the equipment has worn out and been replaced, as long as two conditions are met. First, the replacement equipment must be of the same type. Second, the utility does not take credit for additional high-efficiency equipment obtained without a rebate (i.e., resulting from market progression). Thus, the resulting savings estimate must be interpreted as an estimate of gross savings.

Carryforward* Statistics Used in the LILCO Study

$$\text{Carryforward} = \left[\frac{(\text{Installed \& Operating}) + (\text{Normal Replacement With No Rebate})}{\text{Number Inspected}}\right]$$

$$\text{Carryforward Including Additional Equipment} = \text{Carryforward} + \chi\left[\frac{\text{Additional HE Equip.}}{\text{Number Inspected}}\right]$$

Where:

Number Inspected = Program measures surveyed less those that could not be identified or inspected or excluded for other survey reasons.

Installed & Operating = Number of measures still installed and operating.

Normal Replacement With No Rebate = Number of measures replaced after normal operating life with high-efficiency equipment, without a rebate.

Additional HE Equipment = Additional high-efficiency equipment obtained without a rebate.

χ = Proportion of additional high-efficiency measures obtained without a rebate which survey indicates is due to the program.

Two units of measure are used, percentages and kWh.

* Carryforward is an adjustment to cumulative savings that consists of estimated annual energy savings after one year of a measure's life (Parker 1993).

Source: Parker (1993)

The Jacobson *et al.* (1993) study used energy audit data on installed measures to form an engineering estimate of "actual savings." These savings estimates then were compared to the initial pre-retrofit engineering estimates with the resulting percentage change denoted as an estimate of net persistence. No attempt was made to verify pre-retrofit conditions, confirm retrofit wattages, or evaluate program retrofit decisions. This study identified both instances of retrofit savings being greater than expected as well as less than expected. The net findings in some cases are greater than 100%.

4.1.2 Engineering Estimates

The LILCO study used estimates of expected operating lifetimes to project total energy savings. These estimates were based on manufacturer information, studies, and expert opinion, and were used in equations that drew from information gathered on-site.

The post-retrofit engineering savings estimates of the Jacobson *et al.* (1993) study were based on observed equipment counts as well as revised engineering estimates of the associated savings. For measures such as lighting, savings were determined by equipment counts for which few changes in engineering estimates of savings were made. In contrast, for measures such as window film, there was substantial revision of the associated engineering estimated savings with almost all measures still in place. Inputs to the engineering estimates like location, cooling practices, and released shading coefficient differed from those used in the pre-retrofit audit.

4.1.3 Savings Projections

The LILCO study estimated persistence rates for individual measures for each cohort group. However, these individual measure-estimates of persistence were aggregated to a class of measures to calculate annual gross savings by program and cohort group. For example, a category of efficient lighting was used to calculate program savings for individual cohort years. Table 4.1 presents the persistence estimates (i.e., the estimates of "carryforward") for individual lighting measures and the overall category average used to calculate program savings. The carryforward percentages range from a low of 45% for 60-watt lamps installed in 1989, to 100% for several measures in each of the three years of analysis. The "Carryforward Including Additional Equipment," which is not reported in this table, exceeded 100% for four of the measures (including high and low-wattage high-intensity discharge lamps, reflectors, and high-efficiency ballasts) in at least one of the three years, but these "market transformation" effects were not part of the final savings estimates. Table 4.1 also shows the expected life for these lighting measures, which varies from two to twelve years. The Jacobson *et al.* (1993) study used a stratified sampling approach in surveying sites to ensure a representative sample. Average "proposed" savings (pre-retrofit audit estimates) and average "actual" savings at the time of the site audit for each stratum then were used to calculate population-weighted persistence based on both the results for each of the n sites and for each cohort year of the program.

$$\text{Population Weighted Persistence} = \frac{\sum_{i=1}^{n} (\text{\# of Sites})_i \ (\text{Average Actual Savings})_i}{\sum_{i=1}^{n} (\text{\# of Sites})_i \ (\text{Average Proposed Savings})_i}$$

The overall population of retrofit sites is assumed to have the same mix of measures as the survey sample. Since the proposed mix of measures is known for this population of sites, it would have been more representative to have examined the ratio of actual to proposed savings for individual measures. "Actual" program savings then could be projected by multiplying the number of population measures by the measure-specific ratio of actual-to-proposed.

For both of the above studies, the resulting persistence estimates for different cohort groups are based on different numbers of post-retrofit years. It therefore is not possible to determine any within-cohort or across-cohort persistence of savings without a second survey.

Table 4.1 LILCO's Persistence Study Results For Selectected Lighting Measures

		kWh Savings and Percent Carryforward		
	Expected Life (in years)	1988 Cohort	1989 Cohort	1990 Cohort
High Efficiency Ballasts	4	1,969,981 97%	2,298,686 95%	1,977,902 99%
Fluorescent Current Limiters	12.5	736,415 99%	1,798,473 100%	1,318,178 93%
Fluorescent Fixtures	10	2,942,916 100%	30,162,373 99%	6,837,883 100%
High Intensity Discharge ≤ 200 Watts	2	190,787 91%	1,244,165 96%	21,283 100%
High Intensity Discharge ≥ 200 Watts	4	2,942,916 100%	6,369,245 98%	812,651 98%
Reflectors	12.5	1,251,276 100%	15,539,819 100%	9,860,480 100%
Compact Fluorescent Lamps	2	899,977 56%	2,073,328 85%	1,543,749 93%
34-watt, 4´High Efficiency Lamps	4	2,023,344 63%	3,255,790 74%	1,444,247 72%
60-watt, 8´High Efficiency Lamps	2.4	684,926 65%	325,998 45%	640,499 73%
Totals: Annual kWh Savings Percent Carryforward		**14,349,211 86%**	**65,191,380 96%**	**32,925,710 96%**

Source: Parker 1993

4.1.4 Summary

Persistence estimates from the two Engineering studies discussed in this section are gross estimates. In both cases, within- and across-cohort persistence effects are not addressed, since each study is based on a single survey. In addition, even though these studies focus on individual measures, the persistence estimates used in calculating savings are based on aggregated categories of measures. As a result, it is difficult to assess lifetime program performances from these estimates of persistence.

4.2 CONSUMPTION EVALUATION STUDIES

Almost all of the persistence studies that use measured consumption data from billing analysis or metering, are based on pre- and post-consumption measurements. A central feature of the variety of data analysis methodologies that have been applied is weather normalization. Since weather is such an important factor, some studies have focused exclusively on this one factor. Typically, the Princeton Scorekeeping Method (PRISM) (e.g., Hirst, White, and Goeltz 1985; Keating 1991; Narum, Pigg, and Schlegel 1992; White and Brown 1990) is used to estimate normalized annual consumption (NAC) for a building's pre- and post-consumption years. A notable exception is the White, Stovall, and Tonn (1992) study, which is based on a comparison of matched weather days. Weather-normalization techniques, described in the evaluation literature, are not presented in detail in this review.

In modeling consumption changes at the building level, the studies in this class exhibit a range of model structure. Both the White, Stovall, and Tonn (1992) and the Brown and White (1990) studies assume that consumption changes are primarily a function of weather and program effects. Once consumption is weather-adjusted, the analysis essentially is univariate. In contrast, the Narum, Pigg, and Schlegel (1992) study assumes that additional factors, such as year-specific effects, also are determinants of consumption changes. The resulting multivariate model is estimated with ordinary least squares, as well as with more sophisticated methods.

4.2.1 Univariate Analysis of Weather-Adjusted Consumption

The studies discussed in this subsection are based on simple comparisons of weather-adjusted consumption; other factors, such as changes in the price of electricity or the local economy, were not considered explicitly. However, the studies that include a control group implicitly are accounting for these other factors (assuming that the control group reasonably represents the treatment group).

White, Stovall, and Tonn (1992) examined 28 winter days for each year of a four-year study period, which included one pre-retrofit year and three post-retrofit years. Similar winter days for each year were selected for direct comparison to weather normalize the load data. The matched days that were selected covered a typical range of conditions, from extremely cold to mild winter days, with similar humidity and barometric pressure. Thus, this study examined 112 days of a possible 1,460. All changes in loads among years are attributed to the retrofit program.

White, Stovall, and Tonn (1992) developed their load profiles by averaging hourly data across households. Load savings and cumulative load savings were calculated as:

$$\text{load savings} = \text{load}_{(\text{base year})} - \text{load}_{(\text{next succeeding year})}$$

$$\text{cumulative load savings} = \text{load}_{(\text{base, or pre-program year})} - \text{load}_{(\text{current year})}$$

The final results of this study show a high degree of variability. The whole-house electricity load on weekdays for all households at the peak hour of 8:00 AM decreased 15% in the first post-retrofit year, decreased another 11% in the second, and increased 13% in third year. Space heating electricity loads demonstrated a similar pattern with decreases of 30% and another 22% in the first and second years, respectively, and a 27% increase over the second-year figures in the third year. Similar results were obtained for weekends, with loads increasing between the second and third year. Water heating electricity loads also were erratic, with a 3% decline the first year, a 3% increase the second year, and a 10% increase in the third year.

These results are difficult to explain solely as a product of the retrofit program. In general, we expect maximum retrofit savings to occur upon installation and that these savings would decline over time. If year two results are ignored, one might conclude gross persistence is roughly 100%. Alternatively, if full retrofit benefits were not achieved until year two, either because all retrofits were not completed before the first retrofit year or some other reason, then one could conclude that persistence is considerably less than 100%. The large variations of the second and third year indicate the need for additional study, such as an analysis of a larger proportion of the data or considering other time-dependent factors such as electricity price.

The most common univariate approach is to weather-normalize annual consumption (NAC) with a PRISM-type model and compute mean and median changes in pre- vs. post-NAC. A whole series of studies of this type have been conducted to monitor program performance in the ten-year history of the Bonneville Power Administration's residential weatherization program, 1980-1989. These studies all employ a heating-only version of the PRISM model to estimate household NAC, which is computed as:

$$NAC = 365a + bH_0(t)$$

where,

$365a$ = the fixed amount of base load electricity consumed by a household in one year,

$H_0(t)$ = the heating-degree days (base t) in a typical year, so that

$bH_0(t)$ = the proportional amount of heating fuel relative to the outdoor temperature, adjusted for long-term outdoor temperatures.

The three parameters of the model, a, b, t, usually are estimated with twelve or so monthly bills. The change in household NAC from the pre-retrofit year to one or more post-retrofit years, DNAC, is then the focus of investigation.

The early Bonneville studies of this type (Hirst, White, and Goeltz 1984; Hirst, White, and Goeltz 1985; and Goeltz, Hirst, and Trumble 1986) compute the average DNAC for both a participant group and a non-participant group. Net savings simply are the difference in average change between the two groups.

Average Net Savings per Household = Avg[DNAC(P)] - Avg[DNAC(C)]
where P and C denote the participant and control groups, respectively.

Using this approach to examine a 1981 cohort group, Hirst, White, and Goeltz (1984) concluded that net savings increased by 10% (3,370 and 3,750 kWh/year) between the first and second post-retrofit years. However, with nine fewer households for the same cohort group over the same period, Hirst, White, and Goeltz (1985) concluded that net savings was unchanged at 3,800 kWh/year. Additionally, second to third year post-retrofit net savings were concluded to have decreased by 11%. Goeltz, Hirst, and Trumble (1986) examined both a 1982 and 1983 cohort group using the same approach. The results indicate that the 1982 cohort group had net savings decline of 20% (4,100 to 3,300 kWh/year) and 24% (3,300 to 2,500 kWh/year) over a three year post-retrofit period for each successive year. The 1983 cohort group showed a similar decline of 15% over the first two post-retrofit years. Because savings variances estimates for this method were not reported in any of these studies, it is not possible to determine whether there is a statistically significant change in net savings, that is, whether persistence is 100%.

The later Bonneville studies (Schweitzer, Brown, and White 1989; White and Brown 1990; and Brown and White 1992) employ utility weights in calculating overall net savings. This weighting approach is used to adjust for differences in participation rates across utilities, which vary from 80% to 1%. At the utility level, the same procedure as decribed above is employed to calculate utility net savings.

Utility-level results reported by these studies (see Table 4.2) show a wide range of within cohort net savings persistence estimates. The results for the 1986 cohort group in this table provide a comparison of the overlapping studies of Schweitzer, Brown, and White (1989) and White and Brown (1990). The latter study used slightly fewer observations than the former, due to data attrition, to obtain third-year post-retrofit savings estimates. For example, in the case of Tacoma, this difference in sample size reduced the 21% increase in net savings for post-retrofit year two to only a 3% increase. Overall, this table indicates the high degree of variability in persistence estimates and highlights the sensitivity of this analytical approach to small changes in sample size. Persistence estimates over a two-year period vary from a high of 21% to a low of -66%.

Schweitzer, Brown, and White (1989) conclude that net cohort savings decreased from 11.8% to 10.6% over the first two post-retrofit years. Similarly, White and Brown conclude that net savings for the same cohort group over the same time period decreased from 12.6% to 8.7%, with third-year net savings increasing slightly to 8.9%. Brown and White (1992) conclude that total net cohort savings for a later group decreased from 9.3% in the first year to 8.5% in the second. None of these studies consider whether this within-cohort decrease is statistically significant, nor do they present variance estimates for net savings. However, the Brown and White (1992) study does report the standard error of gross savings, which suggests that the difference between 9.3% and 8.5% is not significant statistically.[2]

Table 4.2 Average Net Savings By Utility

	# of Partici-pants	# of Non-Partic.	Post Retrofit Savings				
			Year 1 (kWh)	Year 2 (kWh)	Percent Change Year 1 & 2	Year 3 (kWh)	Percent Change Year 2 & 3
EUGENE							
'86 Cohorts (1)	46	158	3,672	2,368	-36%		
'86 Cohorts (2)	41	149	4,338	2,451	-43%	3,093	26%
'88 Cohorts (3)	97	142	2,640	2,435	-8%		
TACOMA							
'86 Cohorts (1)	50	224	4,037	4,886	21%		
'86 Cohorts (2)	44	201	2,608	2,698	3%	2,160	-20%
'88 Cohorts (3)	76	323	1,341	971	-28%		
RICHLAND							
'86 Cohorts (1)	42	116	2,105	715	-66%		
'86 Cohorts (2)	31	96	2,781	1,132	-59%	2,245	98%
'88 Cohorts (3)	50	75	2,603	3,162	21%		

Sources: (1) Schweitzer, Brown, and White (1989); (2) White and Brown (1990); and (3) Brown and White (1991).

4.2.2 Multivariate Analysis of Weather-Adjusted Consumption

Two of the first studies to apply multivariate analysis to the problem of estimating the persistence of savings were Hirst, White, and Goeltz (1984) and Kushler, Witte, and Crandall (1984). These studies employed a two-stage approach. The first stage applied the PRISM model to estimate NAC for each household over a study period, which included one pre-retrofit year and two or more post-retrofit years. The second stage of the analysis developed a cross-section/time-series model to estimate net household savings while controlling for factors such as the price of electricity, pre-participation consumption, and sample selection bias. This two-stage approach had been used earlier in several different studies to examine a single year of post-retrofit consumption.

The Hirst, White, and Goeltz (1984) study examined two years of post-retrofit consumption. After first applying the PRISM model to estimate NAC, the resulting cross-section/time-series data set of 1,200 observations, collected over three years for 237 participants and 163 non-participants, was used to estimate a one-way random effects model. This model can be expressed as:

[2] The standard error of net savings can be approximated by assuming the covariance of participant and comparison gross savings is zero, in which case the difference in net savings, 8.5% versus 9.3% is not significant.

$$NAC_{t,i} = C + a_1Income_i + a_2Household\ Members_i + a_3Sqft_i + a_4Wood_i + A_5 * Electricity\ Price_{t,i} + a_5Primary\ Electric_i + a_6Participant_i + a_7First\ Retrofit\ Year + a_8Second\ Retrofit\ Year + a_9Sample\ Selection\ Correction + u_i + e_{i,t}$$

where u_i and $e_{i,t}$ are independently distributed with zero means and positive variances σ^2_u and σ^2_e. This error specification allows for the within-household correlation of the model residuals.

The significantly positive estimate reported for coefficent a_6 indicates that higher consumption households are participating in the program in the first program year relative to later years. Many subsequent studies report similar findings. Savings persistence is reflected in the differences between retrofit coefficients, a_7 and a_8. The estimation results indicate that net savings increased by roughly 2%-3% over a two year post-retrofit period, but it is not clear whether this difference is significant statistically.

A similar evaluation of the Michigan Residential Conservation Service program (Kushler, Witte, and Crandall 1984) also collected and analyzed two years of post-audit energy consumption for gas-heated homes. The results showed a slight increase in net annual savings from the first to the second post-audit year of about 6%.

The statistically significant sample selection term in the above Hirst, White, and Goeltz (1984) model indicates that sample selection bias is a problem. The auxiliary model upon which this correction term is based indicates that households with higher heating operating and capital costs were more likely to participate in the program for that cohort year. Correcting for sample selection yields roughly 6% higher estimates of net savings for both retrofit years. This sample selection bias correction procedure was not used in the Hirst, White, and Goeltz (1985) follow-up study of the same 1981 cohort group, which included a third post-retrofit year.

The above multivariate approach was improved in the study by Goeltz, Hirst, and Trumble (1986). Through a series of diagnostic tests, both the model and error specification were expanded and refined. The resulting model specification was expanded to include interaction and non-linear factors. Significant coefficients were estimated for long-run heating degree days (based on PRISM reference temperature estimates), interactions with electricity price, building square feet, and wood use. Squared terms for building square feet, wood use, and long-run heating degree days all were found to be significant statistically. The variance specification also was expanded to include factors such as income, building square feet, wood use, as well as the estimated expected NAC. The estimated net savings results showed some variation among first-, second-, and third-year savings. However, these differences were not significant statistically. This study also included estimated models of NAC changes yielding similar coefficient estimates. The conclusion was that net household savings were reasonably constant over the three-year post-retrofit evaluation period.

A comparison of these multivariate result with the NAC results described in the previous section on univariate approaches indicates that generally the estimates from the two approaches are fairly close. In almost all cases, the difference in estimated net savings is less than 6%. The one exception is Goeltz, Hirst, and Trumble (1986) where the two approaches differ by 25% for the 1984/85 heating season. In this case, the NAC estimates indicated a 21% decline in net savings, whereas the multivariate approach indicated a 9% increase in net savings. One possible reason for this difference is the delayed effect of sharp electricity price increases over the period between 1981 and 1984.

The White and Brown (1990) study also used ordinary least squares to estimate NAC changes as a function of pre-retrofit NAC, total weatherization costs, long-run average heating degree days, and the location of the household (east or west of the Cascade Mountains), as well as a number of specific weatherization measures. More detailed information that was used in prior studies was not available for this study. This modeling effort did not account for heteroskedastic (i.e., non-constant household error variances) model error, yielding large variance estimates for the model parameters. The results were therefore of limited value for hypothesis testing. Since these estimates explained very little variance in gross energy savings (less than 10%), they were not reported.

Similarily, the Narum, Pigg, and Schlegel (1992) study of the persistence of savings from weatherizing low-income Wisconsin residences performed a multivariate analysis of NAC estimates. Like the previously discussed studies, Narum, Pigg, and Schlegel depended on billing data and employed their version of a PRISM model. In contrast to these previous studies, the authors focused on low-income residences (rather than non-low-income residences) that could include multifamily buildings (instead of only single-family residences). Since buildings were the unit of analysis for this study, household consumption was not clearly represented. Another difference between the Wisconsin and Bonneville studies is that the former investigated gas energy consumption and the latter looked at electric energy consumption.

The model specification employed by Narum, Pigg, and Schlegel (1992) was a two-way additive model that distinguished two kinds of effects, those gas consumption changes that affect all buildings (whether weatherized or not) and those changes that result from weatherization. The following equation was used to estimate year-to-year changes in energy use for the duration of the program for each of the two utilities:

$$\mathrm{DNAC}_{i,t} = a_0\mathrm{TREND}_t + a_1\mathrm{PRE}_{i,t} + a_2\mathrm{WEATHERIZATION}_{i,t} + a_3\mathrm{POST\ I} + a_4\mathrm{POST\ II}_{i,t} + a_5\mathrm{POST\ III}_{i,t} + a_6\mathrm{Y86{:}87}_t + a_7\mathrm{Y87}_t{:}\ 88_t + a_8\mathrm{Y88{:}89}_t + a_9\mathrm{Y90{:}91}_t + e_t$$

Where:

TREND represents change in NAC that is common to all buildings in all years

PRE represents change in NAC that occurred among unweatherized buildings

WEATHERIZATION represents change in NAC going into and coming out of the year of weatherization

POST I represents change in NAC between the first and third years after weatherization

POST II represents change in NAC between the third and fifth years after weatherization

POST III represents change in NAC between the fifth and eighth years after weatherization

Y86-87 represents change in NAC common to all buildings from 1986-1987

Y87-88 represents change in NAC common to all buildings from 1987-1988

Y88-89 represents change in NAC common to all buildings from 1988-1989

Y90-91 represents change in NAC common to all buildings from 1990-1991.

This specification is fairly restrictive in that energy-savings effects are assumed to be a constant for all buildings, both single- and multi-unit, and for a mixture of shell and heating measures that change over time, with heating system replacements becoming increasingly common. Results for building subsets based on number of units, ownership, and type of energy measure appear to yield significantly different estimates. A model explaining overall program results should incorporate these known factors.

This model does not estimate any cohort-specific effects. The primary reason for this absence is that late participants define the benchmark by which net savings are estimated. The coefficients of the POST variables are key parameters modeling net savings persistence and are not specific to a particular cohort group. If these coefficents are not significantly different from zero then the hypothesis of 100% persistence cannot be rejected for all cohort groups.

Two different estimation methods were used to estimate the coefficent of this model. Standard ordinary least squares produced mean effects while an ANOVA variant, the median polish, produced median effects. Since median data are less influenced by extreme data values than means, the authors relied primarily on the median polish technique in deriving their findings. However, coefficients of interest for **persistence** effects generally were insignificant statistically. Variance estimates from first-stage PRISM estimates could have been used to obtain more efficient estimates with a generalized least squares estimation method. The resulting variance could alter the conclusion regarding insignificant persistence effects. This estimation method in effect would down-weight high-variance households, which was a primary reason for using the median polish method.

An example of the estimation results for this study are presented in Table 4.3. Model results for the overall Wisconsin Gas program are in the upper portion of this table with result for shell and heating measures provided seperately below. The initial savings due to weatherization are summarized by the column denoted Wx. A comparison of this effect for the individual and combined types of measures indicates that there are significant differences, with both types of measures yielding the highest savings, followed by heating measures and then shell measures. The POST coefficients are labeled 1, 2, and 3 in this table. The only significant POST coefficient in this table is that labeled 3 for heating measures with a median value 75.9, indicating a decrease in net savings.

Table 4.3 Summary of Wisconsin Gas Company Median Polish Results

		Weatherization Effects		Post-Retrofit Periods		
		Pre	Wx	1-3 Years	3-5 Years	5-8 Years
PROGRAM						
Model Results		15.9	-155.6	-4.6	0.0	6.9
Therms	Mean	16.1	-155.5	-4.5	0.4	6.1
	St. Dev.	5.2	6.8	3.8	2.6	5.5
	Low CI	7.4	-166.8	-10.9	-4.3	-2.1
	Hi CI	24.4	-144.5	1.8	4.3	15.9
	Count	3,690	4,040	3,382	1,844	760
SHELL MEASURES						
Model Results		3.9	-121.4	-4.4	0.0	2.9
Therms	Mean	8.2	-120.1	-2.5	1.6	3.8
	St. Dev.	7.4	7.0	3.5	3.9	5.6
	Low CI	-8.3	-133.0	-10.2	-6.4	-6.3
	Hi CI	16.1	-109.9	1.4	6.4	12.1
	Count	1,354	1,853	1,986	1,333	646
HEATING MEASURES						
Model Results		18.6	-142.9	0.0	-4.6	75.9
Therms	Mean	12.8	-146.2	-1.5	-6.1	66.3
	St. Dev.	12.1	19.4	10.3	12.0	43.0
	Low CI	-1.4	-174.8	-16.9	-24.3	5.1
	Hi CI	38.5	-110.9	16.9	15.1	146.6
	Count	401	334	292	124	14
BOTH MEASURES						
Model Results		23.4	-294.7	-14.2	0.0	19.9
Therms	Mean	25.8	-293.4	-11.1	0.4	24.5
	St. Dev.	13.9	17.5	10.0	5.3	18.1
	Low CI	0.4	-323.5	-30.7	-8.7	-9.9
	Hi CI	46.3	-265.9	2.2	8.7	49.7
	Count	1,040	1,356	1,038	384	99

Source: Narum, Pigg, and Schlegel (1992)

Overall, the estimation result indicates that net savings increased over the eight-year post-retrofit period by as much as 30% for the Wisconsin Gas Company and 62% for Madison Gas & Electric. However, these results also are not significant statistically.

4.2.3 Projecting Savings Estimates

The results of these energy consumption studies are used a variety of different ways to extrapolate to a larger scale. White, Stovall, and Tonn (1992), for instance, assumed that their Hood River sample was representative of the Pacific Power service area. They then determined kW impacts by multiplying the kW per house for their sample by the "number of customers with permanently installed electric space heating equipment" (p. 7).

On the other hand, White and Brown (1990) weighted the gross utility savings estimates of both participant and control groups in calculating net cohort program savings. Participant and control weights were used to reflect the proportionate representation for each utility cohort group relative to the total population for all the utilities of the program. The utility weights for participants WP_i were the number of households retrofitted by utility (i) relative to the number households weatherized by all program utilities for a particular cohort year. The utility weights for control group households, Wc_i, were the number of eligible households for a particular utility relative to the number of eligible households for all program utilities. Net program cohort savings therefore was expressed as:

$$\text{Net program cohort savings} = \sum_{i=1}^{n}\{WP_i * \text{Avg}(i)[\text{DNAC(P)}] - WC_i * \text{Avg}(i)[\text{DNAC}(C)]\}$$

For example, when Brown and White (1992) examined first-year savings, a total of 356 households had sufficient data to be considered. Of this total, 97 participants (28%) were from one utility for which a total of 3,971 households were retrofitted. Since the total number of households retrofitted by all program utilities was 4,898, this particular utility had a participant weighting factor of 81%. Thus, less than a third of the participant observations were given a majority of weight in computing net program savings. The utility control weight for the same utility was only 11%, with the largest weight of 56% allocated to another utility. The program net savings estimate therefore was determined largely by two utilities, the participant savings of Eugene, Oregon and the control group savings of Seattle, Washington. This net estimate raises the question of whether Seattle households adequately represented Eugene households.

The early Bonneville studies (Hirst, White, and Goeltz 1984 and 1985; and Goeltz, Hirst, and Trumble 1986) focused on unweighted net household savings. Net within-cohort savings for these studies were found to increase, remain constant, or decrease over the first two retrofit years. However, it appears that all these change in net savings are not statistically significant. Similarly, the later Bonneville studies, which all used a weighted program net savings estimate, uniformly concluded that net savings decreases over a two year post-retrofit period. Only the last study in this series provided any estimate of savings variance, from which it appears that net savings have not changed significantly.

Brown and White (1992) also provided a summary of across-cohort performance for the Bonneville residential program (Table 4.4). Since the program itself changed over time in terms of the measures provided and in terms of how it was administered a simple net kWh/year would not be very informative. Thus, a measure of the cost of net savings is presented in Table 4.4 for different cohort groups for the first post-retrofit year. This table indicates that the cost of net savings increased, particularly for the 1989 cohort group. A statistical test of this observation would of course be desirable to conclude whether across-cohort persistence is significantly different from 100%.

Table 4.4 Historic Costs And Net Savings Of Bonneville's Weatherization Programs

Program Year	First Year Net Savings	Regional Levelized Costs (1989-$)		Bonneville Levelized Costs (1989-$)	
		Per Unit	Mills/kWh	Per Unit	Mills/kWh
Pilot (1980-82)	3,840	3,220	40	(Loan Prg.)	<40
Interim (1982-83)	4,200	2,540	29	1,900	21
RWP 1985	2,610	2,580	47	1,780	32
RWP 1986	3,060	3,130	48	1,750	27
RWP 1988	2,180	2,310	50	1,530	33
RWP 1989	1,330	2,320	83	1,470	52

Source: Brown and White (1992)

4.2.4 Summary

Both the univariate and multivariate approaches strongly depend on a control group to estimate net savings. To the extent that the multivariate model structure "explains" cross sectional variation in consumption, the net savings benchmark is adjusted for differences between treatment and control group factors of consumption. However, univariate approaches, such as NAC estimate tabulations, depend exclusively on having a matching control group in estimating net savings. As discussed earlier, the NAC results appear to be highly sensitive to small changes in sample size. Such control group shortcomings should not matter as much over short evaluation periods as over longer time periods, or, more generally, during periods when key factors like electricity prices are relatively stable.

A related advantage of the multivariate approach is the ability to test hypotheses regarding the persistence of net savings, which can lead to improvements in program design. Within the framework of generalized least squares, a wide variety of hypothesis tests may be conducted relatively easily. The NAC approach which yields estimates of the variance of net savings or weighted net savings estimates typically are used. Hypothesis tests regarding changes in net savings therefore are not easily performed.

The main drawback of the multivariate approach is the cost of acquiring household information beyond the initial audit information and the monthly billing data. The early Bonneville studies used one or more surveys to collect information such as number of household members and wood consumption. However, new multivariate methods recently have been applied to the problem of estimating net savings using only initial audit and monthly billing information (Trumble and MacDonald 1994). These methods easily could be extended to the problem of estimating the persistence of net savings.

The two different types of studies, Equipment Survey/Engineering and Consumption Analysis, are directed at two different notions of persistence, primarily because of their differences in how savings and persistence are benchmarked. The Equipment Survey/Engineering studies, reviewed above, provide both an assessment of whether proposed savings are being realized and useful information about possible problems. Repeated surveys of this type would yield persistence estimates more similar to those obtained by Consumption-based studies, which are benchmarked by first year net savings estimates. In this case, both types of studies could examine both within- and across-cohort effects.

Due to differences in definition, conclusions about persistence from the two Equipment Survey/Engineering studies reviewed here are difficult to obtain. The measure used by LILCO in computing program savings by definition cannot exceed 100%.[3] In contrast, the measure employed by NEPSCO allows actual "savings" to exceed proposed savings. Reported category results in several cases are greater than 100%.

The Consumption-based studies generally indicate that net cohort savings are either roughly constant or slightly decrease over the first two to three years post-retrofit. The multivariate results reviewed here do not indicate any statistically significant changes in net cohort savings. However, the more prevalent NAC results do suggest some decline in net savings. Unfortunately, it is not clear whether these within-cohort changes are statistically significant. Regarding across-cohort persistence, only the Brown and White (1992) study really addressed this issue. For the Bonneville Residential Weatherization Program both net kWh measures as well as cost-adjusted measures indicate a decline in net savings across cohort groups. Whether this decline is statistically significant and what its underlying causes are is not clear.

[3] Results for the "technical persistence of operational life" cannot exceed 100%; the "persistence of efficient technology" does not have this constraint.

5. SUMMARY OF FINDINGS

Just as the goals, research designs, and methods of persistence studies have varied, so have their results. This chapter briefly summarizes the results of persistence studies, focusing on the four example studies that have been discussed throughout this literature review. Because the review did not focus either on the customers' perspective or on methods for improving persistence, no such findings are presented. The review is organized by scale of analysis, focusing first on measure-scale studies then on cohort-scale studies, and finally on program-scale studies. As noted earlier, persistence studies to date have been conducted primarily at the first two scales of analysis.

Overall, the results of persistence studies at all three scales are inconclusive and sometimes contradictory. Measure-scale persistence of savings for different measures and sectors shows considerable variability. Further, while *ex-post* estimates of year-to-year savings associated with measures generally are less than *ex-ante* engineering estimates, the opposite has resulted when stimulated energy savings (i.e., market transformation) is considered. Results of cohort-scale studies, typically focused on the residential sector, also vary. Both declines in savings and net increases in savings have been reported within cohorts of participants evaluated over time. Another reason why cohort-scale studies are inconclusive is that it is impossible to determine the statistical significance of observed differences because confidence intervals and levels of precision frequently are not reported. Because only one program-scale analysis was indentified, it is difficult to generalize that result to the set of program lifecycle impacts.

Virtually all of the persistence studies so far conducted have been retrospective in design. The research conducted by Jeppesen and King (1993) points to some of the limitations of retrospective analyses (see example case, below).

Ex-ante vs. ex-post findings. Studies of the persistence of energy conservation measures generally have found that the savings associated with measures, when calculated on the basis of inspections or consumption data, differed from *ex ante* engineering estimates. Typically, *ex ante* engineering estimates overstate actual savings, for many of the reasons discussed earlier, including their failure to account adequately for human interventions such as premature measure removal and building renovations or remodeling.

Variation in explanations of findings — measure scale. Studies to date also indicate significant variability in the explanations for persistence of savings associated with different measures and different sectors. The LILCO study (Parker 1993) found, for instance, that commercial and industrial lighting measures with the shortest anticipated operating life were among the least persistent measures installed through their programs because they did not remain in place and in operation as long as other high-efficiency measures. However, it found a relatively small premature removal rate for lighting measures in these commercial and industrial sectors. In contrast, Vine (1992) and others have concluded that residential lighting measures (in particular compact fluorescent bulbs) are among the least persistent measures (along with low-flow showerheads and door weatherstripping), largely due to high premature removal rates.

Example case: California Conservation Inventory Group effective measure life study (Jeppesen and King 1993)

Selected Findings

- "no studies were identified that actually tracked measure performance decline over time in customer installations" (p. II-7)
- most efforts to gauge commercial effective measure life have focused on difference among commercial sectors rather than on the measures themselves; few studies have targeted program participants and energy efficiency measures directly
- "energy savings estimates from billing analysis cannot be interpreted to reveal the influences of measure life, behavior, or technological degradation of savings" (p. II-8)
- the retrospective analysis feasibility assessment indicated that:
  - there were wide variations according to measure in both data identification and sampling feasibility;
  - data on commercial measures were particularly difficult to access;
  - residential records tended to be adequate but commercial records frequently were inadequate;
  - there was a much higher completion rate for residential than for commercial telephone surveys; and
  - only a limited number of measures are appropriate for retrospective analysis, due largely to the adequacy and reliability of data over time.

Despite these variations, general estimates of levels of measure persistence have been offered. For instance, Braithwait *et al.* (1994) concluded that persistence rates range from 92 to 100% for commercial energy conservation measures, when estimated one- to five-years after installation.

Variation in findings—cohort scale. Studies focusing on the cohort-scale persistence of energy savings also have produced varying results. Most of these studies center on residential energy these findings (see example boxes, below).

Narum, Pigg, and Schlegel (1992) found an overall increase in net energy savings within cohort groups from the first through eighth years after weatherization. However, the utilities and types of customers examined differed in certain respects. Specifically, savings persistence was greater among gas accounts for multi-unit buildings than for single-unit buildings for the Wisconsin Gas

Company; no such difference was apparent in the results for Madison Gas & Electric. The same type of variability across sectors of customers was found in the studies of measure life reported earlier.

Example case: Long Island Lighting Company (Parker 1993)

Selected Findings

- least persistent lighting measures were bulbs with the shortest expected operating life; these bulbs had the lowest kWh/unit impact and high unit turnover
- relatively small premature removal rate for all lighting measures

Summary findings for the lighting component of the Dollars & Sense Program for Non-Free Riders and Rebated Equipment

	Technical Persistence of Operational Life		Persistence of Efficient Technology		Carryforward* Adjustment (with added equipment)		Carryforward* Adjustment (without added equipment)	
Year	kWh	Percent	kWh	Percent	kWh	Percent	kWh	Percent
1988	16.461.255	99%	16.284.537	97%	14.910.635	89%	14.349.211	86%
1989	66.638.160	98%	67.501.706	100%	66.015.616	97%	65.191.380	96%
1990	33.583.824	98%	34.194.415	100%	33.458.049	98%	32.925.710	96%

* carryforward is "the estimate of annual energy savings following year one of a measure's operational life" (p.37)

The results of the White, Stovall, and Tonn (1992) study indicated an overall pattern of persistent load savings three years after installation for a cohort group. However, the load savings measured in each of three successive years fluctuated considerably (see example box). It generally is believed that within-cohort group persistence declines gradually, but such a trend cannot be confirmed statistically from this study or from Narum, Pigg, and Schlegel (1992).

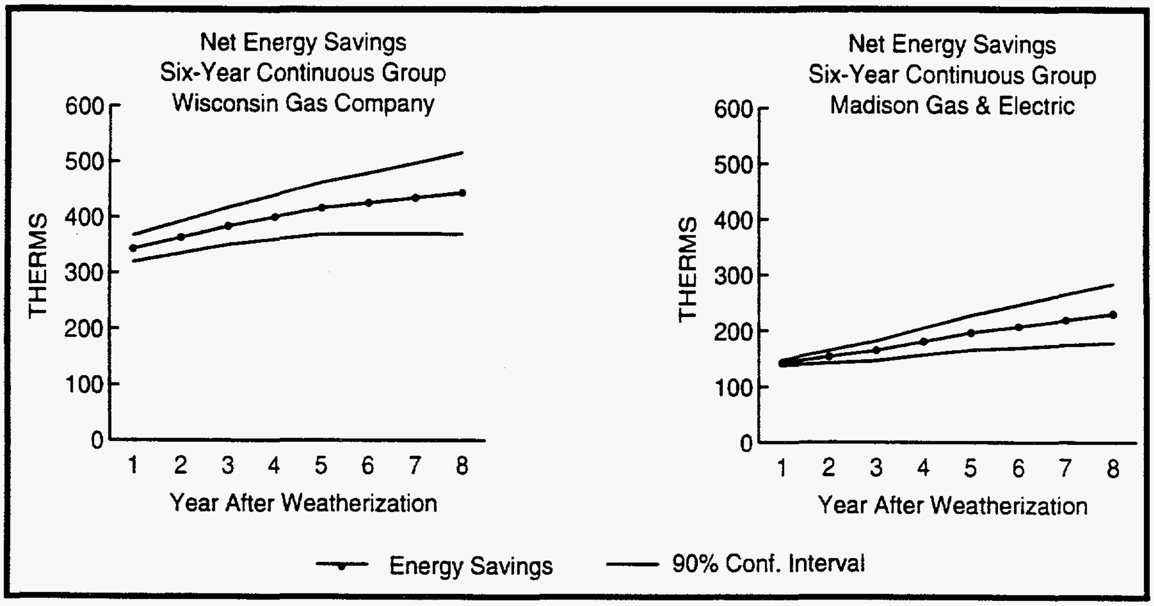
Program-scale findings. The one example of an analysis of persistence across a program's lifecycle indicated that savings can decrease more precipitously across successive cohort years of participants than across the years following program participation for individual cohorts. Brown and White (1992) describe a general pattern of decline in net energy savings, both within and across cohort groups. Across cohorts, persistence appears to decrease dramatically over time (see Brown and White example case), although no statistical tests of significance are conducted to confirm such a trend. In addition, the factors influencing this decline could only be hypothesized. They include a range of factors such as self-selection bias, changes in the retrofit program and how it was administered, and changing economic conditions such as rising energy prices that have motivated households to invest in retrofit measures outside of the program's activities. These factors have caused the program to move from an initial focus on high electricity users to more recent cohorts of participants who did not consume as much electricity prior to participation and who therefore did not offer the same high level of savings potential.

Example case: Wisconsin's Low-Income Weatherization Assistance Program (Narum, Pigg, and Schlegel 1992)

Selected Findings

- 1st-year energy savings: 19% (343 ±25 therms) for Wisconsin Gas Company; 13% (142 ± 30 therms) for Madison Gas & Electric Company
- overall, net savings increased
- persistence varied among subgroups within programs

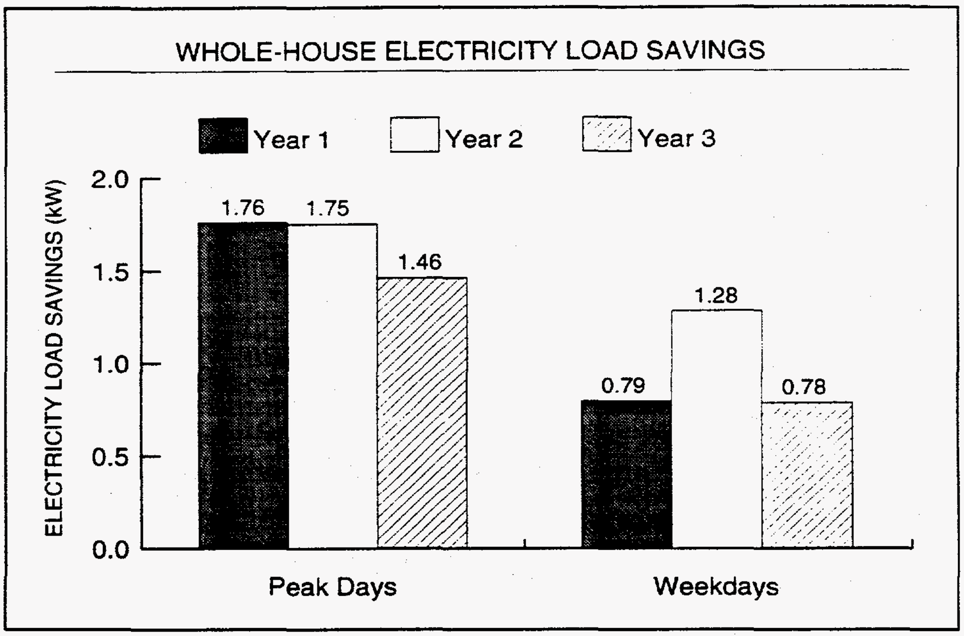
Narum, Pigg, and Schlegel (1992) performed a variety of analyses of data collected from two utilities. For Wisconsin Gas Company, they found that, although post-weatherization gas consumption decreased immediately, gas consumption generally increased over time. Nevertheless, net savings persisted (and actually increased) throughout the eight-year study period. Analyses of subgroups found the estimated magnitude of those net savings to be highly uncertain. The results of data analyses for Madison Gas & Electric presented net persistence of savings trends similar to those for Wisconsin Gas Company (see below), but the magnitude of savings differs. The authors did not explain the magnitude differences between the utilities, but the differences may have been the result of such factors as different housing stocks, different proportions of shell and heating system measures, and different occupant characteristics.



Example case: Hood River Conservation Project (HRCP)
(White, Stovall, and Tonn 1992)

Selected Findings

- load savings were persistent across the sample, one to three years after weatherization
- the analysis of peak days indicated that whole-house and space-heating electricity load each were reduced by 0.8 kW/house
- the analysis of peak days also indicated that water heating electricity load increased by 10% and baseload electricity load did not change



The electricity load of interest was the peak hourly load. Data generally "were averaged across households and then other arithmetic operations were performed to obtain sample values in loads, interior temperatures, and other group values" (p.7).

Example case: Bonneville's Residential Weatherization Program (Brown and White 1992)

Selected Findings

- net energy savings (first year) generally declined for successive cohorts of participants
- net energy savings (from the first to the third post-retrofit year) generally declined over time
- patterns of net energy savings were variable among different cohorts of participants

	Net Energy Savings (kWh/Year)		
	Year 1	**Year 2***	**Year 3***
Pilot (1980-82)	3,840	3,790 (1.3%)	3,410 (11.2%)
Interim (1982-83)	4,200	3,600 (14.3%)	2,500 (40.5%)
Long-Term RWP (1985)	2,610	2,565 (1.7%)	2,600 (0.4%)
Long-Term RWP (1986)	3,060	2,112 (31.0%)	2,140 (30.1%)
Long-Term RWP (1988)	2,180	2,000 (8.3%)	
Long-Term RWP (1989)	1,330		

* Percentages of Year 1 net savings are presented in parentheses.

6. DISCUSSION AND CONCLUSIONS

The ultimate purpose of this literature review is to serve as the foundation for a handbook on the measurement of persistence. Therefore, it has focused much more on the methods used for collecting and analyzing data than on estimates of persistence. The review discussed the underpinnings of persistence studies; namely the definitions of persistence and the purposes of persistence studies. Then, it described issues relevant to both the collection and analysis of data for persistence studies. Findings from persistence studies also were summarized. Throughout the review, four studies were used repeatedly as illustrations of different methodological and analytical approaches to persistence so that readers can track the data collection, data analysis, and findings elements of a set of comprehensive studies that represent alternative approaches.

In part because of the inconclusiveness of findings from persistence studies, one recommendation is to use methods that will provide a basis for statistically strong results. Along these lines, it is important to report levels of precision and variability along with the point estimates of savings over time. At the same time, costs must be considered. Increasingly, utilities are looking for relatively inexpensive and straightforward methods for evaluating their DSM programs. No single method best meets the variety of users' information needs while remaining within their budgetary constraints.

Beyond these methodolgical considerations, the future may present a different type of challenge to the conduct of persistence studies. We do not know how utilities will address presistence as they adapt to a competitive world. On the one hand, accurate information about persistence or how to improve persistence may enhance a utility's competitive edge. On the other hand, expensive persistence studies may be an unaffordable luxury. Competition also may result in multiple utilities cooperating to conduct persistence studies.

7. GLOSSARY

carryforward: an adjustment to cumulative savings that consists of estimated annual energy savings after year one of a measure's operational life (Parker 1993)

free-drivership: the adoption of program measures by non-participants as a consequence of the program

free-ridership: the adoption of program measures by participants who would have adopted those measures in the absence of the program

gross energy savings: total energy savings attributable to a measure or program, without regard to the actions people might have taken in the absence of the program

market transformation: a program's ability to accelerate market trends toward increasing energy efficiency, above and beyond the investments that are caused by the program's incentive payments

measure efficiency or performance: "the actual energy efficiency performance of the measure" (Jeppesen and Rudman 1993, p. 521)

measure life: "the time during which the measure is installed and is accruing energy efficiency benefits" (Jeppesen and Rudman 1993, p. 521)

metering: the collection of whole-building or end-use energy consumption data via meters (Pacific Gas & Electric *et al.* 1993)

monitoring: the use of devices to collect data related to energy consumption, such as weather conditions, duty cycles, and hours of equipment operation (Pacific Gas & Electric *et al.* 1993)

net energy savings: the savings attributable to a measure or a program, taking into account what participants might have done in the absence of the program or measure

persistence: the long-term temporal pattern of energy savings and load reductions from DSM investments

stimulated savings: savings due to installations of additional energy conservation measures by participants or non-participants as a result of a program, but without program incentives

surge effects: "the tendency for some consumers to react to the savings realized by the initial conservation measure installation by expanding their adoption to other conservation measures" (Jeppesen and King 1993, p. II-6); these behaviors are adopted by individual program participants

survival energy savings: the gross energy savings from measures installed by a program

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