My research program: Sustainable energy, behaviour, and policy

Overview

My research program focuses on consumer behaviour and citizen acceptance regarding low-carbon energy and policy. I break this program into four broad, somewhat overlapping themes, which I summarize further in the last four pages of this document:

My research program is highly interdisciplinary by design, addressing sustainable behaviour, technology and policy. To match the context of a particular environmental problem and set of research questions, I draw from behavioral theories and research methods relating to economics, psychology, sociology, geography, policy and engineering. I have been trained in many of these theories and methods myself, and I also seek out collaborators with complementary skills whenever possible—as demonstrated by my diverse list of co-authors including researchers from engineering, public policy, economics, social psychology, environmental science, history, and sociology. My research program addresses many different applications and examples of sustainable behaviour, technology and policy—with particular specialization in alternative fuel vehicles. The breakdown of applications in my accepted publications and publications in progress is as follows:

- Electric-drive vehicles (16 publications, nine in progress)
- Other alternative fuels (four in progress)
- Renewable electricity (two publications, three in progress)
- Unconventional fossil fuels (one publication, one in progress)
- Climate policy (two publications)
- Climate engineering (one publication)
- Carbon capture and storage (one in progress)
- Smart grid (one in progress)

My research methods include quantitative and qualitative analyses of empirical data, and quantitative modeling of energy-economy systems. Many of my research projects involve the collection of empirical data from consumers or citizens, through web- or mail-based surveys (15 of my 21 publications involve survey data that I collected). I have developed several novel survey techniques, including the use of "design space" exercises. These exercises assess consumer interest in plug-in electric vehicles and their designs by allowing respondents to design their preferred vehicles under different scenarios. I typically follow a "reflexive approach" to survey design, which assumes that most respondents have little experience with the technology in question (e.g. plug-in electric vehicles). Accordingly, the survey provides a process for the respondent to learn about the technology and to construct their preferences in a given context.

To analyze empirical survey data, I preform quantitative analyses of survey data according to the research objective, including continuous and categorical statistics, linear and logistic regression, discrete choice modeling, latent class analysis, factor analysis and cluster analysis. One attached reprint exemplifies several of these methods for the case of plug-in vehicles **(Axsen, Bailey and Castro, 2015)** while another does so for the case of citizen acceptance of fossil fuels **(Axsen, 2014).**

I also regularly engage in qualitative data collection, primarily household interviews (5 of my 21 publications involve interview data I collected) which I have analyzed using content analysis and narrative analysis approaches. Where appropriate, I combine quantitative and qualitative research approaches to optimize the strengths of these two data collection methods, that is, the depth of insight that can be discovered through qualitative research, and the representativeness, generalizability and validity of insights from quantitative research. One attached reprint demonstrates my integration of quantitative and qualitative analyses **(Axsen, Orlebar and Skippon, 2013)**.

My research program also includes quantitative simulation models, namely to help inform the design and implementation of climate and energy policy by representing the dynamics of consumer behaviour (informed by survey and interview data) and technological change (typically informed by literature review and expert judgement). Modeling techniques utilized in my program include: hybrid energy-economy modeling (e.g. CIMS), electricity grid dispatch modeling (e.g. optimization), market share forecast or diffusion modeling (e.g. based on discrete choice models), as well as spreadsheet-based modeling to represent energy usage in hypothetical situations (e.g. if plug-in electric vehicle owners can recharge more easily at their workplace during the daytime).

Funding

To date, my research program has been funded by a variety of sources, including the Social Sciences and Humanities Research Council of Canada (SSRHC), Natural Resources Canada (NRCan), the Pacific Institute for Climate Solutions (PICS), the Province of British Columbia, and BC Hydro. Table 1 summarizes the grants I have managed and continue to manage at SFU.

As a longer-term objective, I am working with other faculty members at SFU and stakeholders in the community to establish a "Sustainable Transportation Futures" research center at SFU. Such an institute would fund and coordinate projects relating to low-carbon transportation solutions, including vehicle and fuel technology, urban design, and climate policy. The goal is to bring together research funding and collaboration from a variety of stakeholders (public and private), to support sustained, high-quality, policy-relevant research projects.

Table 1: Research Program Funding

	To date (2011-15)					Future (2016-20)				
	11	12	13	14	15	16	17	18	19	20
Awarded:										
1. SFU Start up Funds ($40k)										
2. SSHRC Partnership Development ($21k)										
3. SSHRC Insight Grant ($223k)										
4. SSHRC Insight Development Grant ($54k)										
5. NRCan ecoENERGY Innovation Initiative ($227k)										
6. Province of BC: Clean Energy Vehicle ($20k)										
7. PICS "Transportation Futures for BC" ($111k)										
8. SFU Community Trust Endowment Fund ($415k)										
Planned or under review:										
9. NRCan ecoEII Add-on Grant ($125k, under review)										
10. SSHRC Insight Grant ($250k, Fall submission)										

Peer-reviewed publications

As noted in my cover letter, tenure-track scholars in my field are expected to publish their research in peer-reviewed journals as their primary output. For co-authored papers, author order proceeds from author with the largest contribution to author with the least. Within the Journal Citation Reports (JCR) system, my primary research field is best categorized as "Environmental Studies", though my publications also include journals within the JCR categories of "Economics", "Transportation" and "Environmental Science." The attached spreadsheet provides further details of journal rankings in each category ("2014 JCR Ranking-Relevant_journals.xlsx").

In summary, among the 21 peer-reviewed publications I have published since 2009:

- **Nine** are published in journals listed within the top 15/100 in "Environmental Studies" (three in the top three)
- **Five** are published within the top 15/29 "Transportation" journals (one more under review)
- **Three** are published within the top 30/332 "Economics" journals (two more under review)
- **Two** are published within the top 25/221 "Environmental Science" journals

Table 2a organizes and categorizes my 21 peer-reviewed publications according to different data collection methods (survey and interviews), analysis methods (qualitative, statistical or simulation), and the four research themes used in my research program (as noted on page 1). Table 2b provides the same detail for the 16 planned publications that are currently under review (four) and in-progress (seven), and five Master's research projects that will lead to publication.

Updated June 30, 2015

Table 2a: Peer-reviewed journal publications (2009-2015)

Year	Article title (PR = "Peer-reviewed")	Journal	Data collection		Analysis			Theme			
			Sur-vey	Inter-view	Qual-itative	Stats	Simu-lation	1	2	3	4
2015	PR1. Characterizing preference heterogeneity among potential plug-in electric vehicle buyers	*Energy Economics*									
	PR2. Is awareness of public charging associated with consumer interest in plug-in electric vehicles?	*Transportation Research D*									
	PR3. Gauging citizen support for a low carbon fuel standard	*Energy Policy*									
2014	PR4. Citizen acceptance of new fossil fuel infrastructure: Value theory and Canada's Northern Gateway Pipeline	*Energy Policy*									
	PR5. Does effective climate policy require well-informed citizen support?	*Global Environmental Change*									
	PR6. Social influence and pro-environmental behavior: The reflexive layers of influence framework	*Environment and Planning B*									
	PR7. Assessing climate engineering solutions as complements to mitigation: An interdisciplinary framework	*Frontiers in Ecology and the Environment*									
2013	PR8. Hybrid, plug-in hybrid or electric—what kind of electric-drive vehicles do consumers want?	*Energy Policy*									
	PR9. Observing social influence and consumer preference formation: a U.K. workplace electric-vehicle trial	*Ecological Economics*									
	PR10.Connecting plug-in vehicles to green electricity through consumer demand: A survey of U.S. new car buyers	*Environmental Research Letters*									
	PR11. Developing sustainability-oriented values: Insights from households in a trial of plug-in hybrid vehicles	*Global Environmental Change*									
2012	PR12. Lifestyle practices and pro-environmental technology	*Ecological Economics*									
	PR13. Social influence, consumer behavior and low-carbon energy transitions	*Annual Review of Environment and Resources*									
	PR14. Who can recharge a plug-in electric vehicle at home?	*Transportation Research D*									
	PR15. Interpersonal influence within car buyers' social networks: Applying five perspectives	*Environment and Planning A*									
2011	PR16. Plug-in hybrid vehicle GHG impacts in California	*Energy Policy*									
	PR17. Interpersonal influence in the early plug-in hybrid market: Observing social interactions	*Transportation Research D*									
2010	PR18. Anticipating plug-in hybrid vehicle (PHEV) energy impacts in California	*Transportation Research D*									
	PR19. Are batteries ready for plug-in hybrids buyers?	*Transport Policy*									
2009	PR20. Early U.S. market for plug-in hybrid electric vehicles: Anticipating consumer recharge potential	*Transportation Research Record*									
	PR21. Combining stated and revealed choice research to simulate the "neighbor effect"	*Resource and Energy Economics*									

Table 2b: Planned publications (under review, works in progress, and Master's projects in progress)

Year	Article Title (UR = " Under review", IP = "In Progress", M = "Master's project")	Target Journal	Data collection		Analysis			Theme			
			Survey	Inter-view	Qual-itative	Stats	Simu-lation	1	2	3	4
Under review	UR1. Picking winners: Assessing the costs of technology-specific climate policy for U.S. passenger vehicles	*Ecological Economics*									
	UR2. Anticipating consumer acceptance of utility controlled charging for plug-in vehicles	*Transportation Research Part A*									
	UR3. Socio-political acceptance of smart grid as a tool to mitigate climate change: The case of British Columbia	*Renewable & Sustainable Energy Reviews*									
	UR4. Understanding perceptions of "green" lifestyle in Canada	*Environment & Behaviour*									
Papers in progress	IP1: Understanding the differences between current plug-in electric vehicle owners and the potential future "early mainstream" market	*Transportation Research Part D*									
	IP2: Hype cycles for alternative fuel vehicles: A U.S. media analysis, 1980-2010	*Nature Climate Change*									
	IP3: It's not easy being green, but it is satisfying: The effects of pro-environmental behaviour on subjective well-being	*Journal of Environmental Psychology*									
	IP4: Social influence on vehicle choice: A synthesis and meta-analysis of empirical studies	*Global Environmental Change*									
	IP5: Forecasting plug-in electric vehicle sales using a constrained choice model	*Environmental Science & Technology*									
	IP6: Modeling a Zero-Emissions Vehicle Mandate in British Columbia	*Energy Policy*									
	IP7: Societal framing of unconventional fossil fuels: A media analysis of the Northern Gateway Pipeline	*Energy Research and Social Science*									
Master's projects	M1: Plug-in electric vehicle buyers in British Columbia: Understanding motives and usage patterns	*Environment & Behaviour*									
	M2: Designing a low-carbon fuel standard for British Columbia: Insights from a hybrid energy-economy simulation model	*Energy Policy*									
	M3: Understanding consumer demand for PEVs and green electricity using qualitative interviews	*Transportation Research Record*									
	M4: Modeling short-term and long-term GHG impacts from plug-in vehicles: Comparing BC, Alberta and Ontario	*Transportation Research Part D*									
	M5: Citizen acceptance of carbon capture and storage in Alberta, Canada	*Climatic Change*									

Research Theme Summaries

The following pages (pages 6-9) provide further details regarding my four research themes.

Theme 1: Adoption of pro-environmental technologies

My primary theme includes general market research on consumer adoption of emerging "pro-environmental" technologies. Examples of pro-environmental technologies include hybrid, electric, and hydrogen-fuel cell passenger vehicles, residential rooftop solar panels, LED light-bulbs, and high-efficiency appliances. To date, much of my work has focused on the market aspects of hybrid vehicle (HEVs) and plug-in electric vehicle (PEVs) adoption. In the coming year I will be expanding my research scope to include other pro-environmental technologies like hydrogen fuel cells and natural gas passenger and freight vehicles. Much of my own Master's, Ph.D. and post-doctoral work focused on this theme, and now 13 of my 21 peer-reviewed publications relate to it (with five more under review or in-progress), mostly in regards to PEVs.

Theme 1 research questions and highlights: Examples

1.1 What is the market's "readiness" (social and technical) for PEVs?

- Consumer awareness of PEV technology is very low (PR20, PR1)
- When the technology is explained, at least one-third of new vehicle buyers are interested in purchasing some type of PEV, and most are interested in plug-in hybrid vehicles (PR8, PR1)
- Most North American new vehicle buyers can already recharge a vehicle at home (PR14)
- Awareness of public chargers is low, but this may not impact demand for PEVs (PR2)
- PEV sales are highly constrained by a limited variety and availability of PEV models (IP5)

1.2 How can PEVs be designed to meet consumer needs?

- Consumers tend to prefer plug-in hybrid vehicles, as the flexibility of these vehicles fits well with other lifestyle needs (PR8, PR1, M3)
- The types of PEVs that consumers want are easily achievable with current battery technology (PR18)

1.3 How can consumers' use of PEVs be influenced to minimize environmental impacts?

- Offering green electricity for sale with PEVs could increase demand for PEVs (PR10)
- Some consumer are willing to let their electrical utility control the charging of their PEV to match with the availability of wind or solar energy (UR2)

1.4 What penetration can we expect for low-carbon technologies under different policy conditions?

- Alternative vehicle fuels have followed several waves of media "hype" over the past 35 years, but none have succeeded in displacing fossil fuels due to a lack of strong policy (IP2)
- Forecasts for PEV sales are low without strong policy, due to limited consumer awareness and limited PEV supply (IP5)
- PEV sales can be much higher with strong climate policy, particularly a Zero-Emissions Vehicle mandate (IP5)

Future plans for Theme 1

My two new five-year grants (PICS and CTEF) include funding to conduct a Canadian survey of the potential consumer market for alternative fuel passenger vehicles. This survey will utilize the novel tools developed in previous research and will include a broader suite of alternative fuel vehicles: PEVs, hydrogen-fuel cell, and natural gas. I am also currently recruiting students to conduct market research beyond the passenger vehicle sector – looking at the needs of fleet vehicle operators, as well as medium- and heavy-duty vehicle users (e.g. freight). To-date there has been little market research on these vehicle sectors (beyond passenger vehicles), so I anticipate that our findings will be highly novel. In the longer term, I aim to conduct a real-world alternative-fuel vehicle demonstration project to better understand consumer preferences.

Theme 2: Pro-environmental motivations (social influence, lifestyle and values)

My second theme relates to the first, but going deeper to understand different motivations of consumer and citizens, and how this shapes their perceptions and preferences regarding low-carbon technology and policy. My largest contributions relate to concepts of social influence and lifestyle. When I began to conduct qualitative household interviews during my Ph.D. research, I saw the importance of consumer "lifestyle." Households tend to describe their identity and their systems of motivation according to lifestyle; a lifestyle is the pattern of symbolic behaviors that people engage in, including career, recreation activities, technology use, and general consumption. I learned that sociological theories of consumer lifestyle yield important and unique insights into consumer motivations relative to the more frequently applied theories of consumer preferences, attitudes and values. I utilized a lifestyle-based conceptual framework as part of my doctoral analysis on social influence. I have also developed a set of lifestyle question scales that assess the frequency of respondent engagement in a variety of activities, which I find can be used as powerful explanatory variables. I have included these scales in several large surveys (e.g. PR1, PR12, UR2, UR4 and IP1)

I have published **seven papers** relating to this theme (with six more under review or in progress), notably on the roles of social influence, lifestyle, and values. My 2011 award for "Young Research of the Year" by the OECD's International Transport Forum was based on my novel research on social influence and lifestyle.

Theme 2 research questions and highlights: Examples

2.1. How can social processes influence pro-environmental behaviors?

- Processes of social influence can be more influential on technology diffusion than changes to the technology itself (PR21)
- Social influence processes include diffusion (sharing knowledge of a new technology), transmission (sharing of evaluations) and reflexivity (sharing of identity) (PR15, PR13)
- Processes of reflexivity are less common, but can be most influential on consumer preference (PR9)
- Social influence can help people to develop (or not develop) pro-environmental values (PR11)

2.2. How does "lifestyle" relate to interest in pro-environmental behaviour and technology?

- Engagement in a "pro-environmental lifestyle" is independent of engagement in seemingly related lifestyles, like nature-based activities (e.g. hiking or camping) or altruistic activities (e.g. giving to charity) (PR12, UR4)
- Consumers with environment- or technology-oriented lifestyle are more likely to want a low carbon technology such as an electric vehicle or green electricity (PR12, PR1)
- Consumers with different lifestyles might like the same technology, for different reasons (PR1)

Future plans for Theme 2

I am currently recruiting a post-doctoral researcher from the field of social psychology to bring further theoretical and methodological insights into my research program. In particular, we will apply theories of social norms and self-image congruence theories to consumer interest in alternative fuel passenger vehicles. I am also collaborating with two faculty members in the Social Psychology department at SFU to conduct surveys and experiments that relate pro-environmental behaviours and values to "happiness" (or subjective well-being). For the longer term, I am seeking an opportunity to study social influence within the context of so-called "sustainable communities"—community-based demonstrations of household infrastructure, energy efficiency, low-carbon energy, or PEV usage. I would design and implement a longitudinal (multi-year) research method combining surveys and interviews to track social interactions among community members, and to track developing and evolving preferences, attitudes, values, identity and social norms.

Theme 3: Citizen acceptance of energy technologies and policy

In the last few years I have expanded my research program to also explore citizen perceptions of and support for larger energy projects and climate policy. In democratic countries, effectively stringent environmental policies such as a carbon tax, cap-and-trade program, or emissions standard will need some degree of public and stakeholder support (or at least an absence of resistance) in order to be successfully enacted. Further, the implementation of large energy infrastructure projects can also be blocked and shaped by citizen opposition, as recently observed in North America with the Northern Gateway and Keystone XL projects. Examples of energy infrastructure project include large hydro dams, wind farms, as well as unconventional fossil fuel projects such as hydraulic fracturing ("fracking"), oil sands, bitumen pipelines, and the construction of liquefied natural gas (LNG) plants.

I have published **four articles** relating to this work, with three more in progress. My work on the citizen acceptance of the low-carbon fuel standard (LCFS) policy in BC may have been particularly influential in maintaining the policy (see "Letters of Support" from Michael Rensing and Ian Thomson).

Theme 3 research questions and highlights: Examples

3.1 What climate policies do citizens tend to support and why?

- Canadian citizens are much more likely to support climate regulation (e.g. efficiency standards or a low-carbon fuel standard) than a carbon tax (PR5)
- Citizens are more likely to support policy that has a less visible or direct impact on the consumer (PR5).
- Awareness of a low-carbon fuel standard is low, but when explained citizen support is high in all regions of Canada including those with economies that are strongly linked to fossil fuel extraction (PR3)

3.2 What explains citizen support or opposition to unconventional fossil fuel projects?

- Support for the construction of an oil-sands pipeline is much higher in the region that stands to gain economic benefits (Alberta) and lower in the region that faces greater environmental risks (BC) (PR4)
- People with biospheric and altruistic values tend to oppose unconventional fossil fuel project such as a pipeline, but these values are leveraged differently in each region (PR4)

3.3 What explains citizen support or opposition to low-carbon technology projects?

- Citizens seem more likely to accept "climate engineering" strategies that are considered to be more "natural" such as reforestation, and to oppose strategies that are more "unnatural" such as solar radiation management (PR7)
- BC citizens oppose smart meters because of a lack of trust in the utility; support could be increased if smart meters were framed in the context of environmental benefits (UR3)
- Alberta citizens are more likely to support carbon-capture and storage if they trust the government and managers implementing the projects (M5)

Future plans for Theme 3

I am now working with my post-doctoral scholar to implement a media and document analysis to gain additional perspectives on the social acceptance of fossil fuels developments such as bitumen pipelines, natural gas fracking, LNG development, and oil sands development. We plan to submit a SSHRC Insight Grant application on this topic in September 2015 (to secure ~$250k for a 4-year project). As part of this, I am also working with a Master's student to design and launch a survey of Canadian citizens to assess perceptions of a full suite of energy options (renewable and non-renewable), with special emphasis on controversial projects that are currently planned in various Canadian regions. My intention is to establish a repeated biannual survey of Canadian citizens to permit longitudinal analysis of some key survey questions, while also allowing flexibility to integrate new questions that address, topical project proposals for respondents in a given region.

Theme 4: Modeling effective low-carbon technology and policy

While Themes 1, 2 and 3 focus on understanding consumer and citizen perceptions, preferences, and motivations, Theme 4 integrates these findings to inform quantitative models of the broader energy system. Such models can be built to represent technological complexity and change, as well as consumer purchase decisions and technology usage behaviour. These models can provide insights into the lifecycle energy and environmental impacts of technologies, and the effectiveness and efficiency of different policies (e.g. carbon tax, regulations, subsidies) designed to induce a transition to a low-carbon economy.

I have published **three papers** on this Theme relating specifically to the energy and environmental impacts of PEVs. I also have another six paper in progress that expand upon this research and inform the design of broader transportation policies, such as a Zero-Emissions Vehicle (ZEV) mandate, or a Low-Carbon Fuel Standard (LCFS).

Theme 4 research questions and highlights: Examples

4.1. What are the likely energy and greenhouse gas emissions impacts of PEVs?

- Adoption of plug-in hybrid vehicles could cut gasoline use in half (PR18)
- Plug-in hybrid vehicles could cut greenhouse gas emissions in California by one-quarter to one-third (PR 16).
- Adoption of PEVs could cut emissions by 60 to 95% in Canada, depending on the province's electricity supply (M5)
- Greenhouse gas emissions from PEVs will likely decrease over time, as electricity grids use more low-carbon sources (M5)

4.2. How can climate policy induce a transition to low-carbon technology?

- Well-designed climate policy can induce changes in technology and changes in consumer preference over time—the latter may be a more powerful (PR21)
- It could be more efficient for government policy to favour one alternative fuel "winner" (e.g. electric over hydrogen or biofuels) rather than equally supporting multiple fuels, due to the existence of "breakthrough thresholds" in technology and behaviour (UR1)
- Demand-focused policies (rebates and charging infrastructure) can have a moderate impact on sales; however, strong supply-focused policy (e.g. a ZEV mandate) is required to substantially push sales (IP5)
- Regions outside California (such as BC) need to implement their own ZEV mandate to achieve deep GHG reductions in the transportation sector; there is limited spill-over from policy in other jurisdictions (IP6)

Future plans for Theme 4

Both of my two new five year grants (PICS and CTEF) include research objectives to model the effects of climate and energy policy on the transition of the transportation sector towards low-carbon fuels. I plan to use several models to simulate the technological and behavioural dynamics among passenger vehicles, fleet vehicles and freight vehicles in Canada (e.g. CIMS as a hybrid-energy-economy model, a market share forecast model, and a techno-economic cost model). I have also recently submitted a proposal for an "add-on" grant to my current NRCan ecoEII grant (~$125k, for one year) to work with a team to produce a highly integrated model of PEV adoption and usage, and how such usage could interact with the uptake of intermittent, renewable forms of energy in the electricity grid. This model will be used to simulate scenarios with different policies, including utility controlled charging and vehicle-to-grid scenarios.