Dear Chris Browne,

On behalf of the Program Committee we are pleased to invite you to present your paper titled “Insulating Expectations: A Dynamical Perspective of the Assumptions Used in Australia’s Home Insulation Program” (ID #1433) in the oral plenary session of the PhD Colloquium within 2011 International Conference of the System Dynamics Society, to be held in the Washington, DC area, July 24-28, 2011.

Reviewer comments on your paper may be viewed online on your "User Menu" page by clicking on the "Submission #1433...” button. On the following page (Menu for Submission) click on the button “Read Submitted Reviews.” You will also have the option to send anonymous feedback to the reviewers. Please consider the comments of the reviewers in the advisory spirit in which they are intended, and make only those changes to your paper that you feel are appropriate.

June 1 is the presenter registration deadline. Please see the conference website for a registration form and updated conference information: http://www.systemdynamics.org, click on “Conferences/Current.” Please use the Hotel Room Reservation Request Form found on the conference website to make your room reservation at the Hyatt Regency Crystal City, located just outside of Washington, DC in Arlington, Virginia. Also note that there will be a separate registration for the colloquium. The details of colloquium registration will be sent soon.

In the near future you will be able find the date and time of your assigned session on the conference website. Once the tentative schedule is posted, please check it and let us know as soon as possible of any conflicts or problems.

We request that the most up-to-date DRAFT of your final version paper, with author information included, be submitted online by June 10 (many
of you have already submitted this). Please use the web submission system at http://www.systemdynamics.org/cgi-bin/sdsweb, using the same email and password you used to submit the paper for review. The papers will be posted on the conference website for viewing in advance of the conference by participants and other interested parties. It may be updated at any time until August 18, the deadline for final version paper submission for the web proceedings. (Each new upload REPLACES any previously uploaded file.) If a final version paper for the conference proceedings is not uploaded, the paper will not appear in the proceedings; your paper submitted for review will not be used.

Detailed formatting information for final version papers is at: http://www.systemdynamics.org/conferences/instruct/guidelines.html.

The main meeting room will be equipped for audio-visual needs, including a computer projector. A Windows computer will be provided with PowerPoint. If you have anything else to present, please bring your own laptop. Provide your presentation material on a CD or USB key so that it can be copied onto the presentation computer. Please give your presentation material to the room staff in advance of your presentation so that they can test it, avoiding any delays.

Your presentation should last just under 40 minutes, including discussion and questions. Depending on the length of the discussion session (which will be about 10-15 minutes), you will have about 25-30 minutes for presentation. The details regarding the oral presentations will be sent later. Please remember that introductions and transition time between speakers erodes a few minutes from the allocated time.

If you plan to use visuals for your presentation, please limit the amount of information on each slide and use a boldface font of at least 24-point size. Avoid overcrowding. Diagrams should be easy-to-read, un-crowded, and focus sharply on the main point.

The PhD colloquium is scheduled to start in the morning on Sunday, July 24. There are also events scheduled such as the Newcomer Orientation, and Informal Gathering after the colloquium. We look forward to seeing you in July!

Best regards,

Onur Ö zgün
David Keith
PhD Colloquium Organizers, 2011 International System Dynamics Conference
Reply to: phdcolloquium@systemdynamics.org

29th International Conference of the System Dynamics Society
Washington, DC area July 24 – 28, 2011
Venue: The Hyatt Regency Crystal City www.crystalcity.hyatt.com

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of the
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Washington, DC

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Hello! Welcome to the 29th International Conference of the System Dynamics Society. This year, the conference is located in Washington, DC, the District of Columbia. Officially declared on July 16, 1790, by the Congress of the United States to serve as the nation’s capital, Washington, DC is centrally located between the North and South along the Potomac and Anacostia Rivers, on the eastern shores of the United States.

Again this year the program shows that the field of system dynamics is thriving. Conference participants come from more than 45 countries around the world. From the PhD Colloquium on Sunday, through the plenary, parallel and poster sessions Monday through Wednesday, and Thursday’s workshops, you will be immersed in conversations and presentations reflecting the state of the art of the field.

This year’s conference will benefit from its location in the Washington, DC area by including plenary and convened sessions that focus on applications and impact in governance in the United States and worldwide. Of special interest will be sessions on health dynamics and policy; conflict, defense, and security; sustainability, including energy and climate; diverse issues in public and corporate policy; and K-12 education. Our program schedule also includes exhibits, model assistance workshops, panel discussions, special sessions, topical roundtables, and Society business meetings.

To further increase your enjoyment of the conference, there will be time for social and professional interaction in a relaxed and fascinating setting, including an Informal Gathering on Sunday during and after registration, the Poster Symposium and Buffet on Monday, and the Conference Banquet on Tuesday. Although not included in your registration fee, local tours may be arranged through Destination DC via their website http://washington.org. These tours include visits to National Monuments, the Pentagon, the White House, and the Smithsonian Museums. The Travel and Tour Information link on the conference website provides additional information on what to see and do in the Metro DC area.

This year, 32 Thread Chairs, supported by a host of other volunteer reviewers, worked tirelessly to screen and comment on almost 400 submissions. In addition, several dozen volunteers worked many hours to ensure a successful conference. Without the commitment of these reliable volunteers our conference would be impossible. A special thanks goes to all who helped.

In addition to all our other sponsors and our conference hosts, Booz Allen Hamilton and Powersim Solutions, we are also very fortunate this year to have two conference partners, The Boeing Company and PA Consulting Group. We sincerely appreciate the enthusiasm and support of all our sponsors.

We know that you find the conference stimulating and rewarding. We ask that you bring to our attention anything that may help us to ensure the success of the current conference, as well as future ones. Thank you for attending!

On behalf of the hosts and conference committees, best wishes from,

Richard Phares, Imrana Umar, George Richardson, James Lyneis, Jack Homer and Roberta Spencer
PhD Colloquium Presentations

**Plenary Presentations**

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**Haley Jones**  
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**Zerrin Doganca**  
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Bogaziçi University

**Teaching Dynamic Ecological Problems with Systems Based Approach**

**Rhonda Jordan**  
**rjordan@mit.edu**  
MIT

**Incorporating Electricity Demand Dynamics into Capacity Expansion and Electrification Planning Models in Developing Countries**

**Tom Rust**  
**tom.rust@va.gov**  
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**Dynamic Modeling of Service Delivery in Health Care: VA Compensation and Pension Exams**

**Heather Skaza**  
**hjskaza@hotmail.com**  
University of Nevada Las Vegas

**Using systems simulations in STEM education: An example from an undergraduate environmental science course**

**Bert L. P. J. van Nistelrooij**  
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**The effect of modeling support and power on communicative exchanges.**

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**POSTER PRESENTATIONS**

**Fernando A. Arenas**  
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**The Dynamics of the Relationship between Knowledge and Organizational Performance**

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**Modelling the Consequences of Biodiesel Production in Remote Areas in Brazil – A System Thinking Approach**
Insulating expectations: a dynamical perspective of the assumptions used in Australia’s home insulation program

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Abstract. The Australian Government responded to the 2008 Global Financial Crisis by providing stimulus for the domestic economy. One measure created jobs through a program that encouraged householders to retrofit ceiling insulation. The Home Insulation Program intended to provide immediate low-skill employment and reduce national greenhouse gas emissions by improving household energy efficiency.

This stimulus measure lasted 12 months. Installer electrocutions and deaths, fires in roofs and reports of installer misconduct forced the program to be cancelled. The program failed to achieve its goals, and its administration has been the focus of media attention and political review.

This paper questions the assumptions behind choosing insulation as the technology to achieve the program goals. It shows that these assumptions were naive, and do not overcome wider trends such as an increasing affluence, larger houses, and lower house occupancy rates. This paper highlights the importance of questioning the capacity of technology to effect change when designing policy.

Keywords: Technology, policy, system dynamics.

1. Introduction

Investment in technology is often heralded as a solution to problems in society. A more efficient car design will reduce greenhouse gas emissions\textsuperscript{1}. Technology has the capacity to enable great change, but behavioural tendencies and population multipliers can cancel these benefits out. A more efficient car means I can drive further without buying more fuel. The relationship between technology and policy becomes increasingly important as governments around the world face problems caused by an increasing demand on planetary resources.

Insulation is a simple technology that, along with measures to stop air leakage, can improve the thermal efficiency of a building when installed correctly (ICANZ 2007, 8). The Home Insulation Program (HIP) was established by the Australian Government in 2009 to retrofit thermal roof insulation in over 2 million detached houses that did not have insulation. The HIP was established to achieve two main goals (Hawke, 2010):

1. To stimulate the economy by creating jobs, and;
2. To improve the energy efficiency of homes.

\textsuperscript{1} see Parliament of Australia (2010)
The program was cancelled after 12 months, in part due to public outcry over installer deaths and fires in roofs. Despite this, the program is reported to have generated significant projected energy savings and greenhouse gas emissions (DCCEE 2010).

This paper questions the validity of this claim by considering the assumptions that led to the selection of insulation to achieve the second goal. By reviewing the trends in insulation and energy use in Australia, this paper proposes that:

1. It is unclear how insulation effects household energy consumption;
2. Thus, insulation is not a useful metric for measuring greenhouse gas emissions.

In Section 2, background trends of insulation use and the HIP timeline will be explored. In Section 3 we question and test the mental models and underlying assumptions that led to the technology choice using causal loop diagrams. This leads to the discussion in Section 4 and conclusions in Section 5.

2. **Insulation history**

This section provides the background of insulation use before the HIP and maps the key events during the HIP. A stock-and-flow model has been created to show the insulation trends before the HIP, and projects the exogenous effect of the HIP on the long-term trend in Section 4. The dynamical history of insulation use in Australia provides the context of the technology in this study.

2.1. **Insulation adoption before the HIP**

The number of houses with ceiling insulation in Australia has steadily increased over recent decades. Growth is due to retrofits and an increased fraction of houses being built with insulation. In 2003, the Building Code of Australia required new homes to be 4-star, and insulation is considered as a relatively easy way to achieve this (ANAO 2010, 65). The graph in Figure 1 shows the housing stock trend from 1980².

![Figure 1: Number of houses with insulation by year (Source: ABS 1988, 1995, 2008). The number of houses with insulation in Australia has increased steadily since 1980.](image)

² In these Australian Bureau of Statistics telephone surveys, respondents chose from: With insulation; Without insulation, and; Did not know. Only ‘With insulation’ has been included in this study.
The trends in Figure 1 can be described through a stock-and-flow model, shown in Figure 2. The housing stocks grow through Annual housing construction, which contributes to either the Insulated or the Uninsulated housing stock. The Uninsulated housing stock is converted at a rate influenced by the Retrofit fraction, which has remained close to constant over recent decades (DCCEE 2010, 116; ICANZ 2008). The HIP additions indicates the single exogenous input of the HIP in 2009.

**Figure 2: The housing insulation stock-and-flow model.**

All houses tend towards becoming part of the insulated housing stock.

The simple model in Figure 2 is a method of interpreting of the ceiling insulation trends in Australia leading up to the HIP, and is run in the Section 2.3 to model the effect of the program on the housing stock.

### 2.2. Insulation adoption during and after the HIP

During the HIP there was a 17-fold increase in the annualised retrofit rate. This dramatic upscaling is shown in Table 1, and is considered as a key factor for the collapse of the program (The Senate 2010, ix).

**Table 1: Key phases in the HIP (retrospective)**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time</th>
<th>Description</th>
<th>Calculated Retrofits p.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-HIP</td>
<td>Prior to 3 Feb 2009</td>
<td>Scenario presented in §2.1</td>
<td>&lt; 65,000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phase 1</td>
<td>3 Feb 2009 - 30 Jun 2009</td>
<td>Early installation stage</td>
<td>&gt; 181,000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phase 2</td>
<td>1 Jul 2009 - 19 Feb 2010</td>
<td>Main program</td>
<td>&gt; 1,113,000&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phase 3</td>
<td>19 Feb 2010 - present</td>
<td>HIP closure and remediation</td>
<td>Data not available</td>
</tr>
</tbody>
</table>

Retrofits calculated from<sup>a</sup>ICANZ (2008);<sup>b</sup>ANAO (2010, 59); ANAO (2010, 117) by taking values from the sources and adjusting to 365 days.

---

<sup>1</sup> This model does not account for houses that leave the stock; for example, houses that are knocked down and become apartments. It is, however, known that this is present in the data collected by the ABS.

<sup>4</sup> Phases 1-3 as shown in ANAO (2010, 21)
This rapid growth of the HIP created many unintended outcomes, including four deaths, numerous house fires and reports of incomplete or fraudulent installations. The key change in the program was between Phase 1 and Phase 2, when the program went from being a customer-driven model to an installer-driven model, as the payment was claimed from the government by the installer. Faced with this rapid growth, management of the program became reactionary. According to early auditing of the program in the remediation phase, only 70% of installations were found to be fully compliant. This 30% shortfall is a damning representation of the poorly designed policy.

The changing dynamics of the program is itself an area full of potential lessons to be learnt, and has been the focus of many program reviews. As far as this paper is concerned, it provides the interesting and changing context for questioning the original assumptions around the capacity of insulation to deliver on the program goals. This is the focus of the following section.

2.3. The effect of the HIP on the housing stock

The program aimed to retrofit insulation in all houses that did not have insulation over two years. As the program didn’t achieve this goal, the effectiveness of what it did achieve comes into question. The housing insulation stock-and-flow model in Figure 2 was run with three separate parameters to investigate projections of how the housing stock has changed after the HIP. These values are shown in Table 2.

Table 2: Parameter values used for the HIP Fraction in the housing insulation stock-and-flow model in Figure 2.

<table>
<thead>
<tr>
<th>Run</th>
<th>Description</th>
<th>Value from 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No HIP</td>
<td>Unchanged (0)</td>
</tr>
<tr>
<td>2</td>
<td>HIP as happened</td>
<td>770,000 additional compliant retrofits</td>
</tr>
<tr>
<td>3</td>
<td>HIP as planned</td>
<td>1.1 million additional retrofits per annum</td>
</tr>
</tbody>
</table>

Note: Additional parameter values are included in the supplementary material

The runs in Table 2 are represented in the graph in Figure 4 until the year 2050. As noted in Footnote 3, the model does not account for houses that leave the housing stock. In addition, a projection to the year 2050 should be viewed cautiously, as future housing trends are not predicted. The model also assumes that the retrofit factor remains constant, though it is likely that the retrofit factor has been adversely affected by the HIP. However, the graph in Figure 4 does show that the short-term rollout of insulation was rapid, but the program has had only a minor effect on the long-term insulated housing stock in Australia.
The graph in Figure 4 highlights the effect that the HIP achieved. It shows that the HIP fell well short of its intended goal. By establishing the effect of the scheme, we can now turn to our hypotheses: the assumptions of insulation on household energy consumption, and; whether insulation is a useful metric for measuring greenhouse gas emissions.

3. The assumptions behind insulation

This section explores the mental models and underlying assumptions of the policy-makers for choosing insulation as the technology to reduce energy consumption and in turn greenhouse gas emissions. In this section, the arguments for and against using insulation are presented, and then measured against the goals of the HIP.

3.1. Simple insulation assumptions

Houses are built to provide, among other things, comfort for their inhabitants. A basic aspect of comfort is thermal comfort. This is an assumption that when the temperature inside a house makes the occupant uncomfortable, they take action until they are comfortable. In practical terms, this might mean putting on or taking off a jumper, using a heater or cooler to change the temperature, or both.

Over time, the costs associated with taking action using a heater or cooler will begin to mount. If this is of concern, occupants can try to slow the rate that the heating or cooling escapes the house, by making sure windows and doors are closed and sealed, and by installing insulation.

The arguments put forward to retrofit insulation can be persuasive. An uninsulated ceiling accounts for 25-35% of heat gains or losses (McGee 2010, 101), and installing the appropriate insulation can reduce that significantly. The Insulation Council of

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5 Collins (1986) states that a comfortable temperature range is between 18°C and 24°C
Australia and New Zealand claim that installing insulation can reduce average home heating and cooling costs by around 30% (ICANZ 2007). This behaviour can be described by a causal chain: by installing insulation, energy consumption decreases and so do emissions.

This causal chain is the key mental model used in the argument to install insulation as part of the program. This mental model is represented in a government fact sheet that shows the number of houses with insulation retrofitted in the HIP directly produce a greenhouse gas abatement of 14.3 million tonnes of CO$_2$ equivalent abatement (DCCEE 2010). The contentious link in the causal chain is that insulation reduces energy consumption. This link is explored in the following section.

3.2. Insulation and energy consumption

However persuasive the arguments for installing insulation, a deeper understanding shows this to be a narrow view. Data presented by ICANZ (2008, 33) show that the majority of households had not changed their heating demands after installation of ceiling insulation. A larger portion of households increased the area heated than the portion which reduced it. This leads to the observation that comfort can be improved by installing insulation, rather than just reducing energy consumption.

Insulation may well improve the thermal efficiency of a house, but does not directly relate to a reduction in energy consumption. If the action to improve comfort was to rely on space heating or cooling, insulation will help the heat stay in the area for a longer period of time. A reliance on insulation only helps to balance the level of thermal comfort.

The link to energy consumption is through heating and cooling, but this is not the whole story. Occupant behaviour (Gill et al. 2010, 506) and income level (Clinch et al. 2003) have been shown to be more important in energy consumption patterns than thermal efficiency. Williamson (2004) points out that many of the insulation assumptions are not substantiated, and that by extension the energy efficiency models used in building codes are flawed. Further, increasing house sizes, decreasing occupancy rates, and increasing expectations of comfort all help to drive an increased demand for energy (Williamson et al. 2010).

To claim that insulation alone reduces energy consumption without considering these other factors is misleading. For example, the trend in Figure 5a shows that whilst overall energy consumed for space heating has only increased slightly in the past two decades, general household appliance energy consumption has almost doubled. Australians also now inhabit almost twice the floor space of 20 years ago, shown in Figure 5b. During this time, greenhouse gases emissions from public electricity and heat consumption have also risen, shown in Figure 5c.

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6 ICANZ do not provide a source for this data or explanation of what level of insulation is required.
7 Of space heated homes: 21% increased the area heated, 71% had no change, and 8% decreased the area heated.
8 This includes the assumptions that inhabitants react to an uncomfortable level of comfort, the basis for the Comfort Assumptions loop. However, this describes the underlying paradigms on which the program was built.
9 Due to both thermal efficiency measures and more efficient heating and cooling devices
Considering these additional factors, investment in insulation—indeed, any energy efficiency—is one element in a series of household interactions that lead to total heating and cooling energy consumption. The HIP method of intervention—increasing the number of houses with insulation—is part of a system where energy consumption trends upwards. Further, greenhouse gas emission levels are an unseen outcome for the occupants, so any variation in the emissions level is an outcome of the system rather than a driver.

### 3.3. Insulation as a metric for emissions

A key benefit for using insulation as the technology in the program was the reported greenhouse gas abatement. However, as discussed in §3.2, these assumptions do not hold in the broader trend of increasing energy consumption. This section, then, questions the validity of using insulation as a metric for the emissions level.

As highlighted in §3.2, insulation—and specifically ceiling insulation—is one part of the energy consumption story. It is one part of the thermal efficiency story too. Heat energy is lost through a number of ways. Installing insulation will have little effect on the thermal efficiency of a house if a window is left open or if there are draughts under doorways. The only way that insulation can have influence the emissions level is if reliance on insulation influences the behaviour of the occupant by reducing their reliance on heating and cooling.

Given that it is this link that relates insulation to thermal efficiency and thus energy consumption, it is important that the validity of this link is verified. For insulation to be used as a useful metric for energy consumption, the relationship between level of insulation and energy consumption must be explicit and measurable. The verification of
this relationship was not a requirement for the HIP, but it is evident in other countries with energy efficiency programs.

For example, Canada’s ecoENERGY Retrofit program requires occupants to have a certified energy advisor to provide an on-site evaluation. This results in a list of recommended retrofits, from improving the energy efficiency of heating and cooling appliances, to ensuring that all aspects of the building envelope are performing. A post-retrofit inspection is required before any rebate is paid (ecoACTION 2009), and includes a blower door test to identify air leakage. This provides validation for the occupant that making these improvements and modifications increased the thermal efficiency of their house.

This example highlights that it is possible to measure the effect of installing insulation. Together with a decrease in energy consumption, it may be possible to measure greenhouse gas emission abatement. Without this validation through physical testing, it is impossible to measure the changes in energy consumption. Hence, counting the number of houses with insulation is not a useful way for representing and projecting energy consumption trends—and, by extension, greenhouse gas emissions—particularly in Australia where little verification exists.

The following section concludes this paper by considering issues required in the next phase of this research.

4. Discussion and Further work

The intervention primarily in the realm of lower order leverage points presented by Meadows (1999). The effect of installing insulation as described by the different projections in Figure 4 adjusts the ‘numbers’, but the structures, goals and paradigms remain unchanged\(^{10}\). Given the goals of the HIP were to create employment and improve energy efficiency, there were a number of ways that this could be achieved.

An alternative place for intervention when trying to reduce greenhouse gas emissions is not where it is used, but where it is produced. Energy consumption is only related to greenhouse gas emissions because of the fossil fuel paradigm. A paradigm shift to the clean production of energy could indeed trump the goals that a technology such as insulation was ever capable of achieving.

The next phase of this research will develop the concepts discussed into a stock-and-flow model. The purpose of the model will be to investigate the feedback structures in the home insulation scheme, especially the relationship between the insulation of housing stocks and energy consumption.

\(^{10}\) See Meadows (2009)
5. Conclusion

This paper set out to explore the assumptions that lead to choosing insulation to achieve the environmental goals of the Home Insulation Program. It questioned whether insulation reduces energy consumption, and whether insulation levels can be used to measure greenhouse gas emissions. The discussion highlighted that the assumptions, though sound in isolation, were influenced by many more unconsidered factors.

Similar programs in other countries have shown that insulation programs can have positive outcomes, largely because of accountability measures. Further investigations may show better program outcomes than was experienced in the Australian program. However, this case study does highlight the need for stronger debate to test the underlying assumptions behind technology when creating technology-based policy.
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