Waste Wood to Heat: beyond technology to quality of life in Christchurch

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1. Introduction

Christchurch has a forty-year history of choking wintertime smog from wood and coal burning for domestic heating. A new methodology for Strategic Analysis of Complex Energy and Environment Systems (SACEES) was employed to provide a sustainable energy solution to a very old and very complex problem. Historical review and characterization of the problem was the first step, including economic, psychological, and cultural factors, as well as technical and environmental factors. A performance-objective design of an optimal form of the energy architecture was generated for the target date of 2008. In order to achieve health standards and fully renewable energy supply, waste wood pellet fire appliances would need to be installed in one half of residences to replace existing solid fuel burners and to heat homes which are presently not heated. An integrated policy, resource, and business strategy for maximizing quality of life over the shortest timeframe was developed, including banning of visible emissions, security of the pellet industry, and subscription-type purchasing arrangements for heating.

The SACEES methodology provided a new and viable solution to a very old and untenable problem. The fundamental premise of the approach is to research the social and economic history of the problem, pick a target date for resolution of the problem, define the performance characteristics for high quality of life, and then design an *energy architecture* within the social, economic, cultural, and environmental context. This study illustrates how, once a relevant solution is visualized and described to all parties, the means to achieving the solution becomes apparent and achievable.

2. Methodology

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A SACEES study must be done for a specific region, and for a specific community requirement. The study requires discovery of local renewable energy availability data, energy conversion technology specifications, and the cultural requirements for a high quality of life. The methodology follows the steps shown in Table 1. The general tenet of the methodology is that an energy architecture for the sustainable reference state is modeled and designed *before* any development scenarios are undertaken. The reference design then acts as a pinning point for forward analysis, as opposed to the standard scenario development practice of projecting present and historical trends, and predicting required energy resource development to supply future consumption growth. The SACEES methodology sets the energy consumption at some future point according to renewable resource availability, conversion technology capability and the performance requirements for quality of life.

Table 1. Problem solving methodology using the SACEES approach

	SACEES Methodology
1	Define performance metrics
2	Build socio-economic and cultural history
3	Develop a regional energy system model and characterize control, feedback, economic, and built environment
4	Develop Performance-Objective design for reference energy architecture
5	Evaluate critical change factors
6	Develop a scenarios for evolution

2.1 Performance Metrics

Performance metrics were set by World Health Organization standards for indoor air temperature minimum of 18°C and maximum 24 hour average exposure to PM_{10} particulate air pollution of 50µg/m^3. The city was built on cleared and drained swamp land, and the climate is relatively humid. Winter-time average daily high temperature is in the range of 4-8°C, but until the early eighties homes were built without insulation. In these conditions, condensation on interior walls and windows produces a serious mold growth problem with negative impacts on health. The quality of life depends on maintaining at least 18°C indoor temperature during waking hours, keeping the wall temperature above the dew point over the course of the night, and reducing the particulate emission levels below 0.5µg/m^3 for all heating systems.

The analysis is based on 14,000 to 18,000 households that report using open fires for heat on winter days, and 55,000-65,000 households which rely on enclosed burners. Many of the homes with open fires also have substandard living conditions, because the open fire doesn't do a good job of providing heat to the living space. In addition, 1000-2000 households report having no heat source. Wood stoves have not been permitted in new construction for the past decade, so most of the homes with wood burners also have no insulation. The target date for the energy architecture design was 2008, and it was determined that in this time frame, few homes would undergo the major renovation required for installing wall insulation. Thus, 80,000 households, representing 50% of homes in Christchurch, are targeted for a new energy system to attain the WHO standard comfort level with a low emissions heat source from renewable energy.

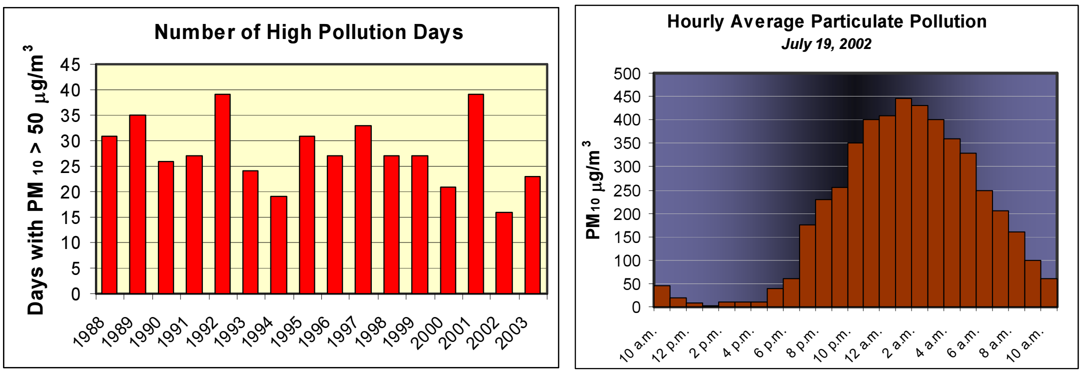

FIGURE 1. Historical winter particulate air pollution in Christchurch, and an example of the exposure level on a particular night.

2.2 History

The history of the air pollution problem in Christchurch was investigated through city council archives. Citizens have been struggling with poor air quality for nearly one hundred years. There have been numerous initiatives to regulate or ban solid fuel burning in the city, but each time public outcry has stymied the regulation. The most common opposition to a ban on solid fuel burning has roots in a shared vision of old and poor people suffering. This is a moral position of concern for others, and does not tend to waver, even when contradictory evidence is presented. There is also a strong aversion to regulation concerning what people do in their own homes.

The nature of the problem and the technical aspects of the solution have been well established through previous work. The air pollution situation as a threat to health does not seem to raise the same level of concern seen in other countries, most notably in America. In fact, the particulate pollution data, shown in Figure 1, is often met with skepticism about the scientific methods.

2.3. Regional Energy System Model

The energy system model shown in Figure 2 was used to describe the winter residential heating situation. The control for the system model is the result of the cumulative decisions that people make to achieve their desired *Quality* of life. The pollution problem is due to the people with wood burning appliances deciding to purchase wood to provide the service of heating the home. This decision is made in the autumn, after which time fire operation is determinant. Current government regulations require the sale of dry fire wood and installation of accepted models of wood stoves. These regulations cannot be correlated with any improvement in the air pollution problem. The *Availability* feedback is a plentiful supply of firewood and coal with a price range of $130-$300NZD per cubic meter of wood. The *Performance* feedback is the warmth gained from the fire, regardless of energy efficiency.

In the Christchurch *Economy*, wood is affordable to most households. People perceive electricity as terribly expensive (currently around $0.15/kWh). We calculated the price per kWh for several households for both wood and electricity. None of the people had perceived, prior to the calculations, that they were paying more for wood than for electricity. Many people perceived the wood heat was “free”, probably because it was paid for several months earlier. Hydropower provides 75% of the grid electricity, but the resource has become critically low three of the last four winters due to low rainfall. There is no reticulated natural gas supply in the city.

The *Built Environment* is characterized by nearly 40% of homes having no or gravely inadequate insulation. Although sub-zero weather conditions are common in the winter months, and the 43^{o} south latitude geographical location means low winter sun, nearly 95%

of all homes are built without central heating. Energy audits of several typical un-insulated homes gives a heating load on frosty winter nights in the range of 15-30kW.

Research by the regional council has established that 90% of the particulate pollution is due to domestic heating. The pollution *Impact* is printed in the daily newspaper and is obvious to people going outdoors. The dangerously high air pollution occurs on nights with meteorological temperature inversions, which often coincide with cold nights. Public health analysis has estimated that at least seventy deaths per year can be attributed to the high air pollution events. People with existing heart and lung ailments are the most susceptible to medical crisis brought on by air pollution. A majority of citizens surveyed reported curtailing outdoor activities to avoid exposure.

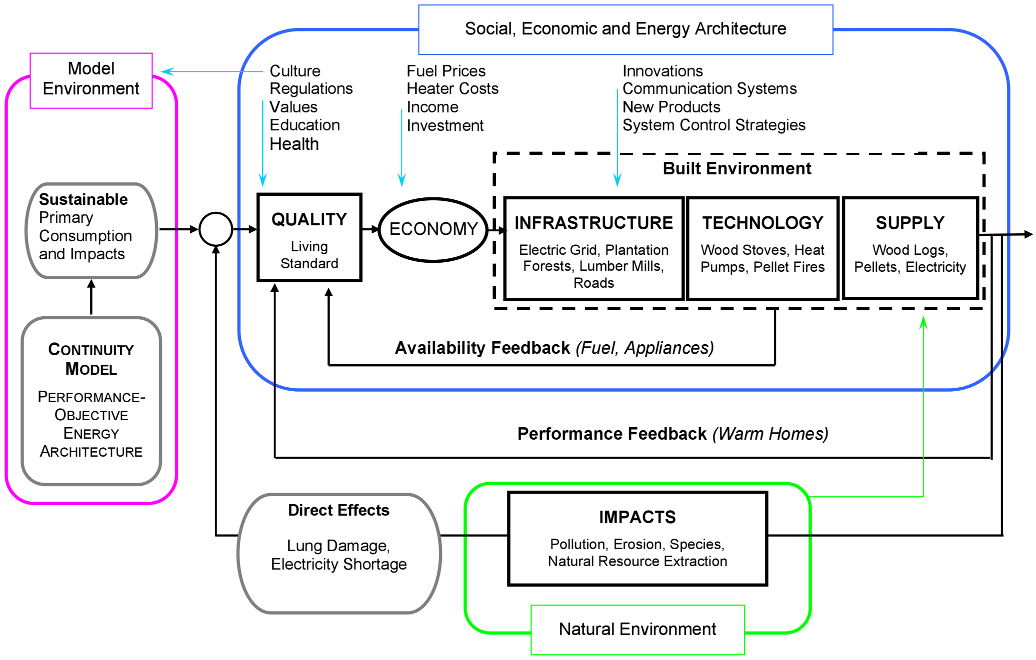

Figure 2. The energy/environment/economy system model used in SACEES methodology, showing the role of the performance-objective model in determining the necessary and critical system changes for development toward sustainability.

4. *Performance-Objective Energy Architecture*

The required performance target (warm homes, clean air, healthy conditions) in reference to the objective (affordable, renewable and sustainable energy supply) was used

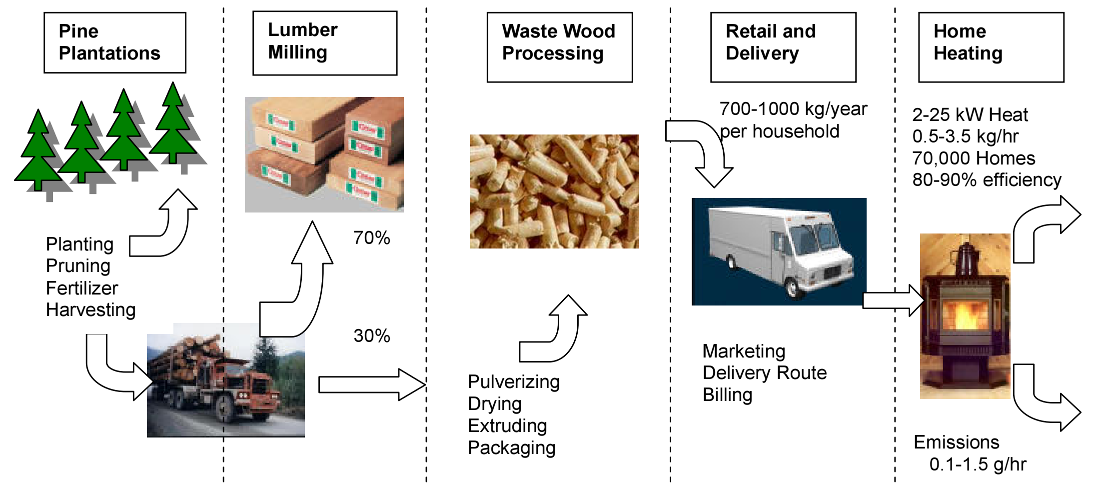

Figure 3. The energy architecture for a sustainable system that delivers high quality of life for the residents of Christchurch, New Zealand in the year 2008.

to develop a energy architecture solution. Although the heating loads necessary to achieve WHO standards in un-insulated homes are very high, a widespread local custom to heat only the occupied part of the house reduces the effective heat load by about 30%. A sustainable source of waste wood from local lumber plantations is sufficient to provide the energy resource if the conversion efficiency was at least 75%. Wood pellet stoves placed in every one of the 80,000 target households would reduce overall electricity and wood consumption, and result in clean air. The energy architecture can be described by a massive injection of heating into the existing built environment through wood pellet stoves. Figure 3 shows the 2008 Sustainable Energy Architecture.

5. Critical Change Factors

The critical factors for change involve primarily cultural, economic and technology factors. Even though many people rate winter air pollution as a problem, the cultural factors all seem to present a resistance to change. An important factor in this is distaste for regulations about what people can do in their own homes. In general, the citizens of Christchurch abide by council regulations and do have concern for fellow citizens. We found no evidence that low-income and elderly people represent a large, or even significant, number of homes that rely on open fires. However, there is a very common perception that banning open fires would disproportionately harm poor and elderly people. Even people who did not use fires for heat were not inclined to accept a ban on other people using them.

Wood stove owners were found to be often unaware of low emission combustion practices. Many were unwilling to take responsibility for the environmental pollution they generate. The council has attempted voluntary "no-burn" nights and public education campaigns but these have had no measurable impact.

Pressure for change in the decision to use wood in fires and stoves seems unlikely to come from higher wood prices, as wood is abundant and perceived as low cost. Our survey indicated that the initial capital cost of a pellet heating system would pose a large resistance to change, even though the pellet fire is only marginally more expensive than a an approved wood stove. Our survey of real estate agents showed that the heating system of the home would influence the market potential of a property. They indicated that the “warmth” and the moisture conditions of a home were second only to location as top priorities for potential home buyers.

Although the local people seem to embrace new technologies in other areas, like electronics and appliances, they were unfamiliar with the pellet stove and not willing to trust that the pellet stove would provide the same comfort or that the pellet fuel supply would remain reliable. The pellet stove is a mature technology for high efficiency, convenient, low emission heat from waste wood. It appears that if the pellet stove were to somehow become the "next big thing" that the rush to acquire one could carry the evolution to the new energy architecture forward.

6. SACS Scenario

The sustainable system providing high quality of life in 2008 could be realized through uptake of wood pellet stoves to replace all wood stoves and open coal and wood fires. The SACS scenario is a strategic plan to bring about this change, starting from summer, 2003. The immediate necessary action is a ban on visible emissions from domestic chimneys.

The ban would need to be enforced strictly during temperature inversion episodes, and penalized with a fine. Just like speed cameras, a digital photo taken by the air pollution officer would provide the evidence and a ticket would be issued and sent to the residence, along with information about pellet stoves. The smoking ban would regulate the impact that people have on their neighbors, rather than restricting their ability to burn wood to keep warm. Thus, it would fit with the local sentiment. The smoking ban would also generate an effective pressure for change as has been seen in North American cities and towns.

The second strategic move would be to build confidence in the pellet stove technology and particularly in the pellet fuel supply. This would be accomplished by the regulatory agencies giving clear support and approval of the technology, and through financial backing of the industry. The third important step would be a business investment in the pellet stove industry which includes aggressive and inclusive marketing and financing. Given the perceptions of appliance and fuel prices, the company should set up a purchasing and supply system that reduces capital outlay and spreads the fuel cost out over the year. We would suggest an arrangement similar to cable or satellite service where a basic service is installed and regular payments made automatically. The marketing should emphasize the modern and high technology aspects of the pellet stoves, the convenience of use and the high level of performance and comfort.

Conclusion

The SACEES methodology resulted in a solution which has not been considered by the local council. The measures called for in the strategy have not been a part of the public debate surrounding the issue. Given the strategic nature of the solution and the plan for achieving it, and the fact that it was developed within the local economic, social and historical context, the results of this study introduce an innovative and potentially successful solution to an old and persistent problem.