Fuel Retail Management System

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What will happen when transport fuel supply falls short of demand? If you are a Mechanical Engineer, this is an ideal innovation space, an important situation where a solution does not yet exist. Our concept-generation, modelling and design research has yielded a possible new technology allowing business as usual to be that which happens when supply falls short of demand. The Fuel Retail Management System (FRMS) is a novel ICT concept which uses the design elements of allocation market systems to manage constrained fuel supplies – *if* it is deployed in time.

Keywords: Transportation, Fuel, Rationing, Fuel Supply

1. Motivation/Background

The likelihood of New Zealand experiencing an oil shortage – where demand exceeds supply – is increasing due to rapid demand growth in developing nations, depleting oil reserves, and stressed production and supply systems. The recent World Energy Outlook by the IEA states that a "*supply side crunch in the period to 2025, involving an abrupt run-up in prices cannot be ruled out*" due to the uncertainty of new production being sufficient to offset the decline of existing fields and projected demand increases (IEA, 2007a). As additional fields go into decline, world production will eventually peak and go into decline at a rate of approximately 3% p.a. (IEA, 2007a; Energy Watch Group, 2007; Hirsch, 2006). As a signatory to the International Energy Programme (IEP), the agreement put in place by countries in the International Energy Agency (IEA), New Zealand may be required to reduce total oil consumption by up to 10% in the event of a global supply disruption (IEA, 2007b). Consequently, a situation in which demand exceeds supply is still possible even if New Zealand undertook measures to reduce oil consumption in accordance with declining availability.

A shortage in oil, more specifically transport fuel, is very detrimental both socially and economically. The UK fuel shortages, in 2000, created a chain reaction among critical infrastructure sectors such as transportation, health care, food distribution, financial and government services due to their interconnectivity and interdependencies (PSEPC, 2005). The financial impact of the week-long fuel drought was estimated at close to £1 billion. Preferably, if demand can be controlled to match the supply, the negative effects of a shortage are mitigated.

The paper reports on research to develop a fuel retail management system (FRMS), such that a constrained or reduced supply of oil can be effectively managed. Section 2 of this paper reviews existing mechanisms for reducing demand; primary price adjustments and oil demand restraint options. The short term nature and limited effectiveness of these measures is highlighted. Section 3 describes the process for designing the FRMS. The design process includes identifying features of other supplier-customer relationships in which the product or service is constrained. Section 4 describes the FRMS and examines existing information communication and technology systems that could be used for implementation. Modelling results of the FRMS are provided in the Section 5, where the shift in cost and fuel use is shown for different users. Future research and challenges are described in Section 6.

2. Mechanisms for reducing Demand

Simple price increases alone are not an effective mechanism for reducing demand, particularly in the event of a fuel shortage. Using data from 1978, the short term (one year) price elasticity of demand for petrol was determined to be -0.15; petrol consumption would decrease by 1.5% within a year given a 10% price increase (Kennedy and Wallis, 2007). However, in recent years, consumption of fuel by the household sector (personal transport) has continued to increase despite the real price of fuel increasing as shown by figure 1 (StatisticsNZ, 2007; StatisticsNZ, 2008; MED, 2008).

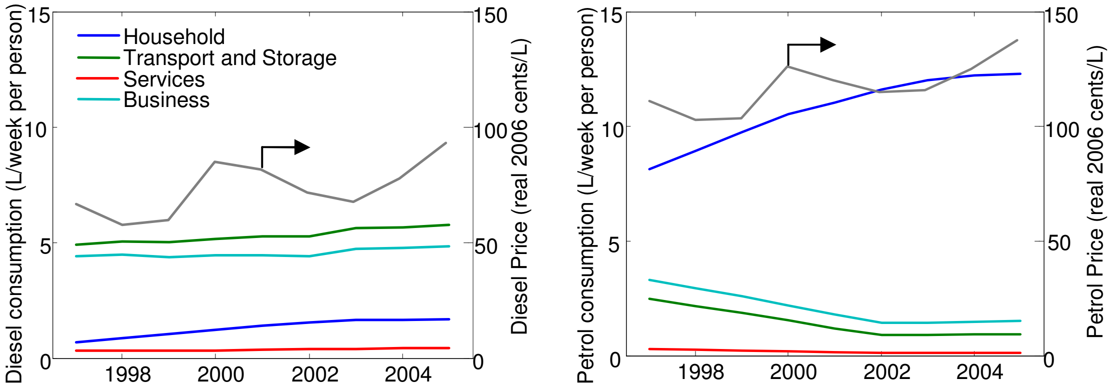

Figure 1. Historic consumption and price of diesel and petrol

Even as the cost of fuel continues to increase, methods by which users can reduce fuel consumption are limited. For example, although 68% of New Zealanders stated they would significantly reduce fuel consumption if the cost exceeded $3/L, only 29% had an available public transport option for the journey they make most often (ShapeNZ 2008). Furthermore, 19% of New Zealanders would not reduce fuel consumption, even if the price exceeded 5$/L.

There has been increased attention, both internationally and within New Zealand, on methods to reduce fuel demand in the event of an oil shortage. (IEA, 2005; Denne et al., 2005; MED, 2006). Figure 2 shows the type of measures that could be implemented. The most appropriate measure would depend on the severity of the shortage, with voluntary measures used in the event of a small supply disruption, and mandatory measures required if a large reduction was necessary.

A number of these measures were implemented in New Zealand during the second oil shock of the late 70's and early 80's. Carless days were imposed between July 1979 and May 1980, in which cars could not be driven on a nominated day of the week, indicated by a sticker on the windshield. Carless days were largely ineffective as people found ways to circumvent the measure; for example, buying a second car. However, an open road speed limit reduction to 80 km/h was somewhat successful, and remained for several years (Anon, 2008a; Anon, 2008b). In general, usage based mechanisms – where restrictions are imposed on fuel use rather than the fuel itself – have limited effectiveness as people find ways to circumvent the restriction.

In a recent report commissioned by the Ministry of Economic Development, a reduction in oil demand of 7.1% could be achieved using all voluntary measures (listed in figure 2) in conjunction with mandatory speed limit reductions (Denne *et al.*, 2005). The report further suggested that the best option for additional demand reduction is a rationing scheme in which paper tickets, each representing a quantity of fuel, are issued to all residents (through the electoral roll). To increase the market efficiency of the approach, trading is encouraged, possibly through existing facilities such as the online platform www.trademe.co.nz.

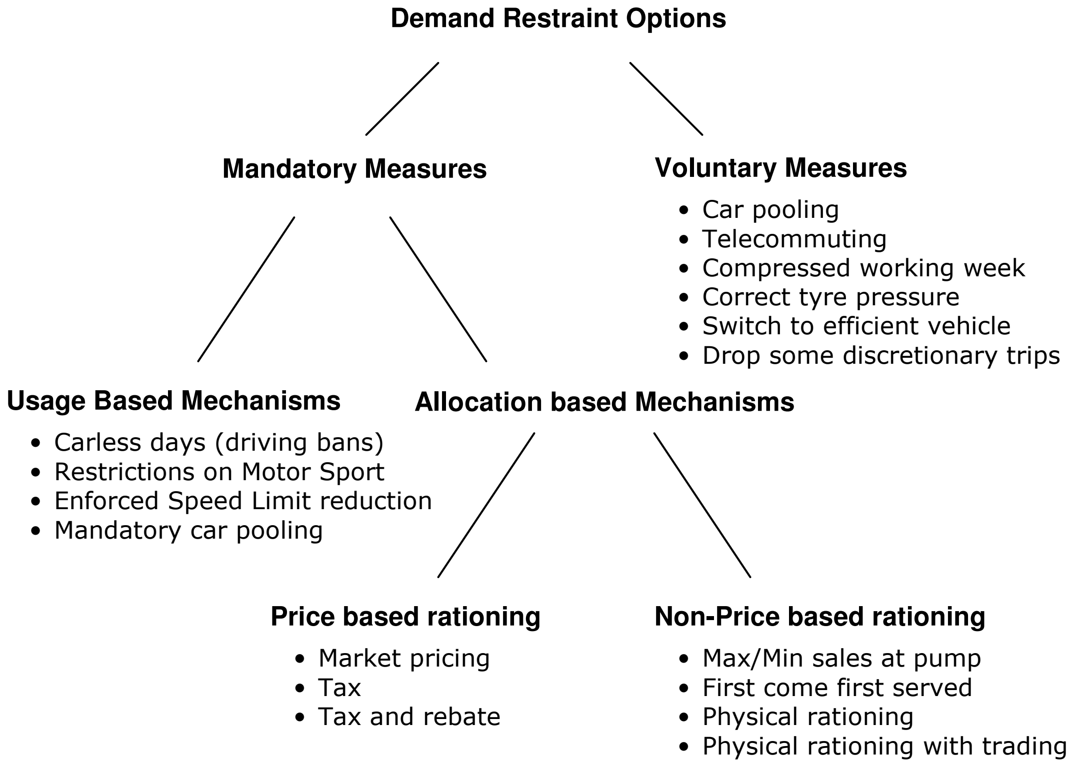

Figure 2. Demand restraint options

With all demand restraint measures, but particularly rationing, a public perception of a fuel shortage is likely to induce panic buying and fuel hoarding behaviour, as occurred during the UK fuel protests of 2000 (PSEPC, 2005). Panic buying and hoarding can greatly exacerbate the situation and increase the severity of the shortage; any demand restraint measure must be carefully designed to avoid such behaviour. In summary, New Zealand has no mechanism to significantly reduce fuel consumption, and certainly not for a prolonged duration.

3. Design of an alternative Fuel Retail Management System

The current system for selling fuel works well only if the supply of fuel is unconstrained. Oil shortages arise because the supply of fuel becomes constrained; the traditional approach is to react to the shortage event (through price or demand restraint), rather than managing the constrained supply. The FRMS approach is to change the fuel retail system such that it inherently manages a constrained supply.

There are many common examples of supplier-customer relationships that do not only rely on price to determine demand. Internet and cell phone service providers offer fixed quantities of service for an agreed (low) price, with additional charges incurred if the customer exceeds the predetermined quantity. An important feature of this customer-supplier relationship is the availability of information regarding the quantity used, Mb downloaded or talk time remaining. Under these contracts, people tend to adjust their consumption to maximise use, but not exceed the agreed amount. Electricity is usually provided in an unconstrained manner; however, during 2001 and 2003, when the country was encouraged to save around 10% to avoid power shortages, mechanisms other than price increases were employed. For example, Mercury Energy, Mighty River Power's retail arm, launched the Beat-Your-Bill campaign in which rebates were offered to customers for each kWh they saved, compared to the same month the previous year. With the rebate set at $0.05/kWh in 2001, 72% of customers received a total of 2 million in rebates and 4 million in savings (MRP, 2003a). The rebate was increased to $0.10/kWh in 2003, in which customers received a total of 4.3 million in rebates alone during June-August, and saved 43GWh; enough to power a town the size of Taupo for a year (MRP, 2003b; MRP, 2004).

During the campaign, power saving information was provided to customers that enabled consumption reduction without compromising the level of activity or energy service. For example, alternative heating and insulation advice was provided, rather than simply advising a reduction in the electricity used for heating, which would result in a less comfortable environment. Although pricing was a factor in reducing demand during the Beat-Your-Bill campaign, consumers' primary motivation was found to be the national good during the shortage, rather than financial reward (Williams, 2005). Analysing the way constrained resources/services are managed is not only informative in terms of the customer-supplier relationship, but also regulatory aspects such as those in the electricity industry.

There are three common features of the customer-supplier relationship when a resource/service is constrained. These are;

- Customers are informed of quantity (not just the cost) of their consumption
- Differing price brackets exist; either as a rebate on usage under a certain quantity, or a surcharge on overuse;
- Information on how to reduce consumption is provided, when desirable (preferably allowing users to reduce consumption while retaining the same level of service).

It is these three features that must be contained in a Fuel Retail Management System.

3. Designing the System

The concept of an FRMS was tested against a range of possible demand restraint measures, to see if other schemes offered a better solution (Rendall, 2007). The only requirement of any system employed in the event of a shortage is that demand must be reduced to match supply. Other desired features include; ubiquitous nature, adjustable to shortages of varying degree, equitable, minimises hording and panic buying behaviour, and facilitates users to reduce consumption. The current technological environment is favourable for the application of Information Communication Technology (ICT) systems, which could be used for a nationwide system of fuel use monitoring and price control. A number of solution concepts were generated after consideration of the project context, and requirements and expectations of the system. These are;

- **Do nothing**; allocation on first come first served basis – accepted as the base case (control) during system design.
- **FRMS**; an amount of fuel is allocated to all users through an ICT system, and available for purchase at the retailer price. Additional fuel purchased above the allocation amount incurs a per litre surcharge, while users not utilising their entire allocation receive a rebate (equal to the surcharge). The ICT system also provides information on fuel usage and methods of reducing consumption.
- **Surcharge and rebate**; financially equivalent to the FRMS, without any monitoring system or the need for multiple prices at the pump. All users are given a periodic rebate, while all fuel is sold with a surcharge.
- **Ticket rationing**; paper tickets representing the right to purchase a predetermined quantity of fuel, which may be traded, are given to all drivers.
- **Monitoring an information system (only)**; computerised monitoring and information system employed by the allocation scheme is provided to consumers, but there are no imposed price modifications.

Each scheme was analysed to determine if it would meet the system requirement, and then ranked overall on the quality of response to each of the system expectations. Through this process, only two systems were identified to have the necessary features; the FRMS, and the Surcharge and Rebate scheme with an information system. Both systems share many common aspects, and are discussed below.

4. Mechanics of the FRMS

The fuel retail management system is primarily an information system that enables people to reduce their fuel consumption while maintaining their activities. The FRMS also ensures that some fuel will be available to individuals in the event of shortage, thus eliminating the potential for panic buying and hoarding behaviour that would exacerbate a shortage event. It should be noted that the FRMS is designed for reducing demand in the household sector, rather than the service or business sectors. The ability of the household sector to reduce fuel use while maintaining the same activity is inferred from the significant increase in per capita consumption over the past 10 years (as shown in figure 1).

Informing customers of their personalized consumption, and methods by which to reduce fuel use, is the primary feature of the system. Information on personalised consumption is provided to customers who purchase fuel using a fuel card. A person may have a card for each vehicle, allowing vehicle consumption to be monitored, but each fuel card would be linked to a single user, via a driver license number for example. The customer could access their own consumption data via a number of methods; including the internet, as fuel is purchased or in a weekly/monthly statement. Together with fuel consumption data, information on alternative travel options and other methods to reduce fuel use would be provided. In the event of fuel supply becoming limited, individual (and national) targets could be set together with a pricing incentive (discussed below). Personalised fuel use, consumption/reduction targets and information on how to reduce consumption, are the main features of the FRMS.

In the event of a shortage, the FRMS ensures an allocated amount of fuel can be purchased at the lowest possible price, set by retailers. Additional fuel can be purchased, but will incur a (per litre) surcharge. The amount of fuel allocated to each user, and the size of the surcharge/rebate will depend on the level of reduction required. As an example, let us assume that the New Zealand was requested by the IEA to reduce total oil consumption by 10%. For all savings to be achieved within the household sector, the average consumption must decrease from 14.0 L/week per person to 10.7 L/week per person; equal to the 1999 consumption level. A surcharge would then apply to every litre of fuel purchased in excess of 10.7 L/week. As users purchase fuel using a fuel card, their consumption level, hence cost, would be calculated when payment was made. People using less than the allocated amount of fuel receive a rebate (equal to the surcharge). People opting not to partake in the scheme would simply pay the surcharge on all fuel purchased. The surcharge/rebate would be adjusted such that the scheme was fiscally neutral, and the required reduction was achieved. Although the pricing mechanism encourages fuel reductions, providing information on how to reduce consumption while maintaining the same level of activity is predicted to be the main actuator. People reducing consumption for the national good, as was found during the Beat-Your-Bill campaign, will also be a motivating factor. Although reducing consumption from 10.7 to 14.0 L/week per person may sound significant, it should be compared with the consumption level in 1997, just 8.8 L/week. Clearly, the issue is in managing and facilitating a fuel reduction, not the fuel reduction itself.

With the FRMS, the fuel card system that provides information on consumption is also responsible for administrating the price incentive. However, it is possible to separate the information system from the pricing incentive. A surcharge could be added onto each litre of fuel purchased, with a periodic rebate supplied to each customer; this is financially and fiscally identical to the FRMS. A fuel card information/monitoring service could also be supplied, but it would be separate from the pricing mechanism. This surcharge and rebate plus information system may be easier to implement, as a separate regulatory authority could control the pricing incentive, with fuel retailers administering the information system. A surcharge and rebate system is preferable to traditional rationing (DOE, 1980). The ICT system requirements, and pricing system, remain the same as for the FRMS.

There are a number of fuel card and fuel purchasing systems already in operation that may be adapted to function as part of the FRMS. These systems are supplied by each major fuel retailer, and provide companies with a large fleet of vehicles an easy method to manage and pay for fuel. Existing functionality of the systems includes setting the maximum amount of fuel that can be purchased for a particular driver or vehicle (BP, 2008). The amount and cost of fuel purchases are monitored, and available to the fleet manager. The presence of existing ICT systems managing fuel use, albeit for large consumers of fuel, indicates that the cost of an ICT system for a FRMS is not prohibitive.

5. Research and Modelling

A model that enables the analysis of a range of prices, required reduction levels, and responses to prices signals has been developed in Matlab. The model uses the price elasticity of demand to predict changes in consumer use under the FRMS. Model inputs are; the distribution of fuel consumption over the population, values of price elasticity of demand for different usage types and the current fuel price (91 Octane). Fuel consumption over the population was calculated using the population distribution of vehicle kilometres travelled (VKT) and the average vehicle fleet efficiency (MOT, 2005).

Model assumptions;

- Price elasticity of demand figures were divided into three categories based on the importance of using fuel to perform the service; essential, necessary and discretionary. Essential fuel use, by definition, has an elasticity of zero (it is essential to use fuel, no matter what the price is), necessary fuel use an elasticity of -0.12 and discretionary an elasticity of -0.25. The average elasticity is equal to the assumed short run elasticity for household fuel consumption, -0.123 (VTPI, 2007).
- The allocation model assumes that those users gaining money under the allocation scheme do not increase their consumption; it is probable (but not factored into the model) that these users may in fact reduce their use anyway, for the national good, during a crisis.

Given a targeted average fuel reduction from 14.0 L/week to 10.7 L/week, a base fuel price of $2.00/L and an allocation amount of 10.7L the model calculates that surcharge would need to be $10.95/L. The change in cost to the user, in terms of the original cost, is shown in figure 3.

Users consuming under the allocation amount (initially spending less than $21.40/wk) receive a rebate for the amount not consumed, and end up with lower overall cost. Consumers exceeding the allocation amount spend more than they initially did, and a small proportion of these users are increasing their spending by a significant amount.

Figure 4 shows the proportion of users consuming various amounts of fuel, and how this distribution changes under the FRMS allocation and pricing mechanism. Users consuming under the allocation amount maintain their original use, but once the allocation point is reached, users who exceed the allocation significantly reduce their consumption.

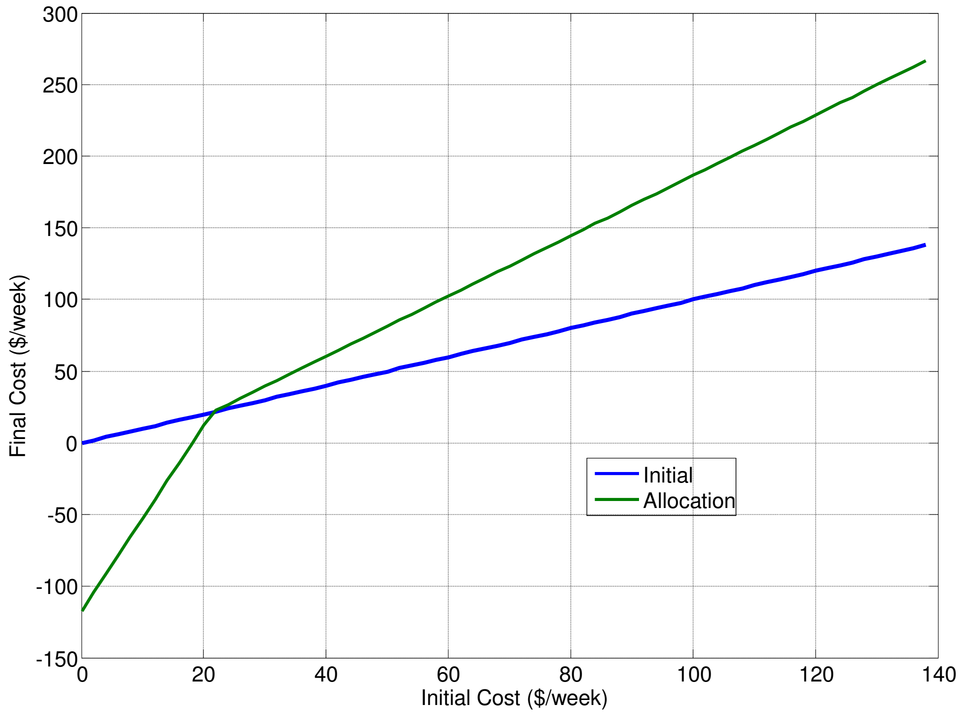

Figure 3. Change in cost to users

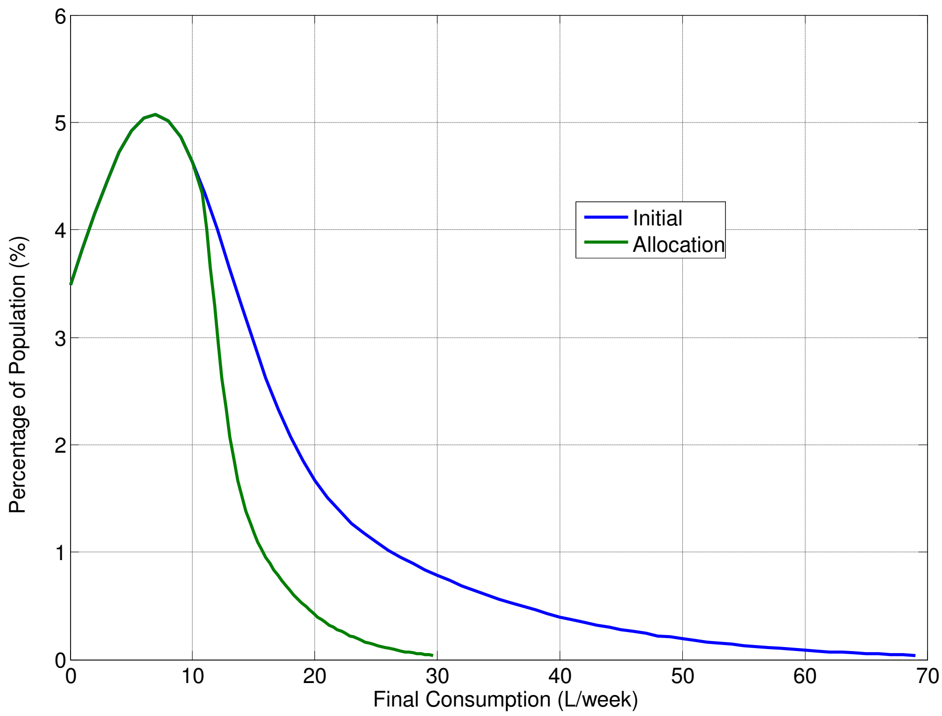

Figure 4. Consumption shift of users

The FRMS model provides some initial insight into the likely results of the demand management scheme. Population distribution of consumption, elasticity values, distributions of elasticity values and fuel prices can all be altered within the model to test different scenarios. The results presented show a somewhat extreme case, as users that were initially consuming less than the allocation amount would likely reduce consumption as well, reducing the surcharge value.

6. Summary and future work

This paper has documented the development of a system to manage fuel supply shortfalls, based on the examination of supplier-customer relationships in which the resource or service is constrained. The FRMS is a novel concept that employs ICT technology to ensure users have some access to fuel and facilitates consumer reductions in a shortage situation.

This research has raised a number of further questions that need answering. Possible future work;

- A focus group study to analyse the social perceptions of such a system.
- Model refinement and capability expansion.
- Examination of current ICT systems that could integrate with the FRMS.
- Examination of social, particularly equity, issues that arise when allocating fuel to users.
- Continued consultation with industry and government to develop the FRMS.

With the unpredicted and unprecedented recent price increases that have already lead to some fuel protesting throughout the world, a situation in which the fuel supply is constrained appears to be near, thus there is an urgent need for the continued development of the FRMS.

7. Acknowledgements

The authors are very grateful for the time provided, to discuss this work, by personnel from the National Energy Research Institute (NERI), Energy Efficiency and Conservation Authority (EECA), Ministry of Economic Development (MED), and the Ministry of Research Science and Technology (MoRST)

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This paper was peer reviewed and orally presented at the NERI ETS Symposium by Dr. Susan Krumdieck