THE FUNCTIONING AND POLITICS OF
THE SOLAR PV TECHNOLOGICAL INNOVATION
SYSTEM IN NEW ZEALAND:
A MIXED METHODS STUDY

BY

ANDREW BOYLES

A thesis

submitted to the Victoria University of Wellington
in partial fulfilment of the requirements for the degree of
Master's of Environmental Studies

Victoria University of Wellington

2013

Acknowledgements

There are many who deserve acknowledgement here, first and foremost my parents. I've missed you and someday I'll come home. Promise. The rest of my family and friends mean the world to me and have had to put up with my thesis conversations for far too long to not receive special mention here.

A very special thanks to Ralph Chapman, my supervising professor. This arrived here on a boat floating through your intellect, and I have nothing but respect and thanks for the time you gave in helping me achieve this.

For the rest of the Victoria experience and all my professors and classmates: It's been a true pleasure, memories for a lifetime. Ed and Jean specifically, I owe much of this to you. Working with you two has resulted in some of the best successes of my life- whether academic, road trip or by camp fire. Thanks for being great friends and donating time to this.

This Master's Thesis was made possible by a Rotary Ambassadorial Scholarship. A deep gratitude goes to Rotary International for this opportunity, and for being beacons of goodness in the world. Further, Dr. Morgan Williams has graciously offered wisdom and thought to this thesis and deserves mention for his role in my Master's experience.

To those who participated as interviewees in this thesis along with anyone else who has inspired, supported, believed in or doubted me: the fire you've helped stoke within me is appreciated more than you know. I wish I had time to thank you individually.

Abstract:

As human society nears the middle of the second decade of the 21st century, the cultivation of fossil fuels for energy shows little sign of large scale abatement. The need for large scale, worldwide transitions to more renewable energy is increasingly being emphasised by organisations such as the International Energy Agency. Some countries are leading the way and innovating in energy sources that are much more efficient, create industry, and bring many system benefits- like solar photovoltaic systems (PV).

Despite having insolation similar to, or greater than, many of those countries seeing vast uptake of solar PV, New Zealand is falling behind. New Zealand has policies in place that emphasise new renewable energy technology uptake and innovation; however these are not occurring with solar PV on a large scale. These contradictions underpin the examination in this thesis of the solar PV innovation system.

Using a Technological Innovation System (TIS) framework, this thesis examines the innovation system for solar PV in New Zealand. It identifies the achieved functionality in eight areas (Entrepreneurship, Knowledge Development, Networks, Guidance, Market, Legitimacy, and International Influences), and assesses the overall system's functioning to identify system weaknesses.

To build a more complete picture of the innovation system, this thesis also examines the political environment that influences the sustainable transition to more solar PV. The key stakeholders, political influences, priorities, preferences, and political dialogue are assessed using a quantitative questionnaire. The results of this political analysis contribute to a robust conclusion on the state and functioning of the solar PV TIS in New Zealand.

Key Words: solar PV, innovation system, politics, New Zealand, Sustainable Transitions

Table of Contents

Chapter One:

1.1- Introduction.....	1
1.2- Background.....	1
1.3- Preview.....	3

Chapter Two: Literature Review and Theoretical Background

2.1- Theoretical Background.....	5
2.2- Sustainable Transitions.....	5
2.3- Four Frameworks for Studying Sustainable Transitions.....	6
2.4- Functions of Technological Innovation Systems.....	8
2.5- Research Gap: Politics of Sustainable Transitions.....	10

Chapter Three: Research Context

3.1- New Zealand Context: Energy.....	12
3.2- New Zealand Context: Solar PV.....	14
3.2.1- New Zealand PV Industry.....	14
3.2.2- New Zealand PV Potential.....	14
3.2.3- Perceptions, Barriers, and Role in Gov't Strategy.....	15
3.3- New Zealand Context: Innovation and Governance.....	16

Chapter Four: Research Questions and Methodology

4.1- Research Questions.....	20
4.2- Methodology.....	20
4.3- Research Process.....	21

Chapter Five: Research Findings and Analysis- Functions

5.1- Analysis of Functions: Function 1- Entrepreneurship.....	25
5.2- Analysis of Functions: Function 2- Knowledge Development.....	28
5.3- Analysis of Functions: Function 3- Networks.....	31
5.4- Analysis of Functions: Function 4- System Guidance.....	34
5.5- Analysis of Functions: Function 5- Market.....	41
5.6- Analysis of Functions: Function 6- Resources.....	45
5.7- Analysis of Functions: Function 7- Legitimacy.....	48
5.8- Analysis of Functions: Function 8- International Influences.....	50
5.9- Overall Innovation System Functioning Analysis.....	52

Chapter Six: Research Findings and Analysis- Politics

6.1- Quantitative Questionnaire.....	57
6.2- Overall Questionnaire Analysis.....	69

Chapter Seven: Interpretation.....

Chapter Eight: Discussion and Conclusions

8.1- Literature Implications.....	72
8.2- Research Limitations.....	73
8.3- Further Research.....	73
8.4- Conclusions.....	74

References.....

Appendix:

Interview Schedule (Appendix 1)	
Interview Framework and Questions (Appendix 2)	
Questionnaire Template (Appendix 3)	

List of Figures

- Figure 1- Functions TIS Research Process p. 10
- Figure 2- Convergent Parallel Design p.21
- Figure 3- Questionnaire Responses- Question 1 p. 58
- Figure 4- Questionnaire Responses- Question 2 p. 59
- Figure 5- Questionnaire Responses- Question 3 p. 60
- Figure 6- Questionnaire Responses- Question 4 p. 61
- Figure 7- Questionnaire Responses- Question 5 p. 62
- Figure 8- Questionnaire Responses- Question 6 p. 63
- Figure 9- Questionnaire Responses- Question 7 p. 64
- Figure 10- Questionnaire Responses- Question 8 p. 65
- Figure 11- Questionnaire Responses- Question 9 p. 66
- Figure 12- Questionnaire Responses- Question 10 p. 67
- Figure 13- Questionnaire Responses- Question 11 p. 68

List of Abbreviations

NZ- New Zealand

PV- photovoltaic

TIS- technological innovation system

R&D- research and development

kWh- kilowatt hours

c/kWh- cents per kilowatt hour

BOS- balance-of-system components

MLP- Multi-Level Perspective

NZEECS- New Zealand Energy Efficiency and Conservation Strategy

CRI- Crown Research Institute

OECD- Organisation for Economic Coordination and Development

DSIR- Department of Scientific and Industrial Development

RMA- Resource Management Act 1991

LGA- Local Government Act 2002

EECA- Energy Efficiency and Conservation Authority

MBIE- Ministry of Business, Innovation, and Employment

NERI- National Energy Research Institute

MP- Member of Parliament

SEANZ- Sustainable Energy Association of New Zealand

CHAPTER ONE: INTRODUCTION

1.1 Introduction

At this stage of human and societal evolution, there are massive issues that need confrontation in order to secure a more sustainable future. In many aspects of modern life, unsustainable methods exist with negative environmental, social and economic effects: transportation, fossil fuel energy generation, food supply, among many others. These issues are compounded by the incremental nature of societal change caused by entrenched “user practices and life styles, complementary techniques, business models, value chains, organizational structures, regulation, institutional structures and even political structures” (Markard et al. 2012 p.955). The field of sustainable transitions has arisen to address the issue of how to drive technological innovation to promote more sustainable outcomes in response to the aforementioned negative effects.

Smil (2008, 2010) notes that these transitions to new technologies must compete against the predictability, availability, knowledge, and marketing of less-efficient predecessors, and therefore take long periods of time to achieve large market shares. Fouquet (2010) makes the case that although these transitions are often slow, the *urgency* for more rapid innovation and transition to low-carbon sustainable energy forms is high. After examining past transitions, Fouquet (2010) notes that government policies have historically played a strong role in combatting the forces that inhibit these sustainable transitions.

Against this backdrop, this thesis examines one aspect of sustainable transitions: renewable energy technologies and specifically solar PV. Tyagi et al. (2013) review the latest solar PV research and trends, and note that the market is growing worldwide at a rate of 35-40%, largely at the hands of government support. It is under the assumptions that there exists untapped potential for solar PV in New Zealand, there are opportunities for PV industry growth and innovation, and there are benefits for the whole of New Zealand in increased solar PV uptake that this thesis is undertaken. It is acknowledged that there are many other renewable energy options in New Zealand, however the development of solar PV, and in particular the encouragement of innovation in this sector, is the focus of this study.

1.2 Background

All energy that is currently utilised by human society is derived from the sun. Fossil fuel deposits are even called “buried sunshine” by fossil fuel industries (Dukes 2003, p. 33). These fossil fuels that have been utilised for energy purposes are highly inefficient uses of solar energy, with coal formed from plant material less than 10% efficient and oil and natural gas from phytoplankton at less than .01% (Dukes 2003, p.41).

With current fossil fuel deposits dwindling and the resulting increase in costs and environmental damage from their use, a sustainable transition to energy generation that directly harnesses the sun’s power in a cleaner, cheaper, and more efficient way could bring many benefits. This could come in the form of solar PV energy systems. Transitioning to solar PV will develop the solar PV

industry resulting in economic benefits, lessened costs for energy consumers, and eased burdens that current energy use puts on our environment and infrastructure (Hoffmann 2006).

Distributed solar power is an increasingly economic and realistic alternative to the current fossil fuel-dominated, centralised modes of electricity generation (Bradford 2006). Whether grid-connected or stand-alone, Bradford (2006) makes the case that solar PV will inevitably become economically viable, and preferred, in the near future. The economics of solar power show that as current energy prices rise and PV technology becomes cheaper, solar photovoltaic energy is an alternative way forward that has many benefits. Bradford (2006) discusses many of these such as: more stable energy supply, less environmental damage, long operating life with low maintenance, modular energy generation, and lower costs, among others. In addition to these benefits, economic growth can arise from innovation and entrepreneurship in renewable energy (Walsh 2012). Economic growth can be an additional, powerful incentive for governments to adopt more policies to encourage innovation in the solar PV industry.

Renewable energy experience curves show that as a technology is adopted in greater volumes, prices per unit of output (kWh) will decrease (Tyagi et al. 2013). Tyagi et al. (2013) note that solar PV module prices have decreased by over a third in the past five years alone. The experience with solar PV proves that the more a technology is accepted, adopted, and produced or consumed, the more its costs will decrease. Harmon (2000) makes the case that only through increased investments into research and development (R&D) and resulting uptake of solar technologies can prices be further reduced to make solar even more economic.

Harmon (2000) noted the difference between the experience curve of the PV panels (40-60% of system costs) as well as the balance-of-system parts (all other aspects of solar PV systems: mounting frames and support, inverter or electrical components).

Harmon (2000) found that PV panels will continue price reductions through increased modular efficiencies, manufacturing experience, and economies of scale. As an importer of PV panels, New Zealand is unlikely to experience any innovation in this area.

The picture for balance-of-system (BOS) components, however, is different for New Zealand. These components are not likely to experience price reductions through cheaper parts, but rather through the experience of installers creating greater efficiencies and standardisation of installation processes. Experience here can result in cost reductions “equal to or even greater than that of modules” (Harmon 2000, p. 13).

As this study will show, experienced installers are a key determinant of the uptake of solar PV. Therefore, innovation and entrepreneurship in the PV sale and installation sectors can help realise overall cost reductions for the technology. These cost reductions will increase the demand for PV and have the potential to drive the market and uptake of this renewable, efficient technology in New Zealand. This notion of innovation improving the costs and driving demand or uptake is inherent throughout this thesis.

According to Walsh (2012), New Zealand is seen as an “innovation nirvana” for renewable energy systems. This is due to its present market (pull) eco-sophistication as well as availability of technology (push).

An Innovation Nirvana commercialization environment, and sequential innovation processes in renewable energy systems can be expected to be met by wide-spread acceptance and demand, limiting the economic risk and allowing for commercialization through the use of venture capital, equity investments, or through the acquisition of their innovation by larger incumbent energy firms (Walsh 2012 p.7).

However, there are currently few policies in place in New Zealand to encourage both producers and consumers to specifically transition to solar PV despite the benefits that distributed solar power offers. According to Kelly (2011), New Zealand has ample amounts of sunshine (insolation) to support solar PV use; even more so than Germany, a world leader in solar PV use. Kelly also notes that the only support given for solar technology systems in general was a modest subsidy given to solar hot water systems, which ranged from NZ\$300-500, and has now been discontinued. This thesis explores how policies for solar PV might contribute to innovation and entrepreneurship and potentially allow New Zealand industry, not to mention consumers, to reap the benefits of solar PV energy use sooner.

The World Economic Forum's Global Competitiveness Report provides a way to compare countries' levels of innovation and competitiveness (Tang and Koveos 2004). In looking at the report from 2011-2012, a few important facts about New Zealand stand out. First, New Zealand's overall competitiveness ranking is falling (World Economic Forum 2011). But, there are encouraging indicators as well. The report shows that New Zealand is "innovation driven" and has many factors in place to increase its overall competitiveness rankings. However, it is currently underperforming compared to other OECD nations. The report also shows New Zealand's governmental institutions are ranked third best in the world, so a path forward would be to use these institutions to create policies to encourage innovation and entrepreneurship.

Overall, the pace with which solar PV is being taken up worldwide suggests that transitioning to solar PV energy has benefits for producers and consumers and it certainly has climate change mitigation benefits for the environment. New Zealand is a prime location for innovation and entrepreneurship in renewable energy, and movement along the experience curve through further innovation and entrepreneurship in solar PV energy is likely to increase the many system benefits it can provide.

New Zealand's worldwide competitiveness ranking is currently falling, but the country appears to have an opportunity to utilise its highly-ranked governmental institutions to stop its competitive downslide. Therefore, policies to encourage innovation and entrepreneurship in general, but also specifically for solar PV energy, could be a pathway forward with many system benefits.

1.3 Preview

This thesis examines the sustainable transitions literature and utilises the framework of "functions of technological innovation systems" to assess the solar PV innovation system in New Zealand. Analysis of this system can offer insights into how the system can be better guided towards increasing innovation and therefore uptake of a particular technology, which in this case would lead to more sustainable energy use in New Zealand. Key to this is a thorough understanding of the politics and political structure that Markard et al. (2012) note can contribute to slow or incremental change. These aspects will be assessed to give a more complete understanding of the solar PV innovation system and its context.

The next chapter of this thesis provides the theoretical and literature backdrop to the sustainable transitions field, and specifically the functions of TIS framework. It highlights the usefulness of that framework, and gives insights into research gaps that this thesis addresses in the area of politics of sustainable transitions. Chapter Three gives a more detailed examination of the New Zealand energy, solar PV, and policy context to show the relevancy of this study and why it was undertaken. Chapter Four describes the methodological approach and research participants. Chapter Five details the findings and analyses the functioning and gives overall technological innovation system issues and conclusions. Chapter Six analyses the data gathered on the politics of the system. Chapter Seven brings together the findings from the functionality and politics of the innovation system. The last chapter situates the findings in the literature, assess the methodology of the research, and gives final highlights of the thesis.

CHAPTER TWO: LITERATURE AND THEORETICAL BACKGROUND

2.1 Theoretical Background

This thesis is based in the emerging literature of sustainable transitions, and specifically the functions of technological innovation systems (TIS) approach. This study emphasises the politics underlying the system, reflecting the current agreement in the literature that government policies have a strong role in encouraging renewable energy uptake and innovation.

Martin and Rice (2012) describe the literature that persuasively theorises that policies are the best way to address the barriers to renewable energy in general, but also specifically for solar PV. This is due to the fact that most renewable energies face major institutional and economic challenges that can only be overcome by policy, as opposed to free market forces. This reflects arguments that new energy technologies face competition with entrenched technologies and industries (e.g. coal, oil, nuclear, natural gas) that were all heavily subsidised in the early stages of their market penetration and are still recipients of current subsidies (Tyagi et al 2013, Sovacool 2009, Lund 2007).

Should renewable energy technologies like solar PV receive similar policy guidance and support, Branker and Pearce (2010) make the case that renewable energy technologies can provide new revenue streams for governments from taxation, carbon offsets, sales, and also from health, environmental, and economic savings that arise from using less fossil fuels.

These benefits would seem to be spread community-wide. Zweibel (2010) makes the argument that supportive policies for the long-term societal good are already made for infrastructure like roads and hospitals, which are not explicitly for short-term financial or economic benefits, and therefore policies to support solar PV should be seen in this same light. This alludes to the fact that many governments view solar PV as a strictly economic case, including those in New Zealand.

It is clear from the literature that policies to address the barriers facing solar PV are necessary to overcome the entrenched nature of energy systems and can have many co-benefits. For those reasons, the major focus of this research will be centred on the theory that governmental policies can increase the uptake of solar PV in New Zealand.

2.2 Sustainable Transitions Background

Innovation and advanced renewable energy generation can be seen as occurring within an “innovation system”. This systems view of technology and innovation will be the main theoretical lens for this thesis with the aforementioned understanding that policy solutions have a potentially significant role in developing the innovation system of solar PV in New Zealand.

Innovation systems and the emerging field of “sustainable transitions” have roots in the literature on technological (or technical) innovation and socio-technical systems. Transitioning to significantly more solar PV would mark a distinct change in the electricity generation status quo, and should be seen as a major technical transition. For this reason, it is important to understand the many different factors that interact in a socio-technical system to allow policy to be formulated that reflects the realities of the system.

Schroeder (2010) identifies much of the key literature relating to socio-technical systems and technological innovation. In it, he notes that any study to guide a transition in technology requires thorough understanding of the aspects of the system within which that technology occurs. Social institutions such as legislation, strategies, incentives, norms, and behaviours are just as important to understand as the technology's form and capabilities in the system.

For this thesis, it will be crucial to gain an understanding of both social and technical system characteristics as they relate to solar PV in New Zealand. With these, a thorough analysis can be conducted to address what areas should be targeted for effective policy measures to allow a sustainable transition to more solar PV innovation and uptake.

Combining the aforementioned theories on socio-technical regimes and systems, and technical transitions has recently become known as the field of "sustainable transitions" (Markard et al. 2012, Van Den Bergh et al. 2011). This field has arisen due to the widespread agreement that a "market failures" approach to understanding these transitions simply does not explain thoroughly enough why transitions do or do not occur (Jacobsson and Bergek 2011, Negro et al. 2012). Instead, using a systems approach, as the sustainable transitions field advocates, allows for the identification of "system weaknesses" or "system failures" rather than "market failures" (Jacobsson and Bergek 2011, Musiolik et al. 2012, Bergek et al. 2008).

Sustainable transition analyses look at the many actors (individuals, firms, policy makers, R&D, formal networks) and institutions (formal and informal regimes, policies, behaviours, and norms) that interact to influence transitions. They identify these system failures, and find ways to leverage those weaknesses into strengths. Weber and Rohracher (2012) give a framework for understanding these system failures, and separate them into structural system failures and transitional system failures.

Structural system failures include elements such as:

- infrastructure failures (physical and knowledge)
- institutional failures (hard: e.g. lack of policy, weak policies; and soft: e.g. social norms, behaviours)
- network failures (strong: e.g. technological lock in, dependence on established actors; and weak: e.g. limited interaction amongst actors prevents knowledge diffusion)
- capability failures (not enough resources at firm and actor level to encourage innovation)

By addressing these weaknesses and strengthening the system, innovation can increase and support the diffusion of new technologies, which is the main goal of the sustainable transitions field. These strengthening actions can be termed systemic instruments (Wieczorek et al. 2010). This thesis will use the sustainable transitions approach for analysing the system's weaknesses and identifying systemic instruments to address them.

2.3 Four Frameworks for Studying Sustainable Transitions

There are four accepted frameworks for studying and analysing sustainable transitions, and therefore identifying system weaknesses. These are the multi-level perspective (MLP), strategic-

niche, transitions management, and technological innovation systems (TIS) frameworks (Markard et al. 2012, Van Den Bergh et al. 2011).

Multi-Level Perspective (MLP): According to Markard et al. (2012), this framework concentrates on activities at three levels: niche, regime, and landscape, working from the particular and micro up to the macro. These activities are cross influencing and dynamic. Activities at higher levels affect the development of niches, and once niches grow those, in turn, influence the higher levels. Van Den Bergh et al. (2011) note that the MLP's main policy contribution is to find ways to align user practices with new technologies. This allows the niches to grow into more dominant regimes (De Haan and Rotmans 2011).

Strategic-Niche Management (SNM): According to Markard et al. (2012), niches are specific markets and applications that involve a new technology. Nurturing these niches can allow them to grow into larger segments of the overall socio-technical system. The framework holds that understanding how social learning and networking occur can lead to a bottom-up approach to technology development. This view on sustainable transitions involves understanding how niches develop in relation to existing technologies and regimes.

Transition Management: The transition management approach has a strong basis in complex systems theories and governance (Markard et al. 2012). The approach attempts to analyse practically the interactions and governance implications of multi-stakeholder systems, and find ways to develop coalitions and monitor the influence that different policies have in action. Van Den Bergh et al. (2011) note that active experimenting with different policies, and reflexive judgement of them, play a key role in the transition management framework.

Technological Innovation Systems (TIS): Markard et al. (2012) state that TIS approaches attempt to identify emerging technologies and find the institutional and organisational changes that allow technologies to emerge. Through identifying key processes, or functions, the system can be analysed to see how changes can be brought about. Markard et al. (2012) mention that the TIS approach's ability to identify key drivers and barriers is one of its main strengths. TIS's main goal is to identify system weaknesses or failures, and find policy responses (Van Den Bergh et al. 2011, Markard et al. 2012). Jacobsson and Bergek (2011) show this framework has the ability to identify many different system weaknesses and is therefore a strong approach for finding ways to create change. Jabri (2011) notes that the concepts of vicious and virtuous cycles play a large role in TIS because of the way the functions are interrelated and co-influencing.

Of these, the TIS approach has solidified itself as a main pathway for a comprehensive analysis of the dynamics of the system. Specifically, Jabri (2011) sets out a chart listing the characteristics of many of the frameworks, and argues the TIS approach is the only framework that allows for an analysis that is technology-specific, includes multiple actors, is dynamic, allows for identification of difficult interactions, allows for long range analysis, includes research and development (R&D), and has a focus on diffusion of the technology. Thus, the TIS approach is a richer sustainable transitions framework compared to the others because of its ability to measure more processes and relationships. For those reasons, the TIS framework is the method used in this thesis.

2.4 Functions of Technological Innovation Systems

Specifically, the functions approach to TIS has emerged as a viable way of using the TIS conceptual framework in a practical analysis of specific systems (Bergek et al. 2008, Hekkert and Negro 2009, Markard et al. 2012, Jabri 2011, Van Den Bergh et al. 2011). The accepted form of these analyses of functions uses seven separate functions that are dynamic processes themselves, but also interact with each other to influence the level of innovation a system produces.

These functions originally appeared in Bergek et al. (2008), and have since been further accepted as a viable and appropriate approach to using the TIS framework to study sustainable transitions (Jacobsson and Bergek 2011, Markard et al. 2012, Van Den Bergh et al. 2011, Hekkert and Negro 2009, Jabri 2011.)

The seven main functions of the system are:

Entrepreneurship- Role is to create business opportunities to take risks relating to innovation, and to develop knowledge by learning through doing. The amount and type of entrepreneurship in a system is a strong indicator to the strength of the TIS.

Knowledge Development- Role is to develop knowledge (a key system resource) through R&D, as well as through learning by doing. This also applies to the amount of knowledge consumers have about a specific technology as well as other actors like policy makers.

Knowledge Diffusion Through Networks- The strength and availability of academic and professional networks has a strong influence on how much knowledge there is, as well as how that knowledge can be coordinated into increasing innovation and diffusion.

Guidance of the Search- How the technology is presented to the public through industry and policy impacts the innovation of the technology. Visions for the future are also key components of guidance.

Market Formation- Understanding market size, supply, and demand is necessary for understanding the ability for a system to increase innovation. User preferences and modes of technological use are key components of understanding the market for a technology.

Resource Mobilisation- Financial and human capitals are crucial for the ability of a system to induce innovation. Availability of funds of industry, research, and consumers, raw materials, skilled employees, and changes in these areas are fundamental to understanding the functioning of the overall system.

Legitimacy- Understanding the level of support a given technology has, and how that support can be used to further legitimise a technology is also a key determinant of innovation. Advocacy groups and lobbying are a key aspect of developing legitimacy.

(Bergek et al. 2008, Jabri 2011)

Jacobsson and Bergek (2011) give a description of the seven functions of TIS and how each can be approached through analysing the system (institutional, network, and actor) weaknesses, and what implications for policy these hold.

Jabri (2011) proposes adding an eighth function, which brings into the analysis the influence of the larger international system for that selected technology. It is important to understand the larger context that the specific TIS is situated within, since many factors such as overseas prices of technology, expectations, and policies can have direct influences on the specific TIS. This eighth function will be included in the analysis of the solar PV innovation system in New Zealand.

Jabri (2011) mentions that this can be seen as a bridge between the TIS approach and the MLP approach, which has been espoused as a way forward in sustainable transitions literature using complementarities of the different frameworks to provide a more thorough analysis of the system (Weber and Rohrer 2012). Weber and Rohrer (2012) combined the TIS and MLP perspectives in their system failures framework described in sec. 2.2.

Bergek et al. (2008) explain a process for analysing the seven (or in this thesis, eight) functions of a given system. This will be the basic framework and process used to conduct the research in this thesis.

In Bergek et al. (2008), the steps are listed in a numbered order, although it is noted that the process is not linear and is iterative:

Step One: Identify the specific TIS in focus, set the baseline for analysis

Step Two: Identify the system's structure (actors, networks, institutions)

Step Three: Identify the achieved functionality of the system (e.g. how the system's functions are currently operating)

Step Four: Apply a normative basis to each of the seven functions to determine the "goodness" of the function

Step Five: Identify drivers and barriers to making changes to the functions (system strengths and weaknesses)

Step Six: Specify how weaknesses can be influenced by policy

Figure 1: Functions of TIS Research Process (Adapted from Bergek et al. (2008) and Jabri (2011))

As mentioned above, this process has been confirmed as a robust and useful means of analysing TIS functioning (Hekkert and Negro 2009, Jacobsson and Bergek 2011, Markard et al. 2012, Van Den Bergh et al. 2011, Jabri 2011). Once these functions are analysed, system weaknesses should emerge and provide targets for policy responses, which are widely accepted as the best, and often the only, way to address system weaknesses to spur innovation (Jacobsson and Bergek 2011, Bergek et al. 2008, Negro et al. 2012, Meadowcroft 2011).

A number of recent articles have discussed further research areas with a specific focus on the TIS approach within the sustainable transitions literature. Many of these discuss the need for a more thorough understanding of the politics that influence the system (Markard et al. 2012, Van Den Bergh et al. 2011, Meadowcroft 2011, Musiolik et al. 2012).

This thesis will identify the system weaknesses of solar PV in New Zealand and go on to explore the politics of the system as well. The reasons for doing so are explained below.

2.5 Research Gap: Politics of Sustainable Transitions

Politics is the constant companion of socio-technical transitions, serving alternatively (and often simultaneously) as context, arena, obstacle, enabler, arbiter, and manager of repercussions (Meadowcroft 2011, p. 71).

Understanding the politics of the transition process is seen as a critical need in developing these relatively new frameworks of sustainable transitions, as the political dimension is recognised as significant but has been somewhat neglected in past research (Markard et al. 2012, Meadowcroft 2011, Jacobsson and Bergek 2011). Meadowcroft (2011) mentions that sustainable transitions are in and of themselves a political process, and there is no escaping the politics if a true system analysis is to be undertaken. There are many avenues that still need to be explored relating to politics in the literature, as follows.

Markard et al. (2012) mention the need to understand where power resides, and how it is exerted within the transition process. They also discuss the need to know whose voices remain unheard, and how the balance between technology-specific and technology-neutral policies is decided upon. Van Den Bergh et al. (2011) notes that a full understanding of what criteria are used in policy decision-making and how those are chosen are concepts that need to be explored.

Meadowcroft (2011) mentions that understanding the resistance strategies of transition opponents and their influence on policy is important. He states it is also crucial to understand the differing priorities of decision makers and their views on the roles of government. Lastly, he claims that finding how sustainable transitions can be incorporated into existing political ideologies to create a better environment for innovation needs to be understood.

By focussing on these areas of politics and how they affect the different functions of the solar PV TIS, a new pathway forward in the sustainable transitions literature can be forged. It is clear that these issues are pertinent to system functioning, and gaining an in-depth view of the politics of policy can result in a stronger analysis of the system.

Addressing this aspect will make the research conclusions of this paper more rooted in the actual functioning of the system, and create more robust findings that combine functional and political analyses of the innovation system. It will also address the gap in the sustainable transitions literature relating to politics, and provide insights for further research.

CHAPTER THREE: RESEARCH CONTEXT

3.1 New Zealand Context: Energy

Understanding the energy situation in New Zealand is important to situating solar PV innovation and uptake. This section will briefly detail the current energy landscape, discuss the makeup of the electricity sector, and detail the main national energy policy documents that are relevant to the content of this study.

According to the NZ Energy Data File (2012), renewable energy has recently made up 39% of the total energy supply in New Zealand, and 77% of the total electricity supply. “Hydro (in 2011) was the major source of electricity generation at 58%, followed by gas at 18%, geothermal at 13%, with coal, wind, wood, biogas, oil and waste heat making up the balance” (NZEDF 2012, p.11). Solar PV is not even mentioned as a current source of electricity generation due to its small scale.

The total energy use by sector is dominated by transport (38.4% of total energy) and industrial (35.1% of total energy) uses. Residential and commercial sectors of New Zealand make up the balance at 11.9% and 8.9% of total, respectively (NZEDF 2012). Solar PV can play a role in all of these areas; especially the industrial and commercial sectors where main peak energy demand coincides with peak sun hours during the work day. As the technology progresses, solar PV can also be utilised in the transport sector (electric vehicles), as well as utilised more economically at the residential scale with improvement in storage technologies and retail tariffs.

The NZ Energy Data File (2012) notes that electricity demand is expected to grow at a rate of 1% per year on average out to 2030 under business-as-usual conditions. It notes that new generation will be needed to meet this increase in demand. As such, solar PV could have a role to play in increasing the electricity generation capacity in New Zealand. The picture of gradual but slow demand growth, together with falling costs of solar PV production, suggests a growing market opportunity for solar PV.

The buying and selling of wholesale electricity in New Zealand is done via a “pool” where generators sell their electricity to the pool and retailers compete to buy electricity at half-hourly intervals. There are five major generators/retailers in New Zealand that together comprise 95% of the retail market: Genesis, Contact, Meridian, Mighty River Power, and TrustPower (NZEDF 2012). The retail electricity prices for consumers in New Zealand in 2011 averaged as follows, in c/kWh: residential sector- 26.23; commercial sector- 15.85; and industrial sector- 9.35 (NZEDF 2012). These rates have been steadily increasing over the last ten years to various extents, with the residential sector showing the largest increase in electricity prices (NZEDF 2012). These increasing prices have strongly motivated interest in the future of solar PV as a viable option¹.

The few relevant national policy documents that pertain to renewable energy generation: the National Policy Statement on Renewable Energy Generation 2011, the NZ Energy Strategy 2011-2021, and the NZ Energy Efficiency and Conservation Strategy (NZECS) 2011-2016.

¹ As this study was being completed, the Empowering NZ proposal by the Labour and Green Parties to lower residential electricity tariffs was announced. However, its timing has not allowed its implications for solar PV to be addressed here.

The National Policy Statement (NPS REG 2011) states in its Preamble that there are two main energy challenges that need to be addressed. The first is to respond to climate change by producing and using cleaner energy to reduce greenhouse gas emissions. The second is to deliver “clean, secure, affordable energy while treating the environment responsibly” (NPS REG 2011, p.3). Solar PV aligns with both these main challenges, and thus should be considered a significant energy source for the future in New Zealand.

In addition, the NPS REG (2011) makes a number of other statements that show how solar PV fits into this plan, for example by increasing diversity of supply as well as:

- renewable energy generation, regardless of scale, plays a vital role in the well-being of New Zealand, its people, and its environment.
- reaffirming the central government’s goal of 90% renewable electricity generation by 2025.
- decision makers shall recognise and provide for the national significance of renewable energy generation and its benefits which include: maintaining and increasing electricity generation while avoiding or reducing GHG emissions, maintaining or increasing security of electricity supply at all levels by diversifying the type and location of electricity generation, and using renewable natural resources over finite resources.

The New Zealand Energy Strategy 2011-2021 states that the central government’s top priority is to grow the New Zealand economy to deliver greater prosperity, security, and opportunities, and that energy is essential to this. Once again, solar PV appears to fit well with this Strategy on a number of accounts:

- capturing the upside of existing and *emerging* (emphasis added) renewable technologies is a source of competitive advantage to New Zealand.
- New Zealand’s future competitiveness will, in many sectors of the economy, require *innovative solutions* (emphasis added) in the sources and uses of energy (NZ ES 2011-2021)

From this it is clear that innovation in solar PV is relevant to the long term Energy Strategy of the New Zealand government.

The third major central government policy document that alludes to solar PV’s alignment with government objectives is the companion to the long term Energy Strategy, the New Zealand Energy Efficiency and Conservation Strategy (NZECS) 2011-2016. This document details a group of government policies to be pursued:

- information measures: targeted to consumers and businesses
- incentive measures: offer funding or other financial products to direct investment and build capability
- measures to develop codes and standards: designed to create confidence in new products and effective practices
- research and development measures: to support innovation

All these policies in the NZEECS could greatly benefit solar PV's innovation system in New Zealand, as will be demonstrated in later sections of this thesis.

All of the aforementioned government policies show the role government sees itself playing in regard to renewable energy in New Zealand. The examination of these documents show that solar PV innovation could be a significant solution as it hits many targets set by the New Zealand central government. However, as this thesis will demonstrate, these actions are not being pursued with vigour with respect to solar PV in New Zealand.

3.2 New Zealand Context: Solar PV

Understanding the current state of solar PV in New Zealand will give insights and lay the framework for why this thesis has been undertaken. It is generally acknowledged that New Zealand is developing and using far less solar PV than other climatically and developmentally similar countries. This is the main thrust for investigating the current state of the solar PV innovation system in New Zealand.

3.2.1 New Zealand PV Industry

In New Zealand, there are a number of local distributors who purchase their PV modules directly from overseas, mainly from Australia, Europe, and Asia. This results in PV module prices being dependent on the international market conditions. There is currently limited local manufacturing of PV modules (IT Power 2009). According to IT Power (2009), the companies involved in the PV sector are generally small and diverse, with the majority in New Zealand working in installation or supplying imported products. That report noted there were approximately 100 companies regularly working in those two areas, with employment of around 225 people.

As mentioned in sec. 1.1, innovation in the supply and installation stages has potential to achieve significant PV system price reductions. This thesis focusses on innovation in those areas since those are the main existing industry elements in New Zealand.

3.2.2 New Zealand PV Potential

According to the report for the Ministry of Economic Development concerning PV potential in New Zealand done by IT Power (2009), there are four main applications where PV has opportunities to be deployed:

- large scale generating plants or “solar farms”
- medium scale installations for commercial and industrial uses/daytime load reduction
- small residential grid-tied systems
- off-grid systems

Of those, the large scale applications are not seen as effective without some type of financial incentives until after 2035; the commercial and industrial scale is expected to be cost effective without support around 2020; the residential market can become cost-effective sooner due to

higher residential electricity prices; and the off-grid market is considered cost-effective at current prices and is the original mainstay of the PV market in New Zealand (IT Power 2009).

3.2.3 Perceptions, Barriers, and Role in Government Strategy

Despite the common perception that the solar resource in New Zealand is not adequate to support high levels of solar PV, the facts show that most of New Zealand receives greater insolation than do world leaders in installed solar PV, in particular Germany and Japan (NIWA 2009). According to NIWA's EnergyScape Review (2009), many New Zealand homes are "annually exposed to 20-30 times more energy from the sun than they use in electricity or gas" (p.7 Section 2).

So, the question becomes, "why is New Zealand not taking advantage of this great renewable resource?" The EnergyScape Review (NIWA 2009) notes that this may be due to lack of incentives, historically cheap electricity, and a perception that New Zealand has poor solar resources.

That same report notes the market for solar PV in New Zealand is potentially very large, but a number of barriers, other than the aforementioned, exist to its greater uptake. These are listed on page 19 as:

- large capital costs compared to alternative energy forms/electricity generation
- these capital costs are seen as too high, and not often viewed as a long-term investment
- trust among customers towards the supply industry is perceived to be low
- issues with split incentives of building users vs. building owners
- issues with applying for building consents
- visual acceptance of a system on the roof is still lacking.

Research and development in the area of solar technology in New Zealand "reflects the current policy approach of letting the market take care of it" (NIWA 2009, p.33). NIWA (2009) notes that investment in research and development is lacking, and it is unlikely that significant funding will materialise under current political circumstances. This policy approach leaves New Zealand "as an importer of technology and may lead to missed business opportunities" (NIWA 2009, p.33). This policy context is one potential reason why innovation in solar PV in New Zealand is lacking.

In New Zealand's long term Energy Strategy 2011-2021 it is noted that, "We (New Zealand) pride ourselves on being nimble and quick to adopt new technologies and to develop new technologies. We have real opportunities to use newer, emerging technologies, such as solar"(page 2). Combined the previous policy approach, this suggests a "hands-off" market orientation on the part of the current government, but at the same time an expectation of nimbleness and innovation.

Encouragingly, it has also been noted that "harnessing solar resources is the field with the most opportunity to result in a paradigm shift in energy utilisation in New Zealand" (NIWA 2009). So there is recognition at the central government level and from its Crown Research Institutes (CRI) that despite the barriers, solar PV has strong potential and benefits.

However, in the Ministry's New Zealand Energy Outlook (2011), there is *no mention* of solar PV in the reference scenario that depicts likely future electricity generation in New Zealand. This is despite PV's rapid growth in use worldwide, falling prices, New Zealand's solar potential, the central government priding itself on being "nimble" in adopting new technologies, and some recognition at the central government level that use of solar PV can result in both economic growth and a "paradigm shift in energy use".

In examining the worldwide picture of solar PV use and uptake, it appears that some countries such as Germany, Australia, Japan and to a lesser extent the U.S. have much stronger motivations to transition to solar PV compared to New Zealand. Each of these countries, representing a spectrum of available insolation, has instituted a policy or series of policies to greatly boost the uptake of solar PV and achieve the benefits it provides.

This picture sets the context for this thesis to explore the solar PV innovation system in New Zealand. The challenge is to understand why, despite evidence of the benefits of solar PV and governmental policies that in theory should support its innovation and use, is there not more motivation to it being adopted at a much larger scale in New Zealand?

3.3 New Zealand Context: Innovation and Governance

This section looks at the innovation and governance landscape in New Zealand to assess its implication for this study of the solar PV innovation system.

For much of its history, New Zealand has understood the importance, and benefits, of innovation in new technologies and practices (Narayan 2012). A recent article by its current Prime Minister, John Key, affirms New Zealand's, and the current central government's, dedication to innovation as a means to gain and maintain a competitive edge in the world (Key 2012). Many government documents and official publications also emphasise the importance innovation has to the future of New Zealand (Narayan 2012, Statistics NZ 2011).

However, these calls for innovation appear to be largely going unheeded as New Zealand is falling further and further behind other similarly sized OECD nations in measures relating to innovation (Narayan 2012, Hilhorst 2012). Hilhorst (2012) specifically notes that New Zealand is trailing its peers, according to experts, due to underinvestment by the government. That article states that New Zealand invests only 60-70% of what other similarly sized OECD nations' governments spend on facilitating innovation and R&D.

Historically, the central government in New Zealand played a major role in directing and influencing innovation and institutional research (Narayan 2012). The Department of Scientific and Industrial Research (DSIR) was the main vehicle of innovation in the central government from its creation in 1926 until it was restructured into ten Crown Research Institutes (CRIs) in 1992. It enjoyed robust budgetary financing from the central government for most of that period until the mid-1980s, when it was corporatised as part of the neoliberal reforms that were mirrored in other central government-funded innovation activities, such as investment in tertiary education (Narayan 2012). Narayan (2012) argues that beginning in the early 2000s, the government recognised that privatisation of innovative activities was leading to adverse outcomes and there was a need to begin

taking a larger role in innovation strategic planning. This research sheds light on the role, or lack thereof, that government is playing in the strategic planning of solar PV innovation and uptake.

At present, the central government's role in relation to innovation and R&D include the funding of research and science bodies such as the Marsden Fund, the funding of CRIs, the funding of various other science and innovation-related entities and advisory boards, initiatives to protect intellectual property, and the operation of the newly created Ministry of Business, Innovation, and Employment which provides research funding in areas of strategic interest to government, amongst other activities (Narayan 2012).

Hilhorst (2012) also notes the central governments of the most innovative countries play strong roles in influencing network building amongst government agencies, private industry, and research institutions. That article states that the countries that are innovating best are those where the government plays the role of network-builder, and notes that New Zealand's innovation networks are fragmented and government is not fulfilling that role. Many believe that New Zealand's central government is not doing enough in these fields and needs to show more urgency and commitment to fulfilling its own calls for more innovation (Hilhorst 2012).

Narayan (2012) notes the following striking statistics:

According to a recent OECD report on tertiary education, investment in research and development is an important indicator of the effort government is putting into achieving scientific and technological progress. This report highlights that in GDP terms, tertiary education research and development expenditure increased steadily, from 0.36 per cent to 0.40 per cent across the OECD nations between the period 2000 and 2005, but in New Zealand's case, it declined. New Zealand's current expenditure on government-financed research and development is also much lower than the OECD average" (Narayan 2012, p.322).

In addition to directing and influencing innovative research and activities, the central government's role in solar PV is through key legislation that devolves power to local governments, specifically the Resource Management Act of 1991 (RMA) and the Local Government Act of 2002 (LGA). Both the RMA 1991 and LGA 2002 detail specific actions that local councils can and should undertake, and are directly related to this research.

The RMA 1991 gives local government directional planning guidance related to the environment (Geertshuis 2009). The RMA 1991's purpose is set out in section 5 (1-2) of the act, which, paraphrased, gives local governments the power to promote sustainable development, where sustainable development means providing for the community's social, economic, and cultural well-being while managing the use and development of the natural environment and physical resources and ensuring some bottom lines are protected. In section 7(j), the RMA 1991 states that local governments shall have "particular regard to the benefits to be derived from the use and development of renewable energy." As such, it is clear the RMA 1991 has an encouraging stance in relation to renewable energy, and therefore to solar PV as a form of renewable energy.

A report by EECA (2010) enumerates the powers local government have in promoting renewable energy, and specifically micro-generation (in this case solar PV) under the RMA 1991. "Local government plays an important role through the introduction of policies, plans and actions to support the uptake of renewable energy including small-scale, distributed generation technologies" (EECA 2010, p.4) These powers include simplifying the approval process for resource consents,

writing rules in plans that make specific uses of renewable energy “permitted” activities (or otherwise facilitate renewable energy), as well as weighing the positive effects of renewable energy generation with the adverse effects, which in the case of solar PV are considered to be less than minor in almost all cases (EECA 2010).

The LGA 2002 is also an important part of the local government context. The LGA 2002 was meant to shift local government back into a more primary role in strategic policy after the neo-liberal reforms of the late 1980s rolled back local government power (Asquith 2012, Thomas and Memon 2007). Local government was intended to have flexibility to deal with a range of concerns by bringing together multiple private and public enterprises in the manner of the “third way” or “new local governance” (Asquith 2012, Thomas and Memon 2007). Stocker (2011) notes the vast level of statutory flexibility in the roles and responsibilities of local government inherent in the legislative framework provided by the LGA.

These reforms gave local government in New Zealand a power of competency or general empowerment (Asquith 2012, Thomas and Memon 2007). This allows them to deal with a variety of issues discussed in section 3(d) of the LGA 2002, which states that the Act “provides for local authorities to play a broad role in promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach”. This clearly shows that dealing with renewable energy issues is allowed under the framework of the LGA 2002.

Also, section 14 (1)(g) states that councils “should ensure prudent stewardship and the efficient and effective use of its resources in the interests of its district or region”. In addition, in section 14(1)(c)(ii-iii), the act states that councils should take any decision’s impact on the interests and well-being of future communities into account as well as present ones. In looking at issues such as renewable energy, energy security and long-term energy prices, it is clear that the Act provides for local governments to act at present, for future benefit, using their general competency power to address these.

There is current, on-going debate relative to the role of local governments in New Zealand. Recent changes have been proposed to the LGA that are intended to reduce the scope of local government activity.

A recent policy by the Nelson City Council, called the Solar Saver Scheme, shows how a council’s powers to coordinate long term visions, plans, and business activities under the LGA can be implemented. “By negotiating bulk supply contracts for solar hot water systems and offering fixed interest repayment plans over 10 years as targeted (payments included with) rates, councils can offer systems which are affordable for any household”². This is a model for how local governments can utilise their powers under the LGA to facilitate coordination with the private sector to influence innovation and uptake of new technologies that meet the purpose of the LGA: “to play a broad role in promoting the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach.”

The construction of the role of central and local governments in New Zealand is likely to play an important part in innovation in solar PV, and provides the context for the present research. New

² www.nec.org.nz/SolarSaver (Accessed 10 December 2012)

Zealand shows a deep, if sometimes superficial, interest in innovation and has the governance structures in place to allow innovation to flourish even if the funding commitment is weak. In the following chapters of this thesis, central and local governments will be investigated to assess whether in fact they constitute a critical arena through which innovation and uptake of solar PV in New Zealand might be supported.

CHAPTER FOUR: RESEARCH QUESTIONS AND METHODOLOGY

4.1 Research Questions

As noted in the last section, the overall research question to be pursued in this research is:

Why, despite evidence of the benefits of solar PV, and governmental policies to support renewable energy, is it not being adopted at a much larger scale in New Zealand?

To answer that question, the functions of TIS framework will be applied and the following research questions will drive an analysis of the main research question.

Research Questions: 1- How is the solar PV TIS in New Zealand functioning?

2- What are the key drivers, and barriers, to the system's functioning?

3- What is the political context the system operates within, and how can politics be used to drive innovation in the system?

4.2 Methodology

This thesis adopts and utilises a mixed methods approach to gathering and analysing data. The initial data on system functioning is gathered using semi-structured interviews with key stakeholders, and the quantitative data on the political context are gathered using a closed Likert-scale questionnaire. Creswell and Clark (2011 p.5) give the key characteristics of mixed methods research, and they note the following characteristics apply to this research:

- Collects and analyses persuasively and rigorously both qualitative and quantitative data
- Mixes the two forms of data concurrently by combining them
- Uses these procedures in a single study
- Combines the procedures into specific research designs that direct the plan for conducting the study

Creswell and Clark (2011 p.8) note that "research problems suited for mixed methods are those in which one data source may be insufficient, results need to be explained,... and a second method is needed to enhance a primary method." They give reasons why one data source may be insufficient, and some of these support the use of qualitative interviews and quantitative political questionnaire in this present research.

The qualitative semi-structured interviews are conducted to obtain information and characteristics of the solar PV TIS and its functioning. This was considered by the researcher to be the most time effective and robust way to gather a range of opinions from various system sectors.

Creswell and Clark (2011) note a reason for using a different method is when a single method does not tell the complete story, and when the researcher lacks confidence in one type of method to address a problem. The view of this researcher is that asking participants their qualitative views on

politics is risky because the researcher's preferences may emerge and bias responses. In addition the respondents may feel uncomfortable detailing their views in conversation or may unknowingly give biased responses. This social desirability bias that could affect all participants in the discussion of politics can be addressed by using a methodology with forced-choice items (Nederhof 1985), which this research uses in the form of a Likert-scale political questionnaire.

The political questionnaire enhances the findings from the semi-structured functionality interviews, and allows for more robust conclusions that can contribute to the literature. Combining data on the political context is seen as an ideal way to achieve a more comprehensive picture of the whole of the innovation system (Meadowcroft 2011).

The research that is conducted in this study is, according to Creswell and Clark (2011 p.54) "fixed mixed methods design", in that the research design is predetermined prior to conducting it. They note there are four key priorities involved in choosing a specific mixed methods design- the level of interaction between the methods, the priority of the methods, the timing of the methods, and where and how to mix the methods.

In this research design, the two methods are independent (interaction) in that the qualitative and quantitative methods do not inform one another during the research process. The methods are prioritised equally in that both contribute to the overall findings of the research in the same way. The timing of the research is concurrent, in that the interview and the questionnaire are completed at the same time. Lastly, the methods and findings are mixed at the conclusion of data collection, where they are compared and related with a final interpretation given. Creswell and Clark (2011) call this research plan a convergent parallel design. See figure 2 below (p.69):

Figure 2: Convergent Parallel Design (Creswell and Clark 2011)

This research design is best suited to a pragmatic theoretical paradigm, where the research is intended to address a perceived problem. The problem, in this case, is a search for why solar PV has not been adopted as much in New Zealand as other countries and despite governmental statements that would seem to support solar PV. The functions of TIS approach allows this problem to be analysed, but the pragmatic paradigm and the convergent parallel design provide the way the research is framed and conducted. According to Creswell and Clark (2011), this is the most well-known approach to mixing methods. The purpose of this design is to "obtain different, but complementary, data on the same topic to best understand the research problem" (p.77).

4.3 Research Process

Step One- Identify: -Actors and Networks (Industry, Policy, R&D, Public)

-Corresponds to steps 1-2 of Bergek et al (2008) and **Figure 1** above.

Methods: This is undertaken utilising internet searches and the snowball method. It is intended to identify a range of actors who represent the whole of New Zealand geographically in order to sample all regions and gather as complete a picture as possible of the innovation system.

Step One (A)- Identify achieved functionality (8 functions)

-Corresponds to steps 3(a) and 3(b) of Bergek et al (2008) and **Figure 1** above.

Methods: Qualitative data collected through semi-structured interviews. Interview structured according to specific functions (See Appendix 2 for Interview Framework and Questions) for clear analysis.

Step Two- Functionality is assessed

-**Answer Research Questions 1 and 2**

-Corresponds to step 4 and 5 of Bergek et al (2008) and **Figure 1**

Methods: Analysis of qualitative results from steps 1-1(A). Code semi-structured interviews using NVivo 10.0. Responses coded into specific functions for function analysis, and coded into system weaknesses for full system analysis

Step Three- Identify the political setting within which the innovation system must operate.

-**Answer Research Question 3**

-Corresponds to step 6 of Bergek et al (2008) and **Figure 1** above.

Methods: Quantitative questionnaire to key industry, policy advisers, and R&D (See Appendix 3 for Questionnaire Template). A range of questions will be asked that target areas of interest/need identified through the literature. Respondents will be kept anonymous to encourage unbiased responses. (occurs concurrently with Step Two)

Step Four: Bring together results from qualitative and quantitative aspects of research to gather full picture of system functioning and politics. Identify relevant themes and aspects of each method that can be combined for a larger system view. Summarize and interpret the meanings of the larger system view.

Overview of Participants:

This thesis sought out individuals with expertise on solar PV in New Zealand from private industry, local and central government, and the research and development sector. Individuals representing 17 different organisations were interviewed in semi-structured format, and these individuals are described in the following sections (see Appendix 1 for Interview Schedule).

Private Industry-

An internet search was conducted to locate participants who operate in the selling and/or installing of solar PV in New Zealand. A total of four participants and companies representing the North and South Islands agreed to be interviewed for their opinions and views. These participants were:

- Ian McLaren**- Founder and Director of NZ Clean Energy Systems, Christchurch
- Graeme McIntosh**- Director of Able Solar, Auckland
- Maurice Donald**- Director of SolaPro, Auckland
- Murray Marquet**- Director of Canterbury Power Solutions, Christchurch

Local Government-

It was intended for this study to interview policy advisors from the district councils of the ten largest cities in New Zealand, as these were seen as the councils likely to have relevant policies, markets and industry that would support solar PV. However, for various reasons the advisors from Tauranga, Rotorua, Christchurch, and Dunedin were unable or unwilling to participate. Advisors from Hastings District Council were added to the interview pool due to their leadership on a voluntary targeted rate scheme for solar hot water.

As such, the range of councils contacted and interviewed include councils that have *already* implemented policies for solar technology in the past, those which are *actively* implementing solar technology policies at present and those which are *not planning* on implementing policies for solar technology. These participants and the councils they represent were:

- William Van Ausdal**- Project Coordinator of Sustainability and Economic Development, Palmerston North City Council
- Damon Birchfield**- Senior Strategic Advisor, Infrastructure & Environmental Services; **Eion Scott**- Eco Design Advisor, Auckland Council
- Dean Moriarity**- Senior Policy Planner, Napier City Council
- Grant Gaudin**- Asset and Energy Planner, Hamilton City Council
- Malcom Hart**- Building Consents Manager; **Bruce Allan**- Strategic Financial Advisor, Hastings District Council
- Richard Popenhagen**- Eco Design Advisor, Nelson City Council
- Zach Rissel**- Senior Advisor, Policy Team; **Sandy Winterton**- Energy Manager, Wellington City Council

Central Government-

In seeking out central government participants, it was decided that speaking with policy advisors would be preferable to speaking with politicians or political parties, as it would be more likely to elicit responses that would not contain political motives or underpinnings. As such, contact was made with EECA and MBIE to speak with policy advisors with experience with innovation, as well as solar PV technology. The contact at MBIE directed questions to the advisor from EECA as the one best suited to speak on the topic from the central government.

No other relevant participants from central government were located due to the lack of policy related specifically to solar PV. As such, the participant in this study who represented the central government's views on solar PV was:

-David Rohan- Senior Energy Supply Advisor, EECA

Research and Development-

For this study, it was necessary to interview participants from the range of research and development organisations in New Zealand. Individuals from universities, Crown Research Institutes, and the National Energy Research Institute were interviewed to understand the different views and experiences of researchers and the research landscape in New Zealand. These participants were:

-Eric Jansseune- Former Lecturer on Solar Technologies, Auckland University of Technology; Founder of EWA-TEC

-Dr. Mike Duke- Professor of Engineering, The University of Waikato

-Dr. Bob Lloyd- Associate Professor; Director of Energy Studies Programme, University of Otago

-Alister Gardiner- Team Leader, Industrial Research Ltd.

-Paul Atkins- CEO, National Energy Research Institute

This group of participants represents a wide variety of views and experiences with solar PV across the whole of New Zealand, and covers (or can provide insights into) all aspects of the innovation system. These participants were asked to fill out the politics questionnaire described in the previous chapter, and from this group 12 politics questionnaires were completed. It is from this group of participants that the following analysis, discussion, and conclusions are made.

CHAPTER FIVE: RESEARCH FINDINGS AND ANALYSIS- FUNCTIONS

This chapter discusses and analyses the responses to the semi-structured interviews on the functioning of the solar PV technological innovation system. It addresses each function separately and analyses the general findings, patterns by sector and any differences in views, and assesses each function's overall performance. It discusses the linkages between the functions and gives an overall view of the system's functionality.

The next chapter plots out and analyses the findings from the questionnaire responses and gives an analysis of the politics of the system as a whole.

Final system analysis that merges and integrates the two methods follows in Chapter Seven. The final Discussion Chapter (Ch.8) reflects on the research methodology and outcomes, identifies areas for further research to be conducted, and highlights the final conclusions of the research.

5.1 Analysis of Functions: Function 1- Entrepreneurship

General Findings

A number of themes emerged from the interviews as relevant to entrepreneurship in solar PV in New Zealand, and these are discussed here. These themes are: the role which the general economy is currently playing in entrepreneurship, the current status of entrepreneurship (ie- the types and numbers of entrepreneurs), and the entrepreneurial market's potential and issues.

General Economy's Impact on Entrepreneurship

The general economy in New Zealand was seen as playing a negative role in the way entrepreneurship is functioning. It was agreed upon by various interviewees that the general economy was having a negative impact on entrepreneurship. It was mentioned that many businesses were struggling to generate sales, and especially so for those trying to sell high capital cost renewable energy systems (such as solar PV) due to the overall state of the economy and lack of consumer capital.

However, the general economy also represents some opportunities. Eion Scott from Auckland Council mentioned that they were seeing a lot of people trying to form new businesses perhaps because they were out of work. In addition, they were seeing new migrants to New Zealand attempting to capitalize on the downturn by bringing new capital in and trying to start new businesses.

This is underscored by the general perception that due to the *laissez-faire* attitude of the New Zealand government, it was fairly easy to start new businesses because councils typically are not seeking to regulate the start-up of new businesses in any way.

So, the general economy is seen as a barrier to entrepreneurship on the one hand due to lack of consumer demand from customers in the current economic environment. Yet the economic attitude and market conditions in New Zealand are seen to favour the starting of new businesses.

Current Status of Entrepreneurs in Solar PV

In discussing the number of businesses and new entrants into the solar PV industry, there was general agreement that there were not many businesses operating or starting up. A few advisors from local councils mentioned that they had been in contact with, or were aware of, a few solar PV businesses in their jurisdiction. This seemed to be limited to Auckland, Hastings, Nelson, and Wellington. These were mainly solar PV installers, with Auckland Council mentioning they had been in contact with some new companies bringing in products from Asia.

Although there are not many new companies starting up, there is a correlational, and perhaps causational, perception that the market is fairly well saturated with companies selling solar PV at the moment. This implies that there is currently not sufficient demand for solar PV for many new entrepreneurs to get started. Underlining this is a comment from Eric Jansseune, Founder of EWA-TEC (5/12/12):

There are too many suppliers for a very small market. New Zealand only has 4 million citizens, and if I was an entrepreneur starting in solar PV, I don't think I would make any money the first years because the demand is so low you could only sell a few installations. I could not create a salary from this.

This lack of new companies (or saturation of the market with existing companies), along with other market issues will be discussed in the next section.

Entrepreneurial Market's Potential and Issues

The demand for entrepreneurs to enter into solar PV is not currently great, as will be discussed later in this chapter (Market Function). However, a few interviewees noted that although the situation for entrepreneurship in PV is not currently great, it does have potential to get better.

The technology is widely agreed to be sufficient to supporting mainstream applications, in that there are no current hardware issues that prevent solar PV from being widely sold. It is seen that the grid-tied residential market, in particular, has significant potential due to rising residential electricity prices. In addition, very few systems have been sold in New Zealand, so there is a significant untapped number of homes and buildings that could use solar PV.

Professor Dr. Mike Duke of Waikato University mentioned that once it is cheaper to buy solar PV than retail (grid) electricity, then there is the potential for a secondary market to be established around buying and selling the electricity produced from solar PV, and "small entrepreneurs will come in and offer deals on that." So there is a widespread agreement that the entrepreneurial market has potential due to the availability of technology and rising electricity costs, with the potential for future markets to be established.

However with that noted, there are many more barriers to the entrepreneurial market at present than there is potential. As mentioned above, there is a widespread agreement that there is a current large oversupply of PV panels at present in New Zealand. This leads to quite a risky environment for entrepreneurs to get started, because the competition is so great and the demand from customers is not strong (see Market Function Analysis).

It was noted a number of times that many of the suppliers of PV in New Zealand are only interested in quick sales, and are perhaps over-representing the output of the systems and under-selling the competition. Graeme McIntosh, Director of Able Solar, made this point when he said, “A lot of these players, it is boxes in-boxes out. The numbers (output of power/quality of systems) don’t really matter” (4/12/12). David Rohan, Senior Energy Supply Advisor of EECA concurred and said:

There are a really small number of businesses that are actually looking at ‘What’s the best offering? What does this product really offer, and where is the best place for it? And how can we add value?’... So it’s a very small part of the market. We (EECA/central government) would like to see more people like that. (24/1/13)

Adding credence to this, Ian McLaren, founder of NZ Clean Energy Systems noted, “There’s several people in the marketplace, but we’re not exactly bashing heads against each other to sharpen each other up” (22/11/12). As such, the competition appears to be having a negative impact on new entrants and new knowledge being created that can benefit the solar PV industry in New Zealand, because many sellers are undercutting prices without great knowledge of the PV systems they are selling.

Another relevant point concerns the difficulties that companies face with commercialising research in New Zealand. Both Paul Atkins, CEO of NERI, and Professor Dr. Mike Duke of Waikato University mentioned that it is difficult to commercialise new ideas and research in solar PV in New Zealand because there is a lack of existing industry to support it. There was also widespread agreement that the training facilities for solar PV industry professionals are severely lacking in New Zealand, which impacts the ease with which entrepreneurs can enter the market. As such, a potential entrepreneur with a potential idea would have difficulty getting that off the ground due to the existing lack of industry and training capabilities.

Patterns by Sector and Differences

There was wide agreement on the characteristics and performance of the entrepreneurship function. It was agreed that the oversupply of panels is great, and that some suppliers are merely selling the panels at a low cost without great technical knowledge. This competitive environment combined with lack of public understanding of the technology is not healthy for new entrepreneurs looking to break in, and for competition combined with an educated customer market to result in a better solar PV product.

Function Performance Analysis

In concluding this section, it is clear that entrepreneurship in solar PV in New Zealand brings a mixed bag. The view is taken that the economic structure of New Zealand and *laissez-faire* attitudes make starting new companies relatively easy. With increasing electricity costs there is a great deal of potential for new entrepreneurs to take advantage and sell solar PV.

However, there are many barriers as well. The oversupply of solar PV and the competitive issues mentioned above make it difficult for new entrepreneurs to get their foot in the door of the market, as well as to have competition benefit the overall quality of product of solar PV. There is also a view that the industry is lacking proper knowledge and training abilities, which also impacts the number,

and quality, of entrepreneurs in the system. Lastly, commercializing new ideas is also very difficult for entrepreneurs at present due to the lack of existing industry.

As such, the entrepreneurship function can be seen as underperforming, and not driving innovation in the solar PV technological innovation system in New Zealand.

5.2 Analysis of Functions: Function 2- Knowledge Development

General Findings

There were a number of themes that emerged from the interviews as relevant to knowledge development in solar PV in New Zealand, and these will be discussed here. These themes are: the level of public knowledge, the level of industry knowledge, the level of research and policy knowledge, and where and how research is undertaken and issues with that process.

Level of Public Knowledge

For those in the PV industry the level of public knowledge is widely seen as a major issue in the solar PV innovation system in New Zealand. Industry groups view this lack of knowledge as a major barrier to their success, while the central government view is essentially neutral about it, noting that it may be a benefit to solar PV sales. David Rohan, Senior Energy Supply Advisor of EECA said:

We believe that the lack of public knowledge about the technical specifics and outputs leads to a lot more sales than there would be if people were more aware of the actual costs and benefits.

So this disconnect in views exists, but it is evident regardless of position that the public's low knowledge levels are an issue for the system's functioning.

It was noted by many participants that many of the public they had dealt with were unable to even distinguish between solar PV and solar hot water heating systems. The public, for the most part, was seen as lacking basic knowledge of how PV works, and without better information uptake on that it is clear that solar PV is unlikely to be widely taken up.

In addition to the technical aspects that are not understood, most people were also seen as unable to estimate the 'economics' of purchasing a system. This information barrier makes people unlikely to invest in a (relatively) expensive system, and leads to the strategic selling issues mentioned under the last function where people are at the mercy of what the supplier tells them. Malcom Hart, Building Consents Manager of Hastings District Council, agreed and noted,

So let's say I'm a consumer, I've got \$10,000 to spend. Where should I spend it? I think what will happen is a lot of rhetoric and information will creep in that the consumers won't be able to totally rely on to make their decision. (14/12/12)

So this is an area where information clearly needs to be focused so consumers can learn how to make wise investment decisions.

What is clear is that through more exposure to solar PV uses and information, the levels of public knowledge will correspondingly, and necessarily, increase to boost the performance of this function, which is currently adversely affecting the system.

Level of Industry Knowledge

There was agreement of those in solar PV sales that there were issues with the *number* of qualified installers (See Resources Function), but overall there was agreement that standard PV installations have become fairly routine, and indeed easier than installing solar hot water heating systems.

Ian McLaren, Founder of NZ Clean Energy Systems, noted, when discussing the larger electricity sector's knowledge of PV installation, that getting systems connected to the grid by the lines companies was difficult because:

The people in the lines companies, because there's been so little activity in PV, don't understand what they're about or how to fully work them- that's within the retail and electricity companies as well.

This was corroborated by Assoc. Professor Dr. Bob Lloyd who saw connecting to the grid as one of the most difficult barriers to overcome for standard PV users.

It appears that although the standard installations are well understood by the PV industry and installers, the lines and retailing companies still have learning to do to make the process easier and more efficient.

However, there were some areas that the interviewees thought could be further developed, and this is focussing mainly on the output of systems rather than the installation of them. While it was seen that more training was needed to increase the quantity of *qualified* industry professionals, there is also a perceived information asymmetry in the industry between the installation (angling panels, attaching to rooftops, etc.) and the actual functioning of systems. Eric Jansseune, founder of EWA-TEC, made this point:

Many people in solar PV are not aware that it's not the efficiency of the panels that matters. It's more about the kilowatt hours per kilowatt peak, and many of the solar cowboys will just argue on efficiency because they are not aware that their panel is not even producing efficient kilowatt hours.

This information asymmetry may also explain the perception that some solar sales are misleading customers. It may not be intentional, but rather a consequence of the lack of sophistication and experience and knowledge of the solar PV industry.

It was also agreed that there needs to be further education with regards to the consenting and connecting administration process. It was viewed that if the PV industry can become better at the consenting application process, then that can remove a large barrier to further public demand driving the innovation system.

Research and Policy Knowledge

It was also important to gauge the current research taking place in New Zealand related to solar PV, as well as the levels of knowledge of solar PV within local and central governments. It appears from the conversations with the researchers that there are not many people actively conducting research in New Zealand. Assoc. Professor Dr. Bob Lloyd, the head of the Solar Action NZ research network, compared New Zealand to Australia in the following way in discussing the Solar Action research network:

Solar Action was originally part of the Australia New Zealand Solar Energy Society (ANZSES). ANZSES is a very old organisation, it's largely a university lobby group for renewables. Solar Action split from ANZSES 4 or 5 years ago now, and became Solar Action NZ.

Unfortunately what we found is that in Australia, there are 700 or 800 or 1000 members in all of Australia. The level of academic involvement in solar energy in New Zealand is so low that there's never been more than 50 or 60 members in the whole of New Zealand. Because the numbers have been so low, there are no state, or equivalent of city, branches. In that manner, our ability to influence things is very low.

This lack of research also coincides with a widely held view that government (local and central) is also lacking in solar PV knowledge. Almost every council officer interviewed expressed the view that their organisations, taken as a whole, did not hold a high level of knowledge; except for those councils who have actively pursued some type of solar programme, such as Nelson and Hastings.

In addition, the central government was also seen by private industry and researchers as lacking up-to-date knowledge of PV trends. David Rohan, Senior Energy Supply Advisor of EECA said that that organization holds some higher knowledge levels of the issues and considerations of PV. However, he added that:

Even within this organization, I'd say the understanding of the economics and the benefits of PV is pretty low. So we're working on that as well as with MBIE and Treasury and the MPs.

So it is clear that the level of knowledge in these sectors also contributes to a general lack of knowledge in all sectors of the solar PV innovation system. This perception shows that the knowledge function is generally not performing well.

Where and How Research is Undertaken and Issues

In addition to understanding the levels of knowledge, it is important to understand how research is conducted within the system. Overall, the role of the central government in funding research was seen as the main method for driving research. The researchers interviewed all pointed to the contestable fund administered by MBIE as the main mode for getting the funding necessary to conduct professional research.

Most researchers said that since the government is the main source of funding for research, researchers must tailor what they research according to their perception of what the government wants researched. While there is *some* research, it was generally acknowledged that solar PV is not a priority of the government. In the case of solar PV, this leads to a vicious cycle where since the central government is not promoting solar PV, little research is

proposed or gets done on it. With no research getting done, the solar PV industry suffers. When there is no solar PV industry, there is little incentive for central government to promote it. And the process continues.

So these major issues with the research process are a major impediment to the performance of the knowledge development function in the solar PV technological innovation system.

Patterns by Sector and Differences

This function is characterized by a high level of agreement across the board. There was wide agreement by all interviewees on the lack of public knowledge, as well as acknowledgement that industry, government, and research are lacking in knowledge development and capacity as well. There were no significant differences in perception worthy of note for this function.

Function Performance Analysis

Overall, this function should be considered highly underperforming. All sectors of the innovation system (public, industry- both PV and electricity, local and central government, and research) were seen by all interviewees as lacking appropriate knowledge resources to drive uptake and innovation in solar PV.

Contributing greatly to this underperformance is the fact that although it is acknowledged that knowledge levels need to be greatly increased, there are precious few researchers engaged in the process. In addition, since the level of industry participants and public uptake of PV is so low, it is unlikely that awareness on a large scale will increase any time soon from PV use alone, without specific actions being taken.

5.3 Analysis of Functions: Function 3- Networks

General Findings

There were a number of themes that emerged from the interviews as relevant to the networks relating to solar PV in New Zealand. These themes are: existing professional networks and their characteristics, existing knowledge networks and their characteristics, and network issues.

Existing Professional Networks and Characteristics

It was widely noted and agreed that the only major professional network related to solar PV in New Zealand is the Sustainable Energy Association of New Zealand (SEANZ). Although this professional network is related to solar PV, it is not specifically *for* solar PV. It identifies itself as “the voice of the solar, small wind and mini hydro industry in New Zealand.”³ It was mentioned by a few private industry interviewees that SEANZ was not an ideal operation. It lobbies the central government on behalf of (sustainable) energy companies, but PV is only one of many issues SEANZ deals with. SEANZ also periodically holds conferences for information and industry marketing.

³ <http://www.seanz.org.nz/> (Accessed 15 Feb 2013)

Since SEANZ is the only professional network, and is not explicitly operating solely on behalf of solar PV, there is a clear need for a more robust professional network to drive advocacy efforts, knowledge building and building the PV industry's capacities.

Existing Knowledge Networks and Characteristics

As mentioned in the previous function, Solar Action NZ network is a research network largely for solar PV academics and researchers in New Zealand. Through the interviews, it emerged as the sole research network specifically for solar PV in New Zealand. This network typically functions by holding meetings, conferences, and issuing an occasional newsletter. As also mentioned in the last section, the number of researchers in this network has never exceeded 50 to 60 people, according to Assoc. Professor Dr. Bob Lloyd, the head of Solar Action NZ network. In addition, the network was described by Lloyd as, "just hanging on by the skin of its teeth, to be perfectly frank about it. The level of involvement is not high."

Other than Solar Action, most research networking occurs informally. Most researchers interviewed mentioned collaborating with other researchers at universities as well as the occasional company to conduct research.

Network Issues

As mentioned before, SEANZ is not seen as a particularly strong professional network. David Rohan, Senior Energy Supply Advisor of EECA, was asked to elaborate on the role central government sees SEANZ playing in self-regulating industry practices:

We're seeing a few bad installations and misinformation being given on the part of the industry, and we would always prefer that SEANZ steps and tries to take care of that. It's always better that they act and put something in place.

All they can do, and it's the way a lot of industries work, if you have a good industry association they do a lot of marketing, a lot of promotion, and they have a good name. People tend to use those people (in the network) because they've got a good name and they know that government hasn't quite given their stamp, but they're working together on getting a better quality product. They might get a cheaper price outside, but there's that risk of, "Hey, you're not accredited or approved by the association." Then they can't go to Brendan [Winitana, CEO of SEANZ] or go through the dispute process. So we encourage that type of industry approach.

This quotation provides some insights into the functioning of SEANZ as a professional network, and shows why some industry groups see it as weak. The network was not perceived to have enough resources to devote to solar PV and the bad installations going in were seen as indicative of a system weakness.

In addition, it was mentioned a few times in the interviews that the situation regarding solar PV in New Zealand is highly competitive, both in the industry and the competitive bidding for research funds. As such, there seemed to be, from some interviewees, a reluctance to share knowledge in this area due to intellectual property issues. As Eric Jansseune, founder of EWA-TEC stated:

I think there is a lot of picking of the brain that goes on, and in my area, to be honest, it's even worse. I have to be very careful to protect myself when discussing technical details with engineers that are not well-trained in PV because the need for education and information is very high.

Graeme McIntosh, Director of Able Solar, concurred when discussing the competitive nature of running a solar business and how that impacts information sharing. He said,

Some big companies came in here in the last 3 or 4 years and set up, and they've gone now. They didn't understand the market and they rang me and asked me to explain the market. Well, I'm not telling them, it's not my job to. I've been a bit tough on it, but I'm just sticking up for my staff.

So the fact that knowledge in solar PV is in such demand and the supply is so low in New Zealand, does not support the quality sharing of knowledge and network building that increases the performance of this function.

Lastly, it was seen that there was a strong need for the current networks to be strengthened and/or expanded, as alluded to above. However, where this strengthening was going to come from was the main issue. Maurice Donald, Director of SolaPro, summed this up when he said:

Our time to go out as a flagship and promote it (new or strengthening existing network) we haven't got that time. But it would be ideal to have that. It's not a thing that at the grassroots we're able to see ourselves being able to spend any more time on.

The issues examined here, combined with the lack of networks to advocate or build mutual capacity and knowledge, show that this function is inhibiting innovation in the system.

Patterns by Sector and Differences

Overall, and as with the knowledge function, there was no significant disagreement in the interviews that merit discussion about this function. There was a widespread agreement that the only professional network was SEANZ, and despite benefitting the system in some ways it lacked power and influence to address issues with non-member companies. In addition, there was no mention of any major research networks outside of Solar Action NZ, which is small in nature. It was also agreed that increasing the scope of existing networks faced many difficulties. Lastly, the current innovation system environment did not lead itself to great sharing of knowledge due to high demand and low supply of expertise, and the commercial ramifications of sharing prized intellectual property.

Function Performance Analysis

As such, it can be noted that the performance of the network function is also low. There is one professional network and one knowledge network that both face their own respective issues- lack of power and lack of researchers. The current networking that occurs is mainly done on an informal basis determined by an individual's personal contacts. There is some cooperation in research, but that is mainly due to organizational pushes during the competitive bidding process. There was very little cooperation occurring in the professional and industry sectors of the innovation system due to the competitive issues mentioned above.

Weak networks and network issues means the overall political lobbying power of the industry is lessened, knowledge power is lessened, and the industry association is fragmented and susceptible to the issues mentioned in functions 1 and 2 relating to suppliers misinforming customers and lacking knowledge about PV systems. These factors directly create negative influences on guidance

and advocacy for policy, legitimacy (advocacy), entrepreneurship, and knowledge development functions. This is a key deficiency in the system's overall functioning and innovation output.

5.4 Analysis of Functions: Function 4- Guidance

General Findings

There were a number of themes that emerged from the interviews as relevant to the guidance of the solar PV innovation system in New Zealand. These themes are: government guidance, industry guidance, network guidance, inspiration for policies and actions, and views on solar futures.

Government Guidance

Government guidance of the system was the single most often cited theme in the interviews of all the functions in this thesis, which shows its importance. This section will be broken down into views on central government guidance and local government guidance, with analysis of their respective actions and goals.

Central Government Guidance

Central government is viewed as currently taking a very hands-off approach to implementing policies that boost both innovation and solar PV. It is widely seen as divesting responsibility for research and innovation and renewable distributed energy generation, instead taking a market-guided approach to allowing innovation and uptake to occur.

However, the central government, despite divesting responsibility, still inevitably plays a strong role guiding these areas, simply because research is so heavily dependent on government funding. In addition to being the main funder of R&D in New Zealand as previously discussed in the knowledge development function, the central government also plays a strong role in guiding what research takes place.

In discussing the role that central government policies play in deciding what research is pursued, there was substantial agreement that central government policies played a supreme role in where researchers decide to target their work. As Alister Gardiner, Team Leader at IRL said:

If you don't bid for what the government, or what you interpret the government, wants from its research agencies, then you do not get any funding and you would not get paid.

Paul Atkins, CEO of NERI, concurred. He noted that, "you will angle your research to ensure that you can put a competitive bid in for a funding round."

At present, as mentioned above and in earlier chapters, central government is not making any sort of effort to pursue solar PV, so therefore little research is conducted. This also is a barrier to the innovation system functioning.

The central government also plays a role as an information provider and disseminator for both industry and the public. And lastly, the central government plays a strong role in the innovation system through its policy frameworks, like the long term energy strategy, which provide guidance on the direction in which government would like the energy system to evolve.

The *laissez-faire* approach of central government is widely seen as a barrier to the functioning of the system and the driving of innovation due to the existence of market power of large centralised and incumbent energy companies. This will be discussed further in the concluding overall system functioning analysis.

In any true *laissez-faire* market situation, market players will exert their power to gain the most economic benefit for themselves, consistent with the utility maximization that *laissez-faire* economics espouses. This is seen as occurring in the energy market in New Zealand, and impacts solar PV's competitiveness. As Alister Gardiner, Team Leader at IRL, said:

It's just basically not trying to push any technology and the government is saying "let the market decide." Well to that I'd say it's more like "let the status quo decide" is a better way of saying it as far as energy generating technologies are concerned in New Zealand.

Well what that does, is that the incumbent market in their lucrative areas will try and resist that being taken from them by businesses or independent generators. They're using their market power effectively to make it difficult for people to interact with their system.

Local Government Guidance

In comparison with central government, local governments were seen as much more active in trying to promote policies and schemes that support sustainability and encourage solar PV use.

The majority of the local councils interviewed mentioned that renewable energy and solar PV are important goals that align with the intent of their respective long-term plans. As such, local councils appeared to be much more enthusiastic about encouraging sustainability measures, and solar PV use in particular, than the central government.

The most activist policy to encourage solar technologies discovered were two instances of local councils instituting a voluntary targeted rate scheme for their districts for solar technologies. Voluntary targeted rates are schemes where homeowners purchase a solar technology and the council pays the capital cost of that system. The homeowner is charged for the system through payments over a length of time at a fixed interest rate. These payments are included in the property's annual rates, so if the homeowner moves then the payments stay 'attached to' the property and the new homeowner assumes the payments (while also gaining the benefits of the system as well). This scheme is intended to help homeowners overcome the main capital cost barrier of solar technology, and offering them a security of purchase by going through the scheme. That security is measured in terms of security of quality (system sellers/installers are vetted for quality) as well as security of affordability (high confidence in payback rates as they guaranteed by contract).

Nelson City Council was the first council to implement this scheme of the councils interviewed. Its scheme went into effect in December of 2011. Hastings District Council is currently in the process of implementing a scheme that is heavily based on the Nelson model (as noted in the interview) and is pairing with Hawke's Bay Regional Council to obtain the requisite capital to finance the scheme. Auckland Council is also in the midst of establishing its own solar voluntary targeted rate scheme. Although the Nelson, Hawke's Bay, and Auckland schemes are all focused on solar hot water heating systems, the interviews with all three councils revealed their interest in transitioning the scheme towards solar PV in the future if possible.

These schemes were seen as a positive way for a local council to promote sustainability and renewable energy technologies like solar PV. However, a number of councils spoken with are highly risk averse and would be unlikely to pursue such a policy without proven results from other local councils or from central government. Most councils spoken with mentioned that they have strong time and funding constraints for large scale investigations. In addition to this, councils often noted that they look to other councils for guidance on policies, and for proof that policies are effective.

Taken together, the lack of funds and time and the need for proof from trailblazing councils leads to some councils not willing or able to currently participate in schemes like this. However, all mentioned they would agree with such a policy if it was cost-effective for the residents of their respective district. So, the existence and use of these schemes is a benefit to system functioning because it supports increased use and sale (and the associated benefits) of solar technologies. But it is also an area that is underperforming because only a small number of councils are willing or able at the current moment to undertake schemes like this.

Another simple policy that some councils have implemented is to waive the various building and resource consent application fees for installing a new solar technology system on a roof. This is seen as a relatively minor policy change that can have some positive impact on the uptake of solar technology by lessening the capital costs of installation.

There were other ways that councils are guiding an increase in renewable energy use. These included providing information to constituents through various mailings, communications, or through services such as an eco-design advisor. A few councils noted their role in advising startup businesses or facilitating business connections for parties with mutual interests. In addition, some councils were investigating ways to model solar PV use for their constituents by placing arrays on visible public buildings with information centres that monitored current generation numbers, etc. These are intended to pique the community's interest and provide leadership for transitioning to more renewable energy, and solar PV specifically. Lastly, the Nelson City Council also provided training for industry professionals in installation when it implemented its targeted rate scheme.

In examining this wide array of actions that have been taken that benefit solar PV in one way or another, it is clear that local governments, taken collectively, are being much more active than central government in trying to boost the functioning of the solar PV innovation system through their guidance.

This raises the question of whose role it is to take the lead and implement policies that guide the innovation system. It was noted by a few councils that they had to adhere to any policies that came down from the central government.

It is clear that constitutionally, the central government has authority over local councils in New Zealand. So in that role of supreme authority and with its deeper powers, the central government has the greater ability to implement large-scale system guidance through various policies and actions.

However, it was seen that central government is increasingly divesting itself from some of these large scale system guidance responsibilities, and looking for either the market or local councils to take the lead if anything is to occur. Yet local councils are stretched for resources to assume these increasing responsibilities. So, there is a perception that central government wants local government to take the lead, but does not provide resources. Local governments do not have the resources and tend to look to central government to take those responsibilities.

At present, there is something of a vicious cycle where neither aspect of government is willing or able to take the lead (with the recognition that a few local councils have, but the vast majority have not). The lack of policy guidance towards solar PV is proof of this inaction.

In short, the local government aspect of government guidance is currently performing better than central government to guide innovation, but it faces difficulties, not least fiscally, and these issues must be sorted out to enable enhanced performance of the guidance function.

Industry Guidance

In addition to government guiding the innovation system through its policies and actions, the solar PV and larger electricity industry were also seen as playing a key role in guiding the solar PV innovation system through their actions and policies. This section details what solar PV companies are doing to guide the system. The electricity companies are also discussed in terms of what they are doing to guide the system.

Solar PV Industry Guidance

The solar PV industry in New Zealand is not large, as already mentioned. The majority of those involved are suppliers (who import panels) and installers (those who install the applications), or a combination of the two. These companies do not have as great an ability to guide the system as does the larger electricity industry because they are not particularly large or influential, i.e. not powerful enough to exert their preferences on the system. They report significant resource constraints and this is a major barrier to being able to guide the system.

With that noted, they do have exert guidance on the system at present. This guidance mainly comes from how they interact with customers of solar PV and what information they help to disseminate.

Electricity Industry Guidance

The electricity industry in New Zealand was described in the New Zealand context chapter. The main players from that industry which have a direct impact on the solar PV innovation system are the lines companies (who distribute the electricity generated by PV) and the retail companies (with which PV owners trade electricity with). These industries have an inherent impact on the system merely through their existence, infrastructure, and standard operating procedures without necessarily taking an active role in guiding the functioning of the PV innovation system.

These aspects of the electricity industry and the characteristics of the electricity industry and market itself all impact the functioning of the system as the parameters within which solar PV must operate. The electricity industry is seen as favouring large generating companies and disadvantaging small distributed generators due to the advantages inherent in economies of scale and the way in which electricity is sold in New Zealand. So this could be seen as negatively affecting the functioning of the solar PV innovation system. As Alister Gardiner, Team Leader at IRL, said:

You just cannot buy and sell electricity efficiently in a small way in the New Zealand market. The supply industry set it up, the government sort of guided it, but they set it up for large scale trading of energy.

The electricity industry also guides the system with explicit actions related to solar PV. As the “experts” of the electricity system and market, lines companies and retailers have the credibility to offer guidance to local councils for various decisions. Hastings District Council mentioned that in their current development of a targeted rate scheme, they consulted with the local lines company to get their perception on solar hot water heating versus solar PV as the target of the scheme.

The lines company was firmly of the view that the council should stick with solar hot water for another two to three years and see how the solar PV market matures. As such, Hastings District Council took that advice and will be starting the scheme with solar hot water. There could be some argument as to whether the opinion of the lines company is valid, but nonetheless it is clear that the industry is able to guide council decision making through their role as system operators and experts.

Some electricity industry companies are beginning to see opportunities in solar PV and are starting projects to raise community awareness and knowledge of solar PV. Genesis has a project called “Tomorrow Street” which is a neighbourhood of advanced energy homes that feature some solar PV. They also have a project working with schools (SchoolGen) to install solar PV on their buildings to raise awareness and educate children into future energy sources. Eion Scott of Auckland Council also mentioned other products (e.g. Centameter) that offer very detailed energy use information to households as well as companies offering battery storage PV systems to some customers (e.g. VectorSolar), which improves the economics of using a solar PV system. Vector also has helped Hubbard Foods install New Zealand’s largest commercial thin-film PV array. In short, some actions that electricity industry companies are taking positively guide the functioning of the system.

Another direct way the electricity industry's guidance of the system affects the functioning is in its role as buyer and seller of electricity. There were many issues that various interviewees expressed concerning the way the industry is performing in its role. These ranged from beliefs that the industry was giving too-low buyback prices to small-scale generators to the fact that retailing companies have become known for offering one price and then a short time later changing that price which undercuts the investment decision of buying solar PV. These pricing issues are a major barrier to increased demand for solar PV and are adversely affecting the system's functioning.

However, David Rohan, Senior Energy Supply Advisor of EECA sees the process and pricing as fair, and believes that a lot of the issues are due to misunderstanding of "a very complex industry and I think that's why it gets a bad name." He argued that there are many commercial decisions like: attracting customers, other power purchase agreements with generators, the company's energy portfolio, and regional variables all of which play into how the prices are determined. He was satisfied the industry was giving realistic, fair prices to PV system owners.

In all, the electricity industry plays a strong role in guiding the solar PV innovation system. This guidance ranges from active decisions like pricing, information awareness programmes, and advice to councils, as well as guiding the system passively as it sets the parameters within which solar PV must operate. The electricity industry both positively guides the functioning (through information awareness) as well as hinders the functioning (through favouring large scale generators over small).

Networks Guidance

The professional and knowledge networks were also seen to give some guidance on the solar PV innovation system in New Zealand. This section details the main roles that networks were perceived to be playing.

As mentioned in prior sections and previous chapters, SEANZ is the sole formal professional network that relates to the solar PV industry in New Zealand. It was also mentioned that this network is seen as lacking power due to its inability to control non-member companies. So SEANZ's main role in guiding the system is through bringing together professional conferences, knowledge development, and adding legitimacy to the solar PV industry. This amounts to some guidance being given towards positive functioning of the innovation system from the professional networks of the system.

The research network (Solar Action NZ) is also lacking in ability to guide the system, since the number of researchers in solar PV is not substantial and (as mentioned in the Knowledge Function) research is highly dependent on government funding and guidance. A situation exists where the research network is so weakened from this that its ability to guide what research gets done and drive the system is very low.

Considering this, the research network's ability to break the cycle and better guide the system is very limited.

It appears in practice that the professional network related to solar PV in New Zealand is able to provide some guidance to the system towards positive functioning while the research communities and networks are limited in their abilities to guide the system.

Inspiration for Policies and Actions

It was mentioned earlier that local councils look to each other for inspiration for policies and actions to take. This section details some of these views on where councils get their ideas and motivations to pursue new or perceived “cutting edge” policies.

Local councils were questioned as to what other councils they look to for guidance on new policies. Every council reported that they would be looking to councils that are similar in size, or larger, for proof that certain policies can be effective. Dean Moriarity, Senior Policy Planner of Napier Council said, “Napier looks at its peers, and then the larger ones, rather than look to the smaller councils for inspiration.”

Grant Gaudin, Asset and Energy Planner, from Hamilton City Council shared this perspective and noted, “It would be mainly looking at other similar sized councils, or looking up at larger ones.” This suggests that the largest councils in New Zealand play a strong role in modelling policies and guiding smaller councils into policy development.

Given that some of these larger cities are beginning to implement voluntary targeted rates schemes for solar technologies, this aspect can be seen as positively guiding the system. However, this can also lead to stalemates where councils are paralysed from taking action because they do not want to incur the risk when other councils have not already taken the lead. This could be seen as a weakness in the solar PV innovation system because councils are not pursuing innovative policies without “proven” success.

Views on Solar Futures

Views on solar PV technology’s futures can influence how the system is guided, so it was important to query the interviewees on their perceptions of the technology’s near and mid-term future. This could potentially give insights into how the system is guided.

There was wide agreement that solar PV is in a general long term price decline, but that it was likely that those same cost reductions would level out for a variety of reasons, mainly from the liquidation of excess supply from China. So the majority saw in the mid to long term that prices would most likely stay the same or fall slightly, but not increase in price.

The payback for solar PV investment was still seen as not likely to become highly economic in the short to midterm, with the paybacks likely staying the same as it is currently (described more in Function 5-Market). This is because with panels likely staying at about the same price and no dramatic increases in electricity prices, the economics will likely stay the same (with perhaps minor improvements). The gains in the ‘economics’ over the next two years were not seen to likely be as great as the gains over the past two years.

It was widely agreed that the solar PV technology used in New Zealand was going to remain a standardized form of mono- or poly-crystalline panel. These technologies and rooftop

applications are seen as widely available, cheap, and a known quality, with most companies and installers in New Zealand geared up to sell and install that application. Due to the inherent system characteristics, it was seen as unlikely that any new solar PV technology would usurp the use of mono- and poly-crystalline PV panels in the short term. This widely held view suggests, as much as anything, that most see the innovation system for solar PV as not likely to produce any paradigm shifts in technology, and therefore underperforming in that respect.

Patterns by Sector and Differences

There was fairly wide agreement among sectors interviewed on the general goals, characteristics, and impact of both central and local government. In addition, network guidance was agreed to be fairly weak, as was guidance from the solar PV industry. The incumbent electricity system was generally viewed to be negatively impacting the innovation system, however some saw the system as being fair. Where solar PV pricing and technology will go in the future was also generally agreed on.

Function Performance Analysis

The guidance function of the system is a major impediment to overall innovative output. A number of groups are responsible for collective system guidance; however the power is skewed towards central and local government and the incumbent energy industry.

A follow-the-leader mentality for policies and actions sees central government looking to local, local government looking to central, and some councils needing to see policy performance from other councils. Everyone is risk averse. There is a need for further research and clarification of the roles each will play in the near future.

In conclusion, that there is a widespread view that solar has great potential suggests one would expect to see more guidance from central government to drive innovation and uptake. It is to be expected that the electricity industry is not guiding innovation towards solar PV, as it is generally an economic conflict of interest (although some companies such as Vector are implementing solar PV). The solar PV industry and networks are small in number and lack resources so they are unable to guide the system strongly. It can be said that the guidance of the solar PV innovation system is not strongly influencing greater innovation and uptake of solar PV in New Zealand.

This function is a key cog in the system's functioning and is connected to every other function. The concluding analysis of the system's functioning will discuss this further.

5.5 Analysis of Functions: Function 5- Market

General Findings

There were a number of themes that emerged from the interviews as relevant to the solar PV system market in New Zealand and these are discussed here. These themes are: the current state of the market (supply, demand, prices), and market issues.

Current Solar PV Market

This section describes the current solar PV market in New Zealand, which gives insights into how the market is functioning and how that impacts overall system functioning. This section describes the supply of PV, the demand for PV, and the prices and economics of PV in the current market situation.

As mentioned before, New Zealand's government policies, and general market orientation all are *laissez-faire*, and there is little market regulation or control. Solar PV, as a new market and competitor against an established electricity market, faces many market problems accordingly.

As already stated, there is an oversupply of PV panels in New Zealand at the time of this writing. There are many suppliers and little demand, resulting in low prices. However, as was also detailed, many suppliers do not sell the "best" PV systems, only the cheapest. That results in the uptake of lower quality panels which undermines the system's public credibility.

The supply of panels in New Zealand comes entirely from abroad, mainly Asia. This will be discussed further in Function 8: International Influence.

The demand characteristics are also important to detail. In interviewing the solar PV companies and their experiences with demand for PV, some key characteristics emerged. While overall demand for solar PV at the moment is low, all agreed that the interest or curiosity levels among the public for solar PV are growing, especially so in the last two years as prices have dropped dramatically.

There were a number of drivers for this growth in interest. The main driver that was discussed was that residential electricity users were growing weary of the increasing prices of centralized generation reflected in retail tariffs, and those users were seeking an alternative to free themselves from those rising costs. According to the PV companies, those individuals saw PV as an opportunity to do that.

Moreover, the declining costs of solar PV are making solar PV systems seem more attractive financially to potential solar PV users. As Malcom Hart, Building Consents Manager of Hastings District Council said:

Costs are coming down, yes. I've personally got a price for PV panels on my own home, and two and a half years ago I would have been up for \$18,000 or \$20,000. Now I can probably get a 3kW system for \$10,000.

This exemplifies the attractiveness of the price declines to system purchasers. In addition to these costs falling, there is widespread agreement that centralized generation prices are only going to rise in the future (although perhaps more slowly than in the past)⁴. The picture is one of increasingly cheaper solar PV set against increasingly expensive centralized

⁴ Interviews were conducted before the Empowering NZ announcement by the NZ Labour Party and Green Party of 18 April 2013 (<http://www.greens.org.nz/press-releases/greens-reduce-power-bills>)

electricity with the point of parity approaching. This is driving the growth (albeit small at current) of interest and demand for solar PV.

Combining the supply and demand, one can look at the economics of solar PV in the current market. This view on the payback periods and the economics of solar PV is a main area of difference amongst the interviewees and will be discussed further in the 'Patterns by Sector' section of this function's analysis. At this point, it is important to note that the views on paybacks of a typical solar PV installation (retrofitted to its building) ranged anywhere from 7 years up to 25 years, depending on the size of the system, its application (residential or commercial), and its geographic location and characteristics.

PV Market Issues

The low uptake of solar PV in New Zealand suggests that there are a number of problems with the current market for solar PV. These appear to be hindering the performance of this market function within the larger innovation system.

The oversupply of panels combined with companies frequently selling sub-optimal systems to move products creates an imperfect form of competition. Serious, well-informed competition would be seen as improving the market's functioning. The oversupply of cheap panels and short-term sales motivation means that consumers are not getting the best product, which, from a market perspective, is not ideal.

In addition, the solar PV market is seen as immature in other ways. There are many information barriers to consumers making good decisions. There are few qualified installers nationwide. The larger electricity market's characteristics do not favour small scale solar PV because of low sell-back prices for electricity generated by PV. Corresponding to this is a lack of certainty around future sell-back prices that many feel is keeping consumers from investing in solar PV. There is no feed-in tariff, for example, offering secure long-term sell-back prices. Many see a major capital cost barrier for many consumers that results in lack of purchases. It is widely seen as difficult to commercialize new research into practice in New Zealand.

All of these factors combined suggest a confluence of problems that is keeping the solar PV market from functioning better and developing into a large market in New Zealand.

Paul Atkins, CEO of NERI, noted that the attitude of central government that there won't be any technology-specific incentives means that solar PV is likely to stay a niche market for the foreseeable future.

Assoc. Professor Dr. Bob Lloyd of Otago University mentioned one final, long-term market issue that is perhaps being overlooked. This issue is that 100% of solar panels are imported from abroad. As far as market security goes, that is not ideal as New Zealand's market is reliant upon international trade and fuel prices to import the panels and is therefore subject to fuel price and exchange rate risk (for example, a devaluation of the NZ dollar could rapidly lift PV module prices). This lack of domestic production and sources means the resiliency of

the solar PV market is not strong, and if it should come to a situation where importation of panels is *needed* (e.g. due to an oil price spike), New Zealand would face the consequences of being reliant on other countries. This is a long-term major market issue related to solar PV in New Zealand.

Patterns By Sector and Differences

There was general agreement throughout the interviews that the solar PV market was not strong, and was characterized by numerous difficulties that prevented it from functioning in a way that would benefit the overall innovation system. A strong market is known to drive innovation, and it can be reasonably assumed that a market with difficulties would negatively impact the innovative outputs of the system. However, there was one notable difference between the solar PV and R&D sectors and central and local government that merits closer examination. This difference relates to the economics and paybacks of solar PV in New Zealand.

Both the central government and local government advisors interviewed were generally in agreement that the economic case for residential or commercial solar PV is just not viable at present. These interviewees were of the opinion that the payback period for a solar PV system would be significantly greater than indicated by the solar PV companies and researchers involved. It is not the point who is correct and incorrect in their assertions. It is however of interest and consequence that the government interviewees estimated longer time periods for paybacks, and thus greatly different views on the economics of solar PV compared to the solar PV companies and researchers. On a spectrum, solar PV companies and researchers are on the 'optimistic' end, and government employees on the 'pessimistic' end.

While there is a distinct variation in opinions on the payback periods and the resulting economics of purchasing solar PV, there was wide agreement that the centralized electricity generation prices would most likely increase incrementally into the future. So despite the fact there is a disagreement in views on when solar PV systems pay themselves off, the consensus is that that payback period is likely to improve in the future due to higher savings relative to retail prices of conventional electricity.

Function Performance Analysis

There is widespread agreement that the PV market is not functioning well. There are competition issues, demand issues, and pricing disagreements. The market is immature and will likely stay that way in the interim with government offering no incentives to boost the market- whether in a technology-specific way or system-wide, like a smart grid. The economics of solar PV will gradually improve with increasing power prices and decreasing PV costs (whether short term or long term), eventually having a stronger market. However, the timeframe is dependent on how other functions develop as well; it could be a short time or a long time (5 years or more). Under current scenarios, the market is unlikely to improve in the short term.

Along with system guidance, the market function is a strong driver of innovation and indeed current government guidance relies on the market to drive innovation. This dissonance between guidance and the market will be discussed further in the concluding system functioning analysis and prove to be the key issue facing the system.

5.6 Analysis of Functions: Function 6- System Resources

General Findings

There were a number of themes that emerged from the interviews as relevant to the solar PV innovation system's resources in New Zealand, and these are discussed here. These themes are: the quantity and quality of PV businesses and employment, the amount of capital and funding for PV system purchasers (consumers), solar PV technology availability and considerations, and the funding availability for research and policy for solar PV.

Quantity and Quality of PV Businesses and Employment

In assessing the solar PV innovation system's resources, there are different categories of resources that need to be addressed. Taken in the context of a system resource, the strengths and tools PV businesses possess and the quantity and quality of human capital available is the first resource to be analysed.

In describing this system resource, the first finding from the interviews was that there was perceived to be a general dearth of businesses involved in solar PV. As far as the system's functioning is concerned, a small number of companies has to be seen as a system weakness. Small numbers of businesses leads to a myriad of problems that weaken the quality of most other functions, e.g. entrepreneurship, knowledge development, professional networks, and system guidance.

In addition to there being a small number of businesses in solar PV, there was also a perceived small number of proficient installers. This was noted by local councils as well as solar PV companies looking to contract out installations. Ian McLaren, Founder of NZ Clean Energy Systems, when asked how the amount of human capital in installing solar PV affects his business, said:

Huge. We'd be doing 20 systems a week right now if we could lay our hands on the human capital. Just installers. There just isn't enough that have a clue. We've got to get a training process going.

This lack of installers, as a system resource, is clearly weakening the system's functioning. In addition to there being a lack of installers, there appears to be, as a system resource, a lack of training facilities for installers and PV professionals as well. McLaren went on to say:

The main impediment to growth of the industry here is a lack of proper training facilities for people within the industry, for the electricians and installers to have adequate training. There's an appalling lack of understanding of the fundamentals of what really makes it work within the industry itself.

This sentiment was echoed by other solar PV businesses who noted that their attempt to get electricians to certify themselves in installing solar PV was more or less fruitless. Maurice Donald, Director of SolaPro, discussed this issue and said:

At one stage we tried to contact every electrical contractor in the country suggesting that they should put another feather in their bow and look into becoming qualified to install grid-tied solar. We got a few replies, but very little success from it. They're all possibly a little scared. We'd always point out to them that we'd be quite happy to help them with their first installations and things, but they were not that keen to go out on a limb. So the amount of people qualified and able to install is a major barrier.

A vicious cycle is apparent where the lack of training facilities means there are few qualified installers. The fact there are few qualified installers means that other companies are risk averse to taking the lead. Low demand for solar PV installation training means that there is no drive for training facilities to open. This pattern contributes to a weakness in system functioning.

A related area that emerged from the interviews related to solar PV businesses, as a system resource, is the meagreness of resources the solar PV businesses possess themselves. Some of the solar PV companies interviewed discussed their inability to, on any large scale, market their business and products. This was mentioned in light of the fact that there may be too many suppliers (even though the total number of businesses is small) for such a small demand and turning a profit is difficult. So, these companies have difficulties finding the time or funds to put into marketing and advertising.

Capital and Funding for PV System Purchasers (Consumers)

In addition to the resources relating to solar PV businesses, there are at least two categories of resources that relate to the purchasers of solar PV that emerged from the interviews as being relevant to system functioning: financial capital and knowledge capital.

It was widely agreed that the majority of solar PV system purchasers are those who are relatively well off. This is underscored by the fact that every solar PV company mentioned that the majority, if not all, of the systems they sold were paid for in cash up front. This type of financial liquidity and available capital is not possessed by a large portion of New Zealand society. As Eric Jansseune, Founder of EWA-TEC said:

The market for solar PV is not big at all because nobody can afford it. Even if it's reduced in price down to \$10,000 for a 2kW peak system, who can afford \$10,000? I am an engineer and I can hardly afford \$10,000.

So, the majority of system purchasers pay up front, and can be assumed to be wealthier than most New Zealand households. To the extent that wealthy households have high status in the community and their behaviour helps create aspirations for other households, this pattern may encourage solar PV adoption. Nevertheless, capital cost is likely to be a significant barrier even for middle income households. The thinness of this market means there is limited demand and is an obvious system weakness.

Customer knowledge as a system resource was also described as another important consideration in the system's functioning. As mentioned earlier, there is a widespread perception across all sectors and interviewees that there is not a strong knowledge base about solar PV in New Zealand. Griskevicius et al (2012) argue that social interactions and copying are a strong driver for sustainable decision making, and the unavailability of this resource in relation to solar PV in New Zealand implies that a strong driver for uptake is missing. So the knowledge level, which as a system resource could benefit system functioning, is at a low level and this is hindering system functioning.

PV Technology Availability and Considerations

The available solar PV technology in the innovation system also impacts its functioning. It is apparent from the interviews that the situation in New Zealand's solar PV innovation system is relatively stable in regards to the *types* of PV technology in use. There is not a rush of new PV technology appearing to drive innovation, and in fact it is agreed that the type of PV technology in use now will be in use for at least the short term.

At the current moment, nearly all of the solar PV in New Zealand is either mono- or polycrystalline silicon PV. All of the installers and sellers are geared to that specific technology. The infrastructure available (balance of system components) is geared towards that specific PV technology. As such, it was widely agreed that the current technology would persist into the future. So this technology is widely commercialised and dominant in the system, and becoming locked-in. This prevents large scale innovation and may be insufficiently forward-looking. The available technology and technological resources appear to be hindering innovation in the system at present.

Another technology consideration is that of storage capabilities. This has major implications on the economics of utilizing a solar PV system, as being able to store the electricity generated is seen as a major benefit. At the moment, the (battery) storage technology for solar PV was widely seen in the interviews as expensive and therefore not realistic for most PV system purchasers other than those in remote areas where the cost of the alternative (line charges) is high. So this lack of feasible storage technology, as a system resource, is also negatively impacting the solar PV innovation system.

Research and Policy Funding

The last area of system resources that emerged in the interviews is the availability of funding for research and policies. Such funding is a potentially important driver for innovation systems, and in New Zealand, in terms of solar PV, there is a perceived dearth of funding for both research and policy work. The central government is the main source of funding for research in New Zealand, and is seen as divesting in that area. In addition, as noted above, the funding and resources of government and councils is also perceived to be low and a major barrier to stronger support. Taken together, there are not significant funds and resources for strong research or policies that could potentially benefit the solar PV innovation system. As it is, this funding, as a system resource, is weak and hindering the functioning of the innovation system.

Patterns By Sector and Differences

There were no major contradictions or patterns that emerged from the interviews as being worthy of discussion under this function. There was a high level of agreement on most of the points raised in discussing the state of the system's resources.

Function Performance Analysis

In general, the system's resources, as a function, are not performing well in benefiting the innovation system. There are not many solar PV businesses, which *can* boost the innovation system

in many ways, in New Zealand and the effects of that low level of system resource are felt. There are also not many proficient installers, and there is a lack of training facilities that can aim to grow that low resource. Perhaps the strongest asset and system resource that benefits the solar PV system are the local policies that support business growth in this area. Solar PV businesses also do not have a lot of capital (time and funding) at the company level to do major marketing or advertising campaigns to drive the system's functioning.

Customers and purchasers of solar PV also do not have a great amount of financial or knowledge capital with which the demand for solar PV might be boosted. This would help drive the innovation system, but at present the demand is low so the innovation system is weakly functioning.

The form of PV technology in the system at present is dominant and heavily commercialized and therefore unlikely to benefit innovation on a large scale.

Lastly, research and policy resources are also low. These resources can also drive an innovation system, but in the New Zealand context for solar PV they are not strong enough to do so on a major scale.

As such, the system's resources can be seen to be weak and a major barrier to stronger system functioning. The system's resources affect almost every other function, and are affected by almost every other function as well. As Jabri (2011) noted, the presence of vicious cycles are inherent in the TIS framework and the lack of system resources contribute to many of these. More often than not at present the feedback loops associated with the system resources are not acting positively but instead are hindering the overall system's functioning.

5.7 Analysis of Functions: Function 7- Legitimacy

General Findings

There were a number of themes that emerged from the interviews as relevant to the legitimacy of solar PV in the technological innovation system in New Zealand, and these are discussed here. These themes are: views on solar PV's legitimacy and the effectiveness of advocacy groups in the system.

Views on Solar PV's Legitimacy

The legitimacy of any technology in technological innovation system analyses is a function that determines how accepted the technology is by various groups and actors in the system. If a technology is seen as illegitimate, then it is unlikely to have much support from the system and would therefore hinder the innovation system's functioning.

Solar PV in New Zealand was widely regarded in all sectors covered in the interviews as a legitimate to very legitimate technology. Every policy advisor interviewed noted that in their view, the technology was viable and legitimate. David Rohan, Senior Energy Supply Advisor of EECA said:

Well, I think it's a fantastic technology in a lot of ways. No moving parts, they're giving 20 year warranties for 80% generation, that's fantastic. You don't get that for anything else. So from that point of view its reliability and ease of understanding, its future is bright. The only issue at the moment is that it is just not economic on a national basis.

Other policy advisors noted that it was widely accepted by the public as being a technology that was useful and legitimate. The public's view of solar PV's legitimacy was also corroborated by the private industry professionals that sell solar PV. Maurice Donald, Director of SolaPro, said:

Most conversations we have with the public, when people find out we're in the solar business, it's all very enthusiastic and they think it's good. I've yet to hear a believable negative comment. So I think everyone's enthusiastic. The people we've sold systems to, and had them installed, are delighted with it! They think it's wonderful.

Graeme McIntosh of Able Solar agreed with the assessment of the public seeing solar PV as legitimate. He was asked, however, if he saw any way that the level of legitimacy could be increased even further, and he responded, "If the government got more behind it, the whole world would change." So the level of government guidance, as previously discussed under Function 4 (Guidance), is once again referenced as being a negative pull on the system, and in this case, on the legitimacy function. If government made more of an effort to discuss and promote solar PV in whatever way is politically acceptable, then it is likely that the public's sense of the legitimacy of solar PV would increase and benefit the system's functioning even more.

That all interviewees mentioned that they viewed or experienced solar PV as a legitimate energy generation technology is a strong asset for the system's functioning, and provides a base that can be built off for further innovation system development. While the levels of legitimacy are high, they could be boosted even further with more guidance from the government, which would have flow-on effects to other functions as well.

Advocacy Groups

The types and numbers of groups, or individuals, who advocate on behalf of solar PV can also impact this particular function. In general, more groups advocating for a specific technology results in increased legitimacy because they contribute to knowledge development and system guidance in democratic situations. Although the legitimacy of solar PV as an electricity generation technology is fairly high, the number groups advocating for solar PV is at present low.

Most policy advisors interviewed noted that they deal frequently with people or groups who advocate for different measures and policy preferences. However, in the case of solar PV, this is typically limited to individual solar PV companies. As mentioned in Function 3 (Networks), there are no major solar PV-specific professional industry networks beyond SEANZ, which deals with a range of renewable energy technologies. The lack of a strong industry association for solar PV specifically means that often solar PV companies are left to advocate to policy makers on their own. This is not beneficial for the system's functioning.

In addition, the Solar Action NZ research network does some advocacy for solar PV, but this network suffers from low numbers of participants and is therefore not a substantial advocacy group.

Also important to consider are the advocacy groups that may advocate against solar PV, whether directly or indirectly by advocating for other energy sources. In general, these groups are those aligned with the incumbent electricity system and fossil fuel industry. These groups are much larger, have many more resources, and are therefore much more effective in their advocacy- as will be shown in the political questionnaire analysis later in this analysis section. As Dean Moriarity, Senior Policy Planner of Napier Council said:

The incumbent energy groups, they are quite well funded with lawyers and things, so they often are able to get a bit more quality consultation with council compared to groups without a lot of funding capabilities.

It is important to note here that the presence of more organized and resourceful advocacy groups means that the groups advocating for solar PV have strong barriers to overcome to get their preferences heard and implemented. Taken together, the dearth of available solar PV companies and networks and the presence of other more powerful energy advocacy groups shows that there is more that could be done to improve this function.

Patterns By Sector and Differences

There was widespread agreement among sectors (policy advisors, public, research and the solar PV industry) that solar PV as an electricity generation technology is seen as legitimate. In addition, there was also widespread agreement that there are few advocacy groups working on behalf of solar PV, and those that exist are advocating against more powerful advocacy groups for the incumbent and fossil fuel energy industries.

Function Performance Analysis

To conclude in regard to this function, it is clear that this legitimacy function holds potential for boosting the innovation system for solar PV. There is widespread agreement throughout the system that solar PV is a legitimate technology. This legitimacy can be used as a base to guide the system in the future as it is a short step from legitimacy to greater uptake of solar PV as its costs fall. However, the lack of powerful advocacy groups and government guidance for solar PV mean that this legitimacy is perhaps not growing as fast as it could, and has room for further growth. Overall, this aspect of the innovation system is robust, but could be performing better with assistance from other functions.

5.8 Analysis of Functions: Function 8- International Influences

General Findings

There were a number of themes that emerged from the interviews as relevant to the international influences on the solar PV innovation system in New Zealand. These themes are: international demand for, supply of, and prices for solar PV, international policies, and views on international use of solar PV.

International Demand, Supply, and Prices

Since New Zealand does not manufacture its own solar PV panels, it is completely reliant on the international market to obtain and import solar PV into the country. As such, the functioning of the international market has a large influence on the functioning of the solar PV innovation system in New Zealand.

The international demand for solar PV, in the past year or so, has been outpaced by the international supply largely driven by Chinese manufacturers. This has resulted in a dramatic price decrease, which has seen prices of solar PV correspondingly drop in New Zealand. According to the interviews conducted, the bulk of solar PV in New Zealand comes from this Chinese supply. In addition to the over-supply of Chinese panels, the removal of some government incentives in Australia has also caused some suppliers to shift their focus to New Zealand, which has also increased the supply (and therefore decreased prices given stagnant demand) of solar PV in New Zealand. This is consistent with the observation in regard to earlier functions that noted the vast oversupply of solar PV panels in New Zealand compared to a relatively low demand.

The international market also makes it unlikely that solar PV manufacturing would succeed in New Zealand, in the near- or long-term future, because manufacturers would have to compete with the low cost panels sourced from China. A number of interviewees noted that the Chinese supply was forcing American, German, and in the recent past Australian, manufacturers to close down their solar PV production. In light of that, they noted it was very difficult to see New Zealand entering the manufacturing market.

In short, the international market benefits the functioning of the solar PV innovation system in New Zealand due to the access to low cost, high quality solar PV. However, these low prices have ballooned supply in solar PV in New Zealand, which is currently adversely affecting functioning because the excess supply results in strategic selling to liquidate stock. This in itself is a weakness in overall system functioning compared to, for example, a country like Germany.

International Policies

The policies that are implemented in other countries have a potential to influence the way the solar PV innovation system is functioning in New Zealand, either by indirectly influencing the policies in New Zealand, or affecting the market in New Zealand as noted above.

The influence that international policies have on policies implemented in New Zealand is at present fairly small. More often than not, those contexts are not similar enough for policy advisors in New Zealand to adopt the international policies. Moreover, the strong *laissez-faire* stance of current government policy in New Zealand is unusual internationally. New Zealand is widely viewed as a unique context with its policy configuration, solar PV market and electricity market structure in addition to its portfolio of renewable energy sources.

Given this, the main impact that international policies have on the innovation system for solar PV in New Zealand are the policies adopted overseas that impact the international market.

Views on International Use of Solar PV

The uses of solar PV, and quantities of solar PV being used, also have influence on the general perceptions of the technology within the New Zealand context. It was widely noted in the interviews that increasing adoption and use of solar PV worldwide have given legitimacy to the technology as viable within New Zealand. This influence on perceptions was noted as affecting policy makers, the public, researchers, and solar PV industry professionals. All sectors reported and acknowledged that the increasing use of solar PV worldwide was improving the perceptions of solar PV within New Zealand, and therefore was seen as positively affecting the functioning of the solar PV innovation system in New Zealand.

Patterns By Sector and Differences

There were no variations by sector in regard to this function. Some local councils reported a stronger interest in international policies and experiences than others, but all noted that for those policies to be strongly relevant in New Zealand the context of the country in question must be highly similar to the New Zealand context. All interviewees noted that the innovation system for solar PV was highly dependent on the international market, and that greater uptake of solar PV internationally was contributing to stronger perceptions of the legitimacy and economic viability of the technology in New Zealand.

Function Performance Analysis

This function has a strong influence on the rest of the innovation system's functioning due New Zealand's reliance on the international market for solar PV. As such, the lower prices on the international market benefit the system by making PV systems more affordable, but are also a major barrier to domestic production of solar PV in New Zealand. International policies arguably have some influence on policies and system guidance in New Zealand, but this is mediated by officials' and ministers' stance on policy. International uses of solar PV positively affect the system's functioning by strengthening perceptions of the legitimacy of the technology.

5.9 Overall Innovation System Functioning Analysis

So far each function has been analysed individually; this section integrates the functional analyses. Overall, it is clear why the uptake and levels of innovation of solar PV in New Zealand are so low. Every function analysed demonstrated significant weaknesses and evidence of barriers to better performance. With so many issues present in the system, it is difficult to envision greater uptake of and innovation in regard to solar PV occurring in the near future in New Zealand without some form of intervention.

There are a few function characteristics that are assets to the system. Rising centralised electricity prices will make distributed generation technologies like solar PV increasingly more economic, especially in light of falling PV prices worldwide. Some local councils are implementing voluntary targeted rate schemes to assist their constituents in obtaining solar technologies, which drives uptake and the related business, knowledge, network, market, resource and legitimacy benefits. The widely held view that solar PV is a legitimate energy generation technology is also a system asset

because most actors in the system believe that it is an effective and improving technology with considerable innovation potential.

However, there are many system weaknesses that at present overshadow these system resources. Looking at Weber and Rohrer's (2012) failures framework, the solar PV innovation system in New Zealand is a case study in structural system failures and exhibits all of the following:

- infrastructure failures (physical and knowledge)
- institutional failures (hard: e.g. lack of policy, weak policies, and, soft: e.g. social norms, behaviours)
- network failures (strong: e.g. technological lock-in, dependence on established actors, and, weak: e.g. limited interaction amongst actors prevents knowledge diffusion)
- capability failures (not enough resources at firm and actor level to encourage innovation).

The analysis of the system's functioning clearly exhibits all the above system weaknesses. This leads to the identification of the functions that seem unable to drive the system to stronger output, and the main functions that could perhaps hold the key to spurring innovation: system guidance and market.

The entrepreneurship function has little room for growth in entrepreneurs currently, as supply is ample and demand is insufficient. As it is, there is for improvement in performance and quality in the current situation. Without sufficient demand there will be little growth in the numbers and quality of entrepreneurs, and the lack of growth in entrepreneurship means there will be negligible innovation driven by this function.

The knowledge development function on a macro-level is strongly driven by government guidance. All policy advisors agree that knowledge and awareness development among the public is a main area for policy, and research that is undertaken is dependent on government policies and funding. So government guidance strongly influences this function. However on its own, this knowledge function is unlikely to drive the system to greater innovation and output without better system guidance.

The network function is also a function that is dependent on other aspects of the system. The low numbers of entrepreneurs and lack of a solar PV industry means there are few business networks to diffuse information and lobby the government. Research and researchers are largely dependent on government for funding, and since there is little interest in solar PV in government, there is little research going on in this area; thus there are few research networks. Without these networks, this function is unlikely to drive the innovation system.

The legitimacy function has some strengths; however the fact that the legitimacy of solar PV is already viewed as being strong yet there is little innovation shows the negligible effect this function has in driving system functioning. The weakness of this function lies in the advocacy groups, or dearth thereof, which can compete with incumbent energy industry groups; this is directly related to the network function above. That function's analysis reveals that few parties have resources to form

coalitions, and those that do exist are often resource-strapped. These factors make this function unlikely to drive the innovation system.

Lastly, the international function applies directly to the market function. The market *can* drive innovation if prices come down, demand goes up, and the market gets stronger which would drive innovation and experience in sales and installations through more uptake. However, this is not occurring at present and since international policies and experiences are widely seen as having little relevance to the New Zealand context, this function is unlikely to drive innovation beyond its connection to the market function.

These functions that seem unable to drive the innovation system can be contrasted with the two most likely functions to drive the innovation system: system guidance and the market. The guidance function can drive greater innovation through system intervention and guidance, most likely by government policy, whereas the market function would spur innovation by market development. The latter is the current government's preferred mode of innovation system development.

The guidance function is connected to all other functions and is the main way for the innovation system to better perform. Of all the actors involved in system guidance (policy advisors, incumbent energy industry, solar PV industry, and networks), policy advisors have the greatest potential to drive the system. This is supported by the literature and underlines the fact that policy can apply to all areas of the innovation system. Even the policy measures highlighted in the NZEECS (see section 3.1) state that government should play a role in the following related to renewable energy:

- information measures: targeted to consumers and industry (Entrepreneurship, Knowledge)
- incentive measures: funding or other financial products to direct investment and build capability (Entrepreneurship, Market, Resources)
- measures to develop codes and standards: designed to create confidence in new products and effective practices (Legitimacy)
- research and development measures: to support innovation (Knowledge).

Yet this analysis based on interview findings has shown that the central government is currently perceived to be doing very little to fulfil its own self-stated roles in innovation and system guidance. Of the seven functions other than system guidance, the NZEECS directly states that government has a role to play in areas related to five functions. The international function is not applicable to central government in most areas, and New Zealand's government does not see the leadership from international policies as applicable due to its unique circumstances. The seventh function, and second not represented in the NZEECS, is the network function. Hilhorst (2012) notes that countries which innovate best have governments that act strongly in guiding innovation network development. New Zealand's government is also lacking in this area as shown in that article and this analysis.

An objective reading of its own documents against the body of innovation and renewable energy transition literature reveal that New Zealand's government is underperforming in guiding the solar PV innovation system and could be acting more effectively to optimise innovation system

performance. This could allow the many benefits of solar PV and sustainable industry growth to be realised.

The interviews revealed that most saw this lack of government guidance as a characteristic of the larger government philosophy of *laissez-faire* or “let the market decide”.

The market is the other main function that can drive the innovation system and solar PV uptake. The market function would spur innovation by having prices of solar PV fall to a level where it is competitive with centralised electricity, thus driving demand and greater uptake which would have trickle down effects on other functions such as entrepreneurship, knowledge development, networks and resources.

However, it is clear from the system analysis that an abundant supply of solar PV modules is not in itself driving a strong market; higher levels of demand are needed. However, from the findings of the interviews, it is debateable whether and when this would occur. As mentioned before, prices of solar PV modules are projected to stay relatively stable with small margin decreases in the near to midterm future. The emerging trend for electricity retailers in New Zealand is to offer progressively lower tariffs for the electricity sold back to the grid. As a result, the economics of solar PV will likely stay the same for at least a few years. There does not appear to be a clear economic benefit from solar PV installation compared with centralised generation in the near future, and therefore demand is unlikely to increase.

This means that although the government relies on the market to drive innovation, it is unlikely to happen under the current circumstances or in the near future. This leaves system guidance through policy as the most effective way in the interim to enhance the solar PV innovation system.

A market-based approach to innovation that has pervaded New Zealand’s thinking has shown over the past few decades to give indifferent results in terms of innovative output, as shown in the section 3.3. New Zealand is falling further behind other similar countries in overall innovation, and this analysis may suggest possible reasons behind that. Without some form of innovative guidance from policy, whether that be through research funding or guidance, market assistance, or other options like a smart grid, the status quo is likely to persist and new technologies and innovation are unlikely to develop rapidly.

The findings of the interviews show that under the status quo that innovation is unlikely to occur with a reliance on the market function. Simply waiting for the market to drive innovation ignores the fact that those with current market power will resist new competitors, and the current situation in regard to solar PV’s innovation system in New Zealand shows the many barriers that are unlikely to be overcome without intervention. The incumbent energy industry has many built-in advantages, including the resources to advocate for policy that enable them to leverage their market power. The feedback cycles discussed in this analysis that hinder innovative output and uptake of solar PV will not be solved by simply “waiting for the market”. Rapid innovation requires that the system be guided towards innovation, whereas currently the government and the incumbent electricity industry as the two most powerful system guiders, are guiding the system *away* from innovation in solar PV. This guidance affects all other functions, and is perhaps the key to why the innovation system for solar PV is in its current state.

A “let the market decide” approach overlooks the many potential or even likely benefits of new industry development, and economic development more generally, that arise from innovation. This is not to mention the environmental benefits of solar PV specifically.

The case of the solar PV innovation system in New Zealand exemplifies how difficult it is to achieve innovative output without proper system guidance; this is perhaps reflected in New Zealand’s falling competitiveness rankings (section 1.2) and perceived lack of government guidance in innovation.

Taken in the context of the past century of energy technology innovation, all major energy technologies (coal, oil, natural gas and nuclear energy) have received strong system guidance in the form of policy support and subsidies. This historical context also references a need for stronger government guidance to transition towards disruptive technologies such as solar PV.

CHAPTER SIX: RESEARCH FINDINGS AND ANALYSIS- POLITICS

6.1 Quantitative Questionnaire

The second aspect of this thesis is a quantitative questionnaire that assesses the politics of the solar PV innovation system in New Zealand. It is intended to identify the key actors, power structures, preferences, and political arguments that exist in relation to the solar PV innovation system. Each question is analysed separately, and then an overall view of the politics is given in a final analysis at the end. The discussion of these results, in conjunction with the results of the previous chapter, is presented in Chapter Seven.

In this questionnaire, each respondent was asked to rate their views on a series of questions with multiple responses. These responses are mapped in the following chapter in separate figures for each question, with a short discussion of each question following. Each sector (policy advisor, R&D, and private industry) are assigned a symbol for identification of sector trends and findings. There are a relatively small number of respondents that were recruited for completing the questionnaire. This reflects two main issues. First, the intent was to only question respondents who participated in the semi-structured interviews to maintain cohesion and to not bring in additional viewpoints that were not covered in the previous section. Second, the small number of respondents directly correlates to the size of the solar PV industry and dearth of individuals who are able to comment on such matters.

The small sample size prevents a robust statistical analysis from being conducted, however it does allow for the identification of emerging trends. In the following figures, black brackets are included to focus attention on the trends that are discussed for each question. It was not the intent to identify all trends that emerged, as that would be beyond the scope of this research. Rather, the most important trends were judged and discussed.

FIGURE 3: Question 1: What is the influence the following actors have in the political process that determines energy policy? (10- high influence, 1 low influence) n=11

Notes: One Private Industry respondent said that Business Sector influence was a 4, but should be more like a 8. One R&D sector respondent noted that Local Policy Advisors and MPs have a wide range depending on which council or government is being considered. One Policy Advisor recused from this question.

The analysis of this question suggests two findings. Across the three sectors, chief executives of policy agencies and central policy advisors were agreed to be the most influential on the political process that determines energy policy. All of the other actors' influences on the political process were not seen uniformly by sector.

This leads to a conclusion that if these actors could be mobilized, then their actions would have most influence on energy policy outcomes.

FIGURE 4: Question 2: What are the following constituencies' stake in the development of energy policy? (10- high stake, 1-low stake) n=12

The responses suggest the actors with a stake in the outcomes of energy policy were perceived to include all sectors. The two most highly rated groups of responses were for the incumbent energy industry and the general public. What this implies is that these two groups were seen as having the highest stake in the outcomes of energy policy.

It appears that the incumbent energy industry and general public are perceived to be the two groups of actors that have the most to gain or lose, depending on the specific policies that are implemented. This perception suggests that these are the two main groups of actors with interests in energy policy development; although no conclusion can be drawn from this that these groups do, in fact, have the most influence.

FIGURE 5: Question 3: What is the level of influence that consultation with these interest groups has on government energy policy? (10- high influence, 1- low influence) n=11

Notes: One Policy Advisor mentioned the difference between the general public acting in a large group versus the so-called “lone nutter”, and rated the large group as 8 and the “lone nutter” as 1. Since the question was asked with intent of eliciting a view about mass sentiment, it was scored as 8. One other Policy Advisor recused

There is a wide range of responses in regard to the influence that consultation with different actors has on the outcomes of energy policy. There is more or less an even spread of responses across the range for all actors except new and emerging energy industry and the solar PV industry. The responses for these two actors are clearly much lower than the other actors.

This leads to an indication that new and emerging energy industry and solar PV are not as influential in their consultation in the policy process as the other actors. This has a number of possible interpretations. One is that these groups simply lack political power. Relatedly, it could show that their opinions are not highly regarded and are therefore not influential. Lastly, it could show that the consultation’s effectiveness is lacking because of other issues, e.g. lack of cohesive messaging or lobbying, or lack of substantial numbers to effectively consult on policy.

FIGURE 6: Question 4: How much do current government policies benefit solar PV use and uptake?
(10- high benefit, 1- low benefit) n=11

Notes: One Policy Advisor mentioned that the support for PV is low “because it should be, due to its unrealized costs”

Figure 6 shows that there is almost unanimous agreement that current government policies do not benefit solar PV use and uptake much, if at all. In light of the statement from the Policy Advisor above, the question can be raised of whether a technology should be benefited from policy to make it cost-effective, or whether the technology has to be cost-effective before policy support is given. If the latter, what need would there be for policy support?

Following this line of thinking, it is therefore unlikely then that solar PV would gain policy support under current political conditions. This is a vicious cycle that will be difficult for the PV market to overcome. If PV has high prices (i.e. not commercially competitive) this leads to a lack of government support. A lack of government support results in continuation of high prices (under the assumption that government support would aid prices in some form). Thus, the cycle would continue.

Legend:

- Policy Advisor (Blue circle)
- R&D (Red triangle)
- Private Industry (Black square)

Category	Policy Advisor (%)	R&D (%)	Private Industry (%)
1	95	95	95
2	95	95	95
3	95	95	95
4	95	95	95
5	95	95	95
6	95	95	95
7	95	95	95
8	95	95	95
9	95	95	95
10	95	95	95
11	95	95	95
12	95	95	95

In Fig. 7, it is shown that there is a wide range of responses given. Three out of four solar PV industry groups viewed policies benefitting incumbent energy use as high, and four of six policy advisors did as well. Both R&D respondents viewed this benefit as being low. So there is a bit of difference in views on this topic.

62 | Page

FIGURE 8: Question 6: What is the extent to which the following issues need to be addressed through government policy? (10- high need, 1- low need) n=12

Notes:- One policy advisor gave the answers here based upon the organization's view.

Question 6 posed the question of which strategic goals need to be addressed through policy in the respondent's view. It can be seen that all of the goals were given high scores as being needed to be addressed by government policy. However, some goals consistently scored higher than the others. For example, energy security, reducing carbon emissions and enhancing overall sustainable development had the highest number of responses above an 8, which shows they are seen as the most important areas to be addressed by government policy. It is notable that developing a 'green economy' was consistently supported but that respondents took more varied positions whether innovation and entrepreneurship and new technology and industry needed to be addressed through government policy.

Taken together, these responses give insight into how the actors in the innovation system perceive where government policy and support should be enacted. Ensuring energy security, reducing carbon emissions and enhancing sustainable development or the 'green economy' are the most widely agreed upon areas where government support was seen as necessary.

FIGURE 9: Question 7: Rate the following issues in terms of your personal priority. (10- high priority, 1-low priority) n=12

In question 7 respondents were asked effectively to step back from their organisational priorities and consider their personal priorities. A few patterns emerged as to the personal priorities of the actors in the solar PV innovation system. Enhancing overall sustainable development was consistently the highest overall prioritized issue. Reducing carbon emissions also received a large number of high priority (9-10) responses. Developing a green economy and energy security rounded out the other highest prioritized issues by the actors in the solar PV innovation system.

What is most interesting is the implicit recognition that while respondents desired sustainable development, this might not be in the interests of the organisation they worked for.

FIGURE 10: Question 8: Rate the following issues in terms of your employing organisation's priorities (10- high priority, 1- low priority) n=11

Notes: One Policy Advisor recused from this question.

Respondents were queried to the priorities of their organisations (within the solar PV innovation system) and enhancing overall sustainable development emerges as the strongest priority. Enhancing overall sustainable development had the most responses over 8, while for other priorities (i.e. energy security) there were more lukewarm (scoring 5 or lower) responses. This pattern aligns with the priorities of individuals in the system found in question 7. In addition energy security also was highly prioritized.

In general, the policy advisors consistently ranked all of the priorities here as lower than their R&D and private industry counterparts. This includes the responses for enhancing overall sustainable development and energy security, which implies their respective policy organisations are not motivated by those priorities.

In short, these general priorities appealed more strongly to the individuals in the system than the organisations. There exists significant differences in the priorities of the individuals who work in policy and their organisations (see Fig. 9). This provides some insight into the drivers and motivations that government deems important in policy development.

FIGURE 11: Question 9: Rate the importance of the following criteria in government energy policy goals and development (10- high importance, 1- low importance) n=11

Notes: One R&D respondent recused from answering regarding financial feasibility because of the opinion that the current form of cost-accounting does not include externalities and is therefore a false argument. One Policy Advisor recused from this question.

From the responses to Question 9, it is clear that financial feasibility and cost-effectiveness is the most important criterion to be met in any energy policy, but political feasibility is seen as highly important as well. This suggests that if any policies were to be implemented, they would first and foremost need to be financially acceptable, and the politics would be considered next. The shaping of policies could potentially be geared towards these findings, and focus less on policy adaptability and intergenerational equity- although it could be argued that the result would be narrowly conceived policy. Although some saw adaptability and intergeneration equity as important, they are not widely regarded across sectors as important.

FIGURE 12: Question 10: What is the political attractiveness of the following arguments for a sustainable transition to more solar PV? (10- high attractiveness, 1- low attractiveness) n=11

In analysing the responses to Question 10, several patterns merit discussion. The most politically attractive arguments for a sustainable transition to more solar PV (judged by number of responses of 8 or over) were energy security and framing solar PV as an environmental and energy solution, with seven such responses each. This implies that these are the most attractive arguments for more solar PV, and if there is a political push, it could be centred around these arguments.

However, one issue with energy security as a politically attractive argument is that it was also seen by some as not particularly attractive, with several responses around 5 and 6. This may hint at some problems with using that particular argument, as compared to framing PV as an environmental and energy solution, which had almost all responses at 7 or above.

Although it did not have as many very high scores as the aforementioned two arguments, enhancing overall sustainable development had many high scores as well, and could also be an attractive political argument. Increasing innovation and entrepreneurship is probably the least politically attractive argument for a sustainable transition to more solar PV, based on the responses to this question, although a number of policy advisors were also lukewarm about the argument of solar PV increasing business growth.

FIGURE 13: Question 11: What is the likelihood the following arguments for a sustainable transition to more solar PV would be adopted into mainstream political platforms? (10- high likelihood, 1-low likelihood) n=10

Notes:- One Policy Advisor and one R&D respondent recused this answer.

The responses to Question 11 show an interesting divergence from the previous question on political attractiveness. The most politically attractive arguments (Q.10) were energy security, framing PV as an environmental and energy solution, and enhancing overall sustainable development. However, as can be seen here, only energy security is highly rated as being likely to be adopted by mainstream political parties. The other politically attractive arguments encountered mixed views on whether they were likely to be adopted.

The arguments that are seen as likely to be adopted are energy security, encouraging new energy technologies and industries, and reducing carbon emissions. Therefore, when considering the most politically attractive *and* most likely arguments to be adopted by mainstream political parties, energy security emerges as the most attractive *and* likely argument to be used to argue for a sustainable transition to more solar PV. So, if this issue makes its way into political discourse in New Zealand, energy security is potentially the most politically palatable way to argue and frame the push for a sustainable transition to more solar PV.

6.2 Overall Questionnaire Analysis

As mentioned in the literature review and methods chapters, this questionnaire was designed to assess the politics of a sustainable transition to more solar PV. The politics of such transitions is seen as a key area that needs to be addressed in the literature, as there is a substantial gap in political analyses at the moment. This questionnaire was developed specifically to address this gap in the literature, and provide an analysis of the political climate in which a sustainable transition to more solar PV might take place. The prior question-by-question analysis looked at each one of these issues separately, whereas this concluding analysis brings those individual analyses together for a larger look at the political situation that a sustainable transition to solar PV faces.

These findings give a number of insights into the political system. They show who is the most likely to influence policies (chief executives and central government advisors), and who is the most (incumbent energy) and least effective (solar PV industry) in consulting in the policy process. This suggests that governmental policies are tilted towards those who are best at consulting (incumbent energy industry). The areas where government policy was seen as being needed overlapped closely with the personal and organisational priorities of those in the innovation system, although respondents were more inclined at a personal level to favour a sustainable development approach. The criteria important for new policy development were detailed, and the political arguments for any new policy were also judged, with energy security emerging as the preferred argument for policy support for a sustainable transition to more solar PV.

Collectively, these findings can provide a road map of where to target consultation (in terms of those who are most influential), and suggest that effective consultation can produce results in policy outcomes. There are a number of issues that align with a sustainable transition to solar PV that are widely regarded as needing to be addressed by government policy, and are highly rated priorities of the individuals and organisations in the system. The most politically effective way to frame the argument for a sustainable transition and consultation in the policy process was identified. And lastly, the attractive characteristics of any new policy were uncovered and could also be used to frame the argument and consultation with those who are influential in the political process.

CHAPTER SEVEN: INTERPRETATION

In bringing together the qualitative analysis of the solar PV innovation system's functioning and the quantitative analysis of the politics of the system, a few main conclusions can be drawn. The results of the qualitative analysis show that the innovation system has many problems and barriers, and that stronger system guidance from policy is the most likely way that those problems and barriers could be overcome. The results of the quantitative analysis of the politics provide a pathway by which that system guidance can occur.

If policy is to be implemented to actively guide the solar PV innovation system, it is likely that it would need to come from central policy advisors or chief executives of policy agencies as these are viewed as the most influential in the energy policy process. However, for this to occur there would need to be changes in views on policy support from these groups, as the current policy environment is not conducive to supporting solar PV, whether that is through fiscal or regulatory or other policy mechanisms.

It is clear from the quantitative analysis that the incumbent energy industry is seen as being the most influential in its consultation, and this influence was revealed in the qualitative analysis to be a function of the resources (e.g. lawyers, capital) that the incumbent energy industry possess. This is a major barrier to open-minded policy development or policy support to better guide the solar PV innovation system.

The general public (along with the incumbent energy industry) was viewed by respondents to the questionnaire as having the largest stake in the outcomes of energy policy. So, if policy to drive the solar PV innovation system was to be implemented, the public would need to be mobilised to realise that their stake is high.

The qualitative analysis showed that increasing numbers of the public are turning to solar PV as an alternative to the rising costs of centralised electricity, so that could be a pressure point to motivate the public into action. The quantitative analysis showed that the public is not regarded as particularly influential in consultation, so this would need to be addressed to drive policy change and overcome the influence that the incumbent energy industry possesses in its consultation. The public would need to lobby (or make known their views through the democratic process to) central policy advisors and chief executives, as they are seen as the most influential.

Despite the view shown in the qualitative analysis of interviews with policy advisors that they should not be implementing policy to favour specific technologies, it is clear from the questionnaire that there are a number of *correlated* issues that they do feel need to be addressed through government policy, mainly energy security, reducing carbon emissions, and enhancing overall sustainable development.

Therefore, if policy support for innovation in solar PV was framed in those terms, perhaps policy advisors would be more amenable to the considering support. In terms of organisational priorities, policy advisors rated increasing business growth, employment, and economic growth as the highest organisational priorities reflecting current government priorities. An emphasis on these outcomes is

another way that policy support for solar PV innovation could be framed to encourage more active system guidance.

Energy security was seen as the most politically attractive argument for a sustainable transition to more solar PV, as well as rating highly on being likely to be adopted into mainstream political thinking. Thus, if that argument is used in the political process (whether that be in elections, submissions, debate, etc.) for supporting the solar PV innovation system it is likely to be more successful than using the other arguments.

Taken as a whole, the qualitative aspect of this thesis has shown the many issues facing the innovation system and barriers to further innovation, and revealed that system guidance is the key function, and policy support the key means, to spur innovation most rapidly and most efficiently. The quantitative aspect of this thesis has illuminated a political pathway forward and the groups that would need to be mobilised and barriers overcome to achieve policy support for better system guidance. Overall, the innovation system for solar PV in New Zealand is currently stagnant, but innovation can be mobilised if given the proper leverage and political support. This innovation is likely to benefit the citizens, the economy, and the environment of New Zealand in a number of ways.

CHAPTER EIGHT: DISCUSSION AND CONCLUSIONS

8.1 Literature Implications

This study's findings and conclusions have implications for the literature in a number of ways. First, the study confirms the functions of technological innovation systems approach as a valid way of robustly analysing the innovation system. In addition, it is the first known use of Jabri's (2011) recommendation of adding an international influence function to the functional analysis. This proved to be an important function, as New Zealand's solar PV innovation system is especially influenced by the international market. The influence of international policies and experiences were shown not to be particularly important in this analysis; however that is more a matter of context-specific perceptions of policy stakeholders in New Zealand.

The study also confirms Weber and Rohrer's (2012) framework of structural system weaknesses. This framework provides a valid means of identifying and categorising system weaknesses, and this research's findings give support to its further use. The analysis of the system's functioning and weaknesses leads to a conclusion that policy is the best way to spur innovation and uptake of renewable energy technologies in the New Zealand context. This supports the conclusions of the body of literature that maintains that policy has a strong role to play in those areas (see section 2.1).

This research also brought forth a new method of analysing the politics of technological innovation systems. The questionnaire method allowed for a novel way to assess many characteristics of the political environment that are part of the system's functioning. This approach illuminated many practical matters such as the influence of certain groups in the political process, the priorities of different stakeholders and organisations, and the best ways to politically argue for sustainable transitions. This methodology is repeatable for other technologies, and would only require alteration of the priorities and arguments to fit the context of the specific study.

One way in which the questionnaire could have been extended and improved would have been to have respondents rate the political attractiveness of particular policy options (e.g. feed-in tariff, smart grid implementation, capital subsidy, or others) to identify the policy option that would be most likely to be implemented as well. This would then have illuminated the most politically feasible policy option, along with the most effective political arguments to move it through the system.

The methodology developed has addressed the lack of research into the politics of technological innovation systems and sustainable transitions. The political environment is of such importance to the manner in which sustainable transitions proceed, that it is worth considering the merit of adding an additional function to the functions of TIS framework. Politics influences most of the system, and including this additional function could bring robustness to all future TIS studies. An innovation system analysis which fails to address politics ignores a huge aspect of the system, and with the agreed upon role that policy plays in sustainable transitions, it is important that it be included in same manner. Including it as an additional function could help build its role into the framework and ensure it receives due consideration in TIS analyses.

Overall, the study was successful in addressing the main research questions and revealing a detailed picture of the functioning of the solar PV TIS. The politics questionnaire's usefulness is, however, somewhat limited. The *laissez-faire* attitude currently prevailing in New Zealand means that active policy is unlikely to be implemented to help spur the innovation system in the short term. As such,

an analysis of the politics is rendered moot if there is very little chance of policy implementation. This could change with a change in government or philosophy, but under the current circumstances the politics questionnaire is of limited usefulness other than commentary. Indeed, the whole question of policies is somewhat limited in usefulness under the current political and governmental conditions, but conditions could change in the future rendering these findings more useful.

This research also contributes a view on the functioning of innovation systems under a *laissez-faire* or market-driven governmental philosophy. The research has provided an insight into the results of that philosophy on the innovative outputs and system functioning. The findings of this research illuminate the system weakness such philosophy can create.

8.2 Research Limitations

Limitations with the research methods adopted in this study are apparent. While still seeking objective information in the semi-structured interview, the conversational nature of the interviews could also lead to researcher or interviewee bias coming in. In addition, the researcher has the ability to guide the questions to specific topics, which may unintentionally create certain responses.

The quantitative questionnaire is bounded by the researcher's perceptions and views, and could ignore other aspects of the political context that are unknown but relevant. It is likely that significant research could have been conducted into any one of the many questions explored in the questionnaire, and therefore should be seen as wide-view on the political aspects of the system.

Underlining the limitations in the qualitative and quantitative data collection are the limitations inherent in the process of recruitment. All interviewees (and therefore questionnaire respondents) chose to be a participant, which shows they have some sort of interest in the topic. This could have led to biases in the responses.

Lastly, the number of interviews and responses could have been greater for more robust findings. However, as the interviews proceeded, the diminishing returns on each additional interview became apparent (and is evidenced by the wide agreement in interview responses noted in Chapter Five) as responses were heavily repeated. In addition, as noted in Chapter Six, the industry and quantity of individuals with expertise in this area is relatively low and also reflected by the low number of participants.

8.3 Further Research

There are a few areas of research that would merit being pursued based on this research's findings and conclusions. First, the roles of central and local government in New Zealand in dealing with innovation and renewable energy need to further explored and detailed. Stakeholder perceptions of where power resides and priorities for action should be examined to determine what policies should be pursued, and with whom they should be situated. The current environment in New Zealand governance leads to risk aversion and a follow-the-leader mentality. Without proper identification of roles, this leadership void is likely to continue to the detriment of innovation and renewable energy uptake.

In addition, further research into the views of those within the innovation system on policy options to overcome the system weaknesses identified here should also be conducted. It is important to

determine the political feasibility for different policy options that can address these weaknesses, and drive innovation. Although the current government seems averse to any policy options that might differentially benefit solar PV, a deeper exploration of the public's views on its legitimacy as a technology may show they are not as averse. These general public views and support for policy should be part of any further research into solar PV's innovation system in New Zealand.

8.4 Conclusions

In sum, this study sought insights into the current situation in regard to solar PV in New Zealand. New Zealand has long emphasised renewable energy, both societally and through government policy, and also has strong inclinations towards being innovative. However, despite these characteristics and current government policy documents that support them, solar PV in New Zealand is not being taken up as readily as in other similar countries. This study set out to explore why that was occurring. In that respect, the many problems and barriers that solar PV faces in New Zealand became apparent and it is clear that greater uptake is unlikely to occur in the short-term without some form of government guidance.

Using the functions of technological systems innovation framework allowed the many different aspects of the innovation system to be analysed to identify where the system weaknesses exist, and how they interact. This framework identified the guidance and market functions as the most important functions to drive the innovation system, with the guidance function providing more opportunity to effect rapid positive change on the system.

The political environment in New Zealand was also explored to provide a more robust conclusion on the state of and issues facing the solar PV innovation system. These findings illuminated the key interest groups, the roles their consultation play in policy outcomes, as well as likely political arguments that can be used to frame the discussion for a sustainable transition to more solar PV.

In all of those respects, this study has achieved what it set out to do and answered the main research questions. By addressing these research questions, this study has given insights into technological innovation in New Zealand, New Zealand's policy approach, the potential for solar PV to flourish in New Zealand, and the influence politics has on all of these matters.

REFERENCES

- Asquith, Andy. (2012) "The role, scope, and scale of local government in New Zealand: Its prospective future." *The Australian Journal of Public Administration* 71 (1). p76-84.
- Bergek, A. et al. (2008) "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis." *Research Policy* 37. 407-429.
- Bradford, Travis. (2006) "Solar Revolution: The Economic Transformation of the Global Energy Industry." *The MIT Press*. Cambridge, Massachusetts, 2006.
- Branker, K. and J.M. Pearce. (2010) "Financial Return for Government Support of Large-Scale Thin-film Solar Photovoltaic Manufacturing in Canada." *Energy Policy* 38. 4291-4303.
- De Haan, J. and J. Rotmans. (2011) "Patterns in transitions: Understanding complex chains of change" *Technological Forecasting and Social Change* 78. 90-102.
- Dukes, Jeffrey S. (2003) "Burning Buried Sunshine: Human Consumption of Ancient Solar Energy." *Climatic Change* 61, 2003. p. 31-44.
- EECA. (2010) "Domestic-scale distributed generation: Guidance for local government."
<http://www.eeca.govt.nz/resource/domestic-scale-distributed-generation-guidance-local-government>
- Fouquet, Roger. (2010) "The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service." *Energy Policy* 38. pp.6586-6596.
- Geertshuis, Susan. (2009) "Improving decision making for sustainability: a case study from New Zealand." *International Journal of Sustainability in Higher Education* 10(4). p379-389.
- Griskevicius, V. et al. (2012) "The Evolutionary Bases for Sustainable Behaviour: Implications for Marketing, Policy, and Social Entrepreneurship." *Journal of Public Policy and Marketing* Vol 31(1). P. 115-128.
- Harmon, Christopher. (2000) "Experience Curves of Photovoltaic Technology." *International Institute for Applied Systems Analysis*. Laxenberg, Austria. March 30, 2000.
- Hekkert, M. and S. Negro. (2009) "Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims." *Technological Forecasting and Social Change* 76. 584-594.
- Hilhorst, Marieke. (2012) "Pinning prosperity on innovation and science." *Public Sector* April 2012. P14-15.
- Hoffmann, W. (2006) "PV Solar Electricity Industry: Market Growth and Perspective." *Solar Energy Materials and Solar Cells*, Vol. 93: Issue 18-19. P.3285-3311.
- IT Power. (2009) "Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand." *Prepared for Ministry of Economic Development*.

- Jabri, Tarak. (2011) "Analysis of the innovation systems of photovoltaic technologies in the Netherlands." *Master's Thesis*: Delft University of Technology. December 2011.
- Jacobsson, S. and A. Bergek. (2011) "Innovation system analyses and sustainability transitions: Contributions and suggestions for research." *Environmental Innovation and Societal Transitions* 1. 45-57.
- Kelly, Geoff. (2011) "History and Potential of Renewable Energy Development in New Zealand." *Renewable and Sustainable Energy Reviews* 15. p.2501-2509.
- Key, John. (2012) "Finding a way in a changing world." *New Zealand International Review* 37 (5), Sept 2012. p10-13.
- Local Government Act 2002.
- Lund, P.D. "Effectiveness of Policy Measures in Transforming the Energy System." *Energy Policy* 35 (2007). 627-639.
- Markard, J. et al. (2012) "Sustainability transitions: An emerging field and its prospects." *Research Policy* 41. 955-967.
- Martin, N. and J. Rice. (2012) "Developing Renewable Energy Supply in Queensland, Australia: A Study of the Barriers, Targets, Policies and Actions." *Renewable Energy* 44. 119-127.
- Meadowcroft, James. (2011) "Engaging with the politics of sustainability transitions." *Environmental Innovation and Societal Transitions* 1. 70-75.
- Ministry of Business, Innovation, and Employment. (2012) "New Zealand Energy Data File 2012" ISSN: 1177-6684.
- Ministry of Business, Innovation, and Employment. (2011) "New Zealand Energy Strategy 2011-2021."
- Ministry of Business, Innovation, and Employment. (2011) "New Zealand Energy Efficiency and Conservation Strategy 2011-2016."
- Ministry of Business, Innovation, and Employment. (2011) "New Zealand Energy Outlook."
- Ministry for the Environment. (2011) "National Policy Statement for Renewable Electricity Generation."
- Musiolik, J. et al. (2012) "Networks and network resources in technological innovation systems: Towards a conceptual framework for system building." *Technological Forecasting and Social Change* 79. 1032-1048.
- Narayan, Anil. (2012) "The role of government and accounting in the development of academic research commercialization: The New Zealand experience." *Accounting History* 17(3-4). P311-329.

- Nederhof, A.J. (1985). "Methods for Coping with Social-Desirability Bias: A Review." *European Journal of Social Psychology* 15. pp.263-280.
- Negro, S. et al. (2012) "Why does renewable energy diffuse so slowly? A review of innovation system problems." *Renewable and Sustainable Energy Reviews* 16. 3836-3846.
- Nemet, Gregory. (2006) "Beyond the Learning Curve: Factors Influencing Cost Reductions in Photovoltaics." *Energy Policy* 34. 3218-3232.
- NIWA. (2009) "New Zealand EnergyScape."
- OECD Studies On Environmental Innovation. (2011) "Better Policies To Support Eco-Innovation." ISBN 978-92-64-096677
- Resource Management Act 1991.
- Schroeder, P. (2010). "Leapfrogging in China's Renewable Electricity Development Pathway? The Roles of Policy Frameworks, Innovation and International Cooperation Partnerships in Fostering Renewable Electricity." PhD Thesis: Victoria University of Wellington.
- Smil, Vaclav. (2008) "Moore's Curse and the Great Energy Delusion." *The American*: Nov. 19, 2008.
- Smil, Vaclav. (2010) "Energy Myths and Realities: Bringing Science to the Energy Policy Debate." *The AEI Press*: Washington, D.C. 2010.
- Sovacool, Benjamin. "Rejecting Renewables: The Socio-Technical Impediments to Renewable Electricity in the United States." *Energy Policy* 37 (2009). 4500-4513.
- Statistics NZ. (2011) "Innovation in New Zealand 2011".
- Stocker, Nathan. (2011) "Relationship dynamics in New Zealand territorial authorities." Master's Thesis: *University of Otago*. 2011.
- Tang, Linghui and Peter Koveos. (2004) "Venture Entrepreneurship, Innovation Entrepreneurship and Economic Growth." *Journal of Developmental Entrepreneurship* Aug 2004. p 161-171.
- Thomas, Steven and Ali Memon. (2007) "New Zealand Local Government at the Crossroads? Reflections on the Recent Local Government Reforms" *Urban Policy and Research* 25(2). P171-185.
- Tyagi, V.V. et al. (2013) "Progress in Solar PV Technology: Research and Achievement." *Renewable and Sustainable Energy Reviews* 20. Pp443-461.
- Van Den Bergh, J. et al. (2011) "Environmental innovation and societal transitions: Introduction and overview." *Environmental Innovation and Societal Transitions* 1. 1-23.
- Walsh, Philip. (2012) "Innovation Nirvana or Innovation Wasteland? Identifying Commercialization Strategies for Small and Medium Renewable Energy Enterprises." *Technovation* (2012).

- Weber, K. and H. Rohracher. (2012) "Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework." *Research Policy* 41. 1037-1047.
- Wieczorek, A. et al. (2010) "Systemic policy instruments and their role in addressing sustainability challenges." *Copernicus Institute for Sustainable Development and Innovation*: Utrecht University, Netherlands. 30 May, 2010.
- Wilson, C. and A. Grubler. (2011) "Lessons From the History of Technological Change for Clean Energy Scenarios and Policies." *Natural Resources Forum* 35. 165-184.
- World Economic Forum. (2011) *Global Competitiveness Report 2011-2012*. Geneva, Switzerland.
- Zweibel, Ken. (2010) "Should Solar Photovoltaics Be Deployed Sooner Because of Long Operating Life at Low, Predictable Cost?" *Energy Policy* 38. 7519-7530.

APPENDIX 1

INTERVIEW SCHEDULE

Location	Participants
Palmerston	William Van Ausdal - Project Coordinator, Sustainability and Economic Development PNCC
Melbourne	Hugh Murtagh - Project Manager, Apollo Energy
Christchurch	Ian McLaren - Founder, NZ Clean Energy Systems
Auckland	Eric Jansseune - Former Lecturer Solar Technologies, AUT./ Founder, EWA-TEC
Auckland	Graeme McIntosh - Director, Able Solar
Auckland	Damon Birchfield - Senior Strategic Advisor, Infrastructure & Environmental Services; Eion Scott - Eco Design Advisor, Auckland Council
Auckland	Maurice Donald - Director, SolaPro
Christchurch	Murray Marquet - Director, Canterbury Power Solutions
Napier	Dean Moriarity - Senior Policy Planner, Naper City Council
Hamilton	Grant Gaudin - Asset and Energy Planner, Hamilton City Council
Hastings	Malcom Hart - Building Consents Manager; Bruce Allan - Strategic Financial Advisor, Hastings District Council
Hamilton	Mike Duke - Professor at Waikato University
Wellington	Alister Gardiner - Team Leader at IRL
Nelson	Richard Popenhagen - Eco Design Advisor, Nelson Council
Wellington	David Rohan - Senior Energy Supply Advisor, EECA
Dunedin	Bob Lloyd - Professor, University of Otago
Wellington	Paul Atkins - CEO, National Energy Research Institute
Wellington	Zach Rissel - Senior Advisor, Policy Team; Sandy Winterton - Energy Manager, Wellington City Council

APPENDIX 2

INTERVIEW FRAMEWORK AND QUESTIONS

Indicative Interview Framework

Researcher: Andrew Boyles

September 12, 2012

Analysis of System Functioning Interviews: These topics of discussion will be presented in a semi-structured interview format to policy advisors, industry, and the R&D community. The functions of innovation approach will be explained to participants as the lens through which the research will be conducted. The interview topics will be tailored to the interviewee, with only the most relevant topics discussed with a given interviewee.

Functions of Innovation Systems

Function 1: Entrepreneurial Activity

Results and Information Sought

- Type, number, and increase in entrepreneurs per type of technology/use
- Future plans for companies
- Barriers to Entrepreneurship

Typical Questions

- What is the status of entrepreneurship for solar pv in NZ?
- How has entrepreneurship changed over the last 5 years relating to solar pv technologies in NZ?
- What type of business environment do entrepreneurs find for solar pv in NZ?
- What are the main barriers for entrepreneurs in the solar pv field in NZ?

Functions of Innovation Systems

Function 2: Knowledge Development

Results and Information Sought

- Research done per technology

-Defining which actors are performing research and intended outcomes

-Public knowledge/beliefs about technology

-Learning by doing

Typical Questions

-What types of research are currently being conducted, and who is doing the research?

-Where does the funding for the research come from, and what are the intended outcomes?

-What types of knowledge/beliefs do the public hold around solar technology?

-How has knowledge changed through implementing solar, and what areas of knowledge still need development?

Functions of Innovation Systems

Function 3: Knowledge Diffusion Through Networks

Results and Information Sought

-Available/potential collaborations and networks

-Assessing formalised exchange methods

-Assessing collective projects/research

Typical Questions

-What are the current knowledge and professional networks relating to solar pv in NZ?

-Are there any potential networks that have not been formed?

-How is information and knowledge shared about pv in NZ through these networks?

-Are there better ways to share information and knowledge?

-What collective projects/research are conducted, and how are the results shared?

Functions of Innovation Systems

Results and Information Sought

Function 4: Guidance of the search

- Targets, expectations, communications set by government and how it influences outcomes (policies)
- Targets and initiatives of companies
- Technological expectations and communications
- Relevant policies to solar pv

Typical Questions

- How is solar pv discussed in government plans, documents, and communications?
 - What factors are considered when developing those plans/communications?
 - Does this influence what policies are created? Or do policies influence plans/communications?
 - What are companies' future plans for solar pv?
 - What factors determine or influence those future plans?
 - What are your expectations for solar pv technology in NZ now and in the future?
 - How are these expectations communicated to relevant interest groups?
 - How could these expectations be communicated more effectively to relevant interest groups?
 - What current policies impact the uptake of solar pv use, production, and sale?
-

Functions of Innovation Systems

Function 5: Market Formation

Results and Information Sought

- Assess how technologies were first used and who the users were
- Assess current market for solar pv
- Assess how market is protected/nurtured
- Assess where market is located and where products came from

Typical Questions

- How has solar pv been used in NZ historically, and who were the original suppliers and markets?
 - What is the current level of demand for solar pv, and who are the suppliers?
 - How is demand quantified and communicated?
 - What forces work in favour of the pv market and what works against it?
 - Who are the most likely users of pv, and who are the potential users of pv?
 - Where are the solar pv systems manufactured?
-

Functions of Innovation Systems

Function 6: Resource Mobilization

Results and Information Sought

- Assessing the funding of research/projects
- Assess financial stimulation/characteristics of market
- Assess availability/quality of technology
- Employment

Typical Questions

- How is funding secured for research and experimental projects for solar pv?
 - What type of financial environment exists for purchasing/using solar pv?
 - What are the types and forms of solar pv available in NZ?
 - How does the human capital available impact the use/uptake of solar pv?
-

Functions of Innovation Systems

Function 7: Creation of legitimacy

Results and Information Sought

- Assess the existence of advocacy coalitions and results of their activities
- Views on legitimacy of technology now and future
- Strategies used to counteract legitimation

-Relationship between energy and environmental policy legitimacy

Typical Questions

- What advocacy coalitions exist for solar pv/renewable energy?
 - How do they advocate, and how effective is their advocacy?
 - How legitimate is solar pv seen by policy advisors/public?
 - How does that level of legitimacy influence policies/uptake?
 - What barriers limit increased legitimization of solar pv in NZ?
 - What advocacy coalitions exist that deter solar pv/renewable energy?
 - How do they advocate, and how effective is their advocacy?
 - How important are environmental policy concerns in framing solar pv policies?
-

Functions of Innovation System

Function 8: Role of international markets/use

Results and Information Sought

- Assess availability/pricing of technology
- Assess how other countries' experiences/policies/prices influence NZ

Typical Questions

- Where does solar pv in NZ come from?
- What are the typical costs (wholesale/tariffs/shipping/etc)?
- Do experiences with solar pv in other countries influence your views of solar pv in NZ?
- Do governmental policies of solar pv in other countries influence prices of solar pv in NZ?
- Do prices of solar pv in other countries influence prices of solar pv in NZ?

APPENDIX 3

QUESTIONNAIRE TEMPLATE

Study of Solar PV System Functioning in New Zealand: Questionnaire

Researcher: Andrew Boyles

This questionnaire is designed to explore the political realities facing the increased uptake of solar photovoltaics in New Zealand. It seeks to gain an understanding of those politics from the perspective of a range of interest groups and policy advisers. By understanding the politics of the situation, more nuanced conclusions about policy potentials can be reached.

There is space included at the conclusion of this questionnaire if you have any additional thoughts about specific questions. Please reference the question number when making these comments.

Please check the box that most closely aligns with your primary current position:

☐ Policy Adviser ☐ Business Sector ☐ Research/Development Community

1. On a scale of 1-10, with 1 being no influence and 10 being highly influential, rank the influence the following actors have in the political process that determines government energy policy:

- Business sector: 1-2-3-4-5-6-7-8-9-10
- Local policy advisors: 1-2-3-4-5-6-7-8-9-10
- Central policy advisors: 1-2-3-4-5-6-7-8-9-10
- Chief executives of policy agencies: 1-2-3-4-5-6-7-8-9-10
- Members of parliament: 1-2-3-4-5-6-7-8-9-10
- The courts, eg: Environment Court: 1-2-3-4-5-6-7-8-9-10
- NGOs: 1-2-3-4-5-6-7-8-9-10
- Citizens and public opinion: 1-2-3-4-5-6-7-8-9-10

2. On a scale of 1-10, with 1 being no importance and 10 being highly important, rank the following constituencies' stake in the development of energy policy:

- Incumbent energy industry : 1-2-3-4-5-6-7-8-9-10
- New/emerging energy industry players (not incl. solar pv): 1-2-3-4-5-6-7-8-9-10
- Solar pv industry: 1-2-3-4-5-6-7-8-9-10
- Research and development community: 1-2-3-4-5-6-7-8-9-10
- General public: 1-2-3-4-5-6-7-8-9-10
- Policy advisors: 1-2-3-4-5-6-7-8-9-10

3. On a scale of 1-10, with 1 being little influence and 10 being highly influential, rate the influence that consultation with the following interest groups has on government energy policy outcomes:

- Incumbent energy industry : 1-2-3-4-5-6-7-8-9-10
- New/emerging energy industry players (not incl. solar pv): 1-2-3-4-5-6-7-8-9-10
- Solar pv industry: 1-2-3-4-5-6-7-8-9-10
- Research and development community: 1-2-3-4-5-6-7-8-9-10
- General public: 1-2-3-4-5-6-7-8-9-10
- Policy advisors: 1-2-3-4-5-6-7-8-9-10

4. On a scale of 1-10, with 1 being no benefit and 10 being highly beneficial, how much do current government policies benefit solar pv use and uptake? 1-2-3-4-5-6-7-8-9-10

5. On a scale of 1-10, with 1 being no benefit and 10 being highly beneficial, how much do current government policies benefit incumbent forms of energy use? 1-2-3-4-5-6-7-8-9-10

6. On a scale of 1-10, with 1 being no role for policy and 10 being a strong role for policy, rate the extent to which the following issues need to be addressed through government policy:

- Energy security: 1-2-3-4-5-6-7-8-9-10
- Encouraging new energy technologies and industries: 1-2-3-4-5-6-7-8-9-10
- Increasing innovation/entrepreneurship: 1-2-3-4-5-6-7-8-9-10
- Increasing business growth/employment/economic growth: 1-2-3-4-5-6-7-8-9-10
- Developing a “green economy”: 1-2-3-4-5-6-7-8-9-10
- Reducing carbon emissions: 1-2-3-4-5-6-7-8-9-10
- Enhancing overall sustainable development: 1-2-3-4-5-6-7-8-9-10

7. On a scale of 1-10, with 1 being not important and 10 being highly important, rate the following issues in terms of your personal priorities:

- Energy security: 1-2-3-4-5-6-7-8-9-10
- Encouraging new energy technologies and industries: 1-2-3-4-5-6-7-8-9-10
- Increasing innovation/entrepreneurship: 1-2-3-4-5-6-7-8-9-10
- Increasing business growth/employment/economic growth: 1-2-3-4-5-6-7-8-9-10
- Developing a “green economy”: 1-2-3-4-5-6-7-8-9-10
- Reducing carbon emissions: 1-2-3-4-5-6-7-8-9-10
- Enhancing overall sustainable development: 1-2-3-4-5-6-7-8-9-10

8. On a scale of 1-10, with 1 being not important and 10 being highly important, rate the following issues as priorities of your organisation/employer:

- Energy security: 1-2-3-4-5-6-7-8-9-10
- Encouraging new energy technologies and industries: 1-2-3-4-5-6-7-8-9-10
- Increasing innovation/entrepreneurship: 1-2-3-4-5-6-7-8-9-10
- Increasing business growth/employment/economic growth: 1-2-3-4-5-6-7-8-9-10
- Developing a “green economy”: 1-2-3-4-5-6-7-8-9-10
- Reducing carbon emissions: 1-2-3-4-5-6-7-8-9-10
- Enhancing overall sustainable development: 1-2-3-4-5-6-7-8-9-10

9. On a scale of 1-10, with 1 being not important and 10 being highly important, rate the following in terms of their importance in government energy policy goals/development:

- Political feasibility: 1-2-3-4-5-6-7-8-9-10
- Financial feasibility/cost-effectiveness: 1-2-3-4-5-6-7-8-9-10
- Administrative feasibility: 1-2-3-4-5-6-7-8-9-10
- Policy adaptability: 1-2-3-4-5-6-7-8-9-10
- Intergenerational equity: 1-2-3-4-5-6-7-8-9-10

10. A sustainable transition for the energy sector could be described as one in which there is a steady move towards more environmentally sustainable forms of energy production and use. On a scale of 1-

10, with 1 being no political attractiveness and 10 being highly politically attractive, rate the following arguments for a transition to more solar pv:

- Energy security: 1-2-3-4-5-6-7-8-9-10
- Encouraging new energy technologies and industries: 1-2-3-4-5-6-7-8-9-10
- Increasing innovation/entrepreneurship: 1-2-3-4-5-6-7-8-9-10
- Increasing business growth/employment/economic growth: 1-2-3-4-5-6-7-8-9-10
- Developing a “green economy”: 1-2-3-4-5-6-7-8-9-10
- Reducing carbon emissions: 1-2-3-4-5-6-7-8-9-10
- Enhancing overall sustainable development: 1-2-3-4-5-6-7-8-9-10
- Framing solar pv as speaking to both environmental and energy concerns:

1-2-3-4-5-6-7-8-9-10

11. On a scale of 1-10, with 1 being little likelihood and 10 being a high likelihood, rate the following as likely to be adopted into “mainstream” political party thinking/platforms:

- Energy security: 1-2-3-4-5-6-7-8-9-10
- Encouraging new energy technologies and industries: 1-2-3-4-5-6-7-8-9-10
- Increasing innovation/entrepreneurship: 1-2-3-4-5-6-7-8-9-10
- Increasing business growth/employment/economic growth: 1-2-3-4-5-6-7-8-9-10
- Developing a “green economy”: 1-2-3-4-5-6-7-8-9-10
- Reducing carbon emissions: 1-2-3-4-5-6-7-8-9-10
- Enhancing overall sustainable development: 1-2-3-4-5-6-7-8-9-10
- Framing solar pv as speaking to both environmental and energy concerns:

1-2-3-4-5-6-7-8-9-10

Please include below any further thoughts or clarifications that have occurred to you in answering the above questions (please reference question number, if applicable):