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Adaptation to Climate Change via Insurance and Financial Incentives

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ADAPTATION TO CLIMATE CHANGE VIA INSURANCE

AND FINANCIAL INCENTIVES

by

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Catastrophic climatic events have accounted for 72% of global insurance claims and totaled ~$1 trillion from 1980 to 2012. Costs are driven by socio-economic developments and an increased frequency and severity of climatic disasters in which climate change may have been a contributing factor. Climate change is projected to become a more prominent driver of these changes in the decades ahead. Government policies to reduce systemic risk have been the predominant approach for multi-level mitigation and adaptation to climate change. The analysis presented here shows how forceful and effective market-based approaches for adaptation and mitigation to climate change already operate via the insurance industry. Feedbacks from insurance to society include these primary changes: 1) premiums and insurance policies, 2) non-coverage, and 3) policy making and litigation (Chapter 1). Through these mechanisms, the insurance industry actively manages climate change adaptations and creates incentives to lessen impacts on industry and society. For mitigation of climate change, renewable energy-based energy production has become more of a priority for utilities in recent years (Chapter 2). However, renewable energy is competitively disadvantaged compared to fossil-fuel based systems due to high investment costs, the intermittent nature of

renewables, and a lack of pricing for externalities (Chapter 2). A model is used for calculating the total cost of a renewable utility and the cost of energy for that utility. Three scenarios were modeled (a null scenario with no incentive, an existing incentive in Nebraska, and a federal incentive that until recently was available to renewable utilities) to show the effects of incentives on the cost of production to the utility and the costs to the incentive providers. In Nebraska, the incentive was found to provide some relief to the utility compared to the null scenario and the federal incentive provided significantly more relief to the utility. Costs for the incentive investor with the federal incentive were significantly higher than with the Nebraska incentive, compared to the null scenario. To develop renewable-energy production and mitigate climate change impacts, incentives enable market entry where externalities for fossil fuels are not adequately priced. Adaptation to climate change requires thorough understanding of how the impacts affect society (Chapter 1) and how society might mitigate and adapt to the impacts of climate change (Chapter 2).

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Chapter 1

Climate Change Feedbacks Via Insurance

Introduction

Government policies have been the predominant multi-level approach to adapt to and mitigate the impacts of climate change[1,2]. Yet, past political agreements have been largely unsuccessful to reduce global greenhouse gas (GHG) emissions necessary to avert probable widespread catastrophic effects2[,3] and it is still too early to tell if the Conference of the Parties (COP) 21 agreement from December 2015 will succeed in reducing greenhouse gas emissions. Scientific and political controversies related to climate change have delayed policy implementation and future agreements will probably slowly be established[4,5]. The third UN World Conference on Disaster Risk Reduction produced an agreement, but was found to lack proactive engagement of climate change and indicated a gap in communication between the scientific community and policymakers[6]. While persistent limitations exist for creating effective global policies, the recent costs of climate change provide active feedbacks to business and society via the market mechanism of the insurance industry[7,8,9,10,11]. Feedbacks via insurance (i.e. a one-way reaction from the insurance industry to society in response to societal and environmental stimuli), have been under-recognized as mechanisms to induce adaptation and mitigation to climate change, primarily via the mechanisms of premium adjustments and insurance policy changes, non-coverage, and policy making and litigation. This analysis is the first to document the range of insurance-related feedbacks as adaptation and mitigation strategies.

Downside risks (risks with negative outcomes, such as losses) associated with weather-related disaster events are increasingly managed by the insurance industry, the largest global economic sector with revenue of $4.6 trillion or 7% of the global economy in 20118. Catastrophic climatic events have accounted for 72% of global property and casualty insurance claims and insured losses from 1980 to 2015, totaling $0.98 trillion, and these costs have been steadily increasing (Figure 1). The majority of global insured losses have occurred in North America, Central America, and the Caribbean[12]. These costs only account for catastrophic events, which are 40% of total insured losses compared to 60% of losses from smaller events[13].

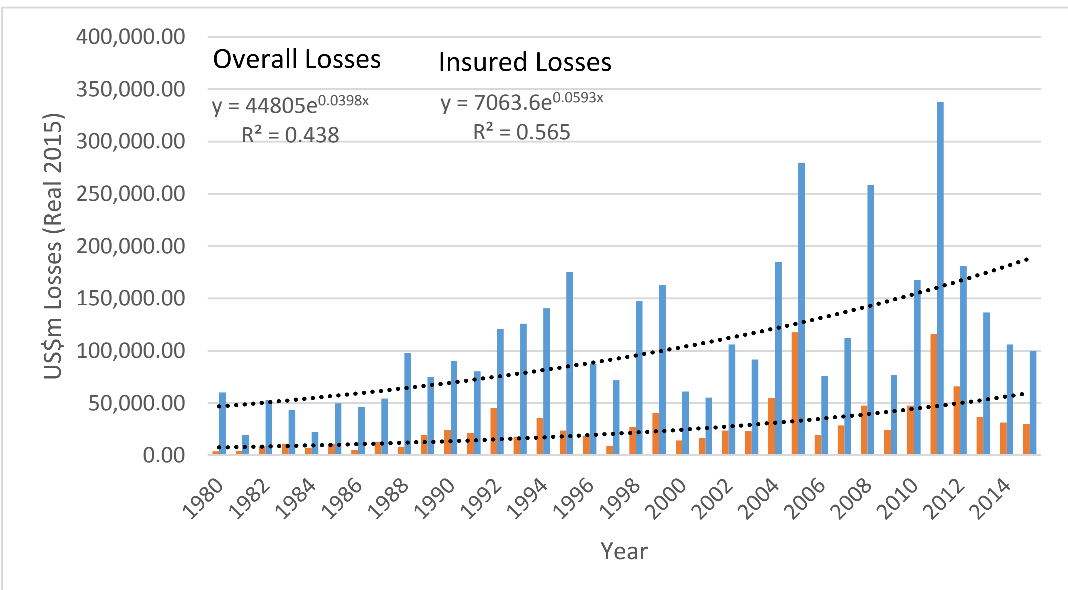


Figure 1.1. Increasing overall and insured losses globally from 1980 to 2015 for catastrophic events only. Source: Munich Re 2016.

Estimated weather-related costs have been ~0.5% of annual, global Gross Domestic Product (GDP) and real costs are increasing at ~6% per year[5]. Furthermore, recent projections estimate that $0.24-0.51 trillion in U.S. property will be below sea level by 2100[14]. In 2016, the World Economic Forum ranked extreme weather events and natural catastrophes as the second and fifth most probable global economic risks to occur in the next 10 years[15]. Additionally, failure of climate change adaptation was ranked first in estimated negative global economic impacts over the next 10 years[15]. Socioeconomic development has been a primary factor for the rapid increase in recent global costs from climatic events[10] and an increased frequency and magnitude of weather-related natural catastrophe costs (Figure 1.2) will result from the future interaction of climate change and socioeconomic development[8,9,10,16,17]. In addition, future economic costs will probably significantly increase if climate change is abrupt instead of gradual[10,18].

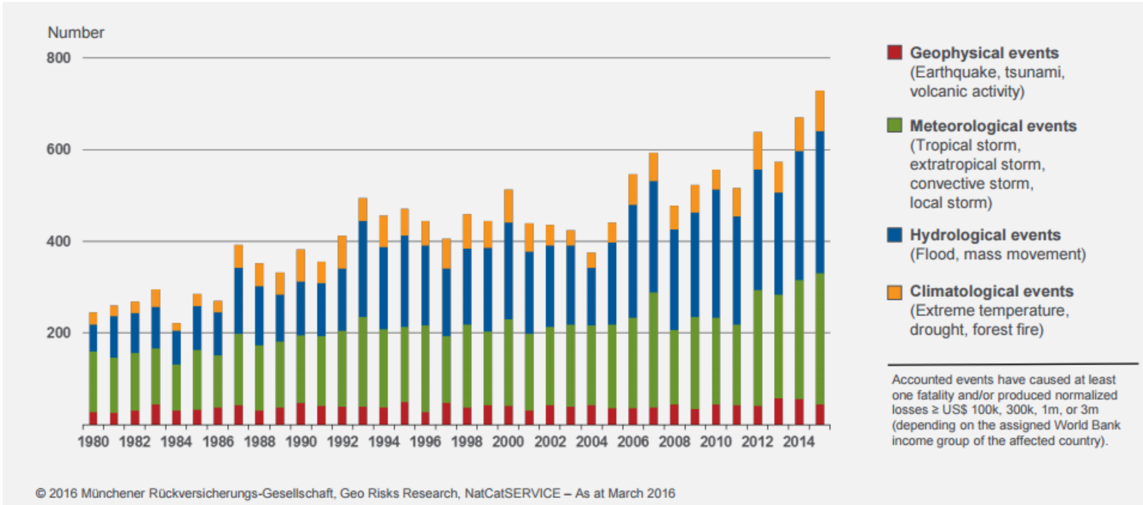


Figure 1.2. Increasing loss events globally from 1980-2013 by type of event. Source: Munich Re.

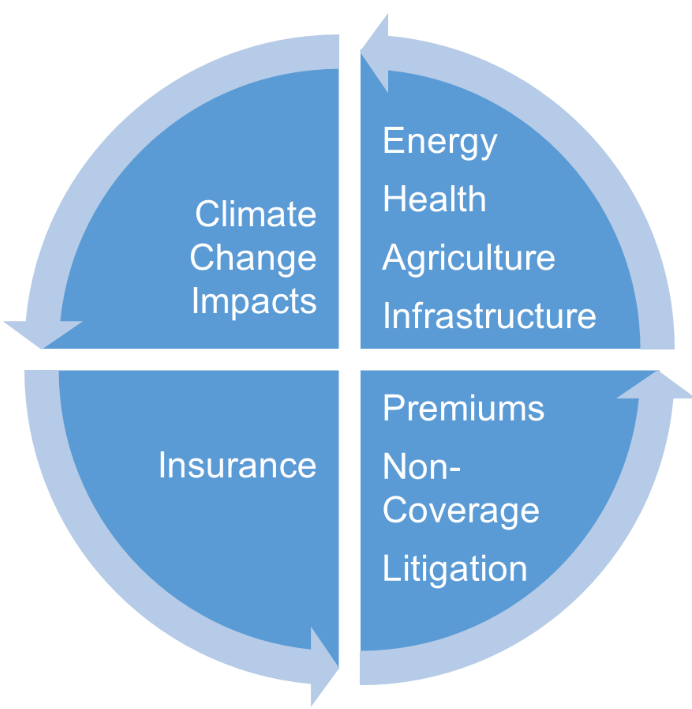
Because of the nonlinear changes associated with climate (e.g. sea-level rise), experience over the last 50-100 years has been identified as an ineffective predictor of future insurance losses[8]. Table 1.1 lists the top 10 costliest disasters by overall losses from 1980-2015, all of which occurred 1994 or after and seven of which occurred in the last 10 years. As conditions change due to climate change, the ability to effectively determine risk is reduced[4,5,13].

Table 1.1. Ten costliest events ordered by overall losses worldwide 1980-2015 Source: Munich Re.

Date	**Event**	**Affected Area**	**Overall Losses in US$ m**	**Insured losses in US$ m**	**Fatalities**
11.3.2011	Earthquake, tsunami	Japan: Aomori, Chiba, Fukushima, Ibaraki, Iwate, Miyagi, Tochigi, Tokyo, Yamagata	210,000	40,000	15,880
25-30.8.2005	Hurricane Katrina, storm surge	United States: LA, MS, AL, FL	125,000	60,500	1,720
17.1.1995	Earthquake	Japan: Hyogo, Kobe, Osaka, Kyoto	100,000	3,000	6,430
12.5.2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an	85,000	300	84,000
23-31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, United States, Canada	68,500	29,500	210
17.1.1994	Earthquake	United States: Northridge, Los Angeles, San Fernando Valley, Ventura	44,000	15,300	61
1.8-15.11.2011	Floods, landslides	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Phthumthani, Nonthaburi, Bangkok	43,000	16,000	813
6-14.9.2008	Hurricane Ike	United States, Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas	38,000	18,500	170
27.2.2010	Earthquake, tsunami	Chile: Concepción, Metropolitana, Rancagua, Talca, Temuco, Valparaiso	30,000	8,000	520
23./24./27.10.2004	Earthquake	Japan: Honshu, Niigata, Ojiya, Tokyo, Nagaoka, Yamakoshi	28,000	760	46

Insurers function on a few assumptions about insurable risks: they are quantifiable (the risk is largely constant over the insurable period and well understood, assuming the law of large numbers), diversifiable (one type of risk may not be a function of another, such as home and auto insurance being independent), fortuitous (may or may not happen), and economically priced (the policyholder can afford to pay)[19]. The three primary feedback mechanisms used by insurance to manage and drive adaptation and mitigation are changes in premium prices and insurance policies, non-coverage, and policy making and litigation (Figure 1.3). The following sections describe the forceful and extensive mechanisms by which the insurance industry manages private property, infrastructure, energy, agriculture, healthcare, and government.

Figure 1.3. Cycle of feedbacks from climate change via insurance.



Feedbacks via Premium Prices and Policy-induced Adaptation

Insurance is a risk management tool which absorbs ~40% of costs from catastrophes in developed countries[20]. Insurance premiums act as a signal of the average probability of a loss9. Premiums from policyholders cover claims, administration fees, and offer a profit to insurers over a designated time period[21]. Insurers will only offer catastrophe insurance if premiums are able to be priced sufficiently and where risks are not excessively uncertain[22,23,24]. As natural disasters increase in frequency and severity, premiums must increase to cover the newly realized insurers' costs and associated unknown risks (Table 1.2). The increase in premiums to cover the costs and unknown risks may leave previously insured assets without insurance and greatly exposed to losses[24,25]. Premiums will also probably increase as a result of socio-economic development, but this is region specific and uncertain[26].

Table 1.2. Ten costliest events ordered by insured losses worldwide 1980-2015 Source: Munich Re.

Date	Event	Affected area	Overall losses in US$ m	Insured losses in US$ m	Fatalities
25-30.8.2005	Hurricane Katrina, storm surge	United States: LA, MS, AL, FL	125,000	60,500	1,720
11.3.2011	Earthquake, tsunami	Japan: Aomori, Chiba, Fukushima, Ibaraki, Iwate, Miyagi, Tochigi, Tokyo, Yamagata	210,000	40,000	15,880
23-31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, United States, Canada	68,500	29,500	210
6-14.9.2008	Hurricane Ike	United States, Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas	38,000	18,500	170
23-27.8.1992	Hurricane Andrew	United States: FL, LA; Bahamas	26,500	17,000	62
22.2.2011	Earthquake	New Zealand: Canterbury, Christchurch, Lyttelton	24,000	16,500	185
1.8-15.11.2011	Floods, landslides	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Phthumthani, Nonthaburi, Bangkok	43,000	16,000	813
17.1.1994	Earthquake	United States: Northridge, Los Angeles, San Fernando Valley, Ventura	44,000	15,300	61
19-24.10.2005	Hurricane Wilma	Bahamas, Cuba, Haiti, Jamaica, Mexico, United States	22,000	12,500	44
June - September 2012	Drought	United States: AR, CO, GA, IA, IL, IN, KS, KY, MO, MS, MT, NE, OH, OK, SD, TN, TX, WI, WY	25,000	12,000	

Premiums are the initial cost of an insurance policy. High initial costs generally deter customers and this includes insurance premiums[21]. Financial viability of policies relies on the application of differential pricing for different cover limits and deductibles[21]. If total-coverage premiums are priced too high for a majority of consumers, then many will choose lower cost policies with less coverage. If these are not available or are also priced too high, then many consumers may choose not to purchase insurance, which reduces insurance profits and exposes the consumer to risk7[,24,27].

High premiums may be a sign from insurers that there is a large amount of risk or uncertainty or that more risk management by at-risk parties is needed[21]. Losses from disaster events were found to be rising faster than premiums in some cases7. If premiums increase too quickly, consumers may choose not to insure or governments may intervene to set limits on premiums where premiums are priced too high for the majority of policyholders, which in both cases may cause insurers to not offer coverage[21], as in Florida in 2010[28].

Where premiums are unable to reflect the true costs of a policy, methods of risk reduction are needed, such as adaptation measures. Individual adaptation or societal mitigation can lead to a decrease in risk to insurers[25,28,29]. There are financial benefits of adaptation to climate change[27] such as cost savings associated with a reduction in risk. In a hard-market scenario, where recent events led to higher premiums and full adaptation (i.e. all buildings retrofitted to meet building code 2004 in Florida), annual premium costs were projected to decrease to $5-6 billion after adaptation compared to $10-14 billion with the existing status of buildings[28]. If all structures also met the requirements set forth by the Institute for Business and Home Safety, the losses from a 1-in-500-year hurricane hitting Florida would be reduced by 50% compared to current levels[28].

Empirical studies show many people do not voluntarily invest in adaptation measures even when they are cost effective[29]. The challenges of reducing the impact of natural disasters is clear from recent catastrophes and the losses associated with them, as well as the failure of residents in these hazard-prone areas to invest in adaptation measures[29,30,31]. Yet, strong market pressure and marketable solutions have been shown to incentivize people to adopt adaptation measures, such as catastrophe bonds which transfer peak risks to capital markets[30].

Experts commonly assess weather-related risks by making best estimates of the probability and potential damage of a hazard using statistical techniques or catastrophe models[10]. These expert assessments, however, often have little influence on actual decision making about risk by lay persons[32]. Lay persons often use very simple rules when they assess risks, which can be described as heuristics[33]. Media outlets are becoming more interested in climate change issues and expert opinions are being brought more to light, changing the frame of media coverage[34]. Individuals may use a so-called 'availability heuristic' in judging natural hazard risk, which implies that they judge an event as risky when it is easy to imagine or remember[32]. People's perception of risk often reflects the automatic, emotional, non-analytic thinking rather than a statistical concept[26,35]. This perception of risk can influence people's decisions for insurance coverage and other preparations for natural catastrophes.

A combination of measures that limit damage and reduce the probability of natural catastrophes has been shown to be the most effective way of reducing extreme costs[36]. Insurers may require households to undertake such measures to mitigate damage or to take precautionary measures[29,37,38]. These measures may also lead to policy benefits such as premium discounts or higher levels of coverage due to increased risk reduction behaviors[39]. These behaviors may also reduce post-disaster risk due to failures in structures or environmental contaminants after a disaster[40]. Precautionary measures have seen some success internationally, such as the flood damage in Germany during the extreme flood of the Elbe in 2002[39,40,41]. Another example is through the National Flood Insurance Program (NFIP) in the U.S. that, after setting compulsory mitigation standards, reduced flood losses on new structures by a factor of six[42], but the NFIP failed to restrain development in flood plains potentially due to premiums not being risk based and being subsidized[43]. Past experiences from other countries show mitigation measures at a household level can be effective in limiting flood damage, reducing costs for insurers over the long term[39]. This same experience may be applied to other aspects of insurance with further research.

Table 1.3. Ten costliest flood events ordered by insured losses worldwide 1980-2015

Source: Munich Re.

Date	**Event**	**Affected area**	**Overall losses in US$ m**	**Insured losses in US$ m**	**Fatalities**
1.8-15.11.2011	Floods, landslides	Thailand: Phichit, Nakhon Sawan, Phra Nakhon Si Ayuttaya, Pathumthani, Nonthaburi, Bangkok	43,000	16,000	813
12-22.8.2002	Floods, flash floods	Germany, Austria, Czech Republic, Hungary, Moldova, Switzerland, Slovakia	16,500	3,400	39
25-30.6.2007	Floods, severe storms	United Kingdom: England	4,000	3,000	4
30.5-19.6.2013	Floods	Austria, Czech Republic, Germany, Hungary, Poland, Switzerland	12,500	3,000	25
20-23.7.2007	Floods	United Kingdom: England, Wales	4,000	3,000	1
10-14.1.2011	Floods, flash floods	Australia: Queensland, Brisbane, Ipswich, Toowoomba, Grantham, Gladstone	3,200	1,900	22
20-28.8.2005	Floods	Austria, France, Germany, Hungary, Slovenia, Switzerland	3,300	1,800	11
19-24.6.2013	Floods, severe storms	Canada: Alberta, Calgary, Canmore, High River, Medicine Hat, Bragg Creek	5,700	1,600	4
October - November 2000	Floods	United Kingdom, Ireland	2,000	1,500	10
27.6-15.8.1993	Floods	United States: MS, MO, IA, IL, ND, IN, MN, WI, KS, NE, SD	21,000	1,300	48

How might insurers appeal to policyholders to adopt mitigation and adaptation measures? One possible solution is multi-year contracts, which would make the benefits of adaptation clearer as the probability of a disaster during the time frame would be higher[22,29,30]. Another possible solution provides incentives to households to limit damage from floods by purchasing relevant materials and taking related action[37,39]. Insurance companies can incentivize policyholders by abandoning riskier markets, raising premiums, insisting on greater deductibles or lowering coverage, and refusing to insure property without a list of protective measures[44]. Other incentives used in the past to reduce risk include founding of government services in areas previously without the service (e.g. fire departments) and regulations (e.g. advocating for building codes or auto safety)[19]. Though potentially effective, these measures are similar to building waste treatment facilities for a polluted river rather than redesigning the processes that dumped the effluents into the river[44]. More proactive engagement of risk management is a valuable investment and ultimately reduces insured losses[45]. In crop insurance, insurers may offer a premium discount if the insured adopted a risk reducing practice. For example, premiums were reduced where producers planted a specific drought-tolerant corn hybrid that was later widely adopted and the discount discontinued.

Feedbacks via Non-coverage

Inaction is a major factor contributing to negative economic impacts from climate change[45]. Non-coverage is the undesired result of inaction, of which there are two subtypes. The first is where insurance premiums are not allowed to reflect true risk, leading insurers to not offer a policy. The second type of non-coverage is when premiums are allowed to reflect true risk, but the premiums and deductibles (amount paid out-of-pocket for a claim) are too costly for the consumer to purchase the policy[9,40,45]. Both scenarios result in uninsured property, persons, or development that leave consumers, industry, and the economy at risk.

Non-coverage is a market failure associated with the forceful mechanisms of the insurance industry on society. Non-coverage is the result of a lack of communication and ability to provide feedback between society and the insurance industry. As a result, we can view non-coverage as an indicator of where failure in these mechanisms occur. Non-coverage can also be used as a deterrent of compounding harmful behaviors related to climate change similar to non-coverage as a deterrent for other safety and health violations[7,27,45].

In the case of a standard insurance policy, two conditions must be met in order for insurers to willingly offer insurance[23]. Insurers must be able to quantify the probability and severity of an uncertain event, and insurers must be able to set premiums for each customer or group of customers[23]. As further climate science and related research is completed and becomes publically available, the comprehension of climate change as a risk source increases and the probability of non-coverage decreases. But as this understanding increases, the perceived risks might increase, causing a rise in premiums in order to cover the potential losses[6,7,23,45]. This places the economic burden on the consumer and can result in non-coverage by choice on part of the consumer, and result in an availability-affordability crisis[45]. Non-coverage also pressures public organizations to assume more climate risks which may lead to more federal debt, such as when the National Flood Insurance program insured damage from Hurricanes Katrina and Ike9[,24].

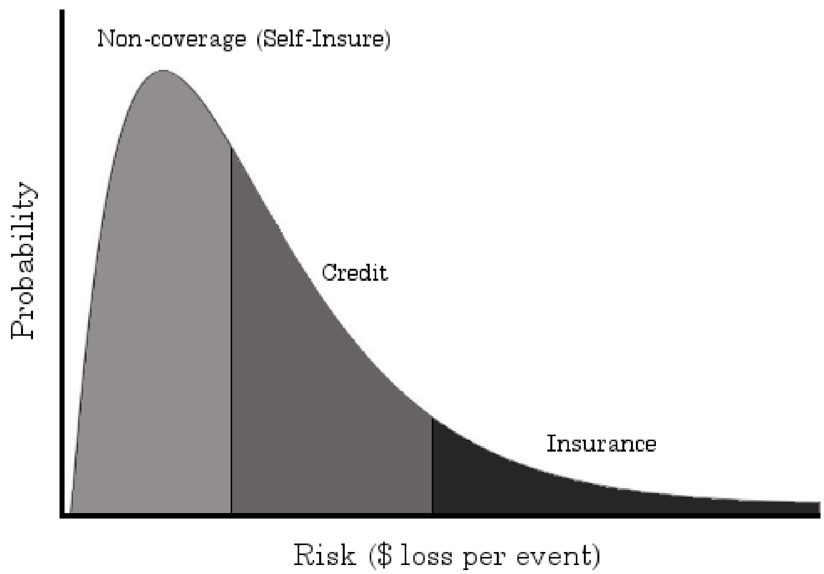


Figure 1.4. Financing climatic loss at different levels of risk.

Financing of risks can come from a variety of sources (Figure 1.4). The primary source is the party itself through non-coverage (savings or working capital) for risky events that are frequent and not severe. The next category, credit, protects against events that are somewhat frequent and severe enough where the party converts equity into cash in order to pay for the event. The final category, insurance, covers events that are rare and have high financial impacts; equity alone cannot cover the financial cost of these events. The insurance category differs from the credit category because they communicate with the party through an offered premium. The ability of the party to self-insure (i.e. have available funds, as opposed to gambling) and/or have access to credit will vary highly upon party characteristics whereas insurance will be offered across almost all characteristics. As a result, there could exist a large gap between insurance and non-coverage.

Change in risks will lead to a change in probability of experiencing an event in non-coverage, credit, and insurance, leading to updated communication between insurance and parties. To lower the probability of non-coverage and credit events, as the probability of rare, financially costly events increase (fattening of the tail in Figure 1.4), insurance companies are required to charge a higher premium to cover higher expected losses. This communication can lead to adaptation by the party to minimize the new risk. In turn at some point in the future, the insurance company will lower premiums because parties took action that lowers risk.

Events leading up to non-coverage and the effects of non-coverage can be seen in the Saint Bernard Parish district of New Orleans after Hurricane Katrina[24]. Hurricane Katrina caused total insured losses ≥$41 billion[46]. This amount of damage and risk has turned insurers away and now a house in the Saint Bernard Parish district (and many other parts of New Orleans) is virtually uninsurable, causing the districts to remain near barren as the area is unaffordable[46]. The risk for insurers to insure parts of New Orleans is extremely high and the lack of understanding of these risks also plays a part in keeping premiums too high to afford or for a lack of available insurance[46]. Hurricane Katrina was estimated as a 1-in-396-year storm, meaning that any given year has a 0.25 percent chance of seeing such a storm by the US Army Corps of Engineers[46]. However, the company Risk Management Solutions saw Hurricane Katrina as a 1-in-40-year storm causing some dissension in interpretation of significant natural catastrophe risk[46]. The lack of understanding and significant losses caused many insurance agencies to choose to not provide coverage and a similar situation could occur in other places as more extreme events occur (Table 1.4).

Feedbacks via Policymaking and Litigation

Laws give our governmental system power to protect its citizens and to standardize responses to issues or problems. With the complexity of climate change, widespread political action has either been criticized because climate change regulation may exacerbate other problems, or favored because standardization of responses to climate change may strengthen the effectiveness of solutions and greatly diminish problems. The insurance industry has a role in influencing policy and regulation9[,11,38].

Government policies impact the insurance industry directly by exempting parties from liability, subsidizing insurance deductibles or premiums, engaging in reinsurance, or providing coverage that competes with private sector insurance7. The role of government in natural disaster relief has decreased over the last 20 years as insurance coverage of natural disaster relief has increased from 20% to 40% in developed countries[24].

Table 1.4. Ten costliest storm events ordered by insured losses worldwide 1980-2015 Source: Munich Re.

Date	Event	Affected area	Overall losses in US$ m	Insured losses in US$ m	Fatalities
25-30.8.2005	Hurricane Katrina, storm surge	United States: LA, MS, AL, FL	125,000	60,500	1,720
23-31.10.2012	Hurricane Sandy, storm surge	Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, United States, Canada	68,500	29,500	210
6-14.9.2008	Hurricane Ike	United States, Cuba, Haiti, Dominican Republic, Turks and Caicos Islands, Bahamas	38,000	18,500	170
23-27.8.1992	Hurricane Andrew	United States: FL, LA; Bahamas	26,500	17,000	62
19-24.10.2005	Hurricane Wilma	Bahamas, Cuba, Haiti, Jamaica, Mexico, United States	22,000	12,500	44
7-21.9.2004	Hurricane Ivan, storm surge	United States, Caribbean, Venezuela, Colombia, Mexico	23,000	11,800	120
20-24.9.2005	Hurricane Rita, storm surge	United States: FL, LA, MS, TX	16,000	9,600	10
11-14.8.2004	Hurricane Charley	United States, Cuba, Jamaica, Cayman Islands	18,000	8,000	36
22-28.4.2011	Tornadoes, severe storms	United States: AL, AR, GA, IL, LA, MO, MS, OK, PA, TN, TX, VA	11,000	7,300	350
20-27.5.2011	Tornadoes, severe storms	United States: AR, GA, IL, IA, IN, KS, KY, MD, MI, MN, MO, NC, NE, NY, OH, OK, PA, TN, TX, VA, VT	10,000	6,900	178

Many countries with smaller economies are finding significant trouble in financing natural disaster relief due to budget constraints, limited tax bases, and existing debt[24]. While countries with large economies still have a buffer to protect them from these widespread losses, as the rate and severity of natural disasters increases, the ability of this buffer to protect nations from the crippling effects of widespread losses is dwindling in the wake of disasters[9,24]. Reliance on outside aid from other nations is a risk as there is no contractual obligation for donor aid and this type of disaster relief is subject to political and societal uncertainty[24]. As the need for more effective natural disaster relief becomes apparent, many governments are beginning to rely on insurance as a major tool to provide a reliable system to their citizens[9,24,45].

Insurance has a role in creating policy and regulation as well. The Affordable Care Act had several influencing factors in its design and implementation but contributions from the health insurance industry played a key role in the eventual compromised bill[27]. The insurance industry's influence brought them several victories in the bill including lower shares of medical costs over the governments cost involvement compared to early proposals of the bill, nearly complete eradication of government rate regulation, and most importantly, government subsidies for low-income clients[27]. Health insurance is but one facet of the insurance industry. Other bills have been influenced that involved other sectors of the insurance industry, such as life insurance, property and casualty insurance (mostly on a state level rather than a federal level), and crop insurance. Another example of government and insurance industry interaction is in the Federal Crop Insurance program. The government interacts with the insurance companies by sharing in reinsurance losses and gains. For example, if there was a widespread drought the insurance company will share with the government in payments to producers. Alternatively, if premiums were larger than payments (a reinsurance gain) then the government receives a portion of the gain. The level of sharing depends upon the size of the loss. Larger losses, which puts pressure on the company to fail, are absorbed at a higher rate by the government. This risk sharing strategy aims to provide efficient and effective disaster relief by minimizing the probability of insurance company failure and government expenses in providing ad hoc disaster aid packages.

The insurance industry influences government and society through campaign donations, lobbying, advertisements, and other monetary and social means. On a national level the Affordable Care Act brought together proponents of health insurance on a matter that affects all of them and high levels of influence was shown[27]. The insurance industry also has lobbying influence at the state level of government where the bulk of insurance regulation is drafted[27]. If the same level of influence is brought to climate change insurance issues, which affect every sector directly or indirectly, the insurance industry can have input to the laws and regulations (or lack thereof) that contribute to climate change costs and be a key part of compromise solutions.

The insurance industry interacts with the public sector in providing protection against risks though there is always disagreement over the allocations of costs7. In the Saint Bernard district of New Orleans, the insurance agencies sent assessors allegedly not to help those stricken by the disaster but to avoid paying out on their policies by asserting that damage was caused by floods and not wind[47]. The insurance agencies had policies that offered protection against wind damage while the government provided policies that offered protection against flood damage (through the National Flood Insurance Program)[47]. The lack of cohesion in the economic response to Hurricane Katrina is one example of non-optimized risk allocation that resulted in $109 billion in post-disaster assistance and $8 billion in tax relief provided by the government[48]. For insurance and government to be more efficient and effective at disaster adaptation, mitigation, and relief, there must be more cooperative policy, but due to the immense costs from climate change there will probably continue to be significant disagreements over the distribution of costs between the two sectors.

Litigation from insurance to government has been the result of ineffective policy or failure to reasonably foresee and adapt to the impacts of climate change. In 2013, The Farmers Insurance Co. sued the city of Chicago, Illinois for damages caused by storm water and sewage overflow on the basis that the local municipalities knew that the drainage systems were inadequate but failed to take reasonable action to prevent these damages[48]. The charges were eventually withdrawn by Farmers Insurance Co., stating that the important issues were brought to the attention of the respective cities and counties and with the hope that policyholders' interests will be protected in the future[48].

As climate change impacts are further researched and understanding of these impacts grows, it is probable that more government entities will be held responsible for damages caused by climate change if proactive action is not taken to increase system resiliency[48]. Higher insurance losses and more claims due to the impacts of climate change will increase the pressure of feedback from the insurance industry to government and will probably increase the amount of litigation unless insurance and government work together to protect policyholders and adapt and mitigate to the impacts of climate change.

Conclusion

Properly priced insurance delivers value to consumers when it covers events that are both rare and highly costly to individuals but common to society[25]. Natural catastrophes fit this category and can have devastating costs that affect members of society and the insurance industry[49]. The occurrence and severity of these natural catastrophes are increasing9[,10,24]. Increased losses will challenge insurance systems to adapt and offer affordable coverage and society to adapt and mitigate impacts from climate change[10]. Risk financing systems, including insurance, will need to be cautious of downside risks that can cause disincentives, market failures, and decrease equity[10]. Through improved research, the interactions between the insurance industry and society can create more efficient and effective risk management strategies for public and private interests to address the challenges from climate change[10]. The risk from climate change to insurers comes from its changing nature. The earth is a complex adaptive system, and non-linearity leads to unintended and unexpected outcomes that are unforeseeable. Encouraging proactive cooperation between private insurers and government can increase the likelihood that mitigation techniques and adaptation can align incentives to protect the environment. Premiums and policy-based adaptation, non-coverage, and policy making and litigation all provide forceful feedbacks from insurance to society. Feedback from the insurance industry to society affects all levels of insurance and so affects the interactions of the insurance industry across all industries (e.g. energy, infrastructure, agriculture, health). With investments in these industries, the insurance industry will be extensively affected by climate change. The insurance industry will continue to be a forceful and extensive mechanism to drive adaption and mitigation measure to climate change impacts in the absence of, and alongside, effective government policies.

Chapter 2

The Effect of a Financial Incentive on Renewable Energy Production

Introduction

To mitigate climate change and develop competitive renewable energy, the need for financial incentives (defined as a payment or concession that incites or tends to incite to action or greater effort, or as a reward for increased productivity) is largely accepted as fact among those in renewable energy[50]. The opposition to providing incentives for renewable energy often occurs because incentives are seen as either aid from the government or an additional tax. Most financial incentives are largely based in government policies and there is often disagreement on incentives among groups with competing interests[50,51], whether it is the nature of the incentive itself or the origin of the incentive. The political nature of incentives can serve to limit the number of incentives offered for renewable energy and to hinder the production of smaller scale utilities[52]. Large utility companies that depend on coal, and some on nuclear, for electricity generation make entrance into the electricity market difficult for small scale utilities or intermittent utilities that deliver renewable electricity[52]. The first chapter of this thesis discussed the climate externalities of fossil fuels as captured in premium prices and the insurance industry. The real costs of climate change (Chapter 1) are not included in the prices of fossil fuels, because these externalities are not recognized; a phenomenon similar for a wide range of products, such as produce or wood production[53]. Renewable energy incentives provide necessary support for entry into the market when externalities are not included in the price of fossil fuels.

Incentives provide a firm foundation to enable new products to enter a market. If society prioritizes renewable energy production it is imperative for incentives to be offered so that renewable energy sources can compete with industries like oil, natural gas, coal, and other fossil-fuel based industries, which receive their own subsidies and have not comprehensively incorporated externalities[50]. According to the U.S. Energy Information Administration, coal-produced energy accounted for 16% of total primary energy consumption in 2015. Natural gas-produced energy accounted for 29%, oil-produced accounted for 36%, nuclear energy accounted for 9%, and all renewable-produced (hydro-electric, geothermal, solar/PV, wind, and biomass) accounted for 10% of consumption[54]. In total, fossil fuels accounted for 81% of total primary energy consumption in 2015, and only 19% from non-fossil fuel sources.

Incentives help lower the starting costs of a utility and can serve to bring the cost of renewables to an economically competitive level in the current market, one without adequately priced externalities[55]. Electricity purchase from renewable sources is low (around 2-3%) except in cases where there are strong incentives such as tax exemptions for electricity consumers[56]. Garcia et al.[50] says "Given the comparatively higher costs of renewable technologies (e.g. wind, solar) there appears to be a consensus on the need for regulatory intervention to promote investment in these technologies."

In the United States, incentives differ from state to state and the types and amount of incentives vary greatly. According to the Database of State Incentives for Renewable Energy (DSIRE), which was created in a joint effort by the U.S. Department of Energy and the North Carolina Clean Energy Technology Center, there exists only 19 total renewable energy incentives in Nebraska, of which only a few are available for large-scale or small-scale utilities and the rest being residential options or policies. Comparatively, California (known for its progressive environmental stance and laws) has nearly 180 different renewable energy incentives, of which a larger proportion are available to large-scale utilities and more options for residential and small-scale utilities. This is in part due to the nature and political climate of Nebraska energy. Nebraska is the only state with 100% public power meaning all utilities are publically owned and are legislatively mandated to use the most inexpensive and reliable energy sources.

For large-scale utilities to be developed, incentives must also be developed to allow renewable energy utilities to be competitive with fossil-fuel based utilities[55]. The purpose of this chapter is to compare state and federal scenarios that incentivize renewable energy development. Data were used to examine the effects an incentive has on the price of energy and on the revenue needed to break even within a large-scale renewable utility. The need for incentives to develop renewable energy projects are discussed as well as the capital needed to provide these incentives if renewable energy production is a priority for society.

Methods

To compare state and federal scenarios for incentives for renewable energy development, an existing cost model was needed to calculate the total cost of a large-scale utility and the cost of energy for that utility. The National Renewable Energy Laboratory (NREL) published a document that highlighted several cost models called *Renewable Energy Cost Modeling: A Toolkit for Establishing Cost-Based Incentives in the United States*[57]. To establish a standard, only one model was needed. The California Renewable Energy Transmission Initiative (RETI) model (Black & Veatch Corp.) was chosen due to its simplicity in calculating costs and the omission of extraneous variables. This model is not limited to one renewable energy technology so it is versatile in the scenarios it can handle.

While the inputs to the model are basic and may not be sufficient in some environments, it has all the inputs needed to generate a cost of electricity (COE) analysis[57]. The model takes into account several factors including user-defined equity return requirements, debt parameters, operation costs, taxes, and several other inputs. The most important inputs for the purpose of this paper are the incentives. Creating incentives for electricity producers to adopt renewable energy technologies allows public policies to be aimed at stimulating technical change and learning processes that enable costs to be brought down to an economically competitive level[55]. Incentives are not based on resources and do not have an inherent cost to them. They are highly variable and can play a significant role in making renewable energy cost-effective[55,58]. If escalation assumptions (the assumed rise in costs of a component of energy production over time) are given (Fixed O&M escalation, Variable O&M escalation, etc.) then the model generates a levelized cost of energy (LCOE) which is the main output of the system. The LCOE is the generalized cost of energy in order for the project to break even over the lifetime of the project. Standard technology assumptions were held constant in the RETI model (values shown in Table 2.1).

Table 2.1. Standard Technology Assumptions section of RETI model with assumed standard values

Project Capacity (MW)	60
Capital Cost ($/kW)	$2,000
Fixed O&M ($/kW)	$35
Fixed O&M Escalation	2.50%
Variable O&M ($/MWh)	$10
Variable O&M Escalation	2.50%
Fuel Cost ($/MBtu)	$0
Fuel Cost Escalation	0.00%
Heat Rate (Btu/kWh)	0
Capacity Factor	37%
Misc Revenue ($/MWh)	$5
Misc Escalation	2.50%
Degradation	2%

Values were changed to better reflect the actual total cost of an average wind farm but due to data constraints many values were set at the default RETI model standards. Project capacity was set at 60 MW to reflect an average large-scale wind energy project in Nebraska[59], specifically modeled after the Flat Water wind farm near Humboldt, Nebraska. Capital cost was set at $2,000 per kilowatt (kW) to reflect average capital costs[60]. Fixed Operation & Maintenance (O&M) costs were set at $17/kW as the average cost[61]. Variable O&M are the costs associated with O&M that may change depending on the amount of electricity generated. This value was set as the default value from the RETI model along with the escalation of both O&M costs. Fuel cost was set at $0, fuel cost escalation at 0%, and Heat Rate at 0 BTU/kWh because of the nature of wind energy electricity generation. Capacity factor is the percentage the plant is operating compared to the maximum (if it was operating all the time). The capacity factor was set at 37% as the average capacity factor[61]. Miscellaneous revenue, escalation and degradation were set at $5, 2.5%, and 2% respectively as the default values from the RETI model. Some values were kept at the default setting of the RETI model due to a lack of easily accessed data for wind energy farms and because they are simply standard values and are not subject to analysis they were set as the default for the sake of ease. Standard Financial/Economic Assumptions were held constant in the RETI model (values shown in Table 2.2).

Table 2.2. Standard Financial/Economic Assumptions section of RETI model with assumed standard values

Debt Percentage	60%
Debt Rate	6.50%
Debt Term (years)	15
Economic Life (years)	25
Percent 5-year MACRS	100%
Percent 7-year MACRS	0%
Percent 15-year MACRS	0%
Percent 20-year MACRS	0%
Energy Price Escalation	2.5%
Tax Rate	39%
Cost of Equity	7.75%
Discount Rate	8.000%

Debt percentage, debt rate, debt term, economic life, percent 5-year MACRS, energy price escalation, and cost of equity were set as the default values of the RETI model because they were common values (debt term, economic life) associated with renewable energy projects or were project-dependent variables and no one value was commonly attributed to it (debt percentage, debt rate). The tax rate was set to 39% as the average tax rate[61]. The discount rate was set to 8.00%[61].

The RETI model gives the LCOE as the main output. The LCOE serves as the point of comparison for the scenarios outlined in this article. Three scenarios were modeled using the RETI model and with LCOE as the output. First, a null scenario was created using the default standards (listed in Tables 2.1 and 2.2) with no incentive. Second, a Renewable Energy Tax Credit scenario was factored into the model. This scenario kept all values as the null scenario except for the incentive category, which was changed to $0.50/MWh. Third, a Renewable Electricity Production Tax Credit scenario was developed in which a large incentive currently offered federally (Renewable Electricity Production Tax Credit) is factored into the model.

The total amount needed to break even (total revenue is equal to total costs over the lifespan of the project) is calculated by multiplying the LCOE times the capacity of the project (60 MW), the number of hours in 25 years (81,030), and the capacity factor (0.37). The values for capacity, capacity factor, and hours of operation were added to the existing incentives section of the RETI model to show the relevant data for the calculation of total amount to break even. This value was added to visualize the total amount of revenue needed over the lifespan of a project to offset its costs in a way that is more approachable than LCOE. The total amount to break even of each project is compared below, in order to analyze which scenario provides the most amount of support for renewable energy production and by how much. The purpose of this analysis is to discuss how incentives provide support for renewable energy production and to determine the differences between a relatively small incentive (the Nebraska incentive) and a larger incentive (the Federal incentive).

Results/Discussion

With no incentive as a standard for comparison, the total amount to break even was $532,756,044.00 (Table 2.3). This means that over the life of the project (25 years) the wind farm must make $532,756,044.00 simply to offset the costs of the project.

Table 2.3. Incentives section of RETI model with values for no incentive.

PTC ($/MWh)	$0.00
PTC Escalation	0.0%
PTC Term (years)	0
ITC	0%
ITC Depr Basis	0%
LCOE ($/MWh)	$109.58
Capacity Factor	0.37
Hours of Operation	81030
Total Amount to break even	$532,756,044

The total amount to break even in Table 2.3 accounts for only the costs and revenues from the renewable energy project developer with no cost reduction from an incentive. However, it serves as a more understandable basis for comparison between the presented scenarios. The null scenario total amount to break even compared to the total amount of the Nebraska incentive shows a savings of $5,445,216 over the life of the project (Table 2.4). With the Nebraska incentive, a renewable energy producer would expect to spend $5,445,216 less before offsetting costs and generating a profit, compared to the null scenario (without any incentive). However, no incentive compared to the federal incentive shows a difference of $126,115,092 over the life of the project (Table 2.5). With the Federal incentive, a renewable energy producer would expect to spend $126,115,092 less before offsetting costs and generating a profit, compared to the null scenario.

Table 2.4. Incentives section of RETI model with values for the Nebraska incentive.

PTC ($/MWh)	$0.50
PTC Escalation	0.0%
PTC Term (years)	10
ITC	0%
ITC Depr Basis	0%
LCOE ($/MWh)	$108.46
Capacity Factor	0.37
Hours of Operation	81030.00
Total Amount to break even	$527,310,828.00

Table 2.5. Incentives section of RETI model with values for the Federal incentive.

PTC ($/MWh)	$23.00
PTC Escalation	0.0%
PTC Term (years)	10
ITC	0%
ITC Depr Basis	0%
LCOE ($/MWh)	$83.64
Capacity Factor	0.37
Hours of Operation	81030
Total Amount to break even	$406,640,952

These differences are comprised solely from the money given to the utility by the incentive program. If the incentive is a state government program compared to a federal program, then the money given to the utility ultimately comes from the taxpayers of that state. In the absence of adequately priced externalities, this money appears to be a cost. When compared to a system that prices these externalities, however, the costs of fossil-fuel based energy production are greater than the money invested in renewable energy development[53]. Nebraska had a population of 1,868,516 people in 2013 according to the United States Census Bureau[62]. Taking the total savings of the Nebraska incentive (~$5.4 million) and dividing it by the population of Nebraska (~1.87 million) gives a cost of $2.91 per person over the course of 25 years (the life of the project) or a little under $0.12 a year per person. The Renewable Electricity Production Tax Credit saw a savings of $126,115,092 over the life of the project compared to the null scenario. This amount divided by Nebraska's population shows a cost of $67.49 per person over the life of the project or $2.70 per person per year. Nebraska generated 34,217,293 MWh in 2012 according to the U.S. Energy Information Administration[63]. This generation divided by the MWh produced by the renewable energy development (81030 hrs x 60 MW x 0.37 = 1,798,866 MWh) gives 19.02 which is the number of electricity generation facilities at 60 MW capacity and with a capacity factor of 0.37 needed to meet total electricity generation for Nebraska in 2012. The incentive amounts of $0.12 and $2.70 per person per year become $2.28 and $51.35 per person per year if all electricity production in Nebraska is generated from renewable energy plants with similar values to the standards set in Tables 2.1 & 2.2 and are incentivized with a program similar to the Renewable Electricity Production Tax Credit.

The amount needed to break even with the Nebraska incentive is an optimal situation in which the program budget is large enough to cover any and all production of electricity from a renewable resource. The program, however, is limited by a budget of $50,000 per year according to DSIRE. This means that for all projects using the incentive the total amount of tax credit given cannot amount to more than $50,000 per year. So a project is actually limited to $1,250,000 over the course of 25 years assuming it gets all $50,000 of the program budget. When several projects are using this incentive at the same time the projected savings of a project is significantly lower, meaning it is less probable that more renewable energy production will develop.

Molly Sherlock[64] states that the PTC has been important to the growth and development of renewable electricity resources, particularly wind. However, Sherlock argues that tax incentives may not be the most economically efficient way to correct for the distortions in energy markets. Tax subsidies (such as a large number of renewable energy incentives are) reduce the average cost of electricity, increasing demand overall. This counters the energy efficiency and emissions reduction objectives.

Conclusion

Incentives serve as a building block for market entry. In a market that is dominated by oil and gas companies, where externalities are not priced adequately, it can be nearly impossible for renewable energies to become competitive. That's why it is vitally important for incentives to play a part in renewable energy generation technologies if development is desired. Without an incentive or other financial tool to make market entry easier many renewables simply do not have the capability to enlarge their market share and establish themselves in the market.

An incentive can be a powerful tool in developing large-scale renewable energy generation projects. While the models were simulated with an average size wind farm similar incentives can be found for other renewables as well. Larger-scale wind projects are also already running or currently in production in Nebraska[59]. However, as energy demand increases more and larger renewable energy production facilities must be built to meet demand and to meet energy emission standards. As the capacity of a system increases the total cost of the project, the LCOE, and the total amount to break even increases. So a higher demand for energy leads to an increase in energy production, leading to more and larger energy projects, leading to increased initial costs, leading to potentially more costs for incentives. This increase is offset by lower energy prices over the life of the renewables and more development leads to an increase in market relevance. Incentives serve as a way for a technology or product to enter a market but does not dictate what happens once it is established. So as the market share of renewables increases the need for incentives will decrease.

A large portion of the accumulated research on regulatory design for renewable energy compares alternative options to incentivize it, rather than whether or not it should be incentivized[50]. Examples of this being Butler & Neuhoff[51], Menanteau[55], Lipp[65], and Mitchell et al.[66]. This leads to the conclusion that it is generally accepted that regulatory incentives are needed for renewable energy development. However, there has been some success in some electricity markets for hydro-electric power without incentives[67]. The key differences being base-load power (a constant source rather than an intermittent source such as wind or solar) and long life spans of hydroelectric projects which are projected at 50 years typically[68] compared to 25 years for wind.

Renewable energy technology has a higher investment cost compared to non-renewable energy technology and is an intermittent source of electricity[68]. Non-renewable energy technology has a lower investment cost but has additional fuel expenditures and carbon emission costs[69]. There is much research on renewable energy and the potential future for renewables in the current electricity system[50,55,66,69,70]. This chapter shows the effect incentives have on renewable energy production and the costs associated with those incentives. In a market without adequately priced externalities, fossil-fuel based energy production is significantly cheaper[53] than renewable based energy production. When the externalities of fossil-fuel based energy production (impacts of climate change) are accounted for the true costs of fossil-fuel based systems become much higher than renewable energy production. In the absence of a system that prices externalities for fossil fuels, incentives serve as a way to enable renewable energy development and act to indirectly mitigate the impacts of climate change.

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