Understanding the Cost of Climate Change:
A Guide for Local Actors

Prepared for King County by:
Erica Asinas
Crystal Raymond
Climate Impacts Group, University of Washington

March 2021
Introduction
The purpose of this review is 1) to provide an overview of key concepts and foundational science related to the study of the economics of climate change and 2) to identify proven methods for conducting economic valuations of climate impacts on a local government scale. The sections covered in this document are as follows:
1. Background
2. Defining the Purpose of the Economic Assessment
3. Approaching Risk and Uncertainty
4. Identifying Climate Scenarios
5. Identifying Socio-Economic Scenarios
6. Translating Climate Impacts into Economic Values
7. Valuation Methods
   7.1 Direct Losses: Market Impacts
   7.2 Comparison Between Valuation Methods for Direct Losses: Market Impacts
   7.3 Direct Losses: Non-market Impacts
   7.4 Indirect Losses: Systemic Impacts
8. Discounting Costs
9. Conclusion

1. Background
Climate change shapes society’s economic and social well-being, and the economics of climate change can inform local governments in their resilience planning. The valuation of potential climate impacts allows decision-makers to better understand and prepare for varying magnitudes of risk, while cost-benefit analyses aid the design of policy instruments for both mitigation and adaptation. Additionally, chronic and acute shifts in weather and climate affect the performance of entire economic sectors, as well as the financial security of private actors and households. Despite widespread impacts, the relatively new and complex field of climate change economics has only been widely adopted in contemporary economics within the last 25 years.

While the foundational science for appraising natural and human systems was established in the 19th century, it was only in 1995 that the Intergovernmental Panel on Climate Change (IPCC)’s globally institutionalized the importance of understanding the economic and social dimensions of climate change (Cooper and Bruce, 1997). In 2008, a United States Court of Appeals decision required the federal government to account for the economic effects of climate change in regulatory cost-benefit analyses, and several state-level assessments were conducted shortly thereafter (e.g in Illinois, Maryland, New Jersey, New York, and Washington). However, in retrospect, these state assessments have been critiqued for taking an overly simplistic approach to determining the cost of impacts (Neumann & Strzepek, 2014). Furthermore, most of the existing work on the economics of climate change has been focused on global and national scale impacts while local-scale assessments remain limited.
While significant scientific and technological advancement in global and national climate modeling showcase progress, climate change continues to challenge available economic techniques to its limits (Nordhaus, 2019). Key areas of concern that analysts continue to struggle with include:

- The treatment of uncertainty in human and natural systems
- The choice of the proper scenarios against which to make comparisons
- The actual valuation of specific impacts
- The aggregation of impacts over time and across differing social and economic contexts.
- Incomplete accounting

Due to the aforementioned concerns, **no economic assessment to date claims that any dollar estimate can or should be used as a definitive cost of climate change.** Rather, monetary values are a means to weigh risk relative to other climate impacts, other geographies, or across varying socioeconomic contexts. They serve as political instruments for decision-makers to understand which assets and communities are most vulnerable, and to allocate limited resources accordingly. The challenges listed above underpin the critical assumptions analysts make that ultimately shape the accuracy and relevance of their assessment. The following sections explore how local actors seeking to do an economic assessment can address these challenges.

### Snapshot: National Scale Economic Assessments

**Risky Business: An American Climate Prospectus**

In 2014, the first national scale assessment in the United States was published through a public-private partnership, entitled “*Risky Business: An American Climate Prospectus*”. This was considered a groundbreaking effort, as researchers combined the best available climate projections from IPCC’s Fifth Assessment Report (AR5) and the US government’s Third National Climate Assessment (NCA3), with state-of-the-art econometric analyses, private sector risk assessment tools, and cloud computing (Houser et.al, 2015). Along with insights on regionally-relevant impacts, the study identified three of the most pressing economic impacts for American businesses and governments, as follows:

- Damage to coastal property and infrastructure from rising sea levels and increased storm surge
- Climate driven changes in agricultural production and energy demand
- Impact of higher temperature on labor productivity and public health

Despite the fact that this national assessment raised concerns around the spatial and temporal aggregation of data, efforts to improve and sustain this work continue to today. In 2017, the Climate Impacts Lab, the primary research group responsible for the Risky Business report, released county-level data on median economic damages from changes in temperature, precipitation, sea levels, and storm activity. Using peer-reviewed regional and local climate projections through year 2100, the study analyzed the combined value of market and nonmarket damage across several sectors such as agriculture, crime, coastal storms, energy, human mortality, and labor.

Source: Hsiang et al., 2014
2. Defining the Purpose of the Economic Assessment

Prior to any form of data gathering or analysis, it is critical that organizations and governments have clarity on their economic assessment’s purpose. By defining key questions to be answered by the assessment, the process is given focus, scope, and direction. From choosing greenhouse gas scenarios to the type of climate models to be used, purpose helps to decide what type of information is needed and how this information will be used. For local governments, economic assessments of climate impacts are most likely to be used for the following:

- **Issue Identification or Analysis:** With this purpose, an economic assessment is used to understand the extent and nature of climate risks. Guiding questions could focus on what the most range of climate impacts that could occur, the scale of fiscal damage related to each impact, and who would bear the costs.

- **Decision-Making:** In this approach, climate-related costs are viewed relative to one another rather than as absolute values. Economic assessments can be used to guide decisions around which climate risks, communities, public infrastructure, and time-scales should be prioritized in resilience planning. While benefit-costs analysis is not within the scope of this study, this method can also be used to compare effects of mitigation or adaptation actions in relation to costs associated with a “business-as-usual” scenario.

- **Policy or Program Evaluation:** When approaching an assessment with this lens, economic costs are used to evaluate the efficacy of policies or programs. The assessment can serve as evidence that a program or policy has delivered on certain milestones, or reached high-level goals.

3. Approaching Risk and Uncertainty

Due to our limited understanding and the irresolute nature of human and natural systems, economists must navigate uncertain, imperfect, and incomplete pictures of how the world will look in the future. As a result, the identification of potential for risk always exists within a degree of uncertainty across all climate economics. One means of managing this uncertainty is to take a probabilistic approach to understanding risk-characterizing risk by the probability or likelihood of a climate-related event occurring, and the severity of its consequences (Hsiang, 2014). In a simple formula, this can be expressed as:

\[
\text{Risk (Loss Estimate)} = \text{Likelihood (Probability)} \times \text{Severity (Consequence)}.
\]

To help identify the organization’s approach to risks, here are some questions to consider: *Is the organization planning for the near future, or are they looking decades ahead? Does the organization have the technical capacity and resources to plan for “tail-risk”climate events -- events that have a very low likelihood of occurring but would be catastrophic if they happened? Or are they only interested in events that are most likely to occur?* While most entities would like to understand the risks associated with every possible future, this framing allows local governments to prioritize risks and focus actions to their specific decision-making context.
4. Identifying Climate Scenarios

Identifying climate scenarios is the critical first step in developing an economic assessment. Climate scenarios provide the baseline information that help us determine climate impacts, as well as identify where our threshold for risks lie in relation to these impacts. In 2014, the IPCC published its Fifth Assessment Report (AR5) in which they adopted a set of four climate scenarios called Representative Concentration Pathways (RCP). These RCPs are labelled after a possible range of future atmospheric greenhouse gas concentrations (CO2) through the year 2100. Within the global scientific community, these scenarios are considered to be the standard baseline for developing climate models and projections for impacts such as mean temperature, precipitation, humidity and sea level rise. In order to understand the results of climate model output and analysis based on these scenarios, it is important for researchers and policy makers to understand the following assumptions associated with each of the RCPs.

**Representative Concentration Pathways**

- **RCP 8.5**: Assumes that fossil-fuel intensive development continues and greenhouse gas (GHG) emissions continue at the same rate as the past two centuries. RCP 8.5 is the highest of the greenhouse gas scenarios, with global temperatures projected to increase by ~4.8°C (8.6°F) above pre-industrial levels by century’s end. Higher temperatures result in greater impacts and subsequently, greater costs.
- **RCP 6.0**: Assumes there is a modest effort to mitigate and adapt, but a heavy reliance on fossil fuels will persist. GHG emissions will gradually increase until stabilizing in the final decades of the century.
- **RCP 4.5**: Assumes a moderately low emission scenario, with substantial efforts to mitigate and adapt. GHG emissions peak by mid-century, and experience a sharp decline shortly thereafter. Global temperatures are likely to rise between 2°C (3.6°F) and 3°C (5.4°F) by century’s end.
- **RCP 2.6**: Assumes aggressive emission reduction takes place. This scenario requires a 50% reduction in GHG emissions by 2050, relative to 1990 levels, and net zero or net negative emissions in the later decades of the century. Global temperatures are likely to rise by less than 2°C (3.6°F) above pre-industrial levels.

It is important to note that all scenarios will result in similar levels of warming until mid-century. Prior to mid-century, projected impacts are driven by warming that is already “in the pipeline”, caused by greenhouse gases that we have already emitted (Snover et al., 2013). Since future scenarios are dependent on GHG emissions produced in the next few decades, we cannot say with certainty which scenarios are likely to occur.
Figure 1. Total greenhouse gas emissions associated with each RCP

Figure 1 illustrates the projected trajectory of greenhouse gas scenarios associated with the RCPs through 2100. The grey line (OBS) represents actual emissions from the years 1990 - 2010. The dotted lines (A1F1, A2, A1B, B1) illustrate trajectories associated with a previous set of greenhouse gas scenarios that are no longer in use, but may be referenced in studies conducted before 2014.

Most studies will analyze a baseline scenario, either on its own in order to understand the cost of inaction or in comparison with lower scenarios for decision-making purposes. RCP 6.0 and RCP 8.5 are considered to be low and high baseline scenarios respectively, as they both illustrate a future in which society has a “business-as-usual” response to climate change and GHG emissions continue to increase until the century's end. More pragmatically, the choice of which RCPs to use in an assessment is often dependent on either of the following factors:

- **Data Availability:** Data used as input in climate impacts models can vary amongst RCPs and often, those seeking to do an assessment are limited to what is available for their region. For example, in the Northwest, there is a desire to be able to use RCP 6.0 more often, yet impacts data associated with this scenario is sparse. On the other hand, global and national scale assessments are often conducted with more resources and the data used is less granular. Therefore, most if not all assessments of this scale study impacts associated with the full range of scenarios.

- **Risk Tolerance:** RCPs provide a means to analyze the climate risks associated with crossing certain biophysical and human thresholds, and the choice of RCPs are often done in the interest of bracketing a range of potential impacts associated with certain levels of GHG concentrations. In this way, the choice of RCPs can be indicative of the assessor’s general risk tolerance.

- **Decision-making Context:** If the economic assessment is being used as a guide for decision-making, appropriate RCPs should be chosen to suit the context. For example, it may not be as valuable or cost-efficient for local actors to analyze multiple greenhouse gas scenarios if they are only looking into the near future. This is because projected impacts will be similar across all scenarios before mid-century. Additionally, presenting costs associated with RCP 8.5 in the
later part of the century may seem too expensive relative to municipal budgets and could deter local decision-makers operating in shorter timelines.

5. **Identifying Socioeconomic Scenarios**

Socioeconomic Scenarios are complementary narratives that describe potential shifts in population, technological advancement, policy context, and income distribution. These scenarios are analysed with climate projections to provide a holistic picture of potential futures (Hallegatte et al, 2008; Hecht, 2013). In an economic assessment, these qualitative narratives are later translated into quantitative values, such as changes in the market price of energy or losses to gross domestic product (GDP). Given the uncertainty of how society will respond to climate change, analysts are presented with two options:

1) **Assess the consequences of chosen climate scenarios relative to the current economy and population.**

In this option, elements such as population and infrastructure are assumed to stay the same over the temporal scale of the assessment. Future climate projections are imposed on the present conditions of the population, economic market, and built environment. This approach is beneficial as different actors likely hold varying perspectives on how society and economy will evolve over time. However, everyone can agree on the size of the population and the structure of the economy today. Additionally, some researchers prefer this approach to separate out the economic effects of climate change from economic effects of changes in population and wealth.

2) **Attempt to predict how the economy and society will change, and assess the consequences of chosen climate scenarios relative to a hypothetical socioeconomic future.**

In this option, factors such as population, rate of urbanization, and economic development are projected out into the future. In global assessments, multiple socioeconomic scenarios are developed, considering other factors such as policy, fossil-fuel development, and socioeconomic inequality. However, this practice is uncommon in local assessments and population projections could be sufficient. If pursuing this route, local governments are also advised to conduct stakeholder engagement and seek out local expertise if projections on the rate of development and resilience of infrastructure is accurate, or if progress on policy are likely.

6. **Translating Climate Impacts into Economic Values**

When translating climate impacts to economic values, analysts must first understand the types of costs that would be relevant in a local-scale assessment and the methods used to define these costs. Within the context of a city or a county, there are two categories of loss to consider, as listed below (Sussman et al, 2011):

1) **Direct Losses** - The direct physical and economic losses that come as an immediate consequence of climate-related events. Some examples of direct losses could include the cost to repair
damaged infrastructure due to sea level rise, revenue loss in commercial fishing industries due to ecosystem disruption, or increased energy prices caused by reduction in snowpack and constrained hydropower generation.

2) **Indirect Losses** - The indirect consequences of direct losses that compound or become transparent over broader spatial and temporal scales. These indirect consequences can consist of either macroeconomic responses or broader systemic losses. Indirect losses can include the following (Halagette et al, 2008):
- Ripple of direct economic losses to the rest of economic systems over short-term and long-term (e.g. the increased premiums for flood insurances)
- Responses to macroeconomic shock (loss of confidence in economic actors, inequality deepening)
- Financial constraints (low-income households unable to recover or bounce back)
- Technical constraints (limited availability of skilled workers)
- Impacts outside local area
- Imports/Export of goods and service
- Decreased property tax from depreciated home values or migration out of vulnerable areas

For direct losses, impacts can be further classified as 1) Market Impacts and 2) Non-Market Impacts which are defined below:

1) **Market Impacts** - Market impacts refer to the change in price of goods and services that are traded within an existing market. Since these goods and services are regularly bought and sold, monetary values are already defined by people’s willingness to pay for it (EPA, 2014). For example, this could include the cost of rebuilding or repairing infrastructure that has been damaged by chronic coastal or riverine flooding.

2) **Non-Market Impacts** - Non-market impacts refer to goods and services that are not traded within any financial or economic market. These could also be defined as open-access resources that benefit the public, but cannot easily be quantified or expressed in monetary values (Rothman, 2003). In the field of climate change, non-market impacts typically include:
   
   a) **Ecosystem Services** - The loss of benefits to humans provided by the natural environment or healthy ecosystems, such as the capacity of wetlands to mitigate stormwater runoff or the amount of energy savings as a result of temperature regulation provided by dense vegetation.

   b) **Human Health and Well-being** - The impacts of climate events to human mortality, morbidity, and mental and emotional well-being. This could include the number of lives lost or the number of people requiring hospitalization after an extreme climate-related event such as a hurricane.

   c) **Socio-Cultural Values** - The loss of physical and natural assets that may not have significant economic value, but represent social and cultural values of a specific group or population. For example, in the Northwest, salmon and other first foods hold both economic, cultural, and spiritual value for tribes and their preservation contributes to the population’s overall well-being.
<table>
<thead>
<tr>
<th>Categories of Loss</th>
<th>Types of Impacts</th>
<th>Examples of Impacts</th>
<th>Methods of Valuation</th>
<th>Expressed As</th>
</tr>
</thead>
</table>
| **Direct Losses** | Market Impacts (Section 7.1) | ● Loss of Employment  
● Business Interruptions | ● Statistical Models  
● Physical Models | Quantitatively as monetary values |
|                   | Non-Market Impacts (Section 7.3) | ● Ecosystem Services  
● Human health and well-being  
● Sociocultural Values | Non-Market Valuation Methods such as  
● Replacement Cost  
● Travel Cost  
● Hedonic Pricing  
● Revealed Preference  
● Stated Preference | Quantitatively as numbers (e.g. number of lives lost, percentage of population requiring mental health support) OR Qualitatively as a descriptive summary of effects |
| **Indirect Losses** | Systemic Impacts and Macroeconomic Responses (Section 7.4) | ● Depreciation of Assets  
● Increase in Taxes  
● Import/Export of goods and services | ● Spatial Analysis  
● Private Sector Tools | Quantitatively or Qualitatively |
7. Valuation Methods

7.1 The Valuation of Direct Losses: Market Impacts

There are two primary models used to estimate the amount of direct physical and economic loss to a municipality or county: 1) Physical Impact Models and 2) Statistical Models. The definition for each of these methods are outlined below, along with case studies to illustrate how these models have been used in conducting local economic assessments in the past.

1. **Physical Impact Models** are spatial models that value climate risks by understanding the extent of damage on physical assets associated with a specific event. Physical Impact Models are also a common tool within the energy sector and in hazard mitigation. The physical properties of a building, such as capacity for insulation, can inform utility companies on expected energy demand associated with varying temperatures. Similarly, physical properties of a building, such as compliance to building codes, can inform ability to withstand extreme climate-related events and the anticipated extent of damage. Based on the estimated damage, researchers can infer costs with specific economic activities such as rebuilding or replacing structures, total population displaced, or amount of revenue lost due to business interruptions.

### Snapshot: Physical Impact Modelling

**FEMA HAZUS Model**

FEMA’s HAZUS model is a commonly used physical impact model for city or county scale assessments. It is a nationally standardized risk modeling tool that is made available as free GIS-based software. It is primarily used for hazard mitigation within the emergency management community and focuses on analyzing risks related to earthquakes, floods, tsunamis and hurricanes (Schneider & Schauer, 2006). The model is based on the following (Hallegatte, 2008):

- A comprehensive dataset of the exposure, i.e. the characteristics and value of the property exposed to a hazard at a fine spatial resolution;
- Vulnerability models, which relate wind speed, flooding depth and any other physical description of a disaster, to a damage ratio, which is the share of the exposure that is destroyed or damaged for a given hazard level.

**Benefits of the HAZUS model include:**

- The software is free and conducting an assessment with the model is relatively inexpensive. If a city or county has a Hazard Mitigation Plan in place, it’s also likely that technical capacity to conduct the assessment already exists within government agencies.
- The tool was designed for mitigation and scenario modeling, meaning it can be appropriately used with forward-looking climate projections.

**Limitations of the HAZUS model include:**

- Out-of-the-box data provided by the model rarely provides locally relevant or accurate results. The quality of results are contingent on the quality of data users input into the model. Since HAZUS is highly customizable, using locally-developed datasets produces more accurate local results.
- The basic HAZUS model is currently limited to analyzing risks related to earthquakes, floods, tsunamis, and hurricanes. HAZUS does have the capacity to analyze wildfire risk, if specialized
Case Study: Physical Impact Modeling

Climate Ready Boston

In 2016, the City of Boston published Climate Ready Boston (CRB), a comprehensive citywide resilience plan which included downscaled city-level climate projections and a vulnerability assessment. Using a Physical Impact Modelling approach, the City estimated the economic cost of the three most significant climate impacts in the region:

1. Chronic Extreme Heat
2. Frequent Stormwater Flooding
3. Acute and Chronic Coastal and Riverine Flooding

While they were able to broadly understand the economic consequences associated with all three impacts, the assessment could only quantify the costs associated with coastal and riverine flooding using the HAZUS Model. This is primarily due to limitations of the HAZUS Model, specifically its limitations in analyzing certain types of risk. The physical and economic consequences of stormwater flooding were not evaluated because stormwater hazard data is not intended for use to assess individual parcels for flood impacts and are less likely to be mapped. Due to limited data, the impacts of extreme heat are expressed qualitatively and mainly refers to impacts on energy infrastructure and public and other facilities without air conditioning or that may house vulnerable populations.

In quantifying the economic consequences of coastal and riverine flooding, CRB only used three out of the four greenhouse gas scenarios in developing their downscaled climate projections: RCP 8.5, RCP 4.5, and RCP 2.6. Specifically, they chose sea level rise (SLR) scenarios that were most likely to occur within the century to focus following discussions on adaptation.

- 9” SLR with initial occurrence likely through 2030’s to 2050’s
- 21” SLR with initial occurrence likely through 2050’s to 2100’s
- 36” SLR with initial occurrence likely from 2070’s or later

They then mapped these various sea level rise scenarios over citywide building data within the HAZUS Model, in order to assess the exposure of assets associated with each scenario. By identifying the extent of damage to the built environment, they were then able to quantify the following impacts:

- **Structure Damage, Content Loss, and Inventory Loss** - Property losses are evaluated based on depth damage functions (DDFs) developed by the United States Army Corps (USACE) following Hurricane Sandy. DDF correlates the depth, duration, and type of flooding to a percentage of expected damage to a structure and its contents, including inventory. Flood depths at each structure are then cross referenced with DDFs to provide expected percent loss for each structure and its contents. This percent loss is then translated to property loss based on structure and inventory replacement costs.

- **Mental Stress & Anxiety, and Loss of Productivity** - Calculations are based on the percent share of the impacted population expected to seek mental health treatment as a result of disruption.
caused by direct physical flood impacts to the structures within which they reside. Lost productivity refers to lost work productivity as a result of mental stress and anxiety alone, and it is calculated based on expected earnings lost over time as a result of decreased work productivity or performance. Both figures only consider impacts for the 30-month period following a flood event.

- **Number of People in Need of Public Shelter** - Calculations are based on expected flood depths within occupied structures, population residing in those structures, and the share of the current population within a given area that is identified as low to moderate income.

All loss estimations are reported by imposing future climate conditions on the present population and built environment. Neither population nor development are projected. However, CRB considered the disproportionate impacts to vulnerable populations by considering demographics such as age, income, disability, and English proficiency. CRB also developed their own detailed asset inventory that combines over 130 local datasets to supplement the general building stock provided by the model. Additionally, CRB convened an Infrastructure Advisory Group (IAG) to identify infrastructure assets, individual and system vulnerability, and existing resiliency measures.

### 2. Statistical Models

Statistical Models are another approach to conducting an economic assessment of climate impacts. These models use the relationship between past climate events and economic activity in a specific sector to predict future damages (Hallegratte, 2008). For example, statistical modeling is often used in global and national scale assessments to understand the historical relationship of temperature to economic growth (Hsiang, 2014). In local-scale assessments, statistical modeling can be used with values obtained from existing literature or studies. Past or current economic costs associated with climate events are then statistically extrapolated to obtain potential costs.

### Case Study: Statistical Modeling

**An Overview of Potential Costs to Washington of a Business-as-Usual Approach to Climate Change**

In 2009, researchers from the University of Oregon’s Institute for a Sustainable Environment and ECONorthwest released a study that analyzed the cost of climate inaction to Washington households and businesses. As this study was conducted prior to IPCC’s release and widespread adoption of the RCPs, an older climate scenario titled “A1F1” was used. While A1F1 is no longer commonly used, it is comparable to today’s RCP 8.5, similarly functioning as a baseline scenario (See Figure 1). Researchers also factored in population growth, using rates estimated by the state through 2030 and rates provided by the US Census Bureau for the nation thereafter. The underlying assumption of this study is that human behavior, consumption patterns, and development trends will continue as they have in the past, with the purpose of illustrating economic consequences to Washington state if actions are not not taken to mitigate climate change.

This research primarily used statistical modeling methods to understand 18 climate-related costs associated with a “business-as-usual” approach to climate change, resulting in expected annual costs for three target years: 2020, 2040, and 2080. Through a literature review, researchers obtained historical data on how previous climate impacts have affected costs related to energy, fish and wildlife, flood and storm damage, food production, timber production, recreation and human health. If these values were available for years outside of the three target years, statistical interpolation or extrapolation was used to predict the relationship between impact and cost. Researchers provided caveats to this methodology, stating that the linear interpolation/extrapolation likely either underestimated or overestimated costs.
One specific example of how statistical modeling was used in this study is through the calculation of costs related to increased energy consumption caused by warming temperatures. Researchers used historical data on the relationship between temperature and indoor cooling from a 2005 Regional Assessment by the Northwest Power and Conservation Council. This original study used data from 2000, then forecasted that the average temperature for July-August would increase 2.9°C (5.2°F) by 2040 and subsequently, increase regional residential energy demand by approximately 200 MW. Washington researchers then used linear interpolation to obtain the estimated change in demand for 2020, and extrapolation for 2080. With data from a 2008 study on historical retail sales by the Energy Information Association, they then used the average monthly residential prices for July-August to estimate consumers’ additional cooling costs.

### 7.2 A Comparison of Valuation Methods for Direct Losses: Market Impacts

Each of the two valuation methods presented above have advantages and disadvantages. While it is possible to use both statistical modeling and physical impact modeling in the same assessment, it is important for assessors to consider the resource, data, and time requirements for each. One method may align more closely with existing efforts, and may be more strategic in terms of budget and effort. These advantages and disadvantages are summarized in the table below (See Figure 3).

**Figure 3. The Advantages & Disadvantages of Two Valuation Methods for Market Impacts**

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Impact Modeling</td>
<td>● May be less resource-intensive. If the city or county has an existing hazard mitigation program, it is likely they have staff capacity to use this method.</td>
<td>● Data-intensive. Models require up-to-date, locally relevant data in order to produce relevant results. Additional data gathering or modeling, which may include interviews and focus groups with stakeholders and experts, may be required.</td>
</tr>
<tr>
<td></td>
<td>● May be cost-effective. The HAZUS model is free and open-source, but other models may require more resources.</td>
<td>● Depending on the physical impact model used, there are limitations to the types of climate risks analyzed. Conducting a comprehensive assessment of multiple risks will likely require several models or mixed methods.</td>
</tr>
<tr>
<td></td>
<td>● Accounts for changes in vulnerability and adaptive capacity of the infrastructure.</td>
<td></td>
</tr>
<tr>
<td>Statistical Modeling</td>
<td>● Cost-effective. It can be conducted through literature review and simple, accessible statistical models that are inexpensive to use.</td>
<td>● Reliance on historical data has limitations in accounting for uncertainty, as well as non-linear relationships between climate impacts and costs.</td>
</tr>
<tr>
<td></td>
<td>● Less data requirements. Data is obtained through literature review, and simple statistical models are accessible.</td>
<td>● Limited in accounting for changes in vulnerability and adaptive capacity of the built environment, as well as natural and human systems.</td>
</tr>
</tbody>
</table>
7.3 The Valuation of Direct Losses: Non-Market Impacts

While market impacts may be easier to quantify, non-market impacts make up the dominant share of risks and 30-80% percent of all climate-related impacts (Rothman et al, 2013). There are also several ethical considerations when assigning monetary terms to natural and human systems that analysts must consider. Putting a dollar value to a life lost and projecting how this impacts economic productivity can be seen as problematic (EPA, 2014). For this reason, thoughtful measures are required in presenting these risks. However, monetization is still necessary as it converts all dimensions of climate impacts into a single metric that policymakers can use to compare different types of risks.

While the list below is not exhaustive, it provides examples of how some methods have been used in local scale assessments in the past.

- **Hedonic Pricing:** The basic premise of this method is that the value of non-market goods and services is, to some extent, reflected in the price paid for goods and services. For example, the value of environmental conditions of where we work and live are reflected in housing prices or in labor productivity and thus, income. This can be a useful tool when attempting to appraise the economic impacts of wildfire and air quality (Tanner & Garnache, 2017).

- **Replacement Costs:** This method develops values by identifying what it would cost to replace a public good or service with a man-made system. For example, researchers from Washington State developed an economic assessment that valued the loss of snowpack by calculating the costs of constructing dams large enough to hold the equivalent volume of water that would have been retained by that snowpack (Niemi et al, 2009). While the building of new dams in the state has been limited for decades, the monetization of this ecosystem service can show the financial benefits of policies to mitigate emissions and subsequently, warming.

- **Travel Cost:** This method identifies values by identifying the costs associated with traveling to experience a specific good or service. This is specifically used to understand the effects of climate change to nature-based tourism or recreation (Halagette, 2013). It has been applied to demand estimation for forest use, hiking, biking, fishing and snow sports. Some researchers have analyzed the impact of changes in temperature on snow depth and coverage and the consequences of these changes on ski season length and the usability of ski facilities (Hamilon & Tol, 2014).
Case Study: Valuation of Non-Market Impacts - Replacement Costs

Snoqualmie Natural Infrastructure Report

The City of Snoqualmie released a report in 2020 that appraised the value of ecosystem services provided by Snoqualmie’s urban forest. As a non-market public good, natural systems such as forests are often economically undervalued, if valued at all. However, they provide extensive fiscal benefits through their capacity to mitigate climate impacts, deterring costs that would otherwise be incurred building and maintaining infrastructure required for cities to adapt. For this study, the City partnered with the King County Conservation District, the Keystone Concept team, and Ecosystem Sciences and Equilibrium to assess three main ecosystem services:

1. Stormwater Retention
2. Carbon Sequestration
3. Water Quality

For these three ecosystem services alone, the study found that Snoqualmie’s public forests generate somewhere between $5.8 to $7.3 Million in goods and services annually. This is not inclusive of revenue generated from their recreational or health benefits. Apart from illustrating the immense value of natural systems, this study also provides a strong argument for conservation policies and basis for economic decision-making.

The methods used in this assessment combined the spatial analysis of existing land cover, hydrologic modeling, and the use of an established ecosystem services valuation method called replacement costs. In this valuation method, market values of built systems, such as water retention and filtration infrastructure, are used to arrive at the cost of replacing an ecological system that has a similar function. This is a commonly used approach. In a simple formula, this can be expressed as:

\[ \text{Biophysical Unit} \times \text{Market Value} = \text{Economic Benefit}. \]

For each ecosystem service analyzed, this formula is adjusted as follows:

- **Stormwater Retention Benefits**
  - \((\text{amount of stormwater retained by natural infrastructure/acreage of drainage basin}) \times (\text{capital cost of stormwater infrastructure/storage volume})\)

- **Carbon Sequestration Benefits**
  - \((\text{sequestered ton of carbon/acre per year}) \times (\text{market price of carbon/metric ton of carbon})\)

- **Water Quality Benefits**
  - \((\text{quantity of compounds filtered from water/acre per year}) \times (\text{capital cost of conventional filtration infrastructure/quantity of compounds filtered})\)

To further understand how the above values were obtained, we can examine the valuation process for stormwater retention benefits. First, a spatial analysis of city-level datasets was employed to identify the total acreage of different types of land cover. This is necessary as bare soil and impervious surfaces have less capacity to absorb stormwater runoff, as compared to irrigated vegetation and forests. Stormwater hydrologic modeling was employed to determine the peak stormwater runoff for a defined land area. This peak runoff then informed pipe-sizing for stormwater infrastructure. Through a literature review of existing capital costs for stormwater infrastructure, the correct market values were determined.
7.4 The Valuation of Indirect Losses

Indirect losses refer to a macroeconomic response or a systemic loss, acting as a compounding consequence of direct losses due to climate change. Indirect losses indicate how direct losses are actually larger when viewed within the broader economic system, specifically in how these costs compound in relation to regional or national markets. This can be particularly challenging for local governments as it presents an issue of scale - it requires them to analyze a scope of impacts beyond their geographic area and deal with another range of uncertainties. Additionally, existing literature indicates that long-term and chronic effects have been primarily studied on a national scale and available local-scale case studies seldom include the assessment of systemic impacts.

However, focused research on specific systemic impacts do exist outside of economic assessments and could be referenced for a more comprehensive illustration of losses. For example, there has been substantial work done to understand how the increased frequency and severity of acute and chronic coastal hazards have inflated flood insurance premiums, and how this disproportionately impacts low-income homeowners. Some researchers have also explored how climate impacts contribute to property tax revenue loss.

Snapshot:
Analyzing the impacts of Sea Level Rise to Property Tax Revenues in Massachusetts

A 2018 study analyzed the systemic losses of climate impacts by exploring how sea level rise could reduce municipal budgets in the state of Massachusetts. Researchers Shi and Varuzzo developed a Geographic Information System (GIS) model that included the extent of Sea Level Rise (SLR) inundation given both aggressive and limited greenhouse gas scenarios from years 2030 to 2100, property tax data at the parcel-level, and municipal fiscal data. They then identified land parcels and buildings that would be significantly damaged with SLR, and calculated the amount of local taxes that could be impacted in one foot increments of inundation from 0 to 6 feet.

Findings indicated that at 3 ft of SLR, 1.4% or $104 million of current property taxes would be threatened across 89 coastal municipalities through the chronic inundation of over 15,000 taxable acres currently valued at $8.89 Billion. They also found that municipalities that shared the similar levels of urban development, dominant land uses, and socioeconomic characteristics also shared similar levels of revenue loss.

Source: Shi & Varuzzo, 2018

Outside of academia and government, there may also be other tools available to evaluate systemic losses. Private-sector tools can be a useful resource for understanding systemic economic consequences of climate change. In recent years, financial asset managers, investment companies and lenders have done a great deal of work to understand how climate risks create negative feedback loops between financial systems and the macroeconomy. For example, climate-related damage to assets serving as collateral for loans could create write-offs that prompt banks to restrict their lending in certain regions, which could then weaken household spending (Geraghty, 2018). Private-sector tools can also be a useful resource for understanding insured losses, such as those related to wildfires and flooding.
8. Discounting Costs

Discounting is a method used by economists to understand what future costs and benefits are worth today. It is particularly important in the field of climate change as the effects of greenhouse gas emissions are long-lasting by nature and will impact society for centuries to come. Additionally, we may incur immediate costs by investing in mitigation and adaptation today but will experience the benefits of avoided damages only decades later (Prest, 2020). Built and natural systems may also appreciate or depreciate in value over time. In an economic assessment, discounting allows analysts to compare these costs and benefits occurring in different time periods by expressing these values in present monetary terms (EPA, 2014). This is done by multiplying changes in future consumption of both market and non-market impacts by a discount rate.

The discount rate reflects time preference-how much people prefer their immediate well-being over their future well-being. It represents how much people are willing to trade savings or benefits received today for benefits they could receive in the future. Generally, if a discount rate is set to zero, future benefits are valued exactly as they are today. The higher the discount rate, the more present outcomes are valued over future ones. For intergenerational issues such as climate change, a high discount rate reflects that current generations are weighted over future generations (Prest, 2020). Currently, the common range for a discount rate is two to seven percent (2-7%). With this, there are several considerations assessors must make when choosing a discount rate and how to apply it.

- **Does the discount rate reflect current society’s values?** There are two broad approaches to choosing a discount rate, reflecting either an ethical or empirical perspective of current society’s values. These approaches are as follows:
  - **Prescriptive** - a discount rate that reflects how society and markets should trade off current and future economic benefits. It requires those conducting the assessment to make a moral or ethical judgment about the well-being of society and the health of the market at different points in time. For example, should society accept a weaker market today if it leads to a wealthier, more sustainable economy generations ahead?
  - **Descriptive** - a discount rate that reflects how society and markets are currently trading off current and future economic benefits. This approach is less philosophical, and relies on evidence provided by observable trends in behavior. Assessors may use existing market interest rates, such as the return on bonds or capital investments.

- **How far are you looking into the future? Does the discount rate reflect the values of future generations?** In general economic practice, the value of assets are typically not considered beyond 50 years. However, economists are advancing methods to address this. Currently, it is common to use a lower discount rate when using longer time horizons (Arrow, 2013). This is meant to reflect that we do not have certainty of the values of future generations or the rate of future economic growth. With this uncertainty, a lower discount rate gives weight to the unknown preferences of these future generations (Burke et al, 205; Freeman and Groom, 2016). It is also a general rule of thumb to use a discount rate that declines over time, rather than a single fixed rate across all time periods.
What type of assets are you attempting to value? As discount rates are also used to reflect how assets change in value over time, it is important to understand the nature of this change for different types of goods and services. Built capital assets are known to depreciate over time, unless they are adapted or improved. On the other hand, natural infrastructure such as ecosystems tend to appreciate over time, unless human intervention causes damage. Thus, natural assets are treated with lower discount rates as compared to built assets. As an example, in the Snoqualmie Natural Infrastructure Assessment referenced above, researchers used two discount rates over 50 years - 0% to reflect the human-caused degradation of ecosystems over time, and 2.75% which is standard use for federal agencies such as the Army Corps of Engineers (Christin et al, 2020).

In the broad field of climate change economics, there is still debate amongst experts on the appropriate discount rate to use across all types of assessments. Researchers differ in their underlying philosophical understanding of society’s values and subsequently, how markets behave. However, the considerations discussed provide a general guide for local assessors.

9. Conclusion

In summary, local actors that seek to conduct an economic assessment of climate impacts will need to make several decisions regarding methods and assumptions for the assessment. Scientific, economic, and even ethical uncertainties require thoughtful consideration in each step of the process. Given this, there is no single best approach for conducting a local-scale economic assessment. For local actors that have limited time and resources, it will be important to consider the existing capacity of the organization when selecting methods and defining the scope of the assessment. For example, while physical impact modeling is a more resource-intensive method of appraising direct losses, it is already well-practiced by some local governments. After climate-related events, it is a regulatory requirement for local governments to submit the cost of damage to physical infrastructure to FEMA when seeking funding. However, it is less likely that local governments have experience appraising natural infrastructure and ecosystem services and may need the assistance of outside experts and consultants. Despite the challenges involved, local-scale economic assessments of climate impacts offer a pertinent, universal means of communicating risk. Most importantly, economic assessments provide local governments with a critical tool for climate risk assessment and resilience planning.
References


