SPECIAL REPORT

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VALUING THE WORLD AROUND US: AN INTRODUCTION TO NATURAL CAPITAL

Highlights

- Natural capital refers to the financial value provided by natural resources and ecosystems. It can be measured in terms of economic value, environmental and social benefit.
- Natural capital provides enormous measurable benefits each year.
- Including natural capital valuation in decisions can help individuals, firms, and governments to better understand the true costs, benefits and return on investment of planned activities. Failure to consider natural capital impacts can lead to sub-optimal outcomes, and unrecognized costs.
- Many methods exist for the economic valuation of natural capital. Unfortunately, a unified standard for their application does not exist at present.
- Two case studies are provided in this report to illustrate the benefits of natural capital, including the valuable annual services. The examples show that by including natural capital in the decision making process, firms, individuals, and governments can achieve better outcomes with greater benefits for society at large.

Environmental benefits and costs are not always properly incorporated into economic and policy decisions. This failure can lead to unexpected costs or unanticipated consequences. Accordingly, it is essential that more consideration is given to the value of natural capital. Regrettably, there is no standardized definition of natural capital. In this paper, TD Economics proposes its own definition that attempts to capture the direct and indirect benefits arising from the current and future stock of natural resources. Armed with a definition, this paper outlines the challenges in valuing natural capital, highlighting that one must capture the direct, indirect and intangible benefits. The good news is that, while not easy, natural capital can indeed be valued through various market and non-market pricing methods. By establishing a definition and valuation framework, it is possible for businesses, governments, and individuals to incorporate natural capital considerations into economic and social decisions. By doing so, better choices can be made that more fully reflect all of the costs and benefits, and more accurate estimates of the return on investments can be made. Natural capital can also provide options and alternatives that are not apparent when traditional thinking is used. Ultimately, this has fundamental economic and social benefits. Since the discussion of natural capital is not a conventional approach, two case studies are provided to illustrate the value of environmental considerations.

Defining Natural Capital

The term natural capital gives one a sense of the subject potential – just as one may talk about capital in the form of machinery and equipment, or human capital in the form of the raw potential of individuals, it is also possible to refer to natural capital (and the potential benefits thereof) derived from the environment.

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However, the subject is complex because the environment provides a plethora of different benefits. As a result, numerous definitions of natural capital exist, and not all of them agree with each other. For instance, the Natural Capital Coalition defines natural capital as:

"The finite stock of natural assets (air, water, land, habitats) from which goods and services flow to benefit society and the economy. It is made up of ecosystems (providing renewable resources and services), and non-renewable deposits of fossil fuels and minerals".

Robert Costanza, a prominent researcher in the field of ecological economics, defines it as "...the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future". Other researchers and organizations have proposed various ways of defining natural capital.

In our opinion, developing a consistent and holistic definition is foundational to any attempt to then quantify environmental considerations. The definition which we feel is most effective is:

"Natural capital is the stock of natural resources (finite or renewable) and ecosystems that provide direct or indirect benefits to the economy, our society, and the world around us."

The benefits take many forms and have many dimensions, and are referred to as natural capital services (also often called ecosystem services). For example,

- A deposit of gold can be mined and used to produce jewelry, industrial products and other outputs, although extraction is likely to have environmental impacts that must also be taken into consideration.
- A wetland provides a breeding ground for fish, opportunities for hunting and other recreation activities, and also filters the water that passes through it.
- An urban park can help clean the air, and reduce the risk of floods, while providing natural beauty and a place to relax.

Natural Capital Services: the output or benefits, both direct and indirect, that natural capital provides.

As Table 1 illustrates, natural capital provides us with a wide variety of valuable services, both direct and indirect.

Re-defining the Production Function

When thinking about how the economy works in an abstract sense, economists often refer to the "production function", a stylized formula that relates economic output to its inputs. The usual form (simplified somewhat) is

$$\mathbf{Y = f(L,K)}$$

where Y is output, L is labor, K is capital, and f() is a function relating these terms.

In effect, the formula says how much can be produced for a given level of inputs. This traditional form of the function ignores the crucial role that natural capital (NC) has in the economy. A more complete function would be

$$\mathbf{Y = f(L, K, NC)}$$

This expanded formulation emphasizes that natural capital is just as important to our economic activity (and thus our quality of life) as the labor working in our factories and offices and the equipment used in production.

Why Value Natural Capital?

There is an old quote that says "if you can't measure it, you can't manage it". As society becomes increasingly concerned with its environmental footprint, it is important to be able to account for exactly what that footprint is and what impact our activities are having on the environment. A challenge in the past is that many environmental services are what economists refer to as public goods: resources available to all, where one person's use does not stop another from using the same resource.[1]

Because of this unique property, the impact on these resources was often not taken into account in past decision-

Table 1: Natural capital services by land type

Land type	Service
Forests	Carbon storage and sequestration, soil formation, waste treatment, air quality, storm water control, recreation, fibre, wildlife habitat.
Grasslands	Carbon storage and sequestration, water regulation, erosion control, soil formation, waste treatment, pollination, food production, wildlife habitat.
Wetlands	Disturbance regulation, water supply and treatment, food production, habitat/refuge.
Lakes, rivers, riparian zones	Water supply, waste treatment, food production, erosion control, habitat.
Croplands	Food production, habitat/refuge, scenic
Other land types	Scenic, existence value

Source: Sauer (2002); Olewiler (2004); TD Economics.

making, as impacts were often considered too diffuse to matter.

> **Public Good:** A good where one person's use does not exclude another from using it, and people may not be excluded from using it. For example, the air we breathe, or a streetlight.

By incorporating natural capital into decision making, the externalities associated with those decisions can be included in the cost-benefit framework. An *externality* refers to the consequence of an activity that is experienced by unrelated third parties, such as the pollution from a factory. While air pollution (for example) may not affect the profitability of a factory, it affects all those who breathe the air. By incorporating natural capital into the decision making process, externalities become included as well, bringing social costs into the equation.

> **Externality**: A consequence of an economic activity that is experienced by unrelated third parties. Externalities can be positive or negative. Examples include the pollution from a factory, or the shade of a boulevard tree

Beyond a more holistic accounting of costs and benefits, including natural capital in decision making may lead to alternative solutions that would not have been considered otherwise. New York City provides a concrete example of the value of including natural capital in decision-making. In 1997, the city saved the $4-6 billion it would have spent on a water filtration plant by instead paying $250 million to buy up land around a source watershed in the Catskill Mountains, ensuring that the land remains a viable natural filter for its water supply – a positive externality of preserving the land.[2] In another case, Dow Chemical constructed a wetland at a facility to remove pollutants from wastewater before it enters the sewage system. By using a wetland rather than a wastewater plant, savings of over $35 million were realized.Valuing natural capital is also important because it allows us to put a value on numerous services that were not previously valued, including the social activities that many already enjoy, such as fishing, hiking, cycling, and other outdoor activities.

It is important to keep in mind that valuing natural capital does not imply its commodification or privatization. Assigning a value to natural capital does not change its fundamental nature. The importance of valuing natural capital isn't the price itself; rather it is to enable informed decision-making that includes all potential impacts. Indeed, including natural capital in the decision making process may lead to more economic growth, both through industries that work to preserve and expand our natural capital, as well as through potential efficiency gains that solutions using natural capital may provide.

What Standards Exist for Valuing Natural Capital?

There is currently no unified standard for the valuation of all natural capital services. Existing frameworks, such as the United Nation's System of Environmental-Economic Accounting (SEEA), and the Canadian System of Resource and Environmental Accounts, are generally focused on the commodity value of items that can be directly measured, such as the harvest value of timber or proven reserves of oil and gas. Many also track money spent on environmental protection, including carbon taxes.

At present, there is no unified, globally recognized system of accounting for the universe of renewable natural capital services, such as flood control, biodiversity, or scenic values. Progress is being made on this front, however, as a number of initiatives are currently underway worldwide to

Figure 1: The Total Economic Value Framework

Total Economic Value

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Direct Use Values:		Indirect Use Values:		Non-Use Values:
• Forestry, Fishing, Mineral Extraction • Tourism, Recreation	+	• Biological support • Physical protection • Climate Regulation	+	• Option Value • Existence Value

Source: NOAA, TD Economics

establish standards. The most prominent of these projects has been initiated by the Natural Capital Coalition (NCC), an international group of private industry and non-profit organizations. The NCC is currently overseeing a number of consortia in the ongoing creation of a Natural Capital Protocol to enable firms and other stakeholders to value natural capital in a scientific, consistent manner.

How Can Natural Capital Be Valued?

Although there is no universally accepted framework and methodology for natural capital valuation, there is a well-established body of economic literature from which a framework and valuation methodologies can be developed.

To value natural capital, a two-step process, based on economic literature, is appropriate. First, a framework of Total Economic Value (TEV - Figure 1) is used to classify the different values that a resource may provide. The goal of the TEV framework is to ensure that the vast majority of benefits and values are being captured. Second, a valuation methodology is chosen that suits the value being measured. Each of these methods and benefits will be covered below.

Direct use values are those which most closely match the values associated with traditional forms of capital. Just as a piece of equipment produces output, or a new apartment building provides rental income, a stand of trees can produce a yield of lumber, or a national park support recreation activities.

Indirect use values derive from the existence of the natural capital, but don't necessarily require consumption. The existence of forests, for example, purifies the air and supports a multitude of animal life. Physical protection can include flood and erosion protection. Indirect use values may also include inputs to direct use values, such as providing habitat for wildlife.

> **Indirect Use Value:** Values gained that don't require consumption of a resource.

A concrete example of indirect use values is the draining of a wetland to make room for a development. Before development, the wetland helps to purify water, prevent soil erosion, and provides a habitat for numerous species. These benefits disappear once the wetland has been drained. It is also possible that the wetland was valued simply for existing – just as there is a value in national parks beyond the monetary value spent by visitors.

Non-use values include option value and existence value. Option value is the value that arises from having a choice to utilize a resource at some point in the future. Existence value is the value of knowing that something exists. A person may not be an active user of a forest, for example, but may still value having it there for future generations to use. A mineral deposit does not need to be mined immediately, but owning it provides the option of future mining, which has value in and of itself. Existence value also includes the value of traditional lands to first nations and other groups.

> **Option Value:** The value of being able to defer consumption to a later date.

It also captures non-measurable benefits – for instance, the value of watching a sunset in your favorite park.

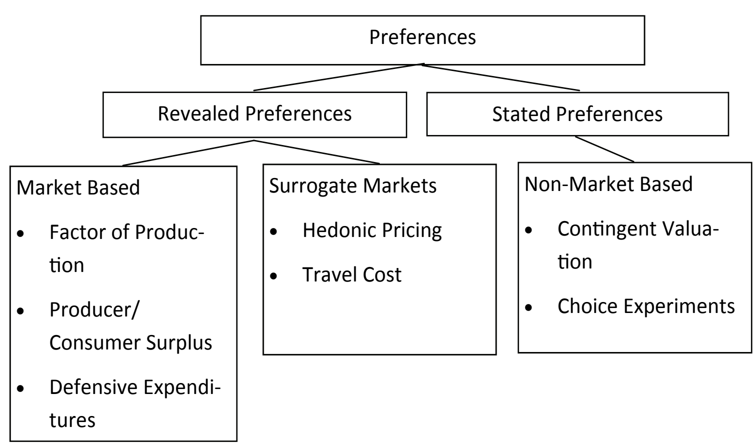
The three categories of use value are not mutually exclusive – for instance, a wetland can support hunting and fishing (direct use value) while still providing water purification (indirect use value), and potentially existence value for those living nearby. By considering the Total Economic Value, all benefits of a resource can be valued, not just the simple commodity value.

Once the values of interest have been identified, a valuation method can be chosen. There are many established methodologies (Figure 2 includes the most common), all of which, like standard economic valuation, rely on preferences.

Revealed preference valuation methods rely on observed spending choices to establish value.

Market based valuation methods are the most straightforward revealed preference method; for products such as timber, minerals, or gas, there is an observable market price. Market based measures can also be used to evaluate

Figure 2: Preferences Allow Values to be Assigned



Source: TD Economics

the impact of natural capital in the reduction of pollution: carbon has a price, and there is an emerging scientific consensus on the value of reducing other pollutants, such as sulphur dioxide. This data can be used to calculate the value of water purification in a wetland, for example. **Defensive expenditures** are a related concept – by observing the amount spent on constructed flood defensives, a value can be assigned to the flood defenses provided by trees, rain gardens, and other resources.

Defensive Expenditures: The money spent to protect against something undesirable. For example, water purification.

Surrogate market valuation methods rely on indirect expenditures. For example, the time and money spent to visit a national park tells us how much people value that park. Hedonic pricing methods, common in real estate valuation, can also be used to value natural capital. The higher price commanded by a home close to a green space relative to a comparable home without the same amenity tells us how much the homebuyer values that space.

Non-market-based valuation methods do not rely on observable prices, but rather use surveys to ask consumers directly how they value natural capital.

- **Contingent valuation** is a process where people are asked how much they would be willing to pay to preserve something.
- **Choice experiments** share many of the methods, but don't ask the question directly (for instance, a survey may ask "Would you rather your taxes went up $5 per year or the city bulldoze the local forest?". If properly constructed, a value for the resource can be inferred from these questions.

Once the value of natural capital services has been determined, the value of the natural capital stock can be assessed. In some cases, such as for mineral deposits, the supply is known and fixed, and assigning a value is straightforward. In the case of renewable resources, because there is a known and recurring flow, the value of future services can be estimated. Through the accounting practice of discounting future values, one can measure the current dollar value of these benefits.[3]

Contingent Valuation: A survey based method which directly asks individuals to value resources.

Can We Run Out of Natural Capital?

Natural capital can be either finite or renewable (regenerating with time). Even renewable resources may be depleted, however, if overharvested. Many of these resources have a *sustainable yield* – the harvest that can be consumed each year without depleting the resource. However due to the public good characteristics of many types of renewable natural capital, it may be difficult to enforce the sustainable yield. Exceeding this yield reduces both the capital stock, and the sustainable yield itself. Continually overharvesting may deplete the resource entirely, as was seen in the Atlantic cod fishery. Economists refer to a situation where overharvesting occurs due to the inability to enforce sustainable yields as "the tragedy of the commons".

Sustainable Yield: The harvest that can be consumed year after year without depleting the natural capital stock.

What Challenges Exist with Natural Capital Valuation?

The valuation of natural capital requires a relatively large amount of data regarding the characteristics and services of a given area, and careful analysis. While most pollutants and other externalities have established values, other services, such as beautification or existence value may be more challenging to evaluate, and there is not yet a consensus on what these values should be. For these reasons, studies of the same resource may result in different values. This underscores the need for a global standard, which is regrettably lacking at the moment.

What Role Can Business Play?

Businesses are typically the largest direct consumers of natural capital, and as such are key stakeholders. There are three primary ways in which business can support natural capital:

- **Growth**: Businesses can help increase natural capital through active programs such as tree planting, restoration of wetlands, or other programs.
- **Protection**: Firms should include natural capital considerations in their decision making processes. This can ensure the future supply of natural capital services (water, clean air, etc.) through the protection of natural spaces, such as: forest, parks, wetlands, etc.
- **Reduction of Loss**: Again, by including natural capital considerations in their actions, businesses can reduce their use of natural capital. Firms would thereby help reduce the strain on the system, helping humanity remain

within the overall sustainable yield of natural capital. This could include reducing their carbon footprint, improving their water use efficiency, or similar programs.

What Role Can Individuals Play?

Individuals can exert great influence through their collective voice, their wallets and their actions. By incorporating natural capital into their decision making and priorities, individuals can help reduce loss and encourage growth and protection of natural capital. This can be accomplished by making conscious decisions that support natural capital, such as purchasing more fuel efficient vehicles (reducing the strain on and loss of natural capital), landscaping their homes using native plants (growing natural capital), volunteering to tree plant, or cleaning up local parks (protecting existing natural capital). Once consumers start incorporating natural capital in their actions, businesses and governments are sure to notice and cater to consumer demands.

What Role Can Government Play?

All levels of government have a role to play in bringing natural capital into the planning process. Government policy can help support natural capital across the three categories identified for businesses:

- **Growth**: Government can help increase natural capital in numerous ways, including afforestation and restoration programs on government owned land and tax or other incentives for firms or landowners to undertake similar efforts.
- **Protection**: Legislation to protect valuable natural capital resources can be a valuable tool. Beyond legislation however, incorporating natural capital into government planning and decision making processes can make a big difference, particularly at the municipal level. Protecting natural capital resources can help reduce infrastructure and other costs.
- **Reduction of Loss**: Similar to the growth category, government programs to encourage afforestation and restoration can help to reduce or offset losses elsewhere. Including natural capital impacts in the land use and development process can also help to reduce loss and result in better planning outcomes.

To make the concept of natural capital more clear, a couple of case studies can demonstrate how to value environmental considerations and how incorporating natural capital into decision making can hold material benefits.

Case Study 1: Rivers and Wetlands in the Lower Fraser Valley

It is difficult to understate the importance of the Lower Fraser Valley to the province of British Columbia. Spread over 16000 square kilometers, the Lower Fraser Valley contains more than 55 per cent of the provincial population. The area centers on the Fraser River, as it makes its way from Hope, through Chiliwack, Maple Ridge, and Surrey, before reaching its terminus at Richmond, just south of Vancouver.

The Lower Fraser Valley provides numerous examples of natural capital, including rivers and waterways, wetlands, forests, lakes, agricultural land, and others. This case study will focus on the value of the rivers and wetlands in the valley. Narrowing the focus will allow us to examine the natural capital features in depth without this example being overlong. The services provided by rivers and wetlands include (per Table 1): Recreational use, disturbance regulation (flood control), water supply and treatment, erosion control, carbon sequestration, and existence value. The Total Economic Value framework can be used to classify these services:

- **Direct Use Benefits** include recreational use, such as boating, fishing and tourism
- **Indirect Use Benefit**s of the Lower Fraser Valley watershed include disturbance regulation, water supply and treatment, and carbon sequestration
- **Non-Use Values** are also present, and include both option and existence values

With the benefits identified, Table 2 outlines the methods to be used in valuing these benefits.

The value of the benefits can be examined in turn to build an estimated total annual value of the selected services provided by waterways and wetlands in the Lower Fraser Valley. A 2012 interprovincial survey found that British Columbians spent a total of $7.5 billion on outdoor recreational activities that year.[4] A conservative estimate that takes into account the types of activities the money is spent on suggests that, in current dollar terms, of the total spent on outdoor recreation, British Columbians spend about $275 million a year on activities specific to the wetlands of the Lower Fraser Valley. This $275 million expenditure provides an implicit value of these services (individuals must assign a value of at least that much to recreation in the area, or they

Table 2 - Valuation Methods for Lower Fraser Valley Wetlands		
Value	**Method to Be Used**	**Details**
Direct Use: Recreation and Tourism	Revealed Preference	Examine annual spending by tourists in the Lower Fraser Valley. Compute annual recreation expenditures
Direct Use: Water Supply	Revealed Preference	Apply average cost of water in region to the supply of water provided by Fraser. Result is value of Fraser's water provision
Indirect Use: Disturbance Regulation	Defensive Expenditures	Determine the cost of equivalent flood control measures
Indirect Use: Water Supply and Treatment	Defensive Expenditures	Calculate cost of treatment at a traditional treatment facility; apply values to the annual treatment provided by rivers and wetlands.
Indirect Use: Carbon Sequestration	Defensive Expenditures	Calculate the social cost of carbon had it not been sequestered. Net out carbon released through decay
Non-Use: Option and Existence Value	Normally contingent valuation	While beyond the scope of this note, survey-based methods would typically be used

would not spend the money). This is a lower end estimate, as it excludes the value of tourist dollars. In 2012, tourists spent a total of $13.5 billion while visiting the province. Unfortunately, we aren't able to determine how much of this spending was for recreation in the Lower Fraser Valley, so it is excluded from our calculations. However, the significant amount spent by tourists each year means that if even just a small fraction is spent in the area, the value of the annual recreation services will increase markedly.

Wetlands play an important role in flood control and mitigation. Through their ability to rapidly absorb large quantities of water before releasing it slowly, wetlands can reduce greatly the impact of floods. Given the large scale development and high population in the Lower Fraser Valley, disturbance regulation is an important service. The value of disturbance regulation is calculated by comparing what a man-made system that provided the same benefits would cost to build (the defensive expenditures method). A 2004 study found that in the Lower Fraser Valley, wetlands provided annual flood protection of between $408 and $2110 per hectare per year.[5] Updating these figures to reflect inflation, the annual value of flood protection by wetlands is roughly $61 million per year.

Beyond the flood control, wetlands also filter the water that passes through them, reducing the strain on municipal filtration plants. Wetland plants – such as duckweed, sedges, and reeds –are effective at removing both phosphorous and nitrogen from the water system. Conservative estimates are that a typical wetland in North America can remove about 80kg per hectare per year of phosphorous, and 550kg per hectare of nitrogen. By comparing the cost of treatment at a plant with the amount removed by wetlands (taking actual agricultural runoff into account), the annual service value of water treatment can be computed. The value of water treatment by wetlands in the study area each year is equal to nearly $45 million dollars.

The Lower Fraser Valley wetlands are also a major source of water for residents of the area. Each year, about 447,000 mega litres are used by individuals and businesses in the area. Of this, about 25% is supplied via wetlands in the Lower Fraser Valley. At current water pricing rates, the water supplied via these wetlands has a value of about $104 million. Combining this value with the water treatment savings, we find a total value of water supply and treatment services of about $150 million per year.

When carbon sequestration is considered as a natural capital service, the typical image is of trees. While trees do an excellent job in removing atmospheric carbon, the plant life within wetlands also removes carbon from our atmosphere. The amount of carbon sequestered will vary by type of wetland (i.e. bog, fen, swamp, etc), but on average, a hectare of wetland will sequester around 0.3 tonnes of carbon per hectare per year (about a third of what a forest sequesters). Across the study area, this results in an annual benefit to residents of just under $15 million each year.

There are numerous other values associated with wetlands in the Lower Fraser Valley. For example, the existence value of the land, plants, animals and other resources that make up the area. Unfortunately, assigning an existence value requires using contingent valuation or choice experiments, both of which require the use of a survey, and so are beyond the scope of this report. Other values include the replacement or commodity value of the trees, shrubs and other life within the area. The land itself also has a price associated with it, as it could be sold for development. Due to data limitations, neither of these values is included here. It is also important to note that these values would be for one-time sales, not annual service benefits.

Table 3 - Annual benefits provided by Rivers and Wetlands in the Lower Fraser Valley		
Benefit	Description	$ value (millions)
Recreation and tourism	Money spent each year visiting/enjoying the region	$277.71
Disturbance regulation (flood control)	Value of flood control provided by wetlands	$60.69
Water Supply and Treatment	Value of water purification service provided by wetlands	$151.35
Carbon Sequestration	Carbon captured in wetlands and riparian zones, net of decay	$13.43
Total		$503.18

Source: Statistics Canada, Destination BC, Olewiler 2004, Wilson et al. 2010, TD Economics.

Adding it all up, the rivers and wetlands in the Lower Fraser Valley provide annual benefits of more than $500 million each year (Table 3). Because some values have not been included, such as existence value and replacement value, this number certainly understates that value of the natural capital services these waterways and wetlands provide.

What would the "sale" price of this natural capital be? These flows can be discounted over 50 years (the typical lifespan of a major capital asset), which gives the current value of these future flows. The choice of discount rate is paramount. At a 0% discount rate (as natural capital does not depreciate), the value of the rivers and wetlands is $25.1 billion. Using a 3% discount rate, as is common in the social sciences, yields a value of $13.3 billion. Finally, using a 5% discount rate gives a value of $9.6 billion. It is important to remember that only a slice of the natural capital assets present in the Lower Fraser Valley have been valued here – the value of all natural capital assets in this area is an order of magnitude higher.

As this study has shown, the benefits provided by natural capital assets can be substantial. Just one slice of the natural capital pie in BC yields benefits in excess of $500 million year after year, both by providing opportunities for recreation, and by saving taxpayers money.

Case Study 2: The Impact of Coal Phase-Out in Alberta

Despite providing approximately 15% of Canadian electricity supply, coal fired generation produces approximately 77% of total greenhouse gas emissions in the electricity and heat sector. To address the disproportionate emissions generated by coal plants, the Canadian government introduced legislation in September 2012 aimed at reducing these emissions. The legislation in effect requires that coal plants be shut down after a lifespan of 50 years, or the end of 2029.[6] Alberta, which has seen rapid growth in recent years, still relies on coal to supply more than 40% of its electricity. This legislation creates a great opportunity for the province to reduce the natural capital impacts of electricity generation, as well as a great example of policymakers taking natural capital into account.

As of 2012, coal plants in the province released 37.8 megatonnes (MT) of carbon each year – equivalent to the average annual emissions of 8 million passenger cars. The cost of this externality is high – over $23 billion each year, based on the social cost of carbon emissions. Fortunately, this externality will be reduced over time as older coal plants are phased out. It can also be reduced sooner through an earlier shut-down of coal-fired facilities, with their capacity replaced by other energy sources. Table 4 provides several scenarios illustrating the natural capital impacts of early phase-outs, as well as the current phase-out plan (the "baseline").

Under the baseline scenario, coal remains responsible for 2.5 GW of electricity production, 43% of its current value.[7] It is assumed that the gap in generating capacity is completely filled by the construction of natural gas power plants using a mix of currently available technology. In this scenario, CO_2 emissons are reduced by 10.5MT. Because only 57% of current generating capacity has to be replaced, capital outlays are lowest in this scenario, and Albertans receive $1.32 for each dollar spent constructing new power plants.

The next scenario assumes that all coal generating plants are phased out by 2034, replaced entirely by new natural gas fired generation facilities. This scenario provides the greatest ratio of benefits per dollar spent: $1.54 in benefits accrues for each dollar of capital outlay. With current technologies and costs, natural gas power plants provide the best mix of cost and benefits. Natural gas plants cost about 30% as much as renewable plants on a per megawatt basis, while at the same time produce approximately half of the carbon emissions of a coal plant per unit of energy output.

The other two scenarios presented incorporate an increasing share of renewable energy sources to replace current coal-fired plants. Renewables are assumed to be a mix of 45% wind, 45% photovoltaic solar, and 10% biomass

Table 4 - 2034 Alberta Energy Mix Scenarios						
Scenario	Generation Mix	CO2 Emissions	Change from Present	Cost of Change (millions)	Value of Change (millions)	Benefit-Cost Ratio
Baseline	43% Coal, 57% Natural Gas	27.3 MT	-10.5 MT	$ 95,915	$ 126,354	1.32
Pure Gas	100% Natural Gas	16.2 MT	-21.6 MT	$ 168,272	$ 259,928	1.54
Half and Half	0% Coal, 50% Natural Gas, 50% Renewables	9.6 MT	-28.2 MT	$ 364,294	$ 339,350	0.93
Pure Renewables	100% Renewables	0 MT	-37.8 MT	$ 560,315	$ 454,874	0.81

Source: Energy Information Administration, TD Economics. Levelized capital costs in 2014 Canadian dollars are shown
Note: Value of change reported is the present value of carbon emission reductions over a 50 year period, using a 5% discount rate

generation. Costs are based on current "best-in-class" commercial technologies. In both of these scenarios, the ratio of benefits to costs is less than one, making them uneconomical even when the social cost of carbon is taken into account.

On balance then, the largest benefit per dollar spent comes from phasing out coal entirely by 2034, replacing the lost capacity with natural gas generating plants. There are a couple of important caveats to keep in mind with this result:

- Natural gas plants have variable cost inputs which aren't accounted for here. A rise in natural gas prices would not affect the capital cost of construction, but would result in higher consumer bills.
- Carbon sequestration technologies can greatly reduce the carbon emissions of coal-fired facilities. As the technology is fairly new, and limited commercial-scale examples exist, we have not included it here. As the technology matures, it may become a cost-effective way of reducing emissions for coal fired generation stations.
- Unburned natural gas has a very high greenhouse impact relative to carbon dioxide. This analysis assumes no leakages in natural gas pipelines. Any leakage would result in higher externalities, reducing the benefit-cost ratio.
- This analysis is based on currently available renewable energy technologies. The cost of renewable energy (particularly solar) has seen significant declines in recent years, and this trend seems likely to continue. It is possible that re-running these scenarios in several years may give different results.

Despite these caveats, at present, natural gas fired electricity generation appears to deliver the best value for money in terms of preserving natural capital. The 100% natural gas scenario results in annual emissions that are nearly 22 MT lower than current levels. A reduction of this magnitude would greatly reduce the strain on existing natural capital. It is equivalent to the annual carbon sequestration of approximately 175,000 km^2 of boreal forest – an area equal roughly to ¼ the area of the entire province of Alberta. Thus, incorporating natural capital into the planning process can help ensure that our energy needs are met while at the same time reducing our impact on precious natural capital resources, ensuring they remain in place for future generations.

Bottom Line: Why Does Natural Capital Matter?

Natural capital is foundational to the economy, providing countless benefits year after year. As this report has shown, these benefits can be substantial. Natural capital isn't infinite however, and decisions made without considering the natural capital implications can be costly not just to businesses, but to society and the economy more broadly. Incorporating natural capital in the planning process results in smarter, better decisions for firms and the communities they serve.

Conversely, failure to incorporate natural capital can lead to sub-optimal decisions, and unrecognized costs that are often borne by society at large. Many firms, individuals, organizations, and governments are making progress towards including natural capital in the decision-making process, but progress is hampered somewhat by the lack of formal systems for natural capital valuation. However, as the case studies have shown, there is much to be gained by bringing natural capital into the decision process.

Beyond the business case, putting a value on natural capital is in many ways like putting a value on the future: incorporating natural capital into decision-making helps ensure that our children and grandchildren continue to benefit from today's natural resources.

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ENDNOTES

1 Clearly not all natural capital resources fit this definition – oil and mineral deposits are an obvious exception. The carbon offsets associated with afforestation projects would also be excluded, although the other benefits provided by trees would not be.

2 Source: The Economist, 23 April 2005 "Are you being served?"

3 Technically, a renewable resource with an infinite life can be valued as a perpetuity. The value of the resource would be given by the formula value = annual benefit / discount rate (%)

4 Source: 2012 Canadian Nature Survey. Available at www.biodivcanada.ca

5 Wilson, 2010. "Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature"

6 The details of the legislation have been simplified. Plants can avoid closure by installing mitigating apparatus, such as carbon capture and storage. As well, certain plants face a 2019 deadline.

7 Under the current legislation, four coal generation plants would remain operational in 2034, all else equal. The energy mix is based on the Alberta Electrical System Operator's 2014 Long-Term outlook.