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An ex-post cost-benefit analysis of Hjerkinn PRO

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"Teamwork makes the dream work" - John C. Maxwell (yr. unknown).

Abstract

The objective of this thesis is to examine the costs and benefit flow at the former military area at Hjerkinn in an ex-post cost benefit analysis to determine whether the ecological restoration of the military area was economically profitable. The results demonstrate that the economical profitability varies significantly depending on the discount rate applied, with a standard discount rate at 4% and a 50-year time horizon, resulting in negative estimates at -124 MNOK for the restoration. Nevertheless, if the discount rate, total costs, and time horizon are modified, the project's socially profitable value is as high as 752,95 MNOK. Leading to a theoretical discussion of whether the classical CBA framework fully allows for environmental effects to be accounted for. If not, how to include it.

Sammendrag

I denne masteroppgaven blir det gjort en analyse av kostnads- og nyttestrømmene av det tidligere skytefeltet på Hjerkinn. Ved å benytte ex-post kost-nytteanalyse evalueres prosjektet ut ifra hvorvidt det kan betraktes som økonomisk lønnsomt. Den estimerte netto nåverdien av prosjektet blir - 124 MNOK ved bruk av en standard diskonteringsrente på 4% og et tidsperspektiv på 50 år. Tillates det justeringer for miljøhensyn i form av lavere diskonteringsrente, ulik definisjon av investeringskostnadene direkte involvert i naturrestaureringen og en utvidet tidshorisont vil netto nåverdien estimeres til 752,95 MNOK. En slik lønnsomhetsforskjell danner grunnlaget for en utvidet diskusjon av det teoretiske rammeverket til kost-nytteanalyser og i hvilken grad slike analyser ivaretar miljøhensyn.

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Abbreviations

NINA - *The Norwegian Institute of Nature Research*

EBA - *ecosystem restoration*

EXP - *explosive Ordnance Disposa*l

PM - *civilian land-use rights*

ADM - *administration*

PP - *planning phase*

UXO - *unexploded ordnance*

TEV - *total economic value*

WTP - *willingness to pay*

WTA - *willingness to accept*

CBA - *cost-benefit analysis*

CVM - *contingent valuation methods*

CM1- *cost model 1*

CM2 - *cost model 2*

1. Introduction

Global climate change and environmental degradation present crucial challenges for current and future generations. To address these challenges, national governments and private industry have set ambitious goals in order to reduce their environmental footprint. Unfortunately, despite these goals, pollution accumulates at a rate higher than natural decay. Through global agreements, such as the UN Sustainability Goals and Paris agreement, national and private actors agree to prioritize environmental concerns in order to prevent an increase of 1,5 degrees in overall global temperature (United Nations, 2016) (United Nations, 2015). Pressure to reach the Sustainability Goals is urgent, and the reduction of emissions is not long sufficient in reaching these goals. Instead, we must depend on new techniques and transition to a new mindset in relating to natural resources in order to prevent catastrophic consequences.

Excessive greenhouse gasses in the Earth's atmosphere are a major concern. Though Earth provides a natural system that addresses these emissions, ecosystems are weakened daily as capital conceived in human terms is frequently used as a substitute for natural capital. Calls to action to slow the rate of climate change are more important than ever and must be viewed in the context of nature degradation worldwide. To emphasize this urgency, the United Nations has declared 2020 - 2030 a decade of ecosystem restoration, emphasizing the pressing need to undo or repair previous damage to the environment and to restore nature to its original condition (Miljødirektoratet, 2021) (United Nations, 2020). To promote the restoration of nature, the contribution of the environment to human well-being is a necessary addition to discussion and to the political and business agenda.

The exploitation of natural resources frequently comes with an environmental cost that is not fully internalized in the market price, as decision-makers relate most often to resources with a well-defined price. This raises the question of whether nature should also be assigned a price in order to influence decision-makers and to prevent the rapid consumption of nature. Information on the monetary value of non-market environmental goods and services, however, is poor and creates the need for a better analytical framework to account for the relationship between the environment and economics. More particularly, an analytical framework is needed that can better determine the value of different ecosystem services, the contribution of ecosystem services to human well-being and potential ecosystem degradation and damage as a result of external intervention. Even with incentives such as carbon emission taxes and the System of Environmental-Economic Accounting (SEEA), environmental benefits to humans are still lacking. Some question the idea, arguing the rationality of exploring such practices and the ultimate usefulness of, for example, placing a market price on a mockingbird. These philosophical questions, however, are not detailed in this thesis. Instead, the thesis acknowledges the claim that valuing the environment is difficult, but also providing the counter argument that - though difficult - assigning a market price on the natural environment may sometimes be necessary, especially if and when it provides a foundation for decision-making in the framework of today's political and policy practices.

From an ecological perspective, ecosystem restoration is recognized as a profitable initiative in preventing further climate change. It is, therefore, interesting to see if this is also the case from an economic perspective. This thesis will examine a large-scale ecosystem restoration at Hjerkinn, Norway, from an economic perspective and explore the profitability of such a restoration. Hence, the research question of this thesis is whether the restoration at Hjerkinn was worth it from an economic perspective. To do so, we will conduct an ex post cost benefit analysis that compares the costs of restoration with the benefits of restored ecological functions. We will apply the theoretical framework of cost-benefit analysis in order to determine the profitability of the restoration.

The very first step in conducting a cost benefit analysis is to choose the perspective. In the case of the restoration of the former military territory at Hjerkinn, the perspective chosen for analysis is that of the human utility of ecosystem services. Once this perspective is adopted, several essential steps follow. First, the project must be clearly specified. Chapter 2 provides a detailed description of the physical project, including its direct public production, then describes project inputs and outputs, generally. Inputs are more specifically introduced in Chapter 5 and examine two cost models. Estimated environmental outputs are more complex. Chapter 6 will, therefore, provide output estimates generated from the benefit transfer method and subsequent calculations. In addition, Chapter 6 will present estimated the social costs or benefits of these inputs and outputs in comparable terms, in this case monetary units. As the final step in the analysis, costs and benefits will be compared. This is presented in Chapter 7, where the results from CBA are given. Sensitivity analysis of the results is also described in this chapter in order to examine the effects, if any, on the baseline model (Field & Field, 2012).

2. Study area

In this thesis, we derive the costs and benefits of restoring a 165km^2 former military area in alpine central Norway, Hjerkinn, to analyze the value society places on the environment and nature. The military area is located at Dovrefjell with a latitude above 1000 meter over sea level and has been used for military purposes since 1923. It was the largest military training facility in southern Norway, consisting of major technical infrastructure, including 90 km of roads, about 100 buildings and constructions, artillery training facilities, gravel pits and mounds. Although major parts of the area did not develop technical infrastructure, it has been affected by being used for military training and as target areas, leaving waste and unexploded ordnance (UXO) behind (Hagen et al., 2022a).

The restoration of Hjerkinn has turned the military area into a part of Dovrefjell-Sunndalsøra National Park. The region is of significant cultural heritage and has well-documented natural value (Miljødirektoratet, 2021). Numerous protected areas surround the former military area, including National Parks, Nature Reserves, and Landscape Protected Areas. The high-mountain ecosystem of Dovrefjell makes it home to wolverine, arctic foxes, golden eagles, gyrfalcons, and a variety of other rare and threatened wildlife species. As most urgent species are the wild reindeer that Norway has an obliged international responsibility to take care of and the value it represents, and the musk ox (Andersen & Hustad, 2004). Also, the ecosystem is a host for many rare and red-listed plant species, as well as a diverse range of vegetation types. The dominant vegetation types are lichen heaths and shrubs heaths, mires, alpine meadows and snow beds (Hagen et al., 2022a).

2.1 Description of the project

In 1999 the Norwegian Parliament decided to close down the military activity at Hjerkinn, along with the establishment of a new military training area in eastern Norway, Hedmark. The decision was a part of a plan to meet the military's training needs with updated facilities surrounded by a more suitable terrain for military purposes (Regjeringen, 1998). Additionally, the White Paper announced that the closure of Hjerkinn should involve the restoration of the region to facilitate civilian use and future protection. The restoration of ecosystems and landscape should be brought in a quality as close to the original state as possible (Regjeringen, 1998).

The planning of phasing out Hjerkinn as a military training area started in the early 2000s and was organized as a specific project who got the name Hjerkinn PRO. With the Norwegian Defense Estates Agency (NDEA) which is an executive agency under the Ministry of Defense as a project manager, it was set ambiguous goals of returning the 165km^2 previous military area back to its natural origin with the goal of a quality required to achieve National Park standards[1]. As Hjerkinn is located in an alpine area with a rough climate and slow ecological processes the restoration project required high competence and strategic work to succeed. The Norwegian Institute of Nature Research (NINA) supported ecological research, provided the necessary competence and monitored restoration (Hagen et al., 2022a).

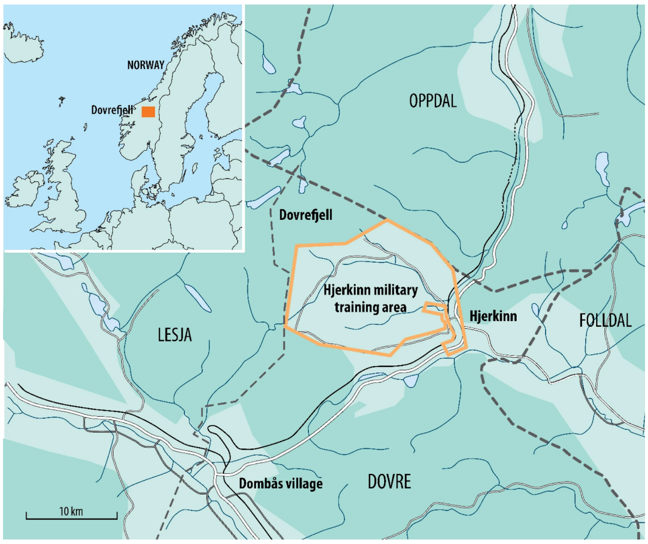
Hjerkinn PRO was divided into three sub projects:

- **Ecosystem restoration (EBA):** with the main responsibility of nature restoration, demolition of houses and roads.
- **Explosive Ordnance Disposal (EXP):** planning, implementing and goal setting for all clearance of explosives. Including technical responsibilities connected to restoration of roads and facilities.
- **Civilian land-use rights (PM):** overall responsibility of all plan processes as municipal and protection plan, pollution monitoring program and participation in the project group for wild reindeer research, as well as handling all civil contractual matters related to the land property.

(Hagen et al., 2022b, p.6)

[1] The Norwegian Environment Agency determines if a natural area passes the National Park standard, which is the area containing unique or representative ecosystems (Miljødirektoratet, 2021b). (https://www.miljodirektoratet.no/ansvarsomrader/vernet-natur/norges-nasjonalparker/) .

Figure 1: Location of Hjerkinn military training area.



Source: (Aasetre et al., 2022).

The timeline of the restoration project was divided into three phases with the first one from 1999-2003, including the planning and preparation of the project. Second, from 2003-2006 involving planning of the restoration implementation, target goals and logistics. And the third phase from 2006-2021 involved the restoration implementation. In the project description, it was stated that the project should be conducted with a 200 year long time perspective, emphasizing the importance of quality but also the following expected benefits from the restoration. The total costs of the project ended up at MNOK 588[2] (Hagen et al., 2022a).

Five principles for nature restoration were constructed for Hjerkinn PRO, which were crucial to maintain focus on the long-term goal and avoid making impulsive decisions along the way.

1. **Promote natural processes and recovery:** Always play on a team with nature, and focus on ecological processes. If it is facilitated well this part takes few resources as nature does most of the job itself.
2. **Avoid new disturbances during the construction phase of the restoration** Restoration on a big scale requires a lot of heavy tools, machines and people that can lead to a lot of damage, therefore it is important to have solid plans before interrupting nature.

[2]Source: Pål Skovli Henriksen (Forsvarsbygg), mail exchange, 29.03.2022.

3. **Prohibition of introduced plant material** The plan of restoring the area to become a national park depended on the prohibition of the introduction of species that would not be a part of the natural fauna.
4. **Some measures should have some spontaneous effects**: The technical part removing roads is a relatively fast process. In contrast, the ecological process in high alpine areas takes a long time before real progress is observed. Even though the restoration goes in the right direction it takes time. It is important to report both the fast and slow progress.
5. **"Zoom in and zoom out"**: In order to succeed in a large-scale restoration project, it is important to have a great overview of the project where details are studied closely but also the large lines. It is not efficient to focus on every small process at a micro level, but sometimes they need to be closely observed in order for the large processes to go right. Both the narrow and wide perspectives are important to use the available resources efficiently (Hagen et al., 2022b).

Restoring nature requires the right competence and tools. So far, the scope of completed nature restoration projects is small, this detailed reporting of projects greatly contributes to the development of this field and data on ecosystem services and data on ecosystem services.

3. Theory

This chapter outlines key theoretical frameworks that have been employed internationally to provide information about the environment's contribution to human well being in monetary terms.

3.1 Environmental valuation

The entire life-support system on Earth relies on functioning ecological systems. The anthropocentric era characterized by human domination and a view that all available resources are designed for human utility may have contributed to prioritizing human welfare over the utility of the planetary systems (Yadvinder, 2017). In the pursuit of economic progress, societies have disregarded the interdependence of humans and nature. Fortunately, perspectives have changed as humans' impact on nature has increased over time and the world's stock of natural resources has decreased. There is consensus that natural resources are inappropriately valued, which lead to a selfish exploitation, rapid depletion, and an environmental legacy that leaves future generations worse off (Hotelling, 1931). An irreversible reduction in the stock of natural capital will permanently restrict the flow of social and economic benefits from natural systems. This implies the negative effect of climate change on human welfare and long-term costs.

One reason that environmental resources are valued too low is the lack of well-defined property rights. An example of such a resource is clean air. While the resource is freely in use and available, it is not traded through markets thus lacks a market price. A generic term for this circumstance is externalities. "*An externality exists where consumption or production activity has unintended effects on others for which no compensation is paid*" (McGilvray et al., 2011, p.11) which occurs because of the lack of well-defined property rights. However, this viewpoint is founded on the classical economic assumption that perfect markets will solve all issues. Even if a perfect market exists, observing the world only in economic terms reduces every aspect of nature being considered as goods and services that are offered on a market. A nonexistent reality since there is no market price for all products on the planet.

The lack of market price for ecosystem goods and services does not imply a lack of value. Ecosystem services encompass all the social, physical and economic benefits humans can obtain from nature. (Wondimagegn et al., 2020, 1). This includes externalities when estimating the monetary value of ecosystem services. When estimating environmental values the presence of externalities must be accounted for and thus also being included in the political decision-making process. An example of this is to impose a tax on harmful emissions. However, this tax can not be calculated if emissions have not been assigned an appropriate market value (McGilvray et al., 2011).

Numerous valuation techniques have been developed for estimating environmental values (McGilvray et al., 2011). SEEA EEA (Environmental and Economic Accounts Experimental Ecosystem Accounting) is an important contributor that will be discussed in chapter (3.3). In the field of economics, the extent to which these techniques can give appropriate valuations for unpriced ecosystem services has been a concern. On one hand, it is argued that making decisions concerning ecosystem services based on monetary value is simply an inappropriate way for society to make decisions. On the other hand, without a valued market price, the environment will default to zero market value.

Internalizing environmental goods and services in the market by attaching a price is heavily debated. Environmentalists question the ability of market-based tools to adequately value natural resources (McGilvray et al., 2011). Including environmental benefits and costs in a market structure will only work *if* the market demand and supply are the same as the marginal cost and willingness to pay (Field & Field, 2012).

Nature as a substantial contributor to human well-being can be considered a public good, especially as humans derive direct benefits without these benefits passing through the market (McGilvray et al., 2011)(Costanza et al., 1997). In its direct translation, a public good is categorized by non-excludability and non-rivalry, which means that if the good is in supply no one can be excluded from its utility, nor can the utility be reduced by others consumption of the good (Hindriks & Myles, 2013). Moreover, individuals derive value from environmental goods beyond direct consumption. For instance, a forest ecosystem can be categorized into a range of benefits or values for humans, including but not limited to: provisioning services (e.g. food, fuel, and timber); regulating services (e.g. climate regulation, flood control and carbon storage); supporting services (e.g. soil formation and nutrient cycling); and cultural services (e.g. aesthetic cultural heritage values, and recreation values) (UNECE, 2022).

In order to account for these values, the framework of SEEA EEA is useful to calculate a total economic value (TEV). TEV evaluates the overall value of environmental assets by calculating two primary values: use values and non-use values. These primary values consist of a number of subordinate categories:

Use value	**Direct use value**; arising from the direct consumption of ecosystems, example: harvesting of timber or hunting deer. In the act of consuming these goods, they will also be destroyed. Such tangible goods are often tradable, resulting in observable market prices (McGilvray et al., 2011). Direct use may also include non-consumptive uses such as wildlife watching.

	Indirect use value; derived from individuals indirect utilization of ecosystems. For example, through positive externalities that ecosystems provide such as clean air and clean water.
Non-use value	**Option value**[3]; arise from the desire to use the resource in the future. Willingness to pay today to assure future access to a resource when uncertain about the future demand for the service or the long-term consequences of a current decision is present. For example, placing a value on the Amazon rain-forest's potential to supply plants for medical purposes. **Existence value**; is considered as the utility derived from knowing that something exists. For example the intrinsic value of natural areas, preserving a resource for the sake of its existence or the satisfaction derived from knowing that species like the musk and reindeer exists. **Bequest value;** which is based on the utility from knowing that the ecosystem may be enjoyed by future generations. **Altruistic value**; which is derived from the utility of knowing that someone else benefits.

The TEV of a natural resource should include both use and non-use values. Concerning the use values, these are assumed to be easier to retrieve an economic value from, as they often are goods sold in the market and thus obtain a market price, such as timber. For economic valuation of non-use values, this is frequently more difficult to obtain due to lack of market prices for, for example, peoples' option to harvest berries in the future. These non-use values can be retrieved through contingent valuation methods, relying on willingness to pay or willingness to accept approaches (McGilvray et al., 2011).

[3] Option value lies in the borderline of use and non-use value. In our study we have chosen to assign it to non-use value.

3.2 Willingness to pay and Contingent Valuation

In the principles and requirements of the Norwegian Ministry of Finances for socio-economic analysis, it is specified that where it is not possible to directly observe market prices, willingness to pay values should be used to account for the benefits or costs of. For instance, environmental values (Det Kongelige Finansdepartementet, 2021,4). Willingness to pay (WTP) is a method of determining the value individuals would be willing to pay for a good or service through surveys.With similar features, willingness to accept (WTA) measures how much individuals are willing to pay before they are not purchasing a good or service (Field & Field, 2012)

WTP approaches identify individuals' revealed preferences and are based on actual behavior and reflect utility maximization subject to constraints. The main limitations of these methods are that they only measure use value, due to the reliance on observed behavior (ABDULLAH et al., 2011). It can be discussed if these methods manage to reveal individuals' real valuation of an environmental good or service. To address the limitations, it is recommended to use stated preference approaches that capture both use and non-use values. WTA approaches are used to identify the stated preference which relies on the constructing of hypothetical markets. Reflected in expressions of the willingness to pay for potential environmental benefits or for the avoidance of their loss, hence it uncovers individuals' non-use values such as option and existence value (Venkatachalam, 2003) (Willis, 2014). In practice, contingent valuation methods (CVM) are used to reveal the WTP or WTA through surveys where respondents are asked about their maximal willingness to pay or accept an environmental good or service. CVM has been criticized because of the validity of the estimates as it assumes rational consumers that are able to relate to hypothetical questions without further bias (Kanya et al., 2019). However, when evaluating non-market goods, these estimation methods are deemed adequate without superior techniques.

3.3 Environmental-Economic Accounting

Environmental and Economic Accounts Experimental Ecosystem Accounting (SEEA EEA) was adopted by the United Nations in March 2021 as a standard for measuring the environment in relation to the economy (Schenau, 2018). The SEEA EEA aims to describe the benefits that society extracts from the ecosystems and their services. The importance of this accounting and measurement standard is that it incorporates the environment's crucial contribution to both the society and the economy. This standard allows ecosystem services to be recognized as an asset that must be maintained and managed rather than solely being considered as an input factor for the economy (Eurostat, 2021). This inclusion is essential and is required to be implemented as a standard that matches other commonly used frameworks, such as national accounts.

The statistical methods of ecosystem accounting enable the analysis of correlational relationships of ecosystem extent, condition, use, and economic value across time. This allows for greater observation of changes in the value of the individual ecosystem assets that make up larger ecosystem types. The accounting system and statistical methods are constructed such that all ecological data is tied to the same fundamental spatial units, allowing for observation of changes in the units' over time (United Nations, 2014).The classification of the different ecosystem types creates the possibility for data and values to be aggregated and compared. This distinguishes the accounting approach from several other index methods, where each index may consist of unique data and where the comparison of indexes may not necessarily be possible.

The data which the ecosystem accounting system relies, consists of five fundamental accounting systems which constitute the SEEA EEA. Each accounting system is constructed by integrating geographically explicit data with information about the functioning of ecosystem assets and the ecological services they generate.

1. **Ecosystem extent accounts**: defines the scope, or boundaries of the ecosystem types within a specific spatial area and records changes in this ecosystem over time to classify geographical units in terms of hectares, wetland, forest, etc. (United Nations, 2021).

2. **Ecosystem condition accounts**: is designed to measure the overall quality and biophysical state of ecosystem assets. This measure can provide information on the health of the ecosystem in terms of, for example: water quality. Additionally it provides indications concerning the capacity of an ecosystem asset to generate ecosystem services (United Nations, 2021).

3. and 4. Ecosystem service flow accounts (physical and monetary): The physical flow account is designed to describe the ecosystem services generated by ecosystem assets in terms of volume, such as cubic meters and tonnes. It identifies changes in the supply, and use of ecosystem services (United Nations, 2021). The monetary flow account describes the ecosystem services in monetary terms derived by the ecosystem flow account in physical units, and estimates prices for each individual ecosystem service.

5. Monetary ecosystem asset accounts: This describes the supply and use of ecosystem services by ecosystem assets in monetary terms. This is calculated through the concept of exchange values, wherein ecosystem services and assets are valued at the current price in the market, or the price they would have been exchanged with on a market. By using units of currency it allows for comparison and ratio estimates. For example, an illustration of the relative share of provisioning, regulating and cultural services (United Nations, 2021).

There are several benefits of this accounting system. If the pricing of ecosystem services is calculated in line with the principles of national accounting, it is possible to compare this pricing with GDP thus making the contribution of ecosystems to the national economy visible (United Nations, 2021). The standardized and international nature of ecosystem accounting can challenge national accounting practices of supply chains and promote the treatment of ecosystem assets as suppliers or producing units. A large degree of economic production in, for instance, the agricultural sectors and fisheries employs direct inputs from the ecosystem. These inputs are not explicitly accounted for in national accounting frameworks. The SEEA EEA approach allows ecosystem services to be considered as ecosystem assets in the production of goods and services. Simultaneously, environmental data, such as the extent and condition of ecosystems can be employed to inform macroeconomic policy and decision-making (United Nations, 2021).

However, there are debates surrounding the UN's development and implementation practices of SEEA EEA in regard to which valuation methods that are most compatible for highlighting the importance of ecosystem services (United Nations, 2021). Market prices reflect only a fraction of the overall socioeconomic value of a good and service. It is well-recognized that a range of societal values associated with ecosystems are not economic and are thus not captured within the principles of valuation in monetary valuation (United Nations, 2021).

3.4 Laws and regulations attached to ecosystem services

For a long time, the value of ecological services to people has been underestimated. It was not until the United Nations issued its worldwide ecosystem study, The Millennium Study Ecosystem Assessment, in 2005 ecosystem services and their significance to humans became a critical international issue (United Nations, 2014). This is seen both on a global, regional, and national scale, where numerous environmental initiatives are present to overcome the challenges connected to climate change.

Restoration is a relatively new strategy for combating climate change and environmental damage. To restore nature is to reconstruct or repair the ecological condition and richness of nature in degraded areas. For example by returning deteriorated areas back to its original vegetation or implementing mitigation actions that prevent the loss of natural values. Nature encroachment and destruction of ecosystems pose the biggest threat to biodiversity, but still, degradation and loss of nature persist worldwide, including in Norway. Thus, what has been destroyed must be restored, it is no longer enough to only conserve nature (NINA, 2022) . Nature restoration is necessary to slow, stop, and ideally reverse the harmful trend of nature loss. Therefore, the United Nations has designated 2021-2030 as the international restoration decade (NINA, 2022). More large-scale restoration projects are being seen internationally, highlighting the importance of reversing the global trend of environmental loss (Hagen et al., 2022). The restoration at Hjerkinn is an example of action taken nationally.

Another strategy to combat climate change is through regional laws and regulations In 2020 The European Union launched The European Green Deal, which stipulates that by 2050, the EU should have zero net greenhouse gas emissions' and strive to be the first climate-neutral continent (EUROPEAN COMMISSION, 2019). As a subset of this, the EU developed the EU Taxonomy Regulation, a legal document which imposes financial institutions and companies with criteria that need to be met in order to be considered as sustainable (European commission, 2020). The Corporate Sustainability Reporting Directive (CSRD) has been implemented as a complete reporting system for companies for being approved as sustainable. Instituting a requirement for large corporations to produce periodical reports on their environmental impact. A regulation that will take effect in 2024. Such actions are crucial for achieving the Climate Goals.

3.5 Stock and flow resources, and the matter of sustainability

There is a distinction between "flow" and "stock" pollution based on the severity of environmental damage associated with their rate of decay (Wang, 2018). Flow pollution can be considered as the consumption or rate of a pollution flow, and its damage will end immediately once the flow ceases. For example noise pollution from traffic, once the cars are removed the noise pollution disappears. Stock pollution, on the other hand, is the accumulation of pollutants, such as greenhouse gas emissions in the atmosphere, which will have long-lasting consequences even if pollution stops today (Wang, 2018). Thus, creating a negative impact for future generations (McGilvray et al., 2011).

In terms of climate change, it is not the flow of pollution that is the primary issue; rather, it is the congestion and accumulation of pollution that produces long-term costs. However, this does not mean that flow pollution is problem-free, as high CO2 consumption flows produce atmospheric stock problems (Willis, 2014). Carbon pricing and quota systems are examples of methods for charging the flow-related climate problem to prevent more stock pollution. Likewise, ecosystem restoration can serve as a solution for flow pollution. Where restoration of, for example, mire generates positive impacts by absorbing carbon, resulting in a positive climate flow effect.

Another key feature to discuss considering natural resources is the term sustainability. According to the UNs Brundtland Commission (1987), sustainable development is defined as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* (United Nations Brundtland Commission, 1987). In environmental economics, it is common to distinguish between "weak" and "strong" sustainability, where the distinction between the concepts is whether or not we consider capital (human made) to be substituted with natural capital. The Brundtland Commission's definition is an example of weak sustainability as this broad definition allows for the concept sustainable to capture more than the state of the natural environment, it also captures economic development in general, thus allows for substitution between human made capital and natural capital while still providing a sustainable development (Sáez & Requena, 2006). Strong sustainability, on the other hand, does not allow for natural capital to be substitutable with any other form of capital. In order to achieve sustainable development in the strong or strict sense, the environmental capital stock must remain constant over time (Pearce & Turner, 1990)

Both definitions emphasize that choices the current generation makes about the natural environment in order to maximize utility today will affect future generations. However, where the weak sustainability does not specify its objective, making human made capital and natural resources interchangeable elements of capital, it will not necessarily ensure protection of future generations' need for natural capital. For example, sustainable use of fossil fuels may not be zero, but some level of at which the benefit to society of using it today as well as negative effects in the future have been accounted for. The strong sustainability will not accept these terms and generates a form of normative goal regarding management decisions in a certain way that it in an ideal scenario will keep the natural capital stock constant. Meaning, regardless of the decision's related benefits and costs, the environmental capital stock must remain constant. For instance, in order to go on with a particular project, the benefits must outweigh the expenses, but in addition, there has to be a condition that any environmental harm created by this project must be compensated through restoration and rehabilitation (Sáez & Requena, 2006).

4. Methods

Cost-benefit analysis (CBA) is the primary method employed in this thesis to compare the costs and benefits of Hjerkinn PRO. For estimating the costs and benefits employed in the analysis, future value, benefit transfer and net present value are applied. This chapter will discuss the theoretical framework of CBA in order to provide an understanding of the underlying assumptions of such analysis.

4.1 Classical cost-benefit analysis

CBA is a method used to determine which decisions to pursue and which to forgo. In principle, a cost benefit analysis sums all the benefits of a project before subtracting the costs to evaluate the profitability (Hayes, 2021). The concept behind CBA is to attach monetary values in a broader perspective for a project which enables it to also include externalities (McGilvray et al., 2011) When conducting a CBA the net present value (NPV) is estimated.

By using the same reference year to integrate flows of costs and benefits appearing at different times, the estimates can be properly compared, and determine whether a project is profitable or not. This is accomplished through the discount rate (Field & Field, 2012).
In Norway, the Ministry of Finance establishes the principles and conditions for the implementation of socio-economic CBA in government projects. The recommended discount rate is 4% for projects lasting between 0 and 40 years, 3% for those between 40 and 75 years, and 2% for those lasting longer than 75 years (Det Kongelige Finansdepartement, 2021, 5).
The decision criteria for CBA is that if the net present value of the project is positive, $NPV > 0$, then the project is considered as economically profitable. Estimating net present value in discrete time takes the following structure:

$$(4.1) \quad NPV = -I + \frac{B_0}{(1+r)^0} + \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \ldots\ldots + \frac{B_T}{(1+r)^T} \Leftrightarrow -I + \sum_{t=t}^{T} \frac{B_t}{(1+r)^t}$$

with B_t as the benefit at time t and *I* as a discounted investment cost. The discount rate is denoted by *r*.

All else equal, a higher discount rate leads to a lower present value of benefits accruing in the future, and opposite for a low discount rate. Discounting reflects time preferences or impatience as it predicts a project's outcome in a longer period. Regarding future generations, a high discount rate for current projects can be a concern when considering the fairness of intertemporal equity (APFM, 2013).

Discounting is a controversial topic. Choosing the appropriate discount rate depends among other things on the time frame of the project, leading to concerns about sustainable development and intertemporal equity issues. The principle of discount rate relates to the prediction of time and several approaches have been developed in order to justify the different levels of discount rate. Since environmental effects can last for decades, some economists advocate for a lower standard discount rate for environmental resources (Sáez & Requena, 2006). On the other hand, it is argued that decreasing the discount rate possibly leads to double accounting, and one should not distinguish the discount rate in such a manner (Pearce & Turner, 1990). However, it is impossible to fully predict the profitability of a project whether it is regarding environmental resources or not. In order to consider the robustness of NPV estimates found, conducting sensitivity analysis is helpful. Through sensitivity analysis, different discount rates should be applied to observe if the project passes the decision criteria at different discount rates. If so, the robustness of the profitability indicates stable results.

Classical CBA is discussed to contain limitations by not emphasizing environmental effects. Several approaches have been developed to address this limitation. Sáez and Requena (2006) stressed the need for new instruments for economic valuation to fairly account for the environmental externalities in CBA and argued that applying the same discount rate for all factors in a CBA potentially leads to under-or overestimation (Sáez & Requena, 2006). To solve for environmental impacts, treating each factor included in the CBA with respect to its characteristic can possibly give more accurate estimates. An important contributor to this is the method derived by Krutilla-Fisher which will be further discussed in the next sub-chapter.

4.2 Krutilla-Fisher

In 1972 Krutilla and Fisher introduced a modification of the classical CBA which allowed for an allocation of environment between development and preservation. Resulting in different discount rates for environmental services and development goods (Fisher et al., 1972). They argued that technological development provides society with a range of substitutes, but no degree of technological development can substitute wilderness amenity services. Further, as nature becomes a more scarce resource, the demand for wilderness will increase, making it reasonable to assume that nature has a high income elasticity of demand (McGilvray et al., 2011). Hence, the value of nature relative to prices of development outputs, will increase over time. To account for this tendency, Krutella and Fisher incorporated a growth rate for environmental resources in the CBA calculations, here denoted by α. In contrast to classical CBA, this allows for different internal discount rates for different factors considered.

Originally, Krutilla and Fisher considered development benefits and costs to be constant, and treated as in regular CBA, while the benefits of preserving nature grow at a rate α. Thus assuming an environmental factor that causing a negative effect on the NPV:

$$(4.2) \quad NPV = NPV' - \frac{EB}{(r-\alpha)}$$

where NPV' denotes the net present value of the development benefits and costs, discounted at the discount rate r. EB is the environmental benefit that could have been obtained, discounted at (r-α). For given NPV', α>0 will lead to lower NPV. If α=r, then the environmental benefit is not discounted, but if α >r the EB will be effectively discounted with a negative rate which makes the flow of EB increase over time. If the Krutilla-Fisher argument is accepted, this means that a development project will decrease its likelihood to pass the decision criteria when α>0.

Krutilla and Fishers original argument was to subtract the environmental factor, as they assumed an environmental cost of initiating a project, thus leading to decreased NPV. For a restoration project purpose, the environmental factor is assumed to increase NPV. Thus, we chose to modify equation (4.2) by assuming a positive relation to the environmental factor:

$$\text{(4.3)} \quad NPV = NPV' + \frac{EB}{(r-\alpha)}$$

Assuming positive sign and α >0, the environmental benefit will be discounted at a lower level than the development costs and benefits, leading to a higher NPV compared to a case without the environmental parameter. For long-term calculations, it is common to use α =2,5% (McGilvray et al., 2011).

4.4. Benefit transfer

In the calculation of benefits at Hjerkinn, this thesis will perform several benefit transfers. The method uses estimates from previous research to adopt estimates in similar projects (Johnston & Rosenberger, 2010). It is commonly used in CBA to create estimates for non-market values when data for primary valuation estimates are unavailable or poor. The method, however, is not without limitations, and requires strong assumptions regarding the validity of the benefit transfer.

To evaluate the validity of a benefit transfer, the researcher needs to decide whether the values from existing studies are transferable. In other words, to what extent the site being evaluated shares characteristics to the site valued in the existing studie(s). Some factors that determine comparability are whether the sites are similar when it comes to type, quality and availability of substitutes. The degree to which all of these characteristics of existing studies are similar to those of the policy site determines the correspondence, which is central to determining the accuracy of the benefit transfer (Plummer, 2009).

Further, it is necessary to determine if the characteristics of the relevant population are comparable. This could be similarity in the preferences of the visitors to the areas or similarity in the demographics between the areas (Plummer, 2009). In benefit transfers of ecosystem service values, issues of continuous distance decay in WTP of a given quantity of environmental improvement, like land preservation, can occur (Johnston & Rosenberger, 2010). Spatial patterns in non-market values can be sensitive to valuation context and resources considered. Thus, it is important to consider distance decay of total and use WTP associated with natural resource changes (Johnston & Rosenberger, 2010).

Benefit transfer that involves transfer across time can cause transfer errors (Johnston & Rosenberger, 2010). It is often presumed that temporal effects may be dealt with through an appropriate specification of discount rates and currency conversions since market changes might be expected to alter preferences or values. Non-market values are temporally robust over short time spans. However, the validity of transfers that reach over longer time horizons is perceived as less certain, since the probability of, for example, the preferences for forest recreation can change significantly over a 20-year period. These changed preferences can create transfer errors (Johnston & Rosenberger, 2010). Therefore, data from more recent studies are seen as more reliable when considering benefit transfers.

Also, in-country data is considered more reliable than out-country data. (Johnston & Rosenberger, 2010). A problem with conducting transfers of any type across national borders one must account for a variety of complications not encountered in intra-country transfer. For example, it may be necessary to adjust for patterns in WTP related to such factors as currency conversion, user attributes, wealth and income measures, cultural differences, the extent of the market and value adjustments. thus may create transfer errors (Johnston & Rosenberger, 2010).

In spite of the possibility to control or adjust for transfer errors when using benefit transfer, the method is rarely the best choice for analyzing the economic value of a policy, but the costs of gathering primary, site-specific data have made it a common practice for studies of the recreational uses of natural sites (Plummer, 2009). It is important when applying benefit transfer in CBA to evaluate the transfers' validity and accuracy. In the literature of benefit transfer, there is a fair degree of consensus that site similarity, including similarity over populations, resources, markets and other site attributes, is an important determinant of transfer validity and reliability. However, there is yet no agreement on a set of criteria for site similarity, so that effects of this consensus on applied practice are difficult to ascertain to assure appropriate benefit transfer (Johnston & Rosenberger, 2010). Our subjective evaluation is evaluated in chapter 6 in relation with the transfer in question.

5. Estimation of total project costs

Data of the costs of Hjerkinn PRO are carried out by The Norwegian Defense Estate Agency (NDEA). The Norwegian Parliament allocated a total budget of 600 MNOK for the project, with 588 MNOK in expenses (Hagen et al., 2022a). As stated in (Ch.2.1) , Hjerkinn PRO was divided into three subprojects, all with separate budgets. In addition, a fourth category of administration was introduced. To illustrate the ecological restoration costs we will use two models, one specific for Hjerkinn PRO; (Cost Model 1) including all expenses, and a second model (Cost model 2) consisting of selected costs with the aim of presenting a more general nature restoration project.

5.1 Costs of the explosive subproject (EXP)

The explosive subproject included search and removal of unexploded ordnance (UXO). Clearing the land and securing it for future civil use was one of the primary objectives of Hjerkinn PRO. From 2006 to 2021, 15 000 soldiers searched and cleared the area resulting in more than 19 000 UXOs destroyed and 550 tons of metal removed (Hagen et al., 2022b). This subproject had the largest cost, with 240 MNOK in expenses from 2006 to 2021.

The elimination of UXOs and waste was critical for successful restoration. The costs associated with this subproject were a significant matter, but with limited transfer value. Thus, EXP is left out of CMl 2.

5.2 Direct restoration costs (EBA)

EBA was responsible for the actual removal of all technological infrastructure, such as buildings, roads, and military installations, in addition preparing the terrain and vegetation for ecosystem recovery (Hagen et al., 2022b). From 2006 to 2021, the subproject generated a total cost of 145,40 MNOK.

This subproject encompassed all technical infrastructure and costs associated with *road maintenance*. The argument for road maintenance regarded safe transport of military waste from the explosive subproject. Road maintenance may not have been carried out with the same standard, or at all if the project's restoration component were the only one taken into account. As a result, we have chosen to omit the road maintenance variable from CM2, due to perception of this variable in practice being a part of the explosive subproject. As for CM1, all the costs from the restoration subproject are included, thus the cost of road maintenance as well.

5.3 Civil matter subproject (PM)

The sub project regarding dialogue with local and regional stakeholders, sourcing out information within the planning process, and monitoring projects resulting in a cost of 33,32 MNOK from 2006 to 2021 (Hagen et al., 2022b).

Civil matter sub projects include monitoring work of for example birds or water pollution. This subproject had expenses associated with contributions to an eight year long research project of wild reindeers in the Snøthetta region. Monitoring of natural resources is crucial for project owners in order to quantify the effect of restoration and determine the extent of restoration required as well as to obtain information for research purposes. Civil matter costs are apparent in restoration projects, thus included in both cost models.

5.4 Administration costs (ADM)

The administration costs for Hjerkinn PRO consists mostly of administrative costs spent internally in the NDEA. As a result, they are not accounted for as part of the individual subprojects, but independently. However, these expenses can be shared across the three subprojects. Together, the administration costs equals 160,21 MNOK.

Without the administration, neither of the subprojects would have been pursued. Thus, the administration costs are important for the project to succeed and should be included in the both cost models, but as different shares. A critical aspect of project management was *Green training*[4] which allowed workers from different fields to share a common goal and consensus of the restoration process, and hence could be accounted for as administration costs associated with restoration.

NDEA has made a subjective valuation of how much of these expenses were allocated to the various subprojects, and concluded that respectively 58%, 34%, and 8% of the overall administration expenditures are allocated to the EXP, EBA and PM. Since CM1 includes all the expenditures from Hjerkinn PRO, consequently all the costs from the administration will be included in that model. Following the same argument, since we exclude EXP from CM2, the administration costs associated with managing the explosive subproject and road maintenance will be omitted.

Note that the percentage share of administration costs given to each subproject are a proportion of the total administration costs and are not accounted for annually. Thus, in CM2, we assume that the relative share of administrative cost remains constant each year throughout the project.

5.5 Planning Phase (PP)

The costs listed above are all implementation-related costs for the period 2006-2021. The years between 1999 to 2005 was a planning stage of the project. NEDA did not have available data for this time period. However, they estimated a total cost between 8 and 10 MNOK during this phase of Hjerkinn PRO. Assuming that the total costs in the planning phase lies at 9 MNOK and is equally distributed over the years (starting in Jan 1999 and last payment in Jan 2005) leading to an annual expenditure of 1,29 MNOK.

[4] During Hjerkinn PRO, a so-called Green training approach was implemented for all project personnel, in which top-down and bottom-up solutions were linked (Hagen et. al, 2022).

5.6 Cost Models

5.6.1 Cost Model 1 (CM1)

CM1, includes all costs of Hjerkinn PRO from 1999 to 2021: civil matter (PM), restoration (EBA), Explosive (EXP), administration (ADM) and the planning phase (PP). Assuming the payments start in January 1999 with the last payment in December 2021, leading to 22 payouts throughout the project. Summarizing all the costs to 588,68 MNOK.

For the costs and benefits to be comparable in the CBA it is necessary to have the values in relative terms. Choosing 2021 as the reference year, and discounting the costs using future value at a 4% discount rate, gives the future value of the cost at 794,55 MNOK. To perform sensitivity analysis of the results, the costs have also been discounted at 2% and 6%.

Table 1: Cost included in CM1 and estimated future value of total costs in 2021 value.

Cost Model 1	**Total costs (1999-2021), MNOK**
DP ADM	160,21
DP EXP	240,75
DP EBA	145,40
DP PM	33,32
PP	9,00
Total	**588,68**
Future Value (r=2%)	682,40
Future Value (r=4%)	**794,55**
Future Value (r=6%)	929,08

5.6.3 Cost Model 2 (CM2)

CM2, looks at selected costs, considered directly involved in the nature restoration of the military area from January 2006 to January 2021. This includes costs of EBA (minus road maintenance), all PM costs and an estimated share of administration costs connected to the EBA, minus road maintenance, and PM. CM2 excludes costs from the planning period and the explosive subproject. Summarizing these costs gives a total expense of 255 MNOK.

Again, assuming reference year 2021 and a discount rate of 4%, this gives a future value of the costs at 341 MNOK.

Table 2: Cost included in CM2 and estimated future value of total costs in 2021 value.

Cost Model 2	**Total costs (2006-2021), MNOK**
DP ADM	92,58
DP EXP	-
DP EBA	145,40
road maintenance	- 16,00
DP PM	33,32
PP	-
Total	**255,30**
Future Value (r=2%)	294,83
Future Value (r=4%)	**341,44**
Future Value (r=6%)	396,40

6. Benefit flows at Hjerkinn

This chapter will determine the monetary value of the benefit flows to be employed in the CBA. The estimated benefits resulting from Hjerkinn PRO will be detailed in this chapter and presented according to the environmental service to which they correspond. The value of wild reindeer will be used to estimate both provisional and cultural recreation services, relying on the Menon Economic (2020) study of Norwegian moose (Menon Economics, 2020). Additionally, the value of tourism is estimated applying the benefit transfer method from Fredman and Emmelin's 2001 study of Femundsmarka, Rogen and Långfjället National Park (Fredman & Emmelin, 2001). As a regulating service, carbon storage in the restored area will be estimated. The total benefits accounted for at a 4% discount rate for Hjerkinn in a 50 year perspective equals 670,63 MNOK.

6.1 Provisioning services

As Hjerkinn is situated in a rich ecosystem, it provides significant benefits both for human harvest as well as for the environment. Goods such as water, big game and lumber are some of the material benefits people obtain from provisioning services (FAO, 2022a). Among these provision services, hunting of wild reindeer is a central contributor at Hjerkinn (Hjortevilt, 2022). In Dovre municipality, 135 active wild reindeer hunters were registered in the 2020/2021 season (Statistisk sentralbyrå, 2021). Maintaining a sustainable habitat for wild reindeer is, therefore, essential for Hjerkinn PRO and explains the inclusion of wild reindeer as a provisioning service in this analysis.

6.1.1 Wild reindeer as meat value

The International Union for Conservation of Nature (IUCN) have classified wild reindeer as a vulnerable species (Gunn, 2016). The only remaining population of wild European mountain reindeer are found in Norway, leading to an international responsibility to protect this vulnerable specie (Villrein, 2022). One of the main arguments for the restoration of Hjerkinn was to increase habitat functionality for wild reindeer in order to maintain a sustainable population. One means of managing the size of wild reindeer stock is through close monitoring and regulation of hunting licenses to control overexploitation of the species (Miljødirektoratet, 2020). Hunting value can be conceived as both recreational value and meat value. Since this subchapter focuses on aspects of hunting as a provisioning service, this section will estimate meat value, while recreational value will be addressed in 6.2.1.

6.1.2 Valuation method, assumptions and data

According to data provided by NINAs monitoring of the wild reindeer at Snøhatta, the average size of the wild reindeer population over the last two decades (1999-2020) has been 2000 reindeer. The annual average of felled animals equals 569,55 with 36,77% being males, 40,7% females and 22.5% young or young adult reindeer[5].

The value of hunting wild reindeer can be estimated as the market value of wild reindeer meat. From a socioeconomic perspective, the value of wild reindeer meat should reflect the meat in its best alternative use. However, wild reindeer meat is sold in commercial shops and groceries in limited supply, a situation which creates challenges for ascertaining its actual market value. In the absence of substantial data on market prices for wild reindeer meat and costs of storage, maturation, packing and transport, the prices utilized in similar studies are a valid alternative for considering benefit transfer. The first of these is a study conducted by Menon Economics on moose hunting in 2020. This study outlines the socioeconomic value of moose hunting at Statskog properties (2020) and estimates meat value as the calculation of carcass weight multiplied by price per kilogram (Menon Economics, 2020). The price applied was the average price landowners placed on one kilogram of moose meat, which is registered as an additional price to the licensing fee. Estimating market value minus the preparation cost of moose meat resulted in an average value added, so this estimate is a lower bound on the true social value of moose meat.

Without further information on landowners' pricing per kilogram for wild reindeer Menon Economics' estimate will be used as a benefit transfer. Their calculations resulted in an estimate of 65 NOK (2020) per kilogram of moose meat, adjusted for KPI, resulting in 66,64 NOK (2021) (SSB, 2022b). Further, assuming identical prices for one kilogram of moose meat and one kilogram of wild reindeer meat. With an average carcass weight for wild reindeer at 29,81 kg in 2021 and a total of 569,55 wild reindeer felled annually at Snøhetta, the total slaughter weight equals 16 978 kg (Miljødirektoratet, 2022). The value added of wild reindeer meat per year at Snøhetta then becomes 1,13 MNOK. This estimate assumes

[5] Source: Olav Strand (NINA), mail exchange, 22.03.2022.

the market for moose and wild reindeer meat are the same. In addition, the total welfare measure ignores the fact that people substitute away from other goods or activities, thus not considering opportunity costs.

6.1.3 Validity of benefit transfer

Menon Economics' study is both recent and is considered in-country data, making temporal effects minimal. However, even though both moose and wild reindeer meat lie in the category of big game meat, the assumption of being perfect substitutes is questionable as they contain different characteristics. Wild reindeer meat is considered a more healthy choice than moose , and wild reindeer hunting is uniquely rooted in the history and culture of the Sami people and thus maintains a high cultural value (Regjeringen, 2015). Such historical and cultural value cannot be applied to moose meat. These attributes may lead to different consumers and different demand, hence affecting the market price. However, as both wild reindeer and moose are categorized as big game meat and offer a taste of wilderness that is assumed to appeal to similar consumer groups, they share enough similar characteristics for the benefit transfer to be considered sufficient.

Despite these arguments for valid benefit transfer, it is important to consider if value transfer is likely to result in an overestimation or underestimation of wild reindeer meat and how this could impact results. According to the distinctions noted in the attributes of the meat, wild reindeer meat seems more exclusive, which would indicate a higher price. In addition, since the supply of wild reindeer meat is lower than the supply of moose meat, the price will be greater given the demand. This can be illustrated in the number of animals harvested. According to Norwegian authorities, in 2021-2022, 29 276 moose were harvested in comparison with 5 652 wild reindeer (SSB, 2021a) (SSB, 2022a). These numbers imply higher exclusivity for reindeer and also implies an underestimation of this meat value based on price calculations per kilogram. In the absence of established practices for calculating the value of wild reindeer meat in the field, this study will rely on previous methods applied for price per kilogram calculations for similar meat value (Menon Economics, 2020).

6.1.4 Hjerkinn specific estimate

Hjerkinn is within the region of Snøhetta. As this study is a cost-benefit analysis of the restoration of Hjerkinn, it is necessary to consider Hjerkinn within the larger region to calculate the value of wild reindeer meat and avoid overestimating this value in the CBA. Using the ratio of Hjerkinn to Snøhetta is a useful technique to achieve this goal. Snøhetta has an area of 3 345 km^2, compared to Hjerkinn's 165 km^2, resulting in a ratio of 4,9%. Assuming the meat harvest is equally distributed through each square kilometer at Snøhetta, the estimated annual meat value at the restored area of Hjerkinn is 0,056 MNOK. Considering wild reindeer are herd animals, it is unlikely that wild reindeer are harvested equally per square kilometer, and even less likely that equal amounts were harvested from each square kilometer. The assumption of equal distribution is bold. Leading to uncertainty in the estimate.

6.1.5 Results

Given the value of meat harvested from hunting and assuming a stable and equally distributed wild reindeer population at Snøhetta and a 50 year time horizon at a 4% discount rate, the present value of wild reindeer meat is estimated at 1,25 MNOK. Higher discount rate at 6%, lower the present value of the collected wild reindeer meat, both for Hjerkinn and Snøhetta estimates, to 0,94 MNOK and 18,96 MNOK. The highest positive value is attained with a discount rate of 2%, and estimated values of 1,81 million NOK for Hjerkinn and 36,69 million NOK for Snøhetta. As the Snøhetta estimates encompass a greater region, and thus a higher quantum of harvested wild reindeers than Hjerkinn, Snøhetta estimates produce a higher present value as presented in Table 3.

Table 3: The estimated Present Value of wild reindeer meat at Hjerkinn and Snøhetta over a 50 year time span, stated in millions of kroners.

Discount rate	Present Value Hjerkinn restored area*	Present value Snøhetta**
2%	1,81	36,69
4%	1,25	25,44
6%	0,94	18,96

**: Based on the estimated meat harvested at the restored area of Hjerkinn.*
***: Based on the numbers from harvested wild reindeers at Snøhetta region. Source: NINA.*

6.2 Cultural services

Cultural services are non-material benefits received from ecosystems that contribute to human well being, and typically include cultural identity, sense of belonging, and spiritual experience related to nature (FAO, 2020b). This chapter will estimate the recreational value of hunting wild reindeer and the recreational value of tourism, as two specific cultural services of Hjerkinn.

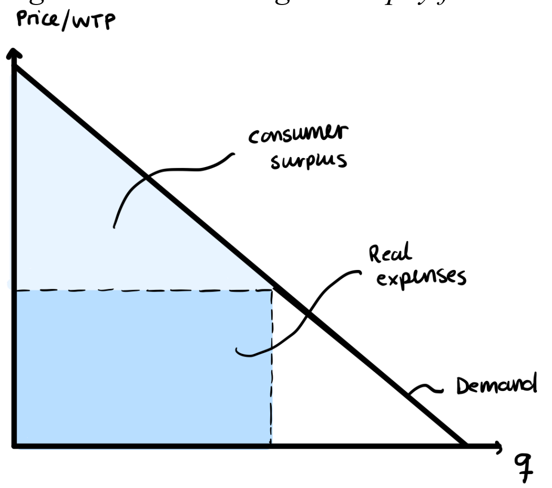
6.2.1 Recreational value of hunting

Recreation refers to activities that are considered as pleasurable and promotes self utility. Individuals engage in recreational activities for numerous reasons, where an appreciation of nature as part of a hunting expedition is one of them (Manning & More, 2002). Motivational factors that drive wild reindeer hunting include, among others, the thrill of the hunt, social aspects and a feeling of oneness with nature. These motivational factors can be classified as recreational values differing from the value of meat for consumption.

6.2.1.1 Modeling the recreational value of hunting wild reindeer

The recreational value of wild reindeer hunting is not directly observable, as there is no actual market for these services, and thus no market price. To evaluate the benefits of recreational values such as these, contingent valuation methods (CVM) and travel cost method (TCM) are commonly used. Previous studies exist that apply these methods, where the most relevant is the Menon Economics report of "*the socioeconomic value of moose hunting*" (Menon Economics, 2020). In this study, CVM was done by using WTP and WTA approaches to calculate the consumer surplus for moose hunters in order to estimate the recreational value of moose hunting. Due to a lack of methods for determining the recreational value of wild reindeer, estimates will be determined as benefit transfer using the same method of estimation as for moose. Menon Economics calculates this value as measurement of recreation defined as "*the stated consumer profit that can be traced to the hunters' appreciation of the nature experience, the social community and the excitement of moose hunting*" (Menon Economics, 2020, p.13). These factors are considered consumer surplus, as determined by hunters' willingness to pay for these minus the associated expenditures. The value of hunting wild reindeer corresponds to the price hunters are willing to pay beyond essential costs. This willingness to pay consists of the interaction of two components - hunter's payment and consumer surplus - as illustrated in Figure 2.

Figure 2: Total willingness to pay for a hunt expedition (costs plus consumer surplus).



The demand curve illustrates the relationship of what hunters are willing to pay and the given quantity of a hunt. The quantity of hunt is represented through q, i.e., number of days on wild reindeer hunting.

By applying estimates for the consumer surplus and recreational value from Menon Economics for wild reindeer as for moose, it is assumed that hunters of both species have identical preferences and are indifferent to differences between these species. This also implies that hunting expeditions are identical in terms of average hunting days per season, costs, benefits of nature, the experience of hunting, and hunting techniques. Moose hunters and wild reindeer hunters, however, are most likely not identical, and the WTP for hunting would thus be different. However, it is reasonable to assume certain similarities. In Menon Economics' report, for example, 9,3% of respondents stated that they hunt wild reindeer as well as moose (Menon Economics, 2020, p.3).

Recreational value of moose hunting was calculated by asking the respondents to distribute 100 points between different categories of motivation which contribute to positive consumer surplus. Results gave the following distribution: a) the thrill of the hunt 25,9, b) the social aspect 24,6, c) experience of nature 21,9, d) the meat itself 14,6 and e) health benefits 13,1 (Menon Economics, 2020, 40). These results are comparable to a study conducted in Hardangervidda (Southern Norway) and Forollhogna (North-Estern Norway), both wild reindeer regions, that revealed the five most important motivations for hunting wild reindeer. In decreasing order, were: the experience of nature, the social aspect, physical activity, excitement and the harvest of meat (Aas et al., 2004). The study indicated that motivational factors driving the hunting of wild reindeer are similar to those of hunting moose, though they differ in preference orderings. The Hardangervidda and Forollhogna study, however, does not calculate recreational value in economic terms. An alternative scenario would have been to consider stated preferences in terms of willingness to pay, travel costs, time used for hunting, hunter wages, etc. Since such data is missing, the estimates in this study are based on figures from the Menon Economics study and assume an identical recreational value for moose and wild reindeer hunters.

6.2.1.2 Validity of benefit transfer

The Menon Economics study of moose hunting can be considered a valid reference for determining the benefit transfer of wild reindeer hunting at Hjerkinn, as it is recent (2020) and geographically appropriate to the context of this study. Theoretically, benefit transfers consider WTP estimates approximate to the time of estimation, as this reduces the likelihood of major changes in individuals' preferences (ref. ch. 4.4). Moreover, as animals living in the wild, moose and wild reindeer share enough similarities to support the claim of legitimate benefit transfer. Of greater concern are similarities in user attributes and site characteristics.

Experience of nature refers to experiencing the tranquility of nature, observing animals in their natural habitats, and escaping hectic everyday life. As wild reindeer and moose live in different ecosystems, the nature experienced when hunting is claimed to be different as well, which may lead to variations in the ranking of the experience. In Menons' survey, moose hunters ranked the experience of nature as the third most important attribute; whereas the study of hunting in the wild reindeer regions of Hardangervidda and Forollhogna found that hunters ranked the experience of nature as most important (Aas et al., 2004). The wild reindeer regions of Hardangervidda and Forollhogna areas are classified as alpine (above 1000 m.o.h) and lower alpine (800 til 1100 moh) areas, respectively (Villrein, 2020). Similarities in natural alpine conditions support the claim that the experience of nature would be similar and could be applied to wild reindeer hunters at Snøhetta. This is a possible explanation of the underestimation of the experience of nature in the Menons' report. The significance of this underestimation, however, is uncertain.

Another difference in hunter characteristics is the social aspect of hunting related to different social benefits derived from hunting, for example, in the number of days hunting. For hunters of moose, the average time spent hunting is 17 days (Menon Economics, 2020); whereas for hunters of wild reindeer, it is an average of 7,92 days (Aas et al., 2004). This can be attributed to a longer hunting season for moose, that is approximately three times longer than for wild reindeer (Miljødirektoratet, 2017). Despite fewer hunting days for wild reindeer hunters on average, its importance is not necessarily ranked lower for wild reindeer hunters than for moose hunters, thus uncertainty if it leads to under- or over-estimation of the attribute. Another factor that could contribute to variation in perceived social benefits could be time spent with the hunting team outside the actual hunt. Such activities could include collaboration in preparation for a hunt or post-hunt tasks, such as slaughtering and reporting as well as other social gatherings with the hunting team. This data, however, has not been collected and is, therefore, unavailable.

Both groups of hunters are motivated by the excitement of the hunt. This could entail the thrill triggered by the mere presence of wild reindeer or moose or by the actual shooting of the target. The excitement of the hunt is estimated to be the most important motivating factor for moose hunters, while this excitement ranks fourth among wild reindeer hunters (Aas et al., 2004)(Menon Economics, 2020). According to these data, the significance of excitement amongst wild reindeer hunters may be overestimated when using Menons' data in the analysis. One reason for excitement to be less significant among wild reindeer hunters might be a lower probability of eliminating a target. Nationally, the wild reindeer stock is significantly lower than moose stock, with approximately 25 000 wild reindeer to 120 000 moose. This situation infers a higher probability of seeing a moose than a wild reindeer. Furthermore, wild reindeers travel in herds while moose are more independent and more likely to be experienced individually (Johansen, 2020a), (Johansen, 2020b). Additionally, wild reindeer are more scarce, so observing one can be assumed to be more rare and lead to greater excitement.

As discussed, probable differences in wild reindeer and moose hunters characteristics and ranking of preferences undermines an assumption of identical preferences. However, the overall user attributes for wild reindeer hunters and moose hunters alike are similar, especially when defining recreational values such as excitement, the social aspect and the nature experience. The ranking of these different recreational values may not ultimately affect the final conclusion, since they overall identify similar motivations. Thus not substantially impacting the validity of benefit transfer. Due to lack of data and available resources, the estimates from the Menons' study are used as a proxy for the recreational value of hunting wild reindeer in this study, as the range of accuracy is considered suitable for the investigation of benefit transfer.

6.2.1.3 Hunting activity

To determine the recreational value of hunting activity, data on the benefit transfer from Menon and data on the numbers of hunters at Hjerkinn will be utilized. As the number of hunters in the area is necessary and the actual number is unknown, the number of licenses issued for wild reindeer hunting will function as a proxy.

Hunting licenses are allocated according to geographical area and species. Despite this, many hunters cooperate across these geographical areas in order to conduct a successful hunt. For that reason, there may be more hunters in an area than the number of licenses issued (Appendix). Therefore, licenses distributed are not a match but comparable to the total hunters in the area. At the restored area of Hjerkinn, Statskog SF and Dovre Mountain Management issue hunting licenses. Statskog SF reports that 7 licenses[6] were issued for wild reindeer hunting at Hjerkinn in 2021. Data on hunting licenses distributed by Dovre Mountain Management is missing and, thus the total number of hunters at Hjerkinn may be underestimated. Due to unknown data, determining the exact number of active hunters at Hjerkinn in 2021 is challenging.

6.2.1.4 Results

Combining the WTP estimates for recreational services from Menon Economics and the number of hunting licenses issued makes estimates of the recreational value of hunting possible. Since the CBA takes into account the benefit from the restoration of Hjerkinn military training area, it can be debated whether the analysis should include the benefit of hunters with licenses only for the restored area or for Snøhetta as a whole, since the restoration has positive externalities for Snøhetta and thus its ecosystem and availability. To isolate the effect of the restoration of Hjerkinn, the number of issued licenses at Hjerkinn was used as a proxy for the quantity of hunting activity. For Snøhetta, estimates of hunting licenses issued at Dovre municipality[7] as a proxy were applied.

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[6] Source: Marius Knudsen (Statskog SF), mail exchange, 28.04.2022.

[7] In 2021 there were 135 issued licenses for wild reindeer hunting at Dovre municipality (Statistisk sentralbyrå, 2021) See ch. 6.1.

Table 4: *Estimated consumer surplus of wild reindeer hunting for the hunting season 2020-2021 stated in millions of NOK (2021 value).*

	Total in Norway for moose hunters*	Total at Hjerkinn**	Total at Snøhetta***
A- Social fellowship	92	0,0109	0,2103
B- Nature experience	83	0,0098	0,1893
C- The excitement	97	0,0115	0,2220
Recreational value (A+B+C)	**272,69**	**0,0322**	**0,6216**
Meat value****	55, 36	0,0558	1,1314
Total consumer surplus	**328,05**	**0,0880**	**1,7531**

**: Numbers from Menon, based on estimates from the hunting season of moose hunting in 2018-2019. Numbers adjusted for KPI and given in 2021 value.*
***: Numbers from Statskog from the 2020-2021 season of wild reindeer hunting at Hjerkinn.*
****: Numbers from SSB from the season 2020-2021 season of wild reindeer hunting at Dovre municipality. Numbers from wild reindeer harvested at Søhetta from NINA.*
*****: The estimate of meat value in column 2 is from Menon Economics, adjusted for KPI. The meat values presented in column 3 and 4 are estimations from chapter 6.1.*

Table 4 illustrates the overall annual recreational value (A+B+C) of hunting wild reindeer at Hjerkinn, as an estimated annual value of 32,2 thousand NOK. For the Snøhetta region, the annual estimate is 62,16 thousand NOK. The total use value of wild reindeer is represented as the consumer surplus as the recreational value in addition to the meat value, resulting in an annual consumer surplus of 88 thousand NOK at Hjerkinn and 1,7531 MNOK at Snøhetta.

Present recreational value

Assuming valid benefit transfer and stable hunting license distribution (e.g. the sustainable population is proportional to the current harvest amount) and applying a 50 year time horizon and 4% discount rate, the current recreational value of hunting at Hjerkinn is calculated at 0,72 MNOK. Similar calculations for Snøhetta result in an NPV of 13,98 MNOK.

Table 5: Estimated present value of recreational value of hunting, over 50 years and stated in millions of NOK.

Discount rate	PV Hjerkinn*	PV Snøhetta**
2%	1,05	20,16
4%	0,72	13,98
6%	0,54	10,42
(r=4%, α=1%)	0,86	16,62
(r=4%, α=2,5%)	1,16	22,38

**: Based on the numbers of hunters at Hjerkinn (Source:Statskog SF mail) and data of the weight appropriated by the different recreational components when hunting (Source: Menon Economics).*
***: Based on the numbers of hunters at Dovre municipality (Source:SSB) and data of the weight appropriated by the different recreational components when hunting (Source: Menon Economics).*

Table 5 illustrates the present value of recreational hunting, depending on discount rate. This aligns with discount theory that states that a smaller discount rate will result in greater present value, for both Hjerkinn and Snøhetta estimates (Hagen, 2011). In row 5 and 6 the environmental parametre, α, is included to illustrate how the Krutilla-Fisher argument affects the result. Compared to the estimates with standard discount rate, r=4%, inclusion of $\alpha = 1\%$ leads to higher present value, for both and $\alpha = 1\%$ and $\alpha = 2,5\%$, the latter resulting in the highest present value.

6.2.2 Recreational value of tourism

The beauty of nature attracts millions of travelers around the globe. Enjoyment of being in nature can be viewed as a cultural service, as it provides visitors with pleasure and benefits in the manner of recreation, sensation, sense of belonging and maintenance of mental and physical health (FAO, 2020b). For national parks, such as Dovrefjell-Sunndalsfjella, nature tourism is a considerable activity. This subchapter will, therefore, estimate the recreational value of tourism for visitors to Herkjenn in monetary terms.

Dovrefjell-Sunndalsfjella National Park attracts tourists who want to experience the unique landscape, wilderness and the many rare species who reside there. As the previous shooting field was restored and gained National Park status[8], it has become open to new opportunities for tourism (Dovrefjell-Sunndalsfjella nasjonalpark, 2022). New tourist attractions arose after

[8]National Park status was given to most of the restored area at Hjerkinn in 2018 (Hagen et.al, 2022).

the closing of military activity in 2008 and have most likely resulted in making the area a more attractive tourist destination. This can be evidenced in the reopening of the Snøheim tourist cabin in 2012 and the opening of Viewpoint Snøhetta in 2011 (Strand et al., 2013). Hjerkinn is also a natural starting point for visitors who entering Dovrefjell-Sunndalsfjella National Park, making the area a natural destination for many tourists.

6.2.2.1 Data of the visitors at Hjerkinn

Several studies have been done to monitor the tourism and visitors to the Hjerkinn in connection with the restoration. In 2013, an interdisciplinary team from NINA conducted a four-year study of wild reindeer habitats in the Dovre-Rondane region. The report found an average hiker activity in the National Park between 34 000 - 40 000 every year, with activity centered at the restored area (Strand et al., 2013)

Data from the report show that visitors make extensive use of the existing infrastructure in the area, such as hikers roads, trails and tourist facilities (Strand et al., 2013). In addition, 47% of visitors to the area are first time visitors and most visits during the summer season (Strand et al., 2013). In total, 75% of visitors come to the area on a day-trip that lasts, on average, approximately 4 hours(Strand et al., 2013) Visitors are both Norwegian and international tourists who want to experience nature in the mountains of Dovrefjell-Sunndalsfjella, making it both a national and international destination (Strand et al., 2013).

To examine the trustworthiness or validity of visitor activity data found in the report as a foundation for estimates for tourist activity at the Hjerkinn restored area, the correspondence of these figures and data on tourist activities at Hjerkinn were investigated:

Snøheimvegen

The most trafficked passage in Dovrefjell is the 14 km long Snøheimvegen, running from Hjerkinn to Snøheim and through the former military area (Gundersen & Rød-Eriksen, 2021) (Strand et al., 2013, 3) . According to a 2017 study, total traffic on Snøheimvegen has been stable during 2009 - 2016, transporting an annual average of 10 000 people in the area (Gundersen & Rød-Eriksen, 2021, 4)

Viewpoint Snøhetta

Viewpoint Snøhetta is a tourist attraction opened in 2011 and was commissioned by The Wild Reindeer Center North to control visitation patterns in a manner favorable to wild reindeer migration (Strand et al., 2013). From 2011 to 2021 the number of visitors to the viewpoint has increased from approximately 10 0000 to 30 000[9]. This excludes the winter season, when the facility is closed to visitors out of consideration to the wild reindeer and musk oxen habitat (Norsk villreinsenter, 2011).

Cabins of The Norwegian Trekking Association (DNT)

The Norwegian Trekking Associations (DNT) have ten cabins located in the National Park that are available to hikers for a short break on their journey or for an overnight stay (DNToslo, 2022).Snøheim and Reinheim are the two cabins closest to the restored area of Hjerkinn. Due to the cabins' location and available infrastructure to reach these cabins, the restored area becomes a natural choice for a shorter and longer hikes. The numbers of visitors to the cabins can, therefore, yield information about visitors to the restored area (DNToslo, 2022), (UT, 2022). In total, 5932 overnight stays were reported for the two cabins in 2021[10].

Chosen estimate of visitors

Data on visitors to the restored area provide useful information about tourist traffic in the area. However, due to the independent nature of the data obtained, it is difficult to synthesize them into total traffic due to the risk of double accounting. Therefore, data from the study of Horisont Snøhetta for the annual number of visitors to the area was selected, as the study considers the restored area as a whole and is not limited to specific tourist attractions. As Snøheimvegen to a large degree lies within the restored area and is central for travel in the area, it is reasonable to assume that most visitors traverse the restored area at Hjerkinn. Relying on conservative estimates, 34 000 visitors is a solid estimate for calculating the recreational value of tourism and corresponds well to the data in Viewpoint Snøhetta (=30 000) (Strand et al., 2013).

[9] Data collected from mail exchange with the general manager at the Norwegian Wild Reindeer Center North (10.05.2022)

[10] Source: Jan Erik Reiten (DNT), mail exchange, 13.02.2022.

6.2.2.2 Valuation method

To estimate the recreational value of tourism, a benefit transfer of the WTP for visiting the Swedish/Norwegian National Park, Femundsmarka, Rogen and Långfjället (FRL) was used, as the area shares characteristics similar to the former military area, resulting in higher correspondence and making value transfer possible.

Through CVM, Fredman and Emmelin (2001) obtained willingness to pay estimates for tourists visiting the FRL National Park located between Norway and Sweden (Fredman & Emmelin, 2001) with 60% of the national park located in Sweden. Among Fredman and Emmelin's findings, they estimated that maximum willingness to pay that prevented trips into the area were 4 058 SEK. The average length of a trip was estimated at 4.4 days, with an average of 2 729 SEK in expenses, where 45.3% (= 1 236 SEK*)* were connected to expenses during the visit and 43.3% (= 1 756 SEK) to experiences in the FRL areas, resulting in 520 SEK on average consumer surplus. These expenses connected to experiences in a national park represent an average expected value of a trip, which indicates the recreational value of visiting the FRL National Park. In order for the estimated values from FRL to be comparable to the estimates used in this thesis, they are converted to Norwegian kroner at the 2001 ratio of 1: 1,149 (SEK/NOK) (Valuta-kurser, 2022). Adjusted for KPI (2001-2021), the average recreational value of visiting FRL is estimated at 3014,78 NOK for a trip of 4.4 days. This leads to a per day estimate equal to 685,18 NOK per visitor. This estimate was used as the expected recreational value of a visit to the restored area of Hjerkinn.

6.2.2.3 Validity of benefit transfer

As 40% of the FLR lies within Norway, the WTP study can be considered in-country data, with relatively small or insignificant differences in income means or cultural differences. However, results are reported in Swedish currency, making a currency conversion necessary and opening for vulnerability in terms of transfer error. However, similar user attributes are considered more important in this case. As the management of national parks are united around the aim of hosting tourists within a natural setting, it is believed that many visitors share this motivation for visiting national parks. FRL and Dovrefjell share many characteristics in terms of the natural setting, animals and tourism activity. Both have similar vegetation characteristics, with meadow vegetation, lichen heat and snow beds (Skarin et al., 2010). While Hjerkinn is situated in a high mountain ecosystem, FRL contains both alpine areas at Långfjallet and Fedumsmarka, a pinewood forest and a 35 km^2 lake at Rogen (Grenselandet, 2010). Similarities in vegetation and ecosystem make both suitable habitats for many of the same animal species, such as wolverine, musk oxen and reindeer (Grenselandet, 2010). However, while Hjerkinn houses wild reindeer, FLR houses the domestic reindeer of the south Sami people (Skarin et al., 2010). Also the musk oxen herd at FRL is much smaller than that at Dovrefjell, consisting of 7 (counted in 2010) and 200 (counted in 2018), respectively (Statsforvalteren i Trøndelag, 2021) , (Grenselandet, 2010). Furthermore, there are similarities in the tourist activities in the areas - including sleepover possibilities, with both offering wilderness camps, DNT cabins (similar to STF cabins), skiing and hiking possibilities and observations of wildlife. Unique to FLR, however, is the lake Rogen, which offers visitors the possibility of paddling and other water activities (Grenselandet, 2010), (Femund conoe camp, 2017).

A possible disadvantage of using the FLR study for benefit transfer is that it was conducted in 2001, raising questions of possible temporal effects and transfer errors. Even though temporal effects have been accounted for through currency conversions and inflation adjustments (KPI-adjustments), the validity of the transfer is less certain, due to the probability of changed preferences of visitors to the national parks. The possibility of changed preferences reduces the transfer's liability. Despite these disadvantages, the advantages in similarities in site characteristics and user attributes make it possible to draw the conclusion that individuals who want to visit the areas would also share characteristics and derive similar utility in visiting the two areas. Thus, using the estimates from Fredman and Emmelin's study as a proxy for willingness-to-pay for Dovrefjell and - as a result - the restored area at Hjerkinn can be considered acceptable for benefit transfer. If the study area at FLR were smaller and focused only on an alpine area, the similarities with the restored area of Hjerkinn would have been greater and thus the proxy more accurate. Although the two national parks share similarities, they are still two unique areas, which raise questions about the applicability of the proxy and possible under-or overestimation of the recreational value of outdoor life at Hjerkinn.

6.2.2.4 Results

Applying 34 000 visitors to the restored area each year, calculations based on a day trip, and a WTP for a day trip at 685,18 NOK, the estimated recreational value of tourism at the restored area is 23,3 MNOK annually. Assuming a 50 year time horizon and a 4% discount rate, the total present value of recreational tourism is estimated at 523,75 MNOK.

Table 6: Estimated present value of the recreational value of tourism at the restored area at Hjerkinn, stated in millions of NOK.

Discount rate / alpha	a=0%	a= 1%	a=2,5%
r=2%	755,34		
r=4%	523,75	622,70	838,65
r=6%	390,49		

A sensitivity analysis was performed with discount rates at 2% and 6% and an environmental parametre, α, at 1% and 2,5% and assuming a 50 year time horizon. The highest present value obtained, when r=4% and α=2,5%, resulted in a present value of 838,65 MNOK. The lowest present value estimated, when r=6% and a=0%, resulted in 390,49 MNOK. This supports the theoretical predictions of the higher discount rate the lower the present value (Hagen, 2011), (Appendix).

6.3 Regulating services

Regulating services refer to maintaining environmental quality through, for example, such measures as pollination or carbon sequestration and storage (FAO, 2020c). Climate change is damaging ecosystems worldwide, with greenhouse gas emissions such as carbon playing a significant role in degradation. Intact nature is critical in addressing global increases in greenhouse emissions, as nature is the world's largest carbon storage and carbon absorption system (IPBES, 2019). Restoration of nature can lead to greater carbon capture and storage and prevent the additional release of carbon stock from degraded nature. Previous research on the capacity of various habitats at Dovrefjell to improve ecological conditions makes it possible to quantify the storage capacity of restored regions at Hjerkinn (Hagen et al., 2022a). Consequently, the market value of carbon sequestration can be quantified.

Ecosystem restoration at the Hjerkinn former military area prioritized growth of the natural landscape primarily. Several willow-plants and seeds of the grass species sheep fescue were planted in areas where needed. Ecosystem recovery can be difficult in alpine areas, since new growth requires more time to settle in and is exposed to more weather disturbance. Certain natural ecosystems grow faster than others as well (Hagen et al., 2022a).

6.3.1 Physical extent

The restored mire and woodland at Hjerkinn offers the largest carbon storage potential in the area. When the vegetation is fully recovered, total carbon storage is estimated to 99 890 tonnes of carbon. Where the mire accounts for 106 906 tonnes carbon alone, the woodlands account for 49 660 tonnes carbon. Once the vegetation is fully restored, it will absorb roughly 6823 tonnes of carbon every year through photosynthesis and additional growth. These carbon accumulation calculations are based on a growing season for the alpine region of 140 days (Hagen et al., 2022a).

Table 7 summarizes the various forms of restored nature at Hjerkinn and accumulated carbon capture based on data from (Hagen et al, 2022a) on deposits following the restoration. The estimates are based on the amount of CO2 absorption for various habitat types per square meter annually (Hagen et al., 2022a). Since the composition of Hjerkinn area according to habitat types is known, it is possible to calculate average photosynthetic efficiency (=carbon capture) per square meter for each habitat type. In sum, 5,2 km^2 of the total 165 km^2 area were directly affected by ecosystem restoration.

NPP represents the annual amount of carbon captured in tonnes of CO2 equivalents for each habitat type when fully recovered. In other words, NPP represents the amount of carbon accumulated each year as a result of photosynthesis and growth in the habitat type. The storage value of a habitat type is the amount of carbon stored over time after full restoration. Carbon storage continues to grow over time, and if the habitats grow at the expected rate and eventually returns to its original vegetation as intact nature, this storage will eventually transfer form NPP values to storage values. The time required for ecosystems to reach the storage stage is unknown. An ecological consensus is that it will occur in the distant future, but an exact timeframe is unknown. The NPP and Storage values in the Table 7 illustrate the number of tonnes of CO2 equivalents accumulated by each habitat type.

Table 7: Estimated absorbed tCO2e for the different restored habitats at Hjerkinn, stated in tonnes CO2 equivalents.

Vegetation type	Assumed tonnes CO2e absorption in 2021	NPP: tonnes CO2e absorbed annually, *fully recovered*	Tonnes CO2e storage, *fully recovered*
Mire	8	40	106 906
Woodland	819	4 093	49 660
Meadow	123	615	20 320
Snow-bed	2	9	2 508
Lichen heath	413	2066	20 496
Total	**1365**	**6 823**	**199 890**

Source:(Hagen et al., 2022a)

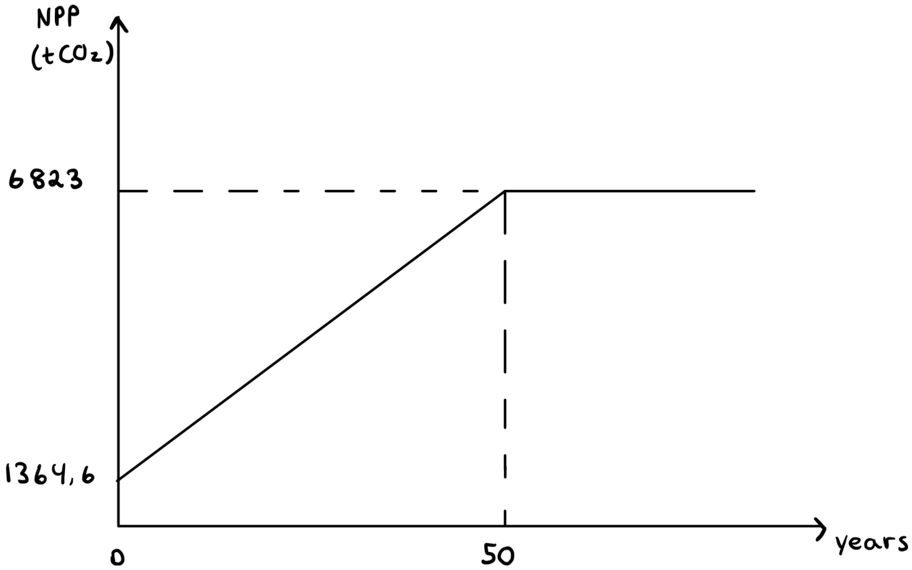
6.3.2 Valuation method, assumptions and data source

The market value of carbon is calculated using the physical amount of carbon stored in various habitat types multiplied by the carbon price. The restored vegetation does absorb carbon but has yet to reach fully recovered NPP values. Due to the unknown time horizon for this full recovery, a "fair" time limit for nature types to revert to their original vegetation must be established for useful estimations. Since the beginning of the restoration process, NINA has regularly monitored levels of vegetation. From 2004 to 2019, data on vegetation development and number of species were collected from restored sites (Hagen et al., 2019) . These were compared to estimated NPP levels and serve as indicators of successful recovery of vegetation. Through consultation with NINA, a qualitative estimate of the time horizon for increased vegetation coverage from 2019 levels to NPP was found to be a time horizon of 50 years. A 50 year time horizon was, therefore, applied in the calculations.

Acknowledging uncertain estimates for the re-establishment of natural vegetation to full maturity was considered in the generation of estimates that could be too small or too large. To get a perspective of time limits considered in restoration projects, it is important to emphasize that the planning and implementation of restoration is often viewed in a long-term perspective. According to the Dovrefjell Management Plan, the perspective for restoration was considered a minimum of 200 years (Nasjonalparkstyret, 2006,). The goal of this long-term perspective is to ensure that time does not compromise quality. In the absence of more detailed information and relevant research findings, this study assumes a 50 year time horizon for the transition from 2021 carbon value to NPP.

Another factor that must be considered is the amount of carbon that the current vegetation is accumulating. In dialogue with NINA, a qualitative approximation of carbon accumulation at the current level was established as below NPP values. A logical assumption is that carbon storage is 20 percent of desired NPP levels. In other words, the restored habitats absorb 20% of the total NPP value (6823 tCO2e), resulting in an annual carbon accumulation of 1364,6 tCO2e. Even though different natural habitats accumulate carbon differently over their lifetimes, with lichen heat accumulating carbon more rapidly in the early stages and mire accumulating carbon slowly at first and then growing faster, for the sake of simplicity, all restored habitat types are assumed to accumulate carbon in the same way. In other words, linearity is assumed, although linearity is probably neither entirely accurate[11]. Unfortunately, there is too little established knowledge about how the different habitats accumulate carbon over time and how long it takes to reach original vegetation levels.

Figure 3: Illustrates the carbon sequestration over 50 years with the assumption of linearity.



[11] A Sigmund curve could be more precise for some of the habitat types according to (Abderrahman et al., 2021).

6.3.3 Carbon pricing

Various carbon prices exist on the market. Carbon price can be measured as the price for the right to emit climate gasses equivalent to one ton of carbon in the atmosphere. The carbon price is an estimate of the costs carbon inflicts to society, through the EU ETS market, which represents marginal costs of climate emissions in different sectors. In the EU, carbon pricing is used as a part of the architecture to reach the EU climate and energy policies which is an emission reduction target of 55% by 2030 (EUROPEAN COMMISSION, 2019). According to the PAGE and their A1B climate scenario, costs put on society of carbon emissions, is estimated to approximately 1 315NOK per tonnes CO_2 in 2020. While the carbon price at the ETA market (EUA) in 2019 lied around 340 NOK per tonnes CO_2. EU carbon Permits have increased from 12,60 Euro (January 2010) a tonne to 88,36 Euro (May 2022) (TradingEconomics, 2022).

The economic intuition behind the link between growth and carbon pricing unfolds as follows. First, economic activity fosters high demand for industrial production goods. In turn, companies falling under the regulation of the European Union Emissions Trading Scheme (EU ETS) need to produce more, and emit more CO_2 emissions in order to meet consumers' demand. This yields to a greater demand for CO_2 allowances to cover industrial emissions, and ultimately to carbon price increases (Chevallier, 2011).

In 2021, SSB published an overview of efficient carbon prices in Norway. Efficient carbon prices mean the sum of all energy-related taxes, CO_2 taxes and the price of allowances. The term is taken from the OECD. The use of fossil fuels depends on both the type of fuel used and who uses it, i.e. companies in different industries or households. The marginal carbon prices vary from 0 NOK, for foreign shipping, to 2 200 NOK on emissions for households. The marginal price shows the price of the last unit emitted, while the average price shows what has actually been paid for the emissions (SSB, 2021b).

In the climate plan for 2020 - 2030, the government announced that they would increase the taxes on greenhouse gas emissions, so that the CO_2 tax, which in 2019 lied around 590 NOK per tCO_2e, will be increased to 2 000 NOK per tCO_2e by 2030. This is part of the commitment with the EU of a 40% reduction by 2030. This could imply that both effective average and marginal prices for emissions increase (Regjeringen, 2019).

Due to various prices of carbon and the price is subject to volatility in the market, it is difficult to predict what the price of one tonne CO2e will be in 50 or 200 years. However, we assume it will rise from today's price. Ignoring the possibility that the price also can decline with new technology of green energy. On the basis of the knowledge discussed above, we will assume a constant price per tonne CO2e emitted of 2000 NOK.

To sum up, we assume the time horizon for nature types to go from its 2021 value to NPP of 50 years, linearity in the carbon accumulation of the nature types and a constant carbon price of 2000 NOK per ton CO2e in our analysis.

6.3.4 Results

With the assumption of linearity and a 50 year time horizon to go from the 2021 carbon sequestration level at 1364,60 tCO2e to NPP, total annual growth of flow variable becomes 109,17 tCO2e. Further, assuming a constant carbon price at NOK 2000 per tCO2e, the present value of carbon in the biomass of the restored habitat types at Hjerkinn in 2021 value, with a 4% discount rate, is estimated to be 144,90 MNOK.

Table 8: Estimated present value of carbon accumulation of the restored nature at Hjerkinn. Stated in millions of NOK.

Discount rate	Carbon Value
2%	235,60
4%	144,90
6%	96,67

Assuming 50 year time span, Table 8 demonstrates that higher discount rate gives higher carbon value, and vice versa.

6.4 Supporting services

Supporting services are necessary for the production of all the goods and services ecosystems provide, they provide living places for animals and plants and maintain the diversity by ensuring, for example, production of biomass, water cycling and production of oxygen to the atmosphere (FAO, 2020d).

Although it is undeniable that Hjerkinn provides supporting services, we lacked sufficient information to assess the environmental benefits this service brings to the area. Therefore, we will not consider this feature in our analysis. However, one of the primary goals of restoring the former military area was to enable nature to provide supporting services, as to restore ecosystem functions. Through the restoration, nature and shape of the land coverage was facilitated, for example, the restoration of the original water infiltration system (Hagen et al., 2022).

7 Cost-benefit analysis of Hjerkinn PRO

Estimated costs (ch.5) and benefit flows (ch.6) of Hjerkinn PRO will now be compared to determine whether the restoration of the previous military area "was worth it" from an socio-economic point of view. Since all the calculations made are in monetary units, with 2021 as a reference year, the estimates are comparable.

The cost benefit analysis consists of a baseline model that assumes CM1 and discount rate at 4% with a time horizon of 50 years for benefit accumulation, starting in 2021. In the baseline model, the costs and all benefits will be discounted at the same rate. The appliance of the recommended 4% discount rate in the baseline model emphasizes the Ministry of Finance's recommended discount rate of projects lasting until 40 years. Even though the time horizon applied is 50 years, we still choose to hold 4% as a baseline since the implementation of the project lasted for 21 years. To examine the robustness of the estimates, sensitivity analysis of the discount rate, and the environmental parameter, will be applied. In addition, the sensitivity analysis will examine how the results in the baseline model change when the horizon changes from 50 to 100 years of benefit accumulation. Since the costs operate with a finite time horizon, with year 0 equating to the reference year 2021, a change in the period will not affect the costs' value. However, it is worth noting that by using a discount rate of

4%, it is likely an overestimation of the true costs because the period in which the costs are made have seen historically low interest rate (Norges Bank, 2021).

Regarding the Krutilla-Fisher argument, it will only be applied to the benefits that are not determined by the market. In this analysis, this will be the recreation value of hunting and the recreation value of tourism. As both the meat value and carbon value are subject to adjustment in its value through market pricing.

To sum up, the estimated costs and benefits Table 9 gives an overview of our findings at a 4% discount rate in a 50 year period that will be applied in the CBA baseline model.

Table 9: Estimated present value of benefits and costs found at the restored area at Hjerkinn.

Costs:	**Benefits:**

Cost model 1: MNOK 794,55
 	
Cost model 2: MNOK 341,44
	Provisioning services:
	- Hjerkinn: MNOK 1,25
	- Snøhetta: MNOK 25,44
	
	Cultural services:
	- recreation value of hunting:
	  - Hjerkinn: MNOK 0,72
	  - Snøhetta: MNOK 13,98
	
	- recreation value of tourism: MNOK 523,75
	
	Regulating services: MNOK 144,90
	
	Supporting services : -

7.1 Results of CBA applying Cost model 1

Assuming a discount rate of 4% the estimated NPV equals -124 MNOK with the Hjerkinn specific calculations for meat value and recreational value of hunting. The sign of NPV is negative, hence Hjerkinn PRO is not considered economically profitable within this framework. Extending the Hjerkinn specific values to include Snøhetta the NPV stays negative at -86 MNOK.

Table 10: Estimated Net Present Value of Hjerkinn PRO over 50 year time span, stated in millions of NOK.

	*NPV Hjerkinn**, MNOK (r=4%)*			*NPV Snøhetta ***, MNOK (r=4%)*		
	$\alpha = 0$	$\alpha = 1\%$	$\alpha = 2,5\%$	$\alpha = 0$	$\alpha = 1\%$	$\alpha = 2,5\%$
CM1 r=2%	*311*	-	-	*365*	-	-
CM1 r=4%*	*-123,92**	*-24,83*	*194,43*	*-86,49*	*15,10*	*236,82*
CM1 r=6%	*-440*	-	-	*-413*	-	-

Note for calculations with alpha, meat value and carbon value are not applied with the Krutilla argument, thus being discounted at 4%.
**: baseline model*
***: Calculation of meat value and recreational value of hunting is of Hjerkinn estimates, assuming the estimated harvest of meat of Hjerkinn and number of hunters at Hjerkinn.*
****: Calculation of meat value and recreational value of hunting is of Snøhetta estimates, assuming the whole wild reindeer herd at Snøhetta and number of hunters in Dovre.*

By changing the assumptions in the baseline model one can determine how changes in the discount rate and environmental parameter affect the NPV. All else equal, a higher discount rate, r=6%, gives a higher negative value of the NPV. Which is true for both the Hjerkinn specific estimate and Snøhetta specific estimate. Thus the project is still not considered economically profitable in either case. When testing for a lower discount rate, r=2%, NPV turns positive for both Hjerkinn and Snøhetta specific estimates at 311 MNOK and 365 MNOK, respectively. Further, when applying the Krutilla argument at $\alpha = 1\%$ and $\alpha = 2,5\%$ to the baseline model with 4% discount rate, NPV turns positive only with $\alpha = 2,5\%$. When including both Krutilla argument and Snøhetta specific estimates, NPV stays positive independently of what alpha is applied.

Further it is interesting to observe if the negative NPV of the baseline model with r=4%, changes if the time horizon gets expanded. Assuming the benefit flows accumulate for 100 years instead of 50 years, T=100. The increased time span has nothing to say for the accumulated costs since they are discounted to reference year 2021. Using the recommended discount rate with $r = 4\%$ and recommended environmental parametre with $\alpha = 2,5\%$ to illustrate the impact of the changed time horizon in table 7.4.

Table 11: Estimated NPV of Hjerkinn PRO over a 100 year time horizon. Stated in MNOK

NPV of Hjerkinn PRO with T=100, (r=4%) MNOK		
CM1	$\alpha = 0\%$	*-0,23*
	$\alpha = 2,5\%*$	*632,43*

The NPV values only take the Hjerkinn specific estimates into account.
**:The Krutilla argument is only applied on the recreational values. Meaning, the recreational value of tourism and hunting is discounted with r=4% and a=2,5%, while the meat value and carbon value is discounted with r=4% and a=0%. Cost discounted at 4%.*

When allowing the benefit flows to accumulate over 100 years, the estimated NPV of the baseline model remains negative, but the magnitude has decreased to - 0,23 MNOK. Following the decision criteria, Hjerkinn PRO is *not* economically profitable with a discount rate at 4% and a time horizon at 100 years. Applying the Krutilla argument at the recreational benefits, however, will make the project achieve a positive NPV at 632, 43 million kroners, and change the result to be economically profitable.

7.2 Results of CBA applying Cost Model 2

Prior to this (ch.7.1), estimated NPVs were reported using Cost Model 1, including all expenses of Hjerkinn PRO. Will now implement Cost Model 2 instead of Cost Model 1 to account for investment costs in the CBA to examine how the results on the socioeconomic value of the project change when excluding the explosive subproject.

Table 12: Estimated Net Present Value of Hjerkinn PRO (50yr), stated in millions of NOK.

	*NPV Hjerkinn**, MNOK*			*NPV Snøhetta ***, MNOK*		
	$\alpha = 0$	$\alpha = 1\%$	$\alpha = 2,5\%$	$\alpha = 0$	$\alpha = 1\%$	$\alpha = 2,5\%$
CM2 r=2%	*698,97*	-	-	*752,95*	-	-
CM2 r=4%	*329,19*	*428,28*	*644,53*	*366,62*	*468,22*	*689,93*
CM2 r=6%	*92,23*	-	-	*120,14*	-	-

For calculations with alpha, meat value and carbon value are not applied with the Krutilla argument, thus being discounted at 4%.
***: Calculation of meat value and recreational value of hunting is of Hjerkinn estimates, assuming the estimated harvest of meat of Hjerkinn and number of hunters at Hjerkinn.*
****: Calculation of meat value and recreational value of hunting is of Snøhetta estimates, assuming the whole wild reindeer herd at Snøhetta and number of hunters in Dovre.*

When CM2 is applied, the NPV of Hjerkinn PRO becomes positive at a 4% discount rate without the Krutilla argument. In other words, the project is economically profitable, with a NPV of either 329,19 or 366,62 million kroners, depending on whether the Hjerkinn specific estimates or the Snøhetta estimates for the meat value and recreational value of hunting are used. These results might not be surprising as the costs (discounted at 4%) in the calculations get reduced from 794,55 MNOK to 341,44 MNOK.

Table 12 demonstrates that the NPV of Hjerkinn PRO varies with the discount rate, r, and environmental parameter, α. Isolated, a higher discount rate results in a lower NPV for both the Hjerkinn specific estimates and the Snøhetta estimates. Nevertheless, the decision rule continues to indicate that the project is economically profitable independent of which discount rate applied, when considering CM2 as the investment costs. In addition, when including the Krutilla argument for chosen benefit flows, the NPV increases compared to the scenario excluding the environmental parametre ($\alpha = 0$). Isolated, the higher α, the higher the positive NPV at a given discount rate at 4%.

If expanding the time horizon once more, the NPV increases. Longer time span has still no effect on the accumulated costs, as they are discounted to the reference year. Using the recommended discount rate of r=4% and the recommended environmental parameter of 2.5%, the impact of the altered time horizon is illustrated in Table 13.

Table 13: Estimated Net Present Value of Hjerkinn PRO with CM2 over a 100 year time horizon. Stated in millions of kroner.

NPV of Hjerkinn PRO with T=100, (r=4%) MNOK		
CM2	$\alpha = 0\%$	*452,88*
	$\alpha = 2,5\%*$	*1085,54*

The NPV values only take the Hjerkinn specific estimates into account.
**:The Krutilla argument is only applied on the recreational values. Meaning, the recreational value of tourism and hunting is discounted with r=4% and a=2,5%, while the meat value and carbon value is discounted with r=4% and a=0%.*

When all flows are discounted at 4%, extending the time horizon results in increased NPV values compared to the scenario with T=50 in Table 13. In other words, when considering the accumulation of benefits over a longer period of time, the project becomes more economically profitable. However, only changing the time horizon from 50 to 100 years, has less effect than including the Krutilla argument for recreational values. Further, considering a T=100, table 13 demonstrates that inclusion of the Krutilla argument of the recreational values, with $\alpha = 2,5\%$, results in a greater NPV than when it is omitted from the calculations.

7.3 Main findings

From the analysis, whether the net present value of Hjerkinn PRO passes the decision rule or not depends on the chosen discount rate, time horizon, inclusion of the environmental parameter alpha, and which cost model is pursued.

As expected, the net present value under CM2 is significantly higher than when applying CM1. The rationale for the significant value disparity in the resulting NPVs is the differences in investment, $I_{CM2} < I_{CM1}$, a consequence of excluding costs associated with the explosive subproject. For CBA including CM1 and benefit flows discounted at 4% over a time horizon of 50 years, the conclusion becomes that Hjerkinn PRO was not economically worth it as NPV is negative, -124 MNOK. Interpreting CM2 with the same criterias results in a positive NPV of 329,19 MNOK. When extending the time horizon from 50 to 100 years with a 4% discount rate, the conclusion for both cost models stays unchanged. Further, including the benefit flows associated with Snøhetta projections (e.g. the meat value and recreational value of hunting) instead of the Hjerkinn-specific estimates has no effect on the concluding outcomes as NPVs of CM1 stays negative and CM2 positive. These findings suggest that the time horizon for benefit accumulation and the Snøhetta versus Hjerkinn estimates affects the magnitude of the NPV, but not to the extent where it alters the conclusion of whether Hjerkinn PRO was economically profitable.

Nevertheless, our thesis reveals that selection of discount rate and cost model has a substantial impact on whether or not Hjerkinn PRO is deemed as economically profitable. When determining which cost model to adopt, the purpose of the CBA must be addressed. CM1 should be applied if the intention is to decide whether Hjerkinn PRO was worth it as a whole. CM2 should be applied if the purpose is to determine if ecological restoration is economically profitable, since it only covers direct restoration expenses.

The sensitivity analysis demonstrates that the sign of the net present value of Hjerkinn PRO varies significantly with the discount rate and the environmental parameter, questioning the robustness of our results. All else equal, a higher discount rate results in a lower magnitude of NPV for both the Hjerkinn specific estimates and the Snøhetta estimates, independent of which cost model applied. In the case of CM2 as the investment costs, the sensitivity analysis shows that the decision rule indicates that restoration is favorable even with a high discount rate at 6%. In addition, when including the Krutilla-Fisher parameter for all recreational benefit flows, the NPV increases compared to the scenario excluding the environmental parameter ($\alpha = 0$). All else equal, higher α, increase NPV at a given discount rate at 4%. Upon replacing investment costs from CM2 to CM1 the profitability is no longer independent of the discount rate applied. Both r=4% and r=6% give negative NPV. The only case where NPV turns out positive is with a discount rate less than 4%. When r=2% or the Krutilla argument with $\alpha = 2,5\%$ is applied on selected environmental factors the NPV is positive. This demonstrates that the discount rate and alpha selected for the estimations contribute a proportionately greater matter than the time horizon and Snøhetta specific calculations when determining whether Hjerkinn PRO was economically profitable.

Regarding the sensitivity analysis resulting in substantial variation in economic profitability, it is evident that the robustness of our results is ambiguous. The next big question is to determine which discount rate and environmental argument gives the most accurate results of the profitability of Hjerkinn PRO.

8. Discussion

This chapter will discuss our findings in the light of the discount rate, limitations and economic valuation of nature.

8.1 Deciding discount rate

Results in response to the main research question regarding the economic value of the Hjerkinn restoration are dependent upon definitions of value or worth, the theoretical framework for the cost benefit analysis, and the degree to which intertemporal equity issues and sustainability are considered. The application of discount rates was also central in determining the results presented in this study.

There is general consensus that discounting is an integral part of determining profitability in ever-evolving markets. The Norwegian Ministry of Finance has set a 4% discount rate as the standard used when considering project profitability within time perspectives of 40 years. However, the application of this rate is problematic, as environmental resources have an extensive time horizon. Therefore, the use of this rate may underestimate the actual impact on environmental resources. To counteract these challenges, the Brundtland Commission defined sustainability in 1987 in a manner that emphasizes the concept sustainable to capture more than the state of the natural environment, involving economic development, thus allowing for substitution between human made capital and natural capital as a basis of sustainable development. This aspect of the definition raises awareness surrounding choice of discount rate in relation to intertemporal equity.

When discussing the use of discount rates regarding environmental concerns, irreversible effects of environmental degradation should be taken into account. Even though restoration increases ecological quality, nature can never reestablish the original state of vegetation. At Hjerkinn, the removal of military installations has returned the local environment more closely to its original conditions, but not entirely, as no quantity of substitute goods can compensate for the loss of natural capital (Sáez & Requena, 2006).

As climate change and natural scarcity affect both current and future generations, environmental factors should be a more integral factor in the consideration of the CBA. Applying a lower discount rate in projects involving natural resources is one means of achieving this goal and of attaching a higher value to natural resources in the future. This is one recommended practice, as natural resources and ecosystems have a high value with no perfect substitutes. Classical CBA discounting, on the other hand, is limited to a time horizon of a few decades at best (Saez and Requena, 2006), and thus under-evaluates long lasting environmental impacts.

Determining discount rate is dependent both on context as well as definition, and several methods claim to have the most appropriate approach. An extreme position is to argue that the only valid discount rate is zero, claiming that only such a discount rate will fully align the CBA with an intergenerational scenario for equity (Harrod, 1948). Proponents argue that discounting is ethically unsustainable and that the zero discount rate is one that fully maintains equity between generations, as it prohibits current generations from ignoring long-term environmental responsibilities. This approach assumes a state of indifference between benefit today and in the future, which is extreme in its disregard of the future impact of decisions made today (Harrod, 1948).

In conditions of weak sustainability, a higher discount rate is accepted. The perspective that all capital, regardless of type, is fully replaceable is problematic, considering certain environmental developments may be irreversible and lead to extinction. From the perspective of strengthening sustainability when natural capital seems to lack substitutes, environmental factors in a CBA should be treated differently and new practices developed. Therefore, a discount rate of 2% is more appropriate, if strong sustainability and time equity are recognized.

When adjusting the standard discount rate for environmental externalities, as described above, consideration needs to be given to the risk of double counting (Pearce & Turner, 1990,). According to Pearce and Turner (1990), a central problem with reducing the discount rate to account for environmental considerations is that no relationship has been established to account for the unique relationship of discount rate and environmental damage. A lower discount rate, on the one hand, could lead to an overestimation of the profitability of a project and potentially harm investment and economic development.

The Krutilla-Fisher arguments offer a more nuanced approach to better alignment of the analytical context of CBA and sustainability concerns. These arguments enhance the possibility for diverse discount rates in analysis. In Table 10 and 12 such arguments are applied, increasing the magnitude of NPV. Justification for applying the Krutilla- Fisher argument to benefit flows is grounded in the argument that such environmental goods have no substitute. Given that future generations have the same environmental demand as the present generation, and that environmental resources are becoming scarce, the demand for the natural environment and wilderness will increase. This indicates that, if the supply of wilderness worldwide should decrease, the WTP for tourists' and hunters' experiences of Hjerkinn and its resources should increase. Thus, the benefit flows must be treated with a parameter alpha that allows for an increase in the value of nature. Krutilla and Fisher suggested this modification of environmental CBAs as early as 1972, leading the arguments considered to be even more relevant today as environmental capital has significantly decreased since then.

The Krutilla-Fisher argument is applied only to recreational values (see Tables 10 and 12, as the remaining values are attached to established markets. As carbon emissions are priced, they belong to a market. In both the EU and Norway, an eventual increase in the price of carbon is predicted, as an intervention targeting sustainability goals. The Krutilla-Fisher argument is indirectly embedded in this market pricing of carbon. However, in this case, the inclusion of the environmental parameter, α, will lead to double accounting, as the market price already adjusts for the environmental growth. In addition, linearity is not considered an assumption compatible with the arguments presented in Krutilla-Fisher, as they require exponential growth. Therefore, there are theoretically tensions in applying the Krutilla-Fisher argument to current practices for carbon valuation. A similar argument for excluding the environmental parameter can also be applied to meat value. Since the price of wild reindeer meat is determined by the market, integrating an alpha can result in the overestimation of wild reindeer meat. On the other hand, given climate changes that threaten wild reindeer habitats and growing tourism at Hjerkinn that negatively impacts the reindeer, the future prospects for wild reindeer meat in terms of scarcity and resultant price adjustments to account for this scarcity are uncertain. In this case, applying the Krutilla-Fisher argument can be a reasonable initiative in addressing this uncertainty. If correct, the value will be underestimated with application of $\alpha = 0$.

As described above, the Krutilla-Fisher argument can be used to provide substitutes for missing market adjustments for recreational and meat values alike, especially for aspects like recreation that is not exchanged in a market and lacks a market price. Since the recreational value of hunting includes the experience of nature, excitement and social fellowship, which also lack market-priced benefits, the Krutilla-Fisher argument can address these deficiencies. These same arguments apply to the recreational value of tourism ah Hjerkinn. While the discussion of the optimal discount rate and alpha in a CBA is broad and consensus has yet to be reached, we argue for the reasonable inclusion of Krutilla arguments in investigations such as this one, as classical CBA lacks a solid framework for the inclusion of long-term environmental concerns.

The discussion of the optimal discount rate and alpha in a CBA is endless, making it difficult to provide a conclusive response to our research question. However, we find it reasonable to include the Krutilla arguments, as classical CBA lacks a solid framework to appropriately include long-lasting environmental concerns.

8.2 Assigning nature a market price

Even though some of the results of our research indicate that the restoration was not economically worth it, this does not entail that it should not be carried out. As SEEA points out *"almost no (if any) proponent of valuation believes economic considerations are the only reason to commit to preserving and protecting the natural world"* (United Nations, 2021). In other words, there are many other considerations and ethics concerning the relationship between humans and nature that lie beyond an economic analysis and thus not accounted for in our CBA.

One consideration that is challenging to quantify in economic analysis is individuals' non-use values. In addition to peoples' use values at Hjerkinn, both visitors and non-visitors of the area can utilize the area's non-use values. To some extent non-use values, such as bequest values and option values, are accounted for through stated preference methods. However, willingness to pay estimates is criticized for whether the method reveals an individual's actual willingness to pay for a good or service since it relies on hypothetical scenarios (Kanya et al., 2019). Making the validity criterion questionable. If ignoring the hypothetical bias, it is still questionable to what extent the method reveals an individual's non-use values (Freeman et al., 2014, 400) (Weikard, 2005). Willingness to pay methods will at best reveal the worth of a resource in relation to the individual itself, not the value of the resource for the resource itself. For example, the intrinsic value of a musk ox or a National Park. Therefore, it is considered almost impossible to fully capture the whole value of priceless assets such as Dovrefjell's iconic habitat and alpine ecosystem.

Despite its limitations, monetary valuation can assist preservation of nature and allow decision-makers to better comprehend the associated trade-offs, as is the case of CBA. By including the found environmentally adjusted economic aggregates it can raise awareness of the trade-offs and help decision makers place some value on nature than none at all. For example by placing a price on carbon emission, which can be seen as an essential support in the fight against climate change and make society carbon neutral by 2050, and through the

EU Green Deal and Taxonomy. Traditionally, ecosystems have in some cases been given an implicit value of zero (United Nations, 2021). Whether one *should* put a price on nature to avoid an implicit price of zero is another debate. However, when applying economic analyses, rather than assigning a monetary value to nature, values are restricted to estimating the economic worth of a limited set of services at a time. Demonstrating the fact that monetary valuations in general are limited in their scope.

The system of SEEA contributes to make monetary valuation more valid as the system is backed up by scientific research gathering data on ecosystem extent and form a basis for monetary valuation techniques that can be a key mechanism for reversing biodiversity loss and achieving consensus over the need to establish global nature goals. In many settings, climate problems and nature problems are viewed as two distinct issues. In reality, they are two sides of the same coin, as intact nature is required to maintain a stable climate. Thus, restoring nature can help to accelerate progress towards the climate goals. Due to the urgency of climate change, it is necessary to not only preserve nature but also restore what has been destroyed or degraded, creating more nature by the end of the decade than at the beginning. Thus increase biodiversity worldwide. By not taking action in favor of climate and nature, it will have a negative impact on biodiversity, human well-being and the economy. The spectrum of these relationships is mostly excluded from economic analysis. Internationally, there are more large-scale restoration efforts, highlighting the importance of reversing the global trend of environmental loss. The restoration project at Hjerkinn and elsewhere likely involves externalities that are not accounted for when evaluating its worth through an economic analysis. Also the costs of not restoring nature are unclear, making the direct cost of Hjerkinn greater than the alternative cost. How much is our existence worth if our future is at stake?

Estimating the value of nature is not a straightforward process. The goal of the estimations is not necessary to attach a monetary value, but in the context of a CBA, it is crucial to apply comparable values which in this case means that either the costs must be transformed into other units of measurement or the benefit should be measured in monetary terms. Either way, there are associated uncertainties. As we measure environmental benefits in monetary terms there are a number of obstacles that can not be easily solved as valuing nature is not objective and can not be made universal.

Many laws and regulations emphasize the component of climate change that the economy has an inertia in highlighting. If it is to have the best possible effect it requires recognition that climate and nature problems are interconnected, so that decision-makers refrain from adopting climate-friendly decisions at the expense of nature. This may be the case when taking into account the emphasis on replacing fossil fuels with green energy sources such as windmills and hydroelectric plants, which can lead to reduced flow pollution and so have a positive impact on climate, but could cause damage to nature. IPBES and SEEA stress this point.

8.3 Limitations

Whether the results from the CBA are reliable, should be seen in the light of the assumptions made when estimating the benefit flows. One obvious limitation in the analysis is the use of benefit transfer.

8.3.1 List of limitations

Benefit transfer: The estimated present value for the meat value, the recreational value of hunting, and the recreational value of tourism is contingent on the validity of distinct benefit transfers. However, this method seldon a preferred approach, as it requires strong assumptions, leading to uncertainty of the estimates which can and can compromise the accuracy of the estimates.

Average estimates: Applying willingness to pay estimates implies use of average values. Thus, the marginal effects have not been isolated, leading to a possible overestimation of the value added in the restoration area of Hjerkinn.

Clear cut off regarding the benefit and cost flows: The assumption of benefit flows only occurring after 2021, is a strong simplification of the reality, as some restoration actions had spontaneous effects, and thus were present before 2021. For example, removal of technical infrastructure such as roads facilitated vegetation growth, and removal of UXO made the area accessible for civil usage. This suggests that befit flows were occuring at an earlier stage, which is not accounted for in the thesis. Exclusion of this matter may have led to an underestimate of benefit flows.

Overlap between estimation methods: The estimation of the recreational value of hunting and tourism has been done separately, without correction for possible overlap. The underlying estimation of the number of visitors to the restored area, may include the number of hunters at the restored area. Thus, possibility for double accountancy when it comes to the estimation of the recreation values. However, since the number of active hunters in the region is low, we consider it to have minimal impact on the outcome. Moreover, the recreational value of hunting can capture additional values that typical visitors do not utilize, and by removing it from our analysis, it can rather exclude important values than deducting an excessive value.

Collectively, the listed limitations and assumptions made throughout the thesis have an impact on the NPV outcome, with some tending toward an overestimation and others toward an underestimation of the value in question, thus affecting the evaluation of whether Hjerkinn PRO was economically profitable.

8.3.2 Omitted variables

In addition to the values identified in our theis, the economic profitability of Hjerkinn PRO may be impacted by:

Improved health: As The Norwegian Directorate of Health stresses the importance of being active to ensure good health, the restored area at Hjerkinn facilitates this as hunting and tourism involves physical activities. It is also proved that being active has a positive effect on mental health. The positive effects of visiting a national park on mental health may be attributable to the social side of going on hikes with friends or family, the pleasure of viewing wilderness, and the nature experience. A portion of this might have been included in the estimated recreational values for hunting and tourism. However, we have not identified the isolated physical or mental health benefits of visiting the restored area at Hjerkinn.

Use value of other animals: The restored area also houses other animals that attach use values, both as provisioning and in a recreation manner. The national park is famous for the musk ox living there which is reasonable to contain a high recreation value. Including a broader set of species would probably increase the estimation of benefits in the area.

Non-use values: Non-use values such as the existence value of nature itself and the option value of visiting the restored area is not accounted for. Exclusion of such values have probably led to an underestimation of the economic value of Hjerkinn PRO.

We lack sufficient knowledge and data to analyze numerous environmental goods and services at Hjerkinn. The ones listed above are just a fraction of left out variables in our analysis. Addition of such factors would likely increase the total benefit value and hence the economic profitability of Hjerkinn PRO. Further research should therefore include the omitted variables, as well as emphasize the limitations from ch. 8.3.1.

9. Conclusion

Whether the restoration "was it worth it" becomes a matter of definitions surrounding the theoretical framework underlying a cost benefit analysis, and of what degree one should consider intertemporal equity issues and sustainability. As the robustness of the answers are questionable since their character changes depending on the discount rate, we can not by certainty conclude whether the restoration was economically profitable. But we do argue that restoration of ecosystems is necessary to ensure human well-being and meet climate goals. From such a perspective the restoration can be considered profitable. If it was economically profitable, it would need further research to add complexity to the current methodologies to answer.

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Appendix

A.5: Costs

Table A.5.1

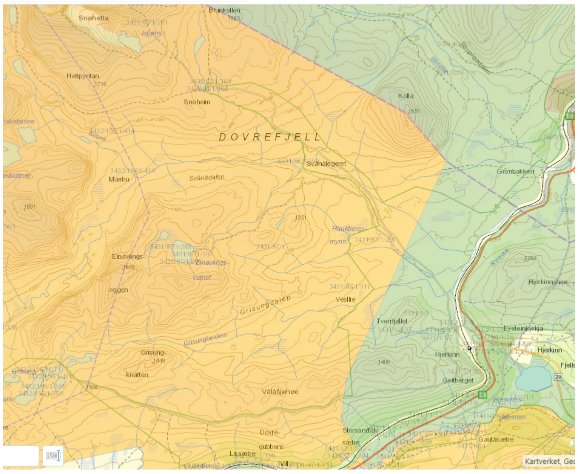
0	0,01	0,02	0,04	0,06	t=T
1285714	1 600 349 kr	1 987 688 kr	3 047 038 kr	4 633 119 kr	22
1285714	1 584 504 kr	1 948 713 kr	2 929 844 kr	4 370 867 kr	21
1285714	1 568 815 kr	1 910 503 kr	2 817 158 kr	4 123 459 kr	20
1285714	1 553 283 kr	1 873 043 kr	2 708 805 kr	3 890 056 kr	19
1285714	1 537 904 kr	1 836 316 kr	2 604 621 kr	3 669 864 kr	18
1285714	1 522 677 kr	1 800 310 kr	2 504 443 kr	3 462 136 kr	17
1285714	1 507 601 kr	1 765 010 kr	2 408 118 kr	3 266 166 kr	16
17624708	20 461 739 kr	23 720 536 kr	31 741 103 kr	42 238 638 kr	15
19966712	22 951 221 kr	26 345 652 kr	34 575 885 kr	45 142 818 kr	14
20980715	23 878 011 kr	27 140 792 kr	34 934 433 kr	44 750 360 kr	13
32672818	36 816 549 kr	41 437 033 kr	52 310 234 kr	65 744 129 kr	12
36792424	41 048 143 kr	45 746 755 kr	56 640 246 kr	69 843 005 kr	11
56420895	62 323 769 kr	68 776 756 kr	83 516 707 kr	101 041 230 kr	10
53869376	58 916 143 kr	64 378 891 kr	76 672 919 kr	91 011 177 kr	9
53261959	57 675 069 kr	62 404 874 kr	72 892 669 kr	84 891 471 kr	8
35718134	38 294 674 kr	41 028 909 kr	47 002 628 kr	53 706 867 kr	7
31610757	33 555 456 kr	35 598 847 kr	39 997 692 kr	44 840 463 kr	6
31253374	32 847 610 kr	34 506 250 kr	38 024 508 kr	41 824 064 kr	5
44789556	46 608 192 kr	48 481 656 kr	52 397 445 kr	56 545 782 kr	4
39551369	40 749 815 kr	41 972 229 kr	44 489 911 kr	47 106 313 kr	3
46133802	47 061 091 kr	47 997 608 kr	49 898 320 kr	51 835 940 kr	2
35049976	35 400 476 kr	35 750 976 kr	36 451 975 kr	37 152 975 kr	1
23986871	23 986 871 kr	23 986 871 kr	23 986 871 kr	23 986 871 kr	0
588683444	**633 449 960 kr**	**682 396 218 kr**	**794 553 574 kr**	**929 077 770 kr**	

Accumulated costs of the projects. All values in the thesis are estimated in 2021 values, thus t=0 equals 2021 calculating backwards to 1999. The ecological restoration started in 2006, in the period before it was approximately 9 MNOK spent on administration cost. Assuming they are equally distributed through the year. In the analysis we apply the costs discounted at 4% in the baseline model. 2% and 6% are applied in sensitivity analysis. 0% represents the undiscounted costs of the project.

A.6 Benefit flows at Hjerkinn

A.6.1 Provisioning services

Figure: A.6.1.1



Map of hunting areas monitored by Statskog SF (green) and Dovre mountain (yellow). As stated there is a lack of data connected to hunting licenses distributed by Dovre mountain. The map illustrates how big this area is which supports under the suspicion of an underestimate connected to the number of hunters.

A.6.2 Cultural services

Table A.6.2.1

	SEK 2001value	SEK/NOK (1:1.149, yr2001)	NOK adj. for KPI (2001 to 2021)
Total cost estimated	2729	3135,62 NOK	4685,27 NOK
Max WTP before not undertaking the trip	4058	4662,62NOK	6966,93 NOK
Expenses incurred during the visit to the area (45,3%)	1236	1420,16 NOK	2122,02 NOK
Experience of the FRL area accounted for (43.3%)	1756	2017,644 NOK	3014,78 NOK
Consumer surplus	520	597,48 NOK	892,76 NOK

Descriptive table over the conversion of monetary values provided by Fredman and Emmelin (2001) from SEK to NOK. Applying the NOK values to the restored area of Hjerkinn. The original values were estimated in 2001 our estimates are additionally adjusted for KPI in order to include for price growth.

Table A.6.2.2

	Total after 50yrs				
−0,05	0,015	0,02	0,035	0,04	0,06
5612641115	**838653053**	**755344214**	**569721009**	**523747671**	**390486317**

NPV values of recreation values estimated through benefit transfer of tourism over a 50 year period. Applyng 4% in the baseline model, 2% and 6% for sensitivity analysis. The value of 0,015/ 1,5% applied in a situation accounting for the Krutilla-Fisher parameter, $(r - \alpha)$ where r=4% and $\alpha = 2,5\%$. Testing different scenarios, observing that NPV increases as expected in a case of r=2% and $\alpha = 2,5\%$.

A.6.3 Provisioning services

Table: A.6.3.1

Antall år frem til	50
Nok/tco2e	2000
r	0,04
NPP	6823
Dages opptak	1364,6
formel	y=a+bt
b (vekstall)	109,168

Framework when assuming linearity in the restored mire. Knowing today's storage and the estimated future maximum together with a time perspective made it possible to estimate the steepness of the development. $y = a + bt$ with y= 6823 tonnes, the future storage. Assumption of 20% storage today leads to a current storage of a=1364,6 tonnes. With t=50 it enabled us to find the growth rate, b. $6823 = 1364 + b50 \Rightarrow b = 109,168$.

Table A.6.3.2

time	Xt	Xt*(NOK/CO2)	NPV
0	1364,6	2729200	2729200
1	1473,768	2947536	2834169
2	1582,936	3165872	2927027
3	1692,104	3384208	3008549
4	1801,272	3602544	3079470

45	6277,16	12554320	2149280
46	6386,328	12772656	2102556
47	6495,496	12990992	2056247
48	6604,664	13209328	2010391
49	6713,832	13427664	1965019
50	6823	13646000	1920164
Totalt			**144903782**

First and last five years of the estimated carbon storage. Xt is the annual growth in storage, Xt*(NOK/CO2) as the market value of the stored CO2 assuming the price of quotes equal 2000. given a CO2 price at 2000 each tonnes. Through time, Xt increases, following the estimated monetary value attached increases. NPV is the discounted value at a 4% level.

Table A.6.3.3*:*

Vegetation type	Restored area m2	Restored area m2 incl 25m buffer	NPP (annually tCO2e absorbed when restored)	Storage (potential stored tCO2e) (Stock variable)
Mire	178983	580738	40	106 906
Meadow	110012	462010	615	20 320
Snow-bed	3089	34775	9	2 508
Shrub-heat/ woodland	55194	1710994	4 093	49 660
Lichen heath	645950	2428133	2 066	20 496
Total			**6 823**	**199 890**

Extension of table 7 including the areal restored of nature types at Hjerkinn and their associated carbon accumulation. Stated in tonnes of carbon equivalents. Source: Hagen et.al.2022.