Reads

Capitals Valuation

Disclaimer

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Acronyms and abreviations

ALARP – As Low As Reasonably Practicable
BAT – Best Available Technique
BIU – Biophysical Impact Unit
CICES – EEA Common International Classification of Ecosystem Services
COC – Contaminant of Concern
CO_2eq – Equivalent tonnes of CO2
EEA – European Environment Agency
EEV – Environmental Economic Value
GEMI – Global Environmental Management Index
GHG – Greenhouse gases
IBAT – Integrated Biodiversity Assessment Tool
IFC – International Finance Corporation
IU – Impact Unit
IUCN – International Union for Conservation of Nature
IOGP – International Association of Oil and Gas Producers
IPIECA – International Petroleum Industry Environmental Conservation Association
KPI – Key Performance Indicator
LC_0 – No lethal concentration
LC_{50} – Median lethal concentration
LC_{100} – Totally lethal concentration
NCC – Natural Capital Coalition
OECD – Organization for Economic Cooperation and Development
O&G – Oil & Gas
PNEC – Predicted No-Effect Concentration
READS – Responsible Environmental Analysis Data System
ROI – Return of Investment
SDGs – Sustainable Development Goals
TEEB – The Economics of Ecosystems and Biodiversity
TEV – Total Economic Value
USD – US Dollars

1 Context

The United Nations, moving to reshape policy and business decision-making toward sustainable development, recently adopted a new framework that includes the contributions of nature in measuring economic prosperity and human wellbeing. This framework, the System of Environmental-Economic Accounting (SEEA-EA), was adopted by the UN Statistical Commission and marks a major step forward that goes beyond the commonly used Gross Domestic Product (GDP) statistic that has dominated economic reporting in recent decades. This decision ensures that natural capital (defined as the stock of environmental resources, such as plants, animals, air, water, and soils, that combine to yield a flow of benefits to people) is recognized in the economic reporting of nations. According to the World Bank 2021 publication, Changing Wealth of Nations (CWON), the wealth provided by nature (i.e., natural capital) is of paramount importance for most countries. For example, close to one third of the wealth of low-income countries comes from their natural capital.

Human wellbeing is directly linked with nature, and human health ultimately depends on ecosystem products and services (such as the availability of fresh water, materials, and food). Biodiversity loss may impair human health if ecosystem services are no longer adequate to meet social needs. Indirectly, changes in ecosystem services affect livelihoods, income, and local migration, and can cause or exacerbate political conflicts (WHO 2015).

The Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) identified the rate of global change in nature during the past 50 years to be unprecedented in human history. The direct drivers of change in nature with the largest global impacts have been the following (ranked by severity):

- Changes in land and sea use
- Direct exploitation of organisms
- Climate change
- Pollution
- Invasion of alien species

Human wellbeing is directly linked with nature, and human health ultimately depends on ecosystem products and services

In its Global Risks Report 2020, the World Economic Forum (WEF) identified the most severe risks on a global scale over the next 10 years, with the first three, climate action failure, extreme weather, and biodiversity loss, being intimately related to natural capital. Global concern has grown in recent years due to the direct relationship between finance and nature-related risks. Almost half of the world's GDP in 2019, 44 trillion USD, was at risk of disruption due to nature loss, and more than half of the world's total GDP is moderately or highly dependent on nature and ecosystem services (WEF 2020), i.e., exposed to risks due to nature loss. Consequently, nature loss and climate change are inextricably linked.

During COP15 (Conference of the Parties to the United Nations Convention on Biological Diversity) in Montreal, the "Kunming-Montreal Global Biodiversity Framework (GBF)", also known as the post-2020 Global Biodiversity Framework, agreed on an ambitious plan to implement actions aimed to halt and reverse biodiversity loss by 2030 with a shared vision of living in harmony with nature by 2050. (CBD 2020)

This framework envisages a whole-of-society approach to its implementation. Companies can contribute by placing nature in the centre of their strategic decisions. To addresses these challenges, companies should:

- Implement an integrated consideration of the different components of nature, such as climate, water and biodiversity, and their relationships with human wellbeing,
- Map, measure, value, monitor, and report their impacts, dependencies, risks, and opportunities related to nature,
- Provide measurable and verifiable results against a fixed benchmark that is also aligned with overall societal objectives, and
- Demonstrate positive returns for nature and human wellbeing.

The IPBES pointed out in their values assessment that the causes of the global biodiversity crisis and the opportunities to address them are tightly linked to the ways in which nature is valued in political and economic decisions at all levels (IPBES 2022). In that sense, several methodologies, frameworks, and guidelines are under development to help companies through this transition. Companies that embrace this challenge will increase the resilience of their operations and value chain and meet stakeholder expectations of current and future regulations.

The following guidelines and standards are helping companies to address this challenge:

- The **Natural Capital Protocol**, released in 2016 by the Natural Capital Coalition as a standardized framework for assessing environmental impacts and dependencies on natural capital. In October 2020, the Capitals Coalition launched the Biodiversity Guidance "Integrating biodiversity into natural capital assessments" (Capitals Coalition 2020) that accompanies the Natural Capital Protocol to help businesses better incorporate the value of biodiversity into natural capital assessments.
- The **Transparent Project**, an EU LIFE-funded project for developing standardized natural capital accounting and valuation principles for business, is in-line with the goals of the European Green Deal. Kicked-off in March 2020, the Transparent project developed a methodology through collaborative effort by bringing together the Value Balancing Alliance (VBA), the Capitals Coalition, and the World Business Council for Sustainable Development (WBCSD) to standardize the methodology for developing a natural capital accounting system (Transparent Project Participants 2023).
- The **Align Project**, launched in March 2021, was designed to develop recommendations for a standard on biodiversity measurements and valuation (UNEP-WCMC *et al.* 2022). Align is a 3-year project to provide businesses and financial institutions with principles and criteria for biodiversity measurement and valuation.
- The **Taskforce on Nature-related Financial Disclosure (TNFD)** will enable companies and financial institutions to integrate nature into decision-making by identifying, measuring, and valuating their impacts, dependencies, risks, and opportunities on natural capital.
- **ISO 14008:2019** provides a set of requirements and procedures for monetary valuation of environmental impacts and related environmental aspects.
- The **ESRS 1: European Sustainability Report Standard** and the specific document

for biodiversity, the **ESRS E4 Biodiversity and ecosystems** (currently available in draft), will be issued by the European Financial Reporting Advisory Groups (EFRAG) to demand that companies adapt and disclose their plans to ensure that their business models and strategies are compatible with the transition to achieve No Net Loss by 2030, a net gain from 2030, and full recovery by 2050.

In this global context, Repsol has adopted an innovative approach that incorporates and aligns some of these methods by developing its own methodology to identify, quantify, value, and manage the positive and negative environmental impacts of the energy sector.

The **Responsible Environmental Analysis Data System** or **Reads** was developed to assess the most common environmental impacts from all industrial projects, including but not limited to energy-related, industrial manufacturing, extractive industries, and civil projects.

Reads addresses impacts on nature and human wellbeing through a monetary valuation approach and allows companies to embed environmental considerations in their business strategies for enhanced decision-making.

The use of Reads complements the development of project-specific environmental and social impact assessments and related studies. Thus, Reads is conceived as a harmonizing method for identifying and assessing environmental impacts that can be used to compare the results of assessments of individual projects or a portfolio of different projects within a company.

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2 Natural Capital Framework

This report summarizes the methodological approach of Reads to make it publicly available for consultation and use.

Undertaking a natural capital assessment requires bridging between disciplines and practitioners while ensuring consistency and transparency with every step of the evaluation. The following is a brief primer on Natural capital, Ecosystem services, and Valuation of natural capital to ensure common understanding of the background framework for Reads.

2.1 Concepts

Natural Capital

Natural capital refers to the stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, and minerals) that combine to yield a flow of benefits to people (Capitals Coalition 2016).

Natural capital benefits business and society by providing ecosystem and abiotic services, as illustrated in Figure 2-1. Consequently, individual and collective actions can either build or degrade natural capital, depending on its use (Natural Capital Coalition 2016).

The Biodiversity Guidance (Capitals Coalition 2020) defines Biodiversity as the variety of life and the living component of what can be thought of as natural capital stocks. Biodiversity plays an important role in the provision of the services that humans receive from nature.

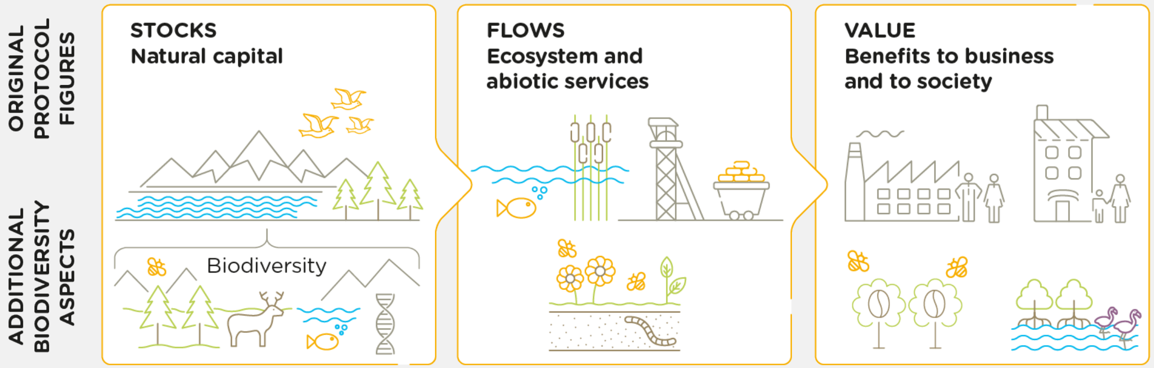

Figure 2-1 Benefits that flow from Natural Capital (source: Capitals Coalition)

The terms “capital” and “stocks” are used as metaphors to help describe the role of nature within the economy. The presence of, and the interactions between, natural capital stocks generate a flow of goods and services. These goods and services create value through the benefits they provide to business and society. Biodiversity is an integral part of natural capital and underpins the goods and services that natural capital generates. It is important to note that biodiversity is not an asset, rather a descriptive feature of assets called Natural Capital (Capitals Coalition 2020).

The economic term “capital” explicitly links the economy and the state of the environment (Costanza *et al.* 2017). An ecosystem is a dynamic complex element of living and non-living components that interact through time and space as a functional unit. Each biotic and abiotic constituent has an important role to play within the ecosystem.

Anthropogenic activities may result in positive or negative impacts on the condition and extent of ecosystems, and the subsequent changes in natural capital flows and services may affect the human wellbeing (IOGP/IPIECA 2016, Natural Capital Coalition 2016).

Consequently, a natural capital approach supports the understanding of the relationship between changes in the natural capital stocks and flows resulting from anthropogenic activities and the subsequent impacts on human wellbeing. In this vein, Reads provides a methodological approach that correlates any company’s activity with changes in natural capital stocks (e.g., plants, animals, air, water, soils, and minerals), ecosystem and abiotic services, and benefits to business and society. This approach widens the understanding of the interplay between a company’s decision-making process and its impact on natural capital and human wellbeing.

Ecosystem services

Ecosystem services can be understood as ecosystem features and dynamics that directly or indirectly contribute to human wellbeing, i.e., ecological processes or functions that have value to individuals or society (IPPC 2007).

The concept of natural capital denotes abiotic and biotic relationships that occur irrespective of whether they are deemed valuable by humans (Costanza *et al.* 2017). Conversely, ecosystem services refer to those aspects of natural capital that positively influence, consciously or unconsciously and directly or indirectly, on human wellbeing (Bagstad *et al.* 2014, Costanza *et al.* 2017).

The European Environmental Agency (EEA) developed the Common International Classification of Ecosystem Services (CICES), which is a steppingstone for the structure of the ecosystem services typology of Reads. CICES applies the three main Ecosystem Services categories proposed by the Millennium Ecosystems Assessment (MEA 2005): Provisioning, Regulating, and Cultural. CICES does not provide a separate category for Supporting Services, which is another category of the MEA. Supporting Services are those provided by basic ecosystem processes, e.g., soil formation, primary productivity, biogeochemistry, nutrient cycling, and living spaces for biotic organisms. CICES identifies the final services linked to goods and benefits valued by people, and the Supporting Services category refers to ecological functions, which are the underpinning structures and processes that ultimately give rise to ecosystem services (CICES 2018).

The three categories of ecosystem services applied by CICES are defined as follows:

1. **Provisioning:** Providing material outcomes to people, e.g., food, raw materials, energy, water, and medicinal resources, of which several are directly included in markets.
2. **Regulating:** Maintaining air and soil quality, avoiding floods, controlling pests and disease, and pollination and seed dispersal, which are often taken for granted and unnoticed by most people.
3. **Cultural:** Non-material benefits for people, including aesthetic inspiration, knowledge, cultural identity, sense of plan, and spiritual experience related to the natural environment.

Reads considers ecosystem services as the basis for providing “human wellbeing”, because they provide the basic needs required for a good life, health, security, good social relations, culture, identity, and freedom of choice, as defined by the MEA (2005) and the Natural Capital Protocol (2016).

2.2 Monetary Valuation

Valuation is the process of estimating the relative importance, worth, or usefulness of natural capital to people (Natural Capital Coalition 2016). A monetary valuation determines the value of impacts in a common unit (e.g., US dollars) to enable comparisons of financial values (e.g., revenues or expenditures). Although not all values generated by natural capital assets can be subjected to monetization, e.g., the intrinsic values of biodiversity beyond economics, the global indicators of monetary value are broadly comparable and can be used to assess how costs and benefits are distributed, as well as the magnitude of changes in impacts and dependencies.

The Total Economic Value (TEV) is the economic concept used to represent the multiple economic values attached to natural resources or ecosystem services, both now and in the future, as summarised in Figure 2-2. Any change in natural capital assets and flows due to the operation of a business must be measured in biophysical terms before the economic value of the impact can be estimated. This value does not necessarily correspond to the TEV if it only refers to one or several economic values related to the loss of and/or damage to ecosystem services.

Economic valuation, which does not pretend to set economic compensation for damages on natural capital, is a reasonable approach to quantify and compare consequences from different impact drivers to the same ecosystem and to assess impacts on different terrestrial and marine environments using the same quantification scale.

Economic valuation provides a framework to make the value associated with nature financially visible for decision-making. If properly used, valuation can contribute to economic accounting and planning for creating more effective natural resource management strategies. Based on international studies and methodologies, using this valuation results in consistent impact quantification. In this regard, Reads is aligned with the standard ISO 14.008:2019, which provides a set of requirements and procedures for monetary valuation. Economic valuation is modulated by accounting for additional environmental and social sensitivities to better reflect the predicted local environmental impact.

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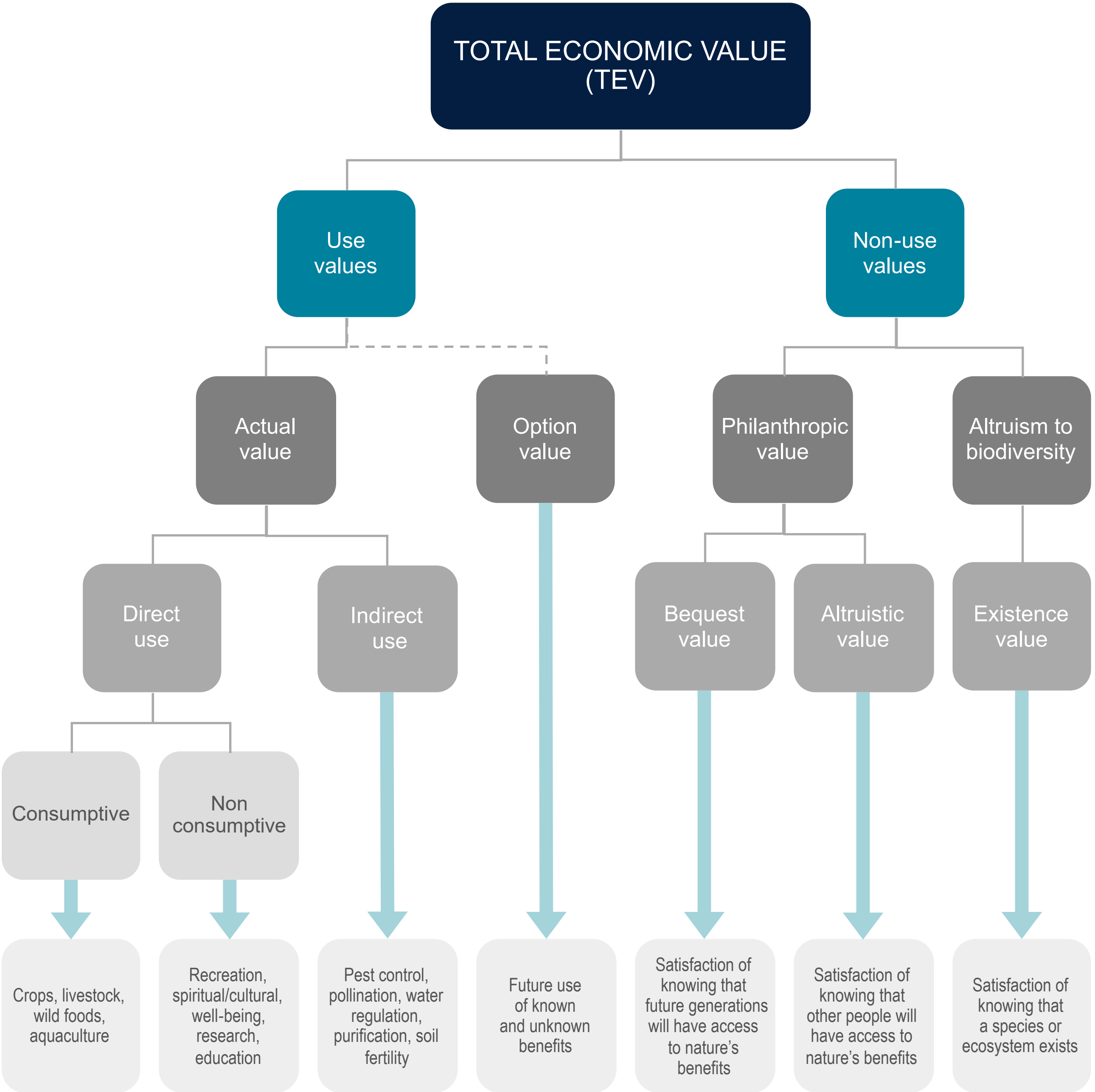

Figure 2-2 Total Economic Value (TEV)
(adapted from TEEB 2010 and ISO 14008:2019)

3 Background

Repsol initially started to develop Reads (formerly referred to as the Global Environmental Management Index or GEMI) in 2014-2015 as a tool for assessing environmental impacts of oil and gas (O&G) projects.[1] Since 2018, GEMI provided the conceptual and methodological backbone for the development of Reads, a bespoke software tool[2,3].

Reads has evolved to encompass all core activities of an integrated energy company, as well as the principles of recently published guidelines for assessing and managing impacts on natural capital and human wellbeing.

Reads can be applied to any economic activity that generates material impacts on natural capital, e.g., energy-related, industrial manufacturing, extractive industries, civil projects, and financial services. Reads provides robust support to incorporate sustainability into business strategy by facilitating decision-making based on the assessment and efficient management of the environmental impact of operations.

Reads adheres to state-of-the-art protocols on natural capital valuation, having been peer-reviewed by the UN Environment Programme World Conservation Monitoring Centre and the Capitals Coalition.

1 GEMI was presented at the 2018 SPE Congress held in Abu Dhabi (16-18 April 2018, Paper No. SPE-190678-MS).
2 Reads tool: https://www.minsait.com/en/reads
3 SHIFT Review: https://shift.tools/resources/1876

Reads has been cited as a successful example or good practice in the measurement and management of impacts on natural capital and biodiversity in several publications and initiatives, including:

- **Natural Capital Protocol Toolkit, 2023,**
- **Project Transparent: Standardized Natural Capital Management Accounting, 2023,**
- **Assessment of biodiversity measurement approaches for businesses and financial institutions, EU Business @ Biodiversity Platform (Lammerant J. *et al.* 2022),**
- **A guide to developing biodiversity action plans, IPIECA/IOGP, Dec 2022, and**
- **Assessment of biodiversity measurement approaches for businesses and financial institutions, EU Business @ Biodiversity Platform, Dec 2022,**
- **Integrating biodiversity into natural capital assessments, Capitals Coalition and Cambridge Conservation Initiative, 2020.**

4 Scope

The Reads approach integrates sustainability into business strategy and facilitates decision-making based on the valuation and effective management of the environmental impacts of economic activities. Reads can be used to quantify and assess impacts on natural capital and human wellbeing, making it possible to understand the effects of any project or activity on the following:

- Climate
- Water resources
- Biodiversity and ecosystem services
- Human wellbeing

This approach, based on the following attributes, is a key factor in ensuring transparency and meeting stakeholder expectations regarding the assessment and management of impacts on natural capital and human wellbeing:

- Provides a standardised, consistent, and transparent approach to quantify and valuate impacts on nature and wellbeing.
- Potentially applicable to any economic activity (e.g., energy-related, industrial manufacturing, extractive industries, and civil projects).
- Enables investors and stakeholders to assess the company's approach and progress toward action plans to manage natural capital risks and opportunities, thereby facilitating access to finance (e.g., EU taxonomy requirements).
- Facilitates internal decision-making based on cost-benefit approaches, allowing for optimal implementation of the mitigation hierarchy (avoidance, reduction, restoration, and offsetting).
- Considered a pioneering methodology for quantifying negative and positive impacts on natural capital and for tracking progress towards goals, such as No Net Loss or Net Positive Impact.

Reads can be used to quantify and assess impacts on natural capital and human wellbeing, making it possible to understand the effects of any project or activity on the following:

- Climate
- Water resources
- Biodiversity and ecosystem services
- Human wellbeing

Reads combines scientific and technical resources for measuring the impacts of projects and operations along the value chain, while simultaneously measuring and valuating the financial and non-financial impacts of business activities in monetary terms and in dimensionless Impact Units (IUs). Impact Units represent a tailor-made indicator that enables the assessment of environmental impacts through a combined economic and qualitative indicator that incorporates the local ecosystem context into the decision-making process.

The Reads methodology quantifies impacts on natural capital, which enables the assessment of the effectiveness (impact reduction) and efficiency (return of investment) of mitigation measures, supporting No Net Loss or Net Positive Impact targets.

Demonstrating positive outcomes through the Reads methodology strengthens the social license to operate and the alignment with upcoming requirements, including access to Green Finance (EU Taxonomy or IFC PS6), support for non-financial disclosures (TNFD), and compliance with international agreements on Biodiversity (EU and legal reporting requirements, e.g., European Sustainability Reporting requirements).

The Reads tool can be applied when limited information is available. Though primary information obtained from field surveys of the condition of natural capital assets and ecosystems can be incorporated (if available), to increase the accuracy of the results, default datasets are provided for most parameters, if required to generate a generic natural capital assessment.

5 Methodology

5.1 Framework

Reads is designed to support management decisions by providing a methodology for quantifying and assessing negative and positive impacts on natural capital, including benefits from offsets. As previously stated, Reads can be used for several sectors, including but not limited to energy, minerals, metals, industrial manufacturing, public infrastructure, and financial.

Reads covers most material impacts of the sectors and sub-industries defined in ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure), which is a tool to help users better understand and visualise the impact of environmental change on the economy. ENCORE was developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC and was financed by the Swiss State Secretariat for Economic Affairs (SECO) and the MAVA Foundation. Some specific impacts, such as radiological, are not included in Reads.

Impacts on natural capital are quantified in biophysical impact units (e.g., hectares, cubic meters, or tons) and transformed into monetary terms on a yearly basis. The yearly impact values over the project lifecycle are converted to net present values and modulated to incorporate social and natural capital features.

Reads utilizes the following stepwise approach, set out in Figure 5-1, to assess impacts on natural capital and human wellbeing, including:

1. Identification of impact drivers (also referred to as environmental aspects) of the activity under assessment.
2. Quantification of impacts in biophysical impact units (BIUs) and other bespoke metrics.
3. Valuation of impacts in monetary terms (USD). In Reads, the economic values of impacts are named as Environmental Economic Values (EEVs). A subsequent transformation process to account for the specificities and sensitivities of the local socio-environmental context is used, which produces a bespoke metric, Impact Units (IUs).
4. Manage impacts based on the implementation of a mitigation hierarchy, using both cost-benefit analysis (CBA) and net environmental benefit analysis (NEBA).

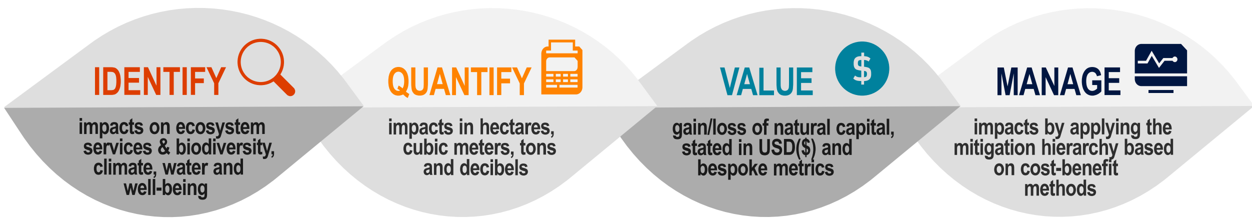

Figure 5-1 Assessment process proposed by Reads

Anthropogenic activities impact natural capital and human wellbeing, either directly or indirectly. The causal relationships between anthropogenic activities, natural capital and human wellbeing are explicitly acknowledged in this methodology at local, regional, and global scales.

Nevertheless, not all environmental impacts can be quantified based on expected changes in natural capital (Natural Capital Protocol 2016). For example, direct exposure to hazardous chemicals may not necessarily produce a loss of natural capital.

For human wellbeing, the methodology follows an acknowledged approach based on environmental prices (CE Delft 2017), which are indices for calculating the cost to society due to pollution and expressed in euros per kilogram of pollutant released to the environment. Thus, environmental prices represent society's willingness to pay to avoid pollution and its effects.

The Transparent methodology follows a similar approach in which non-greenhouse gas (non-GHG) emissions (air pollutants) are assessed based on their consequences on human health and ecosystems, as illustrated in Figure 5-2. [4]

Reads provides a featured approach to support actions aligned with five (5) of these UN Sustainable Development Goals (SDGs): SDG 3 (good health and wellbeing), SDG 6 (clean water and sanitation), SDG 13 (climate action), SDG 14 (life below water), and SDG 15 (life on land).

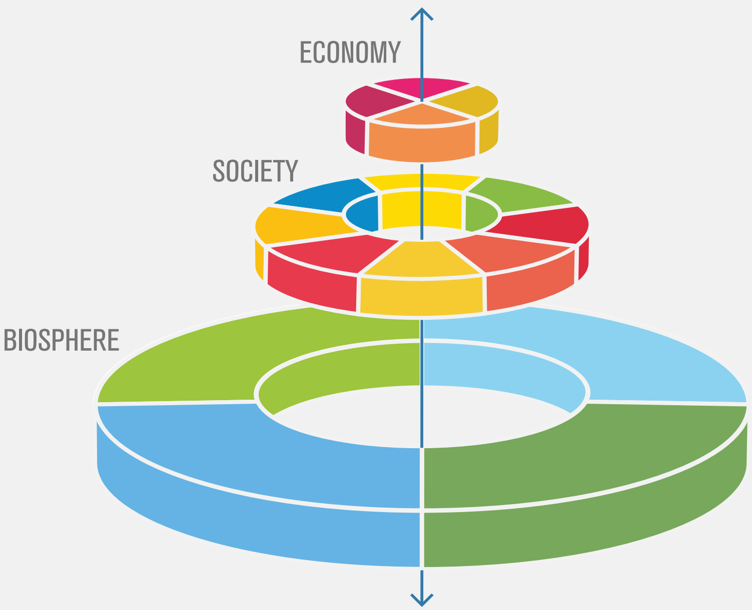

Figure 5-2 Sustainable Development Goals (SDGs) [4]

4 Image provided by Johan Rockström, Stockholm Resilience Centre Director, and Pavan Sukhdev, member of the Advisory Board of the Stockholm Resilience Centre.

5.1.1 Natural Capital Protocol

The Natural Capital Protocol (the Protocol) is a decision-making framework that enables organizations to identify, measure and value their direct and indirect impacts and dependencies on natural capital. The Protocol Framework covers four Stages: "Why" (Frame), "What" (Scope), "How" (Measure and Value), and "What Next" (Apply). These Stages contain specific questions to be answered when integrating natural capital concepts into organizational processes. The Protocol recognises that natural capital has been mostly excluded from decisions and, when included, largely inconsistent, left to interpretation, or limited by moral arguments.

The Protocol aims to support better decisions by including interactions between project activities and nature (or more specifically natural capital), incorporating the natural capital value into the company decision-making process, and offering a standardized framework to identify, measure, and value impacts on natural capital.

The Protocol is not a formal reporting framework or methodology, but it provides a standardized approach to complete the stages of a natural capital assessment or when developing new methodologies.

The Natural Capital Protocol was fulfilled with the "Biodiversity guidance for completing a biodiversity-inclusive natural capital assessment."

The Reads approach is fully aligned with the Natural Capital Protocol and its biodiversity guidance for impacts assessment, as summarized in Table 5-1.

Table 5-1 Alignment of Reads with the Natural Capital Protocol

Natural Capital Protocol			Reads Alignment
STAGE	**STEP**	**QUESTIONS**	**RESPONSE**
FRAME	01: Get started	Why conduct a Natural Capital assessment?	Ensure that the range of natural capital impacts relevant to the energy sector are identified. Apply concepts of natural capital to the business. Identify applications of the assessment results so that the business can see the benefits of better natural capital information. Ensure a consistent and standard process.
SCOPE	02: Define the objective	What is the objective of the assessment?	Measure, monitor and manage environmental impacts at corporate and project level.
	03: Scope the assessment	What is an appropriate scope to meet the objective?	Assess energy projects and operations worldwide. The methodology is replicable for application to different activities.
	04: Determine impacts and/or dependencies	Which impacts and/or dependencies are material?	Identify impacts resulting from business activities/decisions that are material to natural capital and business operations.
MEASURE AND VALUE	05: Measure impact drivers and/or dependencies	How can impact drivers and/or dependencies be measured?	Impact drivers include all potential measurable environmental aspects, e.g., land occupation, chemical discharges to air, soil and/or water, noise (airborne and underwater), fauna deaths, and waste generation. Impact consequences are quantified as Biophysical Impact Units (BIUs).
	06: Measure changes in the state of natural capital	What changes in the state and trends of natural capital are related to the business impacts and/or dependencies?	Effects on natural capital assets and human wellbeing are assessed and monitored throughout the project lifecycle, e.g., variations in the state of the ecosystems can be evaluated by their condition (e.g., capacity to provide ecosystem services over time) and extension.
	07: Value impacts and/or dependencies	What is the value of the natural capital impacts and/or dependencies of the business?	Natural capital gain/loss is measured in Environmental Economic Values (EEVs), monetized as US$ (2018). Impact Units (IUs), are calculated from the EEVs to improve the valuation accuracy/representativeness by using local adjustments that cannot be subjected to monetary valuation. EEVs/IUS are expressed in Net Present Value (NPV) so that the valuation considers the time value of money and better informs decision-making. This information helps to focus on most material aspects and to simulate mitigation measures from a CBA standpoint.
APPLY	08: Interpret and test the results	How can the assessment process and the results be interpreted, validated, and verified?	Ensure data quality and impacts quantification using verified monetization database values. Apply Reads to several examples to calibrate the key assumptions or data.
	09: Take actions	How will the results be applied, and the natural capital integrated into existing processes?	Decision-making and tracking impacts toward targets: maximize positive impacts and minimize negative impacts to ALARP. Methodology applicable to activities worldwide to monitor impacts on natural capital and make informed environmental decisions.

The environmental impacts considered in Reads are grouped into the following four categories, as illustrated in Figure 5-3.

- Climate: Release of Scope 1 GHG (with the potential to include Scopes 2 and 3 GHG) with consequences at a global scale.
- Water: Water use (balance or depletion) with potential impacts at the hydrological basin level.
- Ecosystems: Impacts on local ecosystems are assessed by evaluating their extent and condition, the net balance of ecosystem services provided in the project area of influence, and the potential number of species affected.
- Social–Health (human wellbeing): Release of pollutants with potential health effects at the community level.

This approach is fully aligned with the Transparent methodology. Transparent is built on international principles and frameworks, such as the Natural Capital Protocol, with a scope to standardize and provide practical guidance for corporate natural capital accounting systems. According to the Transparent definition of value-chain boundaries, Reads is limited to the assessment of “Own” operations (activities over which the business has direct control). In this manner, Reads considers direct GHG emissions (Scope 1) with the potential to include indirect emissions (Scopes 2 and 3 GHG).

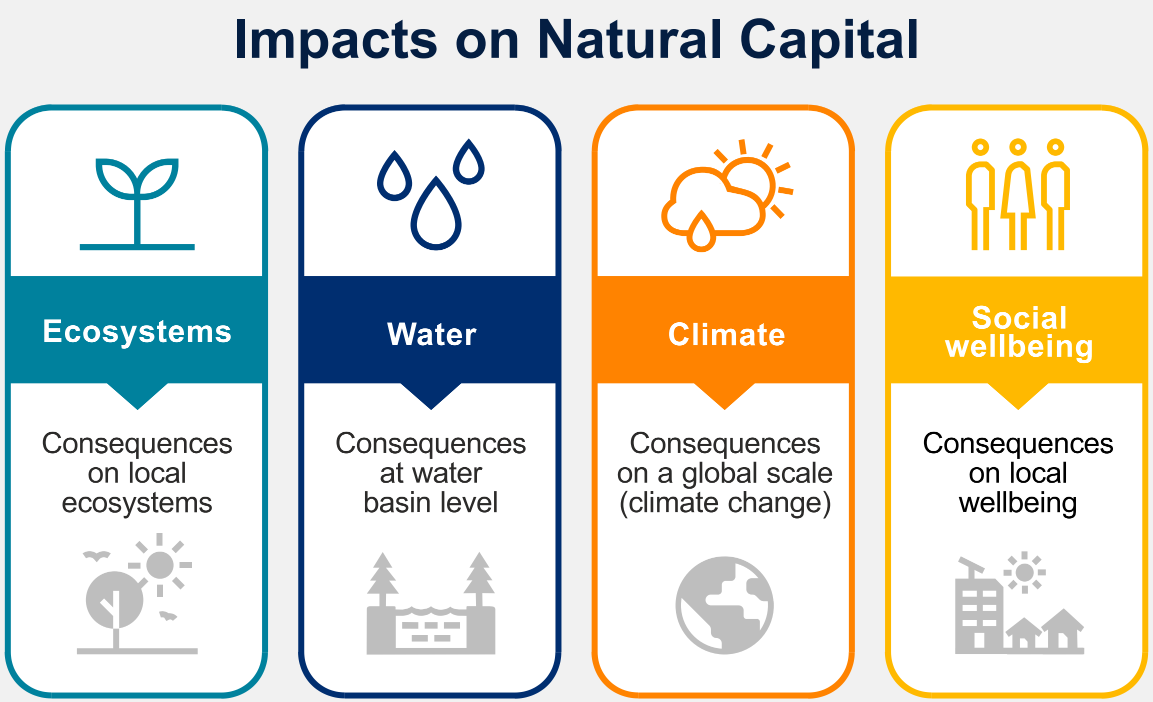

Figure 5-3 Categories of environmental impacts on Natural Capital considered in Reads

5.1.2 ISO 14007:2019 and 14008:2019

Reads is designed for the monetary valuation of environmental impacts by following the Natural Capital Protocol and meeting ISO 14007:2019 and ISO 14008:2019 criteria. ISO 14007:2019 provides guidelines to determine environmental costs and benefits associated with environmental aspects (impact drivers), including use and non-use values, while ISO 14008:2019 specifies a methodological framework for monetary valuation of environmental impacts.

These impacts include effects on human health and on natural and human-modified environments. Releases and the use of natural resources are included among environmental aspects. In ISO 14008:2019, monetary valuation is a way of expressing value in a common unit for use in comparisons and trade-offs between different environmental issues and between environmental and other issues. The monetary value to be determined includes some or all values reflected in the concept of total economic value. An anthropocentric perspective is taken, which asserts that natural environment has value in so far as it gives utility (wellbeing) to humans. The monetary values referred to in this document are economic values applied in trade-offs between alternative resource allocations and not absolute values.

Reads methodology meets the requirements of ISO14008:2019 by incorporating the following main characteristics:

- The elements defined in Reads by default for monetary analyses are: 1) currency of the monetary value (US dollars), 2) a reference year of the monetary value (year 2018, which can be updated by the user), and 3) the period of the monetary value (annual).
- Discount rates are used to estimate the Net Present Value (NPV), which by default in Reads are 3% for environmental and 10% for financial inputs - customizable by the user.
- The following specifications for monetary valuation, as defined in section 5.3 of ISO 14008:2019, are considered in Reads:
  - Whether an increase or decrease in the environmental impact or aspect is valued.
  - The spatial extent and resolution of the environmental impact or aspect for which the monetary value is valid.
  - The temporal extent and resolution of the environmental impact or aspect for which the monetary value is valid.
  - The environmental impact pathway(s) included in the study and the model(s) used.
  - The indicators used to measure the environmental impact or aspect. The unit and quantity of the environmental impact or aspect used to estimate the monetary value of the study.
  - The context of the environmental impact or aspect in so far as it influences the monetary values obtained from the study, such as: 1) the environmental baseline, which can change over time, 2) where appropriate, the name and nature of the source causing the environmental aspect, and 3) the specific stages in the life cycle of a product considered in the monetary evaluation.
- Where applicable, Reads clearly identifies and justifies the elements of total economic value (TEV) in the monetary valuation study (both use and non-use values). Each valuation database suggested by Reads complies with one or more of the valuation procedures described in section 6 of ISO 14008:2019. For example, the TEEB 2013 (McVittie and Hussain 2013) Valuation Database (principal reference for Reads database default values) uses twelve valuation methods. The largest proportion (37%) is from direct market pricing and will relate to provisioning services, and in some cases, visitor spending at recreation sites (as distinct from travel cost estimates). Values derived from benefit transfer, comprising the next largest proportion (23%), are estimates that should be treated with care depending on how the database is used (McVittie and Hussain 2013). Value transfer methods are used in the Reads tool. Value transfer methods have several limitations, which are acknowledged in the Reads methodology and mitigated through the modulation of monetary values to incorporate social and biodiversity non-financial features. Reads offers the option to users to update or modify the default valuation database with user-specific values or data from other studies (i.e., studies included in the ecosystem service valuation database https://www.esvd.info/).

Reads is designed for the monetary valuation of environmental impacts by following the Natural Capital Protocol and meeting ISO 14007:2019 and ISO 14008:2019 criteria.

- Where necessary, the Reads tool adjusts currency, base year, equity weighting, and discounts. The NPV parameter is used to calculate the values and KPIs in Reads reports, including the present value of a stream of future payments. The NPV method considers ‘the time value of money’. Cash payments and incomes are included regardless of the time when they were paid or received; however, the method is highly dependent on the discount rate used. For instance, a 1% unit change in the discount rate may distort the results significantly (European Commission 2006). By default, the variables used in the Reads tool are:
  - Currency and base year: US dollars (2018), and
  - Discount rates: 10% (Financial) / 3% (Environmental), which can be edited for generating pricing scenarios and for sensitivity analysis.

5.1.3 Recent EU advances in measuring/accounting for nature in business decision-making: Transparent Project and Align

The **Transparent project** responded to a lack of standardization across corporate environmental valuation assessments, including natural capital assessments and accounting practices, by developing the first prescriptive set of guidance on which elements of natural capital that companies should include in assessments and how to measure and value them.

The methodology builds on the real experiences of businesses and internationally accepted and harmonized principles and frameworks, such as the Natural Capital Protocol, by taking into consideration the following:

- What to measure when accounting for natural capital from a corporate perspective.
- An overview of impact pathways to be considered for each impact driver and (monetary) valuation approaches.
- Key resources to measure change in natural capital.
- Recommendations on the use of natural capital accounting results.

Transparent suggest the following three-step approach to measure and value impacts on natural capital:

1. Measure your impact driver (related to Step 05 in the Natural Capital Protocol).
2. Measure the change in state of natural capital due to the impact driver (related to Step 06 of the Natural Capital Protocol).
3. Value the impact that this change in capital has on society (related to Step 07 of the Natural Capital Protocol).

As previously described, Reads follows a similar approach to identify and measure impact drivers (Step 1 in Transparent), to quantify the consequences in biophysical impact units (BIUs) (Step 2), to value the impact in monetary (EEVs) and non-monetary terms (IUs) (Step 3), and to assess the evolution in the state and condition of ecosystems.

Transparent suggests a minimum set of impact drivers for consideration: GHG and Non-GHG air emissions, water consumption, water pollution, land use, and solid waste, as given in Figure 5-4.

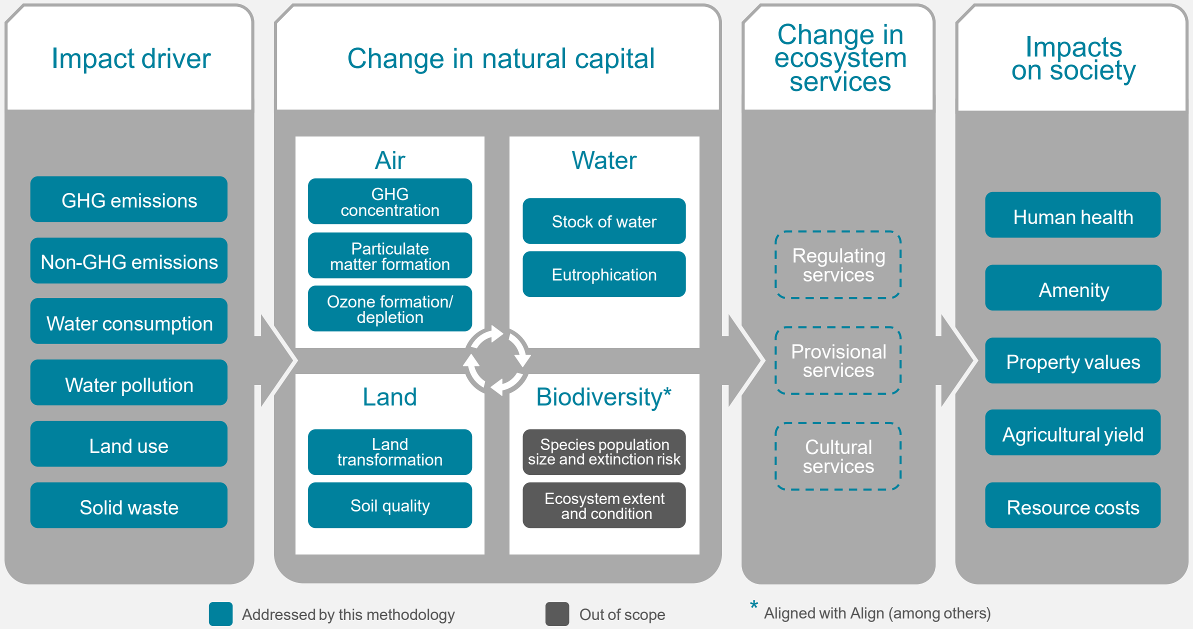

Figure 5-4 Impact Drivers and suggested Pathways under Transparent (Transparent Project Participants 2023)

These impact drivers are considered in Reads in addition to noise and light generation, physical damage to wildlife, discharges to soil and sea, and presence of the facilities with potential impacts on landscape. Reads acknowledges that other impact drivers identified in the IPBES Global assessment report on Biodiversity, such as sea use change, introduction of alien species, or overexploitation of marine resources, could have negative consequences on natural capital. However, these impacts are not included in the current version of Reads, but they will be considered in future updates.

Both Transparent and Reads include the potential effects from the release of pollutants on human health assuming it should be part of the natural capital assessment even though the consequences might directly affect human health without affecting ecosystems.

Align is a set of technical criteria and principles to measure biodiversity in a defined context using the extent and condition of biodiversity through indicators. This approach is acknowledged as a better approach to capture the value of biodiversity of specific ecosystems, but the results make it difficult to compare impacts on biodiversity for different ecosystems.

Reads measures and values environmental impacts on a yearly basis. The approach suggested by Align identifies changes to ecosystems biodiversity but does not quantify the impact in standard units per year. Consequently, Align is a challenging approach to quantify impacts over a defined period.

Reads proposes a supplementary approach to assessing changes in ecosystem services associated with reduced biodiversity services. It is understood that the Reads approach does not account for several components of biodiversity value (e.g., genes). To address the assessment of biodiversity through the analysis of changes in the extent and condition of ecosystems, Reads incorporates an indicator to track changes derived from project impacts on biodiversity. Those changes are compared with the pristine (optimal) biodiversity status to track changes through an indicator of ecosystem extent and condition.

The Reads methodology also includes the assessment of impacts on species by valuating consequences through the quantification of affected individuals and considering their threat status and risk of extinction.

Align suggests several good and best practices for measuring biodiversity impacts at site and project levels, and best SCREEN practices suggested by Align (UNEP-WCMC *et al.* 2022) are required by Reads, as follows:

- Characterization of the project site, including the presence of ecosystems (and their value) and species.
- Characterization and quantification of project impact drivers.
- Quantification of the number of individuals potentially affected by the project (strikes and collisions) and their threat status.
- Use of models to assess environmental consequences of impact drivers (e.g., air emissions, noise, underwater noise, liquid discharges, and drill cuttings discharges).
- A biodiversity index based on impact consequences on biodiversity due to changes to the extent and condition of ecosystems.

Reads was selected by the EU Business @ Biodiversity Platform (Lammerant *et al*. 2022) as good practice for collecting species and ecosystem data according to Align recommendations, but also as a best practice when selecting an approach to screen for or measure biodiversity at site and project levels.

5.2 Identify

The goal of the first stage of Reads is to identify impact drivers (or environmental aspects) and impacts (consequences of impact drivers) that are associated with the activity being assessed.

An Environmental Aspect (EA), as defined in ISO 14001:2015 (ISO Sub-committee 2015), is an "element of an organization's activities or products or services that interacts or can interact with the environment." Environmental aspects can positively or negatively affect biotic, abiotic, and socioeconomic environments within the area of influence (AOI) of the project, resulting in impacts due to the project.

Reads was selected by the EU Business @ Biodiversity Platform (Lammerant *et al.* 2022) as good practice for collecting species and ecosystem data according to Align recommendations, but also as a best practice when selecting an approach to screen for or measure biodiversity at site and project levels.

An impact driver, as defined in the Natural Capital Protocol, is a "measurable quantity of a natural resource that is used as an input to production (e.g., volume of sand and gravel used in construction) or a measurable non-product output of business activity (e.g., a kilogram of NO_x emissions released to atmosphere by an industrial manufacturing facility). Impact drivers are generally expressed in quantitative units (e.g., kilograms, m^3, hectares) and may already be included in company non-financial reporting or generated through life-cycle assessments. An impact driver is not the same as an impact. An impact is a change in the quantity or quality of natural capital that occurs as a consequence of an impact driver. A single impact driver may be associated with multiple impacts." Reads uses the terms "environmental aspect" and "impact driver" interchangeably (without distinction).

Although the methodological approach is universal and applicable to any business activity, as it is consistent with the premises set out in the Natural Capital Protocol and ISO 14008:2019, this manuscript identifies the material environmental aspects and impacts of the energy sector based on relevant documents published by key sectoral organisations (e.g., IPIECA, IOGP) and other works to identify natural capital impacts for the energy sector (e.g., Azentúa, Ecoacsa, Natural Capital Factory 2022).

Identification of environmental impacts is supported by considering the potentially affected receptors. If different receptors, such as flora, fauna, and humans, are expected to be affected by the same environmental aspect (e.g., air pollutant emissions), the assessment considers two or more independent impacts when applicable, such as air pollutant emissions with potential impacts on ecosystems and air emissions with potential effects on wellbeing.

Impact drivers are grouped into the following categories:

- Land or Marine Use: Impacts generated by the presence of the project being assessed (e.g., impacts on landscape, ecosystem fragmentation, and fauna mortality) and physical disturbance (e.g., land occupation, restricted access to the project area, and fishing exclusion zones).
- Emissions: Noise emissions (airborne and underwater), air pollutant emissions, dust generation, GHG emissions, and light emissions.
- Discharges: Chemicals, water and wastewater discharges to fresh water, marine water, and soil.
- Waste: Hazardous and non-hazardous waste generation.

Once impact drivers and potential consequences are identified, each impact driver is characterised and quantified in biophysical units as outlined in Table 5-2.

5.3 Quantify

In Reads, impacts are quantified in Biophysical Impact Units (BIUs), which are expressed in the appropriate units corresponding with the impact category (ecosystems, water, wellbeing, or climate). Thus, the units of the BIUs depend on the final impact quantification criteria (e.g., hectares of ecosystem, tonnes of chemicals released to the environment, or m^3 of water consumed).

The inputs used for impact quantification should always be of the highest quality and may be measured, estimated, or calculated, as appropriate.

5.3.1 Human wellbeing

Reads specifies that the impact of pollutant emissions on human wellbeing should account for indirect economic and social impacts. BIUs correspond to tonnes of pollutants emitted to air, water, and land. A tailored approach, such as dose-response functions to assess the health effects of a population exposed to pollutants, and the potential consequences for health and wellbeing provide more accurate estimates, as suggested in the Transparent methodology. However, such an approach requires site-specific information that is not always readily available for the assessment.

5.3.2 Climate

GHG emissions generate impacts at a planetary scale, not only at a local level. BIUs in this case represent the total amount of GHG emissions expressed as Equivalent tonnes of Carbon Dioxide (tCO_2eq).

5.3.3 Water

Water is a critical resource for human wellbeing and ecosystems, and water consumption can generate negative consequences in areas where water is scarce. For water consumption or depletion, the impact driver is measured in m^3, and the total volume of water consumption

Table 5-2 Characterization of Impact Drivers potentially identified in Reads (with details for quantifying effects)

Category	Impact Driver	Description and potential consequences
Land and marine use	Physical presence	Effects outside the direct site occupation generated by the presence of the infrastructure, e.g., visual impact, habitat fragmentation, invasive species, including direct mortality of fauna species due to different causes (e.g., strikes).
	Marine exclusion zones	Potential restriction to marine activities, e.g., fishing, recreational use.
	Land disturbance	Physical disturbance due to direct land occupation with partial or full reduction of ecosystem services.
	Marine disturbance	Physical disturbance of marine areas, e.g., burial by drilling discharges, sea pipelines or cables, dredging, trenching, and physical anchorage damage.
	Water depletion/ Abstraction	Water depletion/consumption as the balance between water used and water discharged (assuming the discharge meets optimal conditions for the ecosystems).
	Contaminated sites	Effects on ecosystems and human wellbeing.
Emissions	Acoustic (airborne noise)	Disturbance of ecosystems (potential habitat loss) and effects on recreational values.
	Acoustic (underwater noise)	Disturbance of marine ecosystems and species, including temporal or permanent damage to marine mammals, behavioural or communication of masking effects.
	Light, including lighting during night-time	Visual impacts during the night-time and potential ecological interactions (attracting fauna in terrestrial and marine ecosystems).
	Dust	Dust deposition on vegetation.
	Air pollutants	Effects on ecosystems due to combustion processes, flaring, and venting, among others, and consequences on human health.
	GHG emissions	Global warming with social and environmental consequences from combustion processes, vents, fugitives, and transport.
Discharges	Pollutant discharges to inland waters	With potential effects on freshwater ecosystems (rivers and lakes), water availability for anthropogenic use (domestic or irrigation), and human health.
	Pollutant discharges to marine waters	With potential effects on marine ecosystems.
	Pollutant discharges to soil	With potential effects on ecosystems, soil productivity and human health.
	Thermal discharges	Consequences on aquatic ecosystems (both terrestrial and marine).
Wastes	Solid Hazardous waste generation	Hazardous waste with potential consequences on ecosystems and human wellbeing.
	Solid Non-hazardous waste generation	Non-hazardous waste with potential consequences on ecosystems and human wellbeing.
	Liquid waste	Potential consequences on ecosystems unless produced water is treated and re-used or re-injected.

considers the overall water balance, i.e., the difference between water intake and water discharge if the discharged water has been treated and meets the required quality for other potential uses. Potential impacts on water quality are assessed both for wellbeing and ecosystems.

5.3.4 Ecosystems

Impacts on local ecosystems (including species mortality) are expressed in affected hectares (ha) and number of individuals (N).

The impact of an environmental aspect on ecosystems may be total or partial, depending on the intensity and extent of the impact and the spatial distribution of the services present in the impact area. The impacts associated with disturbances to land or sea, e.g., land occupation, could fully reduce the ecosystem services that were previously provided within the occupied site and its area of influence. For example, if a new urban or industrial development requires full land occupation, the occupied area can no longer provide provisioning, regulating or cultural services. This impact is directly quantified (surface area of disturbed land) and valuated in a later stage assuming an environmental damage of 100% (full reduction of ecosystem services that were provided by that surface area per year). However, the impact of an environmental aspect on an ecosystem can be partial, requiring a proxy measurement of impact intensity, as described below.

A traditional impact assessment approach evaluates different impact drivers associated with a new development, such as vegetation clearance, earth movements, soil disturbance, and habitat loss. The natural capital approach taken by Reads evaluates the overall impact associated with land disturbance with one overall consequence, the loss of ecosystem services (and species). For example, a photovoltaic solar power plant could allow several provisioning and regulating services if land below the solar panels is used for grazing and/or pollination services. In this example, the land occupation results in the partial reduction of some ecosystem services within the AOI of the project.

Emissions and discharges to the environment with potential effects on ecosystems require an assessment of the potential effects on receptors. Fate and Transport (F&T) models or equations should be used to assess the aerial extent (affected hectares) of the impact due to the release of contaminants of concern (COCs) to air, land, and water. In addition, impacts due to light or noise emissions from any activity may require tailor-made modelling to quantify the biophysical effects (level of damage) on the ecosystem condition depending on the potential effects on individuals and ecosystem services affected.

Impact valuation, as described above, requires the definition of a tailor-made metric to integrate the degree of loss of each ecosystem service in the area directly affected by the impact. This metric, the **equivalent hectare** (eq.ha), is calculated by multiplying the affected area (ha) by a ‘damage level’ (from 0 to 100%) corresponding to the intensity of the impact.

Equivalent hectares are calculated by first estimating the affected area above a certain threshold, e.g., 1,000 ha of habitat affected by noise with 5% damage due to habitat loss for sensitive species. The equivalent area is then calculated, which in this case is 50 ha (1,000 multiplied by 5%) that are impacted, i.e., 50 eq.ha of full habitat loss, as illustrated in Figure 5-5.

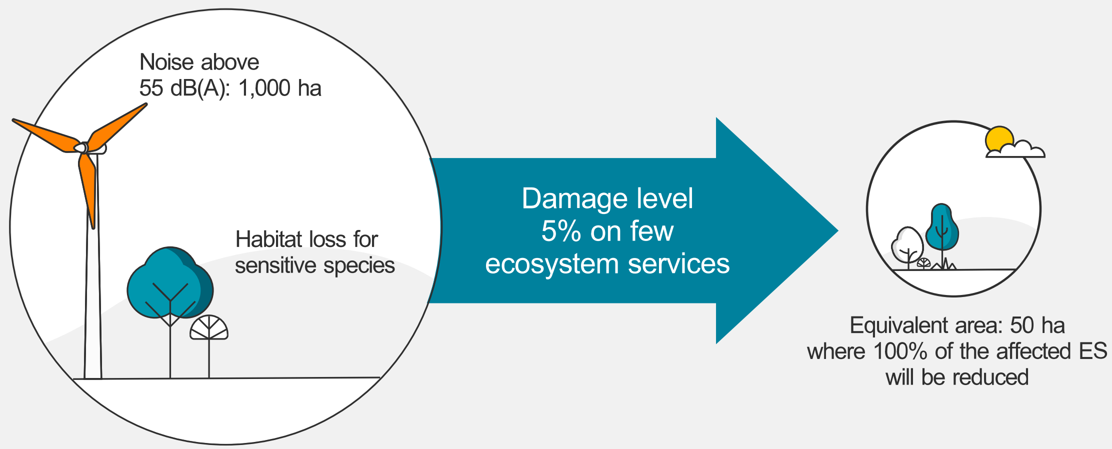

Figure 5-5 Example calculation of habitat loss for species sensitive to noise levels above 55 dB(A)

The same approach is used to estimate ecosystem loss due to pollutant releases, emissions, or discharges to an area, as illustrated in Figure 5-6.

As previously mentioned, not all ecosystem services are affected by all impacts. For example, impacts on landscape due to the presence of facilities may only affect cultural recreational values, while other provisioning services (e.g., food production) might not be affected by the presence of the facilities. Similarly, air pollutant emissions might not affect recreational values if only a small population of sensitive species (e.g., lichens) are impacted along with vegetation growth, but such emissions could reduce vegetation carbon capture rates and species richness.

Defining the damage level is a key requirement when applying the Reads methodology and implies a deep environmental knowledge to justify how the pressure generated by each impact driver would affect the ecosystems and the services that ecosystems provide. This challenging task is approached in the Reads tool using dose-response functions for chemical exposures, expert criteria on environmental assessments, threshold exposure levels defined in international regulations, and calibration to adjust the damage levels to the magnitudes of the impacts based on experimental studies.

Further details on damage levels and suggested models for assessing impact consequences are provided below for a) ecosystem damage level for pollutants; and b) ecosystem damage level for other impacts, such as landscape, light and noise.

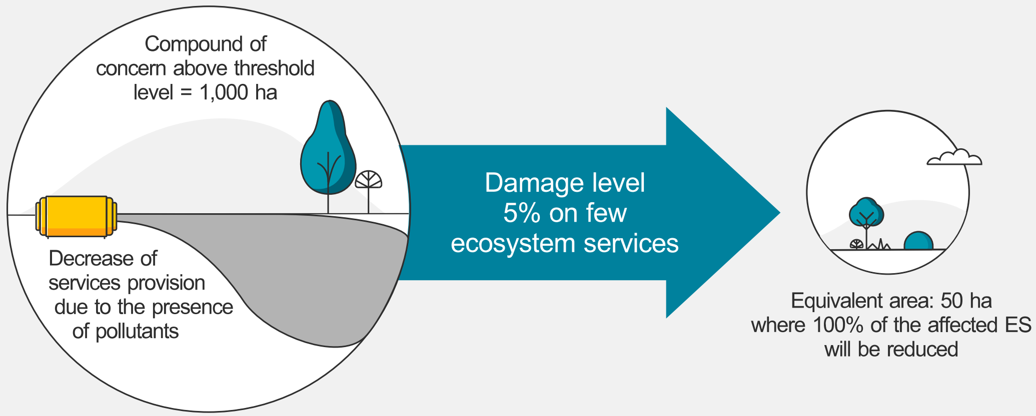

Figure 5-6 Example calculation of ecosystem loss due to pollutant contamination

Exposure to chemicals

The goal of chemical risk assessment is to fully understand the nature, magnitude, and probability of potential adverse effects on health and/or environment due to chemical exposure by considering both hazard (chemical ecotoxicity) and degree of exposure.

In general, chemical risk assessment consists of the following three steps:

1. Hazard characterization: Dose-response determination, i.e., the relationship between the magnitude of exposure to a hazard and the probability and severity of adverse effects. This characterization requires the definition of threshold values.
2. Exposure assessment: Identifying the extent to which exposure occurs; exposure levels are usually estimated or measured.
3. Risk characterization: Combining information from the hazard characterization and the exposure assessment to characterize the nature and magnitude of the risk and to implement additional risk management measures, if indicated.

Like other risk assessment practices, ecological risk assessment estimates the nature, magnitude, and likelihood of undesired effects due to actions or conditions. Above certain exposure levels, environmental contaminants can generate toxic effects on individuals (animal or plant populations). Once a sufficient number of individuals are affected, contaminant exposure can change the structure and function of ecological systems. In Reads, risk assessment addresses the impact on multiple flora and fauna within the full structure, functionality, and complexity of ecosystems.

Threshold values and COC concentrations, either estimated or measured, are used to calculate risk quotients related to the impairment (loss) of certain ecosystem services, expressed as a percentage, where 0% corresponds to no effect and 100% corresponds to full reduction of the ecosystem services provided in the affected area.

Although good environmental performance ensures that released chemicals pose little or no risk to the environment, adverse effects may still occur above No Effect Concentrations (NOECs), which is the highest tested chemical concentration immediately below the Lowest Observed Effect Concentration (LOEC) at which no effect is observed. Responses to a range of exposures are plotted in Figure 5-7.

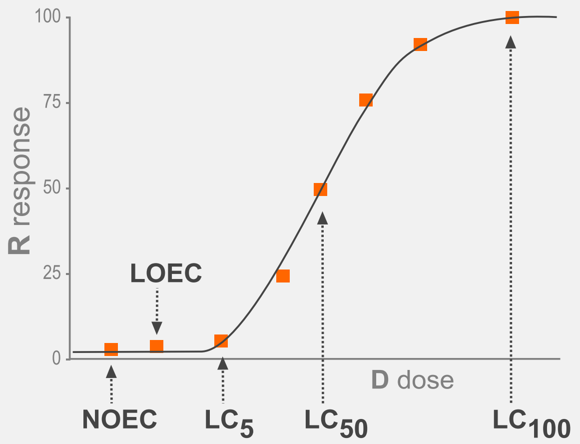

Figure 5-7 Dose-Response Toxicity Values
(Adapted from European Chemicals Bureau and Institute for Health and Consumer Protection 2003)

The Reads tool includes a toxicological database with damage thresholds for most of the more common industry pollutants.

F&T models are used to identify active pollutant linkages, i.e., the relationship between a contaminant, a pathway, and a receptor. Models require specific input information on the impact sources (see Table 5-2), the presence of receptors, and the environmental conditions that drive dispersions processes (e.g., topography or bathymetry, wind conditions or currents).

The four groups of consequence modelling developed in the Reads tool are as follows:

- Inland waters discharges: A water dispersion model is used to predict COC fate and transport along rivers, anticipating the distribution of COC concentrations in surface water and the hectares of riverine environment affected (with predicted values above the considered damage threshold level). Linear screening models are used to assess the dispersion of pollutants in rivers. Damage levels are automatically calculated based on statistical assessment of cumulative lethality levels.
- Marine waters: A marine dispersion model is used to predict impacts due to marine discharges, e.g., drill cutting piles, produced water discharges, and other effluents. A cuttings discharge model helps to calculate impacts from cuttings released directly to the seabed (chemical or burial effects). Marine dispersion models will help assessing effects of pollutant releases in the near- and far-field for chemicals released to the water column. The COC as a function of concentrations distribution/dispersion are compared with damage threshold values based on ecotoxicological endpoints to estimate the affected area (ha).
- Air emissions: Air dispersion models should be used to calculate the dispersion of emitted air pollutants with potential effects on ecosystems. Pollutant concentrations are compared with damage threshold values to determine the extent of the impact and the hectares affected. To assess impacts on ecosystems, long-term averages (annual or seasonal averaging periods) are considered. The dispersion/deposition of resuspended particulate matter near unpaved roads is calculated in the Reads tool.

Reads includes the assessment of consequences on natural capital for contaminated sites, and the quantification of impact consequences depends on the presence and concentration of pollutants in the study area.

Noise

Impacts associated with airborne noise emissions can be assessed by referencing the damage thresholds of sound pressure levels defined by environmental standards; however, references are limited and usually designed to protect sensitive areas. Most animal species use sounds to communicate with partners or conspecifics (of the same species) to detect prey or predators and to alerts others. Animals often avoid noise or reduce some critical biological activities (e.g., breeding, nesting) in the presence of noise. Impacts on ecosystems due to anthropogenic noise include masking effects, stress, and reduced habitats (avoidance/escape behaviour), and high noise levels can impact on reproduction or cause injury.

A similar approach applies to underwater noise, which propagates faster and farther than airborne noise, potentially affecting greater areas. High noise levels can injure sensitive species, such as marine mammals, fish with a swimming blade, and larvae. Underwater noise can also generate avoidance responses and masking effects, which can potentially affect populations and modify behaviours (e.g., communication, feeding).

Noise models calculate sound pressure levels at the nearest receptors due to noise emissions from the project sources. The affected area could be calculated using a noise model or simple calculations of semi-spherical noise propagation to quantify the extent of the effects (e.g., disturbance of fauna, habitat loss or diminished recreational value). Airborne noise models require, as minimum inputs, the location of the noise sources, the noise power of each source, and the topography of the area around the project. Modelling underwater noise is more complex but can be accomplished through underwater noise assessments (if available). The Reads tool uses equations based on noise propagation patterns specific to the power of the source, the water characteristics, and the depths.

Landscape

In Reads, the presence of infrastructures can reduce landscape amenity values, an effect that can occur over the entire viewshed area (area across which the facilities are visible). Ecosystem recreational values can be diminished due to the presence of the infrastructure, and the level of reduction depends on the degree of intrusion of the potential facilities into the landscape.

Light

Impacts due to light emission depend on the extent of the viewshed area and the characteristics of the lighting. Some variables, such as light spectrum and intensity, are used to define the potential damage due to artificial light. Animals (and plants) use cycles of natural light and dark periods to regulate some behaviours related to reproduction, feeding, sleeping, or finding protection against predators. Artificial light at night negatively affects mammals, amphibians, fish, insects (pollinators), and birds, and can affect flora growth patterns. Ecological interactions created by anthropogenic light reduce several ecosystem services associated with natural processes.

Wildlife mortality

Wildlife mortality caused by the operation of an infrastructure (e.g., wind turbines, power lines) and road traffic is assessed in Reads.

Impact quantification associated with species mortality requires the calculation of potential collisions per year and per category of threatened species. Quantifying the number of individuals that could be affected is not straightforward, but inputs can be obtained from statistical data and published or monitoring records. As an example of this complexity, wildlife collisions with wind farms are a well-known impact. Factors that increase the risk of collision are the species characteristics (morphology, sensorial perception, phenology, behaviour, or abundance), the site (landscape, flight paths, food availability and weather), and the wind farm features (turbine type and configuration, and lighting). Traffic collisions are common and depend on many factors, such as traffic density and speed, and species abundance. These impacts are most likely to affect species with limited mobility, such as amphibians or reptiles.

Reads requires as input the estimated (or measured) number of individuals that suffer collisions per year and the potential distribution of the species in the study area per risk extinction category (number of species under different IUCN Red List categories, Critically Endangered, Endangered, Vulnerable, Near Threatened and Least Concern).

5.4 Value

Reads relies on the economic valuation of impacts, which refers to the conversion of biophysical metrics (Biophysical Impacts Units, BIUs) into monetary values, i.e., the Environmental Economical Value (EEV) in Reads. Valuation does not provide a monetary cost that should be paid for generating the impact. It refers to a responsible environmental value that should be considered for decision-making. Environmental valuation enables the measurement of different impacts on the same receptor or set of receptors on the same scale, which can be compared or added.

Impact valuation for nature is analogous to the concept of carbon pricing. The social cost of CO_2 is the social and environmental value assigned to each additional tonne of equivalent CO_2 (tCO_2eq) emitted or captured. It should be used to support decision-making, such as for investments and new developments, or for comparisons of project alternatives.

When considering impacts on ecosystems, water, or human wellbeing, the approach is more complex, because local conditions may influence the monetary value due to various issues, such as water scarcity, biodiversity features, ecosystem productivity, or the population potentially affected by the impacts.

The calculated Environmental Economic Values (EEVs) associated with each impact are used to obtain Impact Units (IUs), which are unitless and can be used to assess and manage environmental impacts based on local conditions. IUs are calculated by multiplying the EEV of each impact by the appropriate modulator.

The main purpose of calculating IUs is to improve the accuracy and representativeness of the valuation by using local adjustments (biophysical and socioeconomic conditions) that cannot be subjected to monetary valuation. For example, while the EEV does not consider the presence of endangered species in a potential project location, Reads takes this unique feature into account by using a specific modulator to convert EEVs into IUs). Biodiversity is therefore incorporated by adjusting ecosystem service values for specific biodiversity features (e.g., abundance of protected species) and threats (e.g., habitat loss and fragmentation) Environmental impacts associated with GHG emissions are not modulated since they are non-specific to the source location and the damage is estimated on a global scale.

Both EEVs and IUs are expressed in NPVs so that the valuation considers the time value of money and better informs decision-making.

The focus can be placed on most material aspects and mitigation measures can be simulated from a CBA standpoint.

The 2-step Reads approach for valuing each impact category based on monetary valuation and modulation (for calculating IUs) is described below.

5.4.1 Human wellbeing

5.4.1.1 Monetary valuation

Anthropogenic activities may directly or indirectly impact on human wellbeing due to changes in the state of natural capital. For direct health impacts, best practice requires site-specific assessments with a high level of detail and accuracy to ensure the protection of public health.

Transparent suggests alternative methods to quantify health impacts, including normalized metrics, such as Years of Life Lost (YLL) or Disability-Adjusted Life Years (DALY), as well as several valuations approaches that account for morbidity and premature mortality. Those techniques can lead to accurate results and represent the best technical approach for assessing health impacts, but they are site-specific and difficult to apply with limited resources and health databases.

Reads has used dose response functions, and metrics, such as YLL and DALY, which are reflected in the adjusted values for pollutant releases. The use of prices for the social cost of pollution, expressed in euros per kilogram of pollutant, is a valid alternative for a wider context. Environmental prices (as defined by CE Delft) indicate the loss of economic welfare that occurs when one additional pollutant kilogram finds its way into the environment. The loss in human health, ecosystem services, and quality of buildings and materials caused by pollution are all captured in a single monetary unit that can be used in a social cost-benefit analysis, in environmental profit and loss accounts, and as a weighting factor in lifecycle analysis.

Environmental prices thus indicate the loss of welfare due to each additional kilogram of pollutant emitted to the environment. In this sense, environmental prices are often the same as external costs.

Emissions and discharges of pollutants

CE Delft, which developed the Handbook of Environmental Prices in 2018 for the 28-member states of the European Union (EU28) and for the Netherlands, designed the Benefito model to adapt the environmental prices of several air pollutant emissions to other regions outside the European Union. The original Handbook (de Bruyn *et al.* 2018) provides environmental prices, including effects on human health and the environment.

In Reads, the impact drivers associated with the release of pollutants can have consequences for human health and ecosystems. The impact on ecosystems is assessed through the potential reduction of ecosystem services; therefore, the value associated with consequences on human health excludes the cost associated with environmental consequences.

These consequences on human health are addressed by a tailored approach developed by CE Delft for Reads, which includes the conversion process for additional air pollutants and releases of pollutants to air, soil, and water.

The assessment conducted by CE Delft addressed the main pollutants associated with industrial activities that could affect wellbeing,

Several factors that affect final cost estimates, such as dispersion and meteorological conditions, population characteristics, and economic factors, were considered in the assessment conducted by CE Delft using regression analysis to identify those factors with higher relevance in the adjustment process. The assessment estimated the elasticity of each factor (% of damage cost increase).

This approach estimated the environmental costs of air pollutants based on several models developed for the European Union. To incorporate adjustments derived from the EU28 costs at different locations, the main factors are Gross Domestic Product (GDP) (since some costs are based on healthcare costs and willingness to pay) and population density (for air pollutants only, as a proxy to account for the number of people exposed to a pollutant).

Other variables, such as the share of exports (incorporated to consider potential impacts derived from food export, which could account for a portion of the emitted pollutants) were found to have minor relevance based on CE Delft assessment.

Waste

The impact driver associated with waste generation can be quantified, and the potential consequences on natural capital are considered. Different waste management practices impact the environment in different ways. Moreover, waste transport generates impacts associated with emissions (e.g., GHG, pollutants and noise) and social nuisances (e.g., odours or impacts on landscape).

Several uncertainties are inherent in waste environmental valuation. If generated waste is managed onsite (e.g., stored, treated, and/or disposed in a landfill), the associated impacts can be assessed as part of project operations (e.g., land occupation, noise generation, emissions), but if waste is managed by a third party, the impacts on natural capital are more difficult to assess.

Waste is divided into two main categories:

- Hazardous waste, as defined by the US EPA, is "waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes to batteries and may come in many forms, including liquids, solids gases, and sludges."
- Non-hazardous waste refers to any waste type not included under the hazardous category, such as industrial waste, domestic waste, and construction debris.

Both waste types are valued considering the inherent environmental value of the amount of generated waste and the impacts associated with waste transport.

Reads estimates the inherent environmental value of hazardous waste generation by considering a different value depending on the type of chemical hazard present in the waste. The environmental value of each tonne of generated waste depends on the amount of hazardous content multiplied by the estimated amount that could reach receptors) multiplied by the associated cost of the pollutants.

The inherent environmental value of non-hazardous waste generation is estimated in Reads as the fixed value associated with each tonne of waste based on the potential nuisances for receptors. As a default approach to assess the inherent environmental value of generated waste, the Reads tool uses the environmental cost per tonne of waste specified by the Australian Department of the Environment for hazardous and non-hazardous waste (converted to 2018 USD).

5.4.1.2 Modulation

The use of generic values to assess impacts on wellbeing does not consider local characteristics that may alter the potential impairment of wellbeing associated with emitted pollutants (see Section 5.4 for more details about calculating IUs using EEVs and modulation factors).

Consequently, a more comprehensive assessment may require consideration of the following:

- Pollutant fate and transport from the source to the receptors. Pollutant concentrations at the point of exposure (receptor location) depend on the dispersion conditions.
- Potentially affected population (number of people and proximity to the pollutant source).
- Baseline pollutant concentration, which determines the impact on wellbeing for the pollutant under assessment.

Modulators for emitted pollutants aim to capture the dispersion conditions, the potentially affected population, and the baseline pollutant concentration, as follows:

1. **Air pollutants:** Modulators depend on the dispersion conditions of pollutants (which directly influence the air pollutant concentrations at receptors), the population density under direct influence (which defines the potential number of affected receptors), and the background air quality levels.
2. **Water pollutants discharged to rivers:** The severity of the expected impacts depends primarily on the water use. The approach distinguishes between drinking water and water for other productive uses (e.g., irrigation). Natural purification processes dilute, transport, remove and degrade contaminants in rivers. Reads considers the main fate and transport attributes, such as dilution and removal (evaporation, deposition and/or degradation). The modulators depend on water use, population density, water quality, and pollutant decay.
3. **Water pollutants discharged to the sea:** The main pollutant pathway that could affect human wellbeing is through impacts on fishing or aquaculture resources; therefore, the presence of economic activities (e.g., fishing) and the pollutant decay rate during the fate and transport process are the main variables that define the modulation factor.
4. **Soil pollutants:** The impact of soil contamination on human wellbeing depends on many factors. Evidence suggests that land use and population density are key attributes to consider. In addition, soil contamination can be transferred to groundwater and impact water resources depending on the potential for COC transport through soil.

5.4.2 Climate

5.4.2.1 Monetary valuation

GHG emissions are estimated for each environmental impact and assessed according to its contribution to Climate Change. Equivalent tonnes of CO_2 (tCO_2eq) are used to compare GHG emissions from various sources based on their Global Warming Potential (GWP) by converting the volumes of other gases to the equivalent amount of CO_2 with the same global warming potential (European Environment Agency - Glossary, based on IPCC Third Assessment Report 2001). To incorporate GHG into the economic and environmental analysis of a project, the shadow price of carbon (USD/tCO_2eq) is multiplied by the annual GHG emissions (tCO_2eq) over the lifetime of the project.

The CO_2 value is estimated using integrated assessment models (IAMs) that couple simplified representations of the climate system and global economy to estimate the economic effects of an incremental pulse of CO_2 emissions. These models depend on the following four components with their associated uncertainties:

1. Population and GDP projections.
2. Estimated atmospheric GHG concentrations, temperature changes, and other physical variables, such as sea level rise based on climate models.
3. Monetized climate change impacts aggregated as economic damages.
4. Economic discount rate.

A well-designed carbon price is necessary for an effective strategy to reduce GHG emissions.

The price of carbon can vary from USD 44 to 413 USD per tCO_2eq due to numerous factors (Rennert, K. *et al.* 2022). Internal carbon pricing is a tool that an organization uses to guide decision-making related to climate change impacts, risks, and opportunities. Currently, more than 80 international carbon pricing initiatives are in place and over 1,300 companies are developing or using internal carbon pricing (World Bank and Ecofys 2018).

The World Bank dashboard on carbon pricing indicates that "Placing an adequate price on GHG emissions is of fundamental relevance to internalize the external cost of climate change in the broadest possible range of economic decision-making and in setting economic incentives for clean development. It can help to mobilize the financial investments required to stimulate clean technology and market innovation, fuelling new, low-carbon drivers of economic growth."

Reads suggests using the company's corporate carbon cost and applying the same value for all projects to ensure the comparability of the results across the entire company portfolio.

5.4.2.2 Modulation

GHG emissions generate social and environmental impacts at a global scale. No modulation is required.

5.4.3 Water

5.4.3.1 Monetary valuation

Water is one of the most important natural capital assets because all life depends on it. The benefit of water to people can be determined by mediating the stocks, flows, and constituents of water. Beneficiaries use freshwater services through consumption (in situ) or by using the products of freshwater systems. Simultaneously, hydrological services can provide irrigation, transportation, or recreational services.

Water scarcity is increasing worldwide due to interrelated causes, such as growing demand and competition for freshwater, inefficient use and allocations, pollution of water bodies, and climate change (Olmstead 2010). Therefore, water scarcity is a critical emerging risk for both the public sector and industries.

Reads incorporates water as an independent issue because of its importance for human consumption, agriculture, and industrial and energy uses. Current market prices associated with water have been proven to underestimate the value of this resource (Morgan and Orr 2015). As the TEV framework indicates, the range of use and non-use values should be accounted for when valuing water. Estimating non-use values, which are highly subjective and context-specific, in monetary terms is challenging, and agreement has not been reached on the approach.

Nevertheless, incorporating TEV water into decision-making by breaking down the values and attempting to quantify some can help to identify potential stakeholders and reputational concerns and make more appropriate decisions concerning water resource management. In addition, scarcity, which influences how society perceives water, should be a pivotal feature when valuing water-supply related impacts embedded in a company's value chain.

Water resource management, especially for water-intense businesses with activities in water-scarce contexts, must be centred on the risks associated with water quantity and quality and the spatial and temporal variability of both. In this regard, there are several tools and frameworks available, such as the World Resources Institute (WRI) Aqueduct, which can serve as blueprints for quantifying water risks. Monetary values for the identified and assessed water risks are needed to internalize the costs associated with water consumption in the context of resource scarcity.

The approach recommended by the Water Monetizer Risk (WMR) Tool by Trucost is acknowledged as one of the best for obtaining an initial estimate, since it considers environmental and socioeconomic risks associated with water provisioning. The Natural Capital Coalition has acknowledged the WMR as a useful framework to assess water-related impacts on natural capital (Natural Capital Coalition 2016).

Monetary values for water consumption should consider:

- Values of ecosystem services that depend on water,
- Human wellbeing trade-offs associated with changes in water quality and quantity, especially impacts on health and productivity, and
- Shifts in domestic-use water values resulting from the depletion of the resource (i.e., costs to ensure water supply to local communities).

As an initial estimate, the Reads approach combines the WRI Aqueduct Water Risk Framework and the range of Trucost Water Risk water prices (expressed in USD per m^3 for the report on Natural Capital at Risk: The Top 100 Externalities of Business for TEEB, TEEB 2016). These estimates range between 0.10 and 15 USD/m^3 depending on water availability (i.e., USD/m^3 and % water scarcity).

Global data on water scarcity are obtained from the publicly available WRI Aqueduct online platform[5]. The WRI Aqueduct Water Risk Framework combines geographical information with 12 water-related risks indicators, which are organized into three main risk categories: physical risk quantity, physical risk quality, and regulatory and reputational risk. Combined, these are used to quantify water-related risks throughout the world into comprehensive scores. Reads suggests only using the physical risk quantity, since regulatory requirements and costs derived from potential water treatments are not considered as good indicators to assess water consumption. The overall water risk, according to Aqueduct, is expressed as low risk, low-to-medium risk, high risk, and extremely high risk.

5.4.3.2 Modulation

The valuation approach for water includes several risks related to the inherent resource status, such as water scarcity and water quality. However, water demand issues need to be addressed by using modulators, to account for water demand, dependency, and competition for the resources.

The water modulator is based on the water dependency of local communities and the different water uses that might be affected by the water consumption of a specific project. The modulator also frames the impact associated with local resource availability.

5 https://www.wri.org/our-work/project/aqueduct

Table 5-3 Equivalences between Ecosystem Services for Reads and CICES (1/3)

Ecosystem Service Type	Nº	Reads	CICES V5.1 Division	CICES V5.1 Group	CICES V5.1 Class
Provisioning services	1	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	Biomass	Cultivated terrestrial plants for nutrition, materials, or energy	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
	2	Cultivated terrestrial plants for materials or energy	Biomass	Cultivated terrestrial plants for nutrition, materials, or energy	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials) Cultivated plants (including fungi, algae) grown as a source of energy
	3	Plants cultivated by in-situ aquaculture grown for nutritional purposes, materials, or energy	Biomass	Cultivated terrestrial plants for nutrition, materials, or energy	Plants cultivated by in-situ aquaculture grown for nutritional purposes Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials) Plants cultivated by in-situ aquaculture grown as an energy source
	4	Reared animals for nutrition, materials, or energy	Biomass	Reared animals for nutrition, materials, or energy	Animals reared for nutritional purposes Fibres and other materials from reared animals for direct use or processing (excluding genetic materials) Animals reared to provide energy (including mechanical)
	5	Reared aquatic animals for nutrition, materials, or energy	Biomass	Reared animals for nutrition, materials, or energy	Animals reared by in-situ aquaculture for nutritional purposes Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials) Animals reared by in-situ aquaculture as an energy source
	6	Wild plants (terrestrial and aquatic) for nutrition, materials, or energy	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials, or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition Fibres and other materials from wild plants for direct use or processing (excluding genetic materials) Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy
	7	Wild animals (terrestrial and aquatic) for nutrition, materials, or energy	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials, or energy	Wild animals (terrestrial and aquatic) used for nutritional purposes Fibres and other materials from wild animals for direct use or processing (excluding genetic materials) Wild animals (terrestrial and aquatic) used as a source of energy
	8	Genetic material from all biotas (including seed, spore, or gamete production)	Genetic material from all biotas (including seed, spore, or gamete production)	Genetic material from plants, algae, or fungi	Seeds, spores, and other plant materials collected for maintaining or establishing a population Higher and lower plants (whole organisms) used to breed new strains or varieties Individual genes extracted from higher and lower plants for the design and construction of new biological entities
				Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population Wild animals (whole organisms) used to breed new strains or varieties
				Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities

Table 5-3 Equivalences between Ecosystem Services for Reads and CICES (2/3)

Ecosystem Service Type	Nº	Reads	CICES V5.1 Division	CICES V5.1 Group	CICES V5.1 Class
Regulating services	9	Mediation of nuisances, wastes or toxic substances of anthropogenic origin	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bioremediation by micro-organisms, algae, plants, and animals Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
				Mediation of waste, toxic and other nuisances by non-living processes	Dilution by freshwater and marine ecosystems Dilution by atmosphere Mediation by other chemical or physical means (e.g., via filtration, sequestration, storage, or accumulation)
				Mediation of nuisances of anthropogenic origin	Smell reduction Noise attenuation Visual screening Mediation of nuisances by abiotic structures or processes
	10	Regulation of baseline flows and extreme events	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates Buffering and attenuation of mass movement Hydrological cycle and water flow regulation (including flood control, and coastal protection) Wind protection Fire protection Mass flows Liquid flows Gaseous flows
	11	Pollination (or “gamete” dispersal in a marine context), and seed dispersal	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat, and gene pool protection	Pollination (or ‘gamete’ dispersal in a marine context) Seed dispersal
	12	Maintaining nursery populations and habitats (including gene pool protection)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat, and gene pool protection Pest and disease control	Maintaining nursery populations and habitats (including gene pool protection)
	13	Pest and disease control	Regulation of physical, chemical, biological conditions	Pest and disease control	Pest control (including invasive species) Disease control
	14	Regulation of soil quality	Regulation of physical, chemical, biological conditions	Regulation of soil quality	Weathering processes and their effect on soil quality Decomposition and fixing processes and their effect on soil quality
	15	Regulation of the chemical condition of waters by living processes	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of freshwaters by living processes Regulation of the chemical condition of salt waters by living processes
	16	Atmospheric composition and conditions	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans Regulation of temperature and humidity, including ventilation and transpiration

Table 5-3 Equivalences between Ecosystem Services for Reads and CICES (3/3)

Ecosystem Service Type	Nº	Reads	CICES V5.1 Division	CICES V5.1 Group	CICES V5.1 Class
Cultural services	17	Physical and experiential interactions with natural environment and with abiotic components	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable promoting health, recuperation, or enjoyment through active or immersive interactions Characteristics of living systems that enable activities promoting health, recuperation, or enjoyment through passive or observational interactions
				Physical and experiential interactions with natural abiotic components of the environment	Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions
	18	Intellectual and representative interactions with natural environment and with abiotic components	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge Characteristics of living systems that enable education and training Characteristics of living systems that are resonant in terms of culture or heritage Characteristics of living systems that enable aesthetic experiences
				Intellectual and represen-tative interactions with abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable intellectual interactions
	19	Spiritual, symbolic, and other interactions with the natural environment and abiotic components	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic, and other interactions with natural environment	Elements of living systems that have symbolic meaning Elements of living systems that have sacred or religious meaning Elements of living systems used for entertainment or representation
				Spiritual, symbolic, and other interactions with the abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable spiritual, symbolic, and other interactions
	20	Other biotic and abiotic characteristics that have a non-use value	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value Characteristics or features of living systems that have an option or bequest value
				Other abiotic characteristics that have a non-use value	Natural, abiotic characteristics or features of nature that have either an existence, option, or bequest value

5.4.4 Ecosystems

5.4.4.1 Monetary valuation

As indicated previously, impacts on ecosystems, whether at the biome or habitat scale depending on the level of detail of the study, are analysed in terms of changes in the provision of ecosystem services.

Ecosystem services that might be impacted by the lifecycle of a project are identified using the Common International Classification of Ecosystem Services (CICES) developed by the European Environment Agency (EEA) as a reference typology of ecosystem services. Potentially relevant CICES Ecosystem Services are selected for inclusion in Reads, after which they are grouped based on common characteristics, such as ecosystem structures and functions underpinning several ecosystem services, or similar human wellbeing benefits provided by more than one ecosystem service[6].

Reads merges abiotic and biotic ecosystem services for the main CICES categories: Regulating (in which physical processes play a significant role), and Cultural (mainly due to aesthetic components). Reads does not consider abiotic provisioning services (i.e., extraction of commercial minerals) since they do not have a direct interaction with the ecosystems. Water is considered as a critical component of natural capital; therefore, water depletion is specifically addressed through a dedicated impact receptor group (see Figure 5-2 and Section 5.3.3)

The same approach was developed by ENCORE[7] to group CICES categories into 21 ecosystem services, which is similar to the grouping in Reads.

The selected CICES Ecosystem Services and the groupings developed for Reads are summarised in Table 5-3. Reads can be applied using any classification system, such as TEEB or ENCORE.

Selection of Biomes and Habitats

Ecosystem valuation studies often assign different values to ecosystem services associated with global land cover classes (i.e., biomes). Biomes, as land cover classes, correspond to planetary regions classified by climate, habitat, fauna and flora adaptations, biodiversity, and human activity features. Accordingly, land cover is used in Reads as the proxy for the provision of ecosystem services.

The selection of a specific biome is not relevant if site-specific values of the ecosystem services in the study area (habitat scale) are available. Using the default values per biome with corresponding adjustments (modulators) based on productivity and population density provides an alternative if site-specific valuation data are not available. The Reads tool includes 19 biomes divided into 3 categories, anthropogenic, terrestrial, and marine, as listed in Table 5-4, for which default parameters are available. These parameters could be adjusted based on productivity and population density data if site-specific valuation information is not available.

6 For instance, CICES Service 1.1.1.2 “Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)” are merged with CICES Service 1.1.1.3 “Cultivated plants (including fungi, algae) grown as a source of energy”. Both services pertain to provisioning benefits. The first could refer to wood production, e.g., as a raw material obtained from a cultivated forest, while the second could refer to firewood extracted from the same cultivated forest. The provision of both services depends on the same ecological factors, e.g., vegetation growth. In addition, the cultivated forest provides the same resource for both services; what changes is the human use of the wood.

7 https://encore.naturalcapital.finance/en/data-and-methodology/services

Table 5-4 Land Uses (Biomes) in Reads as a standard approach (adapted from TEEB 2010 and FAO 2014)

Biomes for Reads
ANTHROPOGENIC
Artificial surfaces
Crops
TERRESTRIAL
Grasslands
Tundra
Tropical and subtropical forest
Template boreal and Mediterranean forests
Shrub-covered areas
Shrubs and/or herbaceous vegetation, aquatic or regularly flooded
Mangroves
Inland waterbodies
Sparsely natural vegetated areas
Terrestrial barren land
Permanent snow and glaciers
MARINE
Oceans
Coastal areas/Continental shelf sea
Estuaries
Seagrass/algae beds
Coral reefs

Valuation Database

Reads requires the monetary value of ecosystem services (USD/ha/year) at project location.

In March 2010, The Economics of Ecosystems and Biodiversity (TEEB) published a complete database for all terrestrial land uses (biomes), representing the first major work in this area of knowledge. Since then, several authors have published updates of values, including studies by de Groot *et al.* (2012) and Costanza *et al.* (2014).

Continued efforts to update and generate new values have resulted in the ESVD database. The ESVD currently contains 9,453 value records from over 1100 studies distributed across all biomes, ecosystem services and geographic regions. It contains over 2000 studies and the number is growing continuously so the number of value records in the ESVD will increase over time. The Reads tool integrates all these updates into a purpose-built database based on the benefit transfer approach.

The Reads tool database of global estimates of the ecosystem services values should be updated through an in-depth analysis of the existing literature on ecosystem services valuation to incorporate updated and more accurate data. This valuation should be based on ISO 14.008:2019 on Monetary Valuation of Environmental Impacts and Related Environmental Aspects, which specifies the requirements and procedures for monetary valuation and the basic standards for benefit transfer.

Reads provides a default database for screening assessments; however, updates the ecosystem services valuation database with the maximum potential accuracy is recommended. The process for updating the database or for developing a database specifically for a site under assessment can be summarized as follows:

a. Identify key peer-reviewed ecosystem services valuation studies for each significant combination of CICES ecosystem services and biomes that are representative geographically and socioeconomically.
b. Validate the identified valuation studies by tracing back to their primary data sources and double-checking the locations and mapping using GIS.
c. Convert the economic values of the original evaluation studies to area/time units (economic value per hectare and year) by applying spatial and time allocation functions from the specialized literature.
d. Adjust the converted area/time economic values to USD as of 2018 using international exchange rates corrected for purchasing power parity to convert from local currencies to USD and to adjust price indexes to 2018 values.
e. Statistically estimate ecological, socioeconomic, and technical value parameters for each combination of ecosystem service and land use, i.e., the type of estimated value and the evaluation method.
f. Apply benefit transfer techniques using the estimated value parameters from the original studies to produce the expected economic values (per hectare and year) of average types of combined ecosystem service and land use. The resulting economic values will be appropriate to use to replace values from, for example, de Groot *et al.* (2012) and Costanza *et al.* (2014), which are employed in the default database available in Reads.
g. Define “edge types” of each significant ecosystem service/land use combination. Edge types should be chosen to represent extreme or close-to-extreme cases (excluding outliers) for different dimensions characterized by the chosen intra-biome adjustment, such as ecological quality socioeconomic data. Both high-edge and low-edge types are needed for each dimension and each ecosystem service/land use combination.
h. Apply benefit transfer techniques with the estimated value parameters to produce the expected economic value (per hectare and year) of the high-edge and low-edge types for each dimension and each ecosystem service/land use combination.

Impact on Ecosystem Services

The change in the provision of ecosystem services is assessed as follows. For each impact, the affected area (ha) is defined and the ecosystem services that may be affected and their estimated degree of change (%) are identified. These services are valued in (USD/ha/year), so the results are expressed in USD/year.

Example: A single impact affects N hectares where three services are present (ES1, ES2 and ES3). The values for each ecosystem service are defined as V_{ES-1}, V_{ES-2} and V_{ES-3}. If only two services are affected by the impact, ES1 and ES3, the total ecosystem service distraction (ESD) from ES1 and ES2 are calculated as follows:

Ecosystem Service Detraction (ESD) = N * (V_{ES-1} + V_{ES-3})

The impact consequences on all ecosystem service groups are added following the appropriate compatibility rules to avoid double accounting, which results in the total ESD of the impact on the local ecosystem service. [8]

8 Not all services are present in all environments (biomes), and not all impacts affect all ecosystem service groups. The presence of ecosystem service groups in each biome was defined based on the reference studies used for economic valuation. In Reads, ecosystem service groups that are not present in the location of a project can be removed from the calculation.

Some impacts may reduce the ecosystem services provision by less than 100%. For those impacts with partial reduction, the Damage Level approach described in Section 5.3.4 should be applied. In this case, the valuation shall consider the corresponding equivalent hectares.

The total ESD for the entire project duration is estimated by multiplying the estimated per year by the number of years until the environmental impacts are completely buffered by the biophysical conditions of the project site.

To assess benefits from offsets, the ecosystem service generation (restoration of degraded habitats and/or recover of endangered species) should follow the same valuation approach.

Impact on species

The impact on species is quantified by the potential deaths of individuals (birds, bats, and other terrestrial and marine species) due to collisions and strikes during the operation of wind turbines, power lines, and other infrastructures, such as road traffic or buildings.

The assignment of economic value to species presents technical and ethical difficulties. Economic valuation methods include use and non-use values (including existence values) to estimate the potential value of a species or an individual.

The purpose of valuating species is not to estimate a compensation value for regulated activities (e.g., hunting), but to estimate the value of a potential impact on the ecosystems due to collateral wildlife death caused by various causes, emphasizing physical damage (e.g., strikes).

Wildlife valuation (fauna) depends on several characteristics of the species, including but not limited to the role played in ecosystems, abundance, reproduction difficulties, and sex of the individual.

Species valuation for use in damage compensation frameworks is used worldwide. A well-known example is the case of valuating wolves. For this specific species, research conducted by Colorado State University[9] determined three types of valuation:

- Use values: Wolf hunting, which generates revenues considered consumptive use, was allowed in much of the Northern Rocky Mountains (NRM) at the time of the study. The potential for revenue based on consumptive use is clearly present in Colorado when hunting is allowed in the state. For example, the sale of hunting and trapping permits for wolves in Montana is about $400,000 per year, and expenses for travel, housing, food, and equipment generate income for hotels, restaurants, and hunting guides. Some ranchers offset livestock losses associated with predatory wolves by providing access to their property and services (guides, housing) for hunting wolves in Colorado. Private ranches in Colorado charged $2,400-$2,950 per hunter in groups of 4-6 for private elk and deer hunts (up to $90,000 per ranch). An Idaho outfitter offers wolf hunting on Idaho ranches for $3,800 per hunter.
- Non-use values: Wolves provide opportunities for people to view, film, photograph, listen to, or otherwise experience wolves in their natural habitats, e.g., tourists travel to Yellowstone National Park for a chance to see wolves. When wolves were first introduced in Yellowstone National Park in 1995, economists estimated that visitor use would increase by 5% for out-of-area residents and 10% for local residents. By 2005, economists confirmed that visitation was as predicted, and wolf-related visits produced $47 million annually in travel expenditures in Idaho, Montana, and Wyoming. At the time of the study, guided hiking to view wolves in Yellowstone costs $600 to $900 per day, depending on the size of the group, and a six-day ‘wolf vacation’ costs $1,950 per person. The benefit of wolf-related tourism in Colorado may be more limited than the unique wolf viewing opportunities in Yellowstone’s northern range, which has a high wolf density, radio-collared wolves, outstanding viewsheds, and year-round access via paved roads. However, Colorado is also a top tourist destination, and many of its citizens would likely benefit from developing a wolf-related tourism industry.
- Existence and bequest values: Few studies have estimated the existence value of wolves; however, one study estimated the existence value of introducing wolves in northern Yellowstone to be $11million per year by summing the willingness to pay by United States residents. Existence values can be compared to the costs of introducing wolves, along with other benefits and costs, to help policy makers manage natural resources. If benefits outweigh costs, society gains by introducing wolves. Existence values would likely be important in Colorado, but an estimate would require a specific study.

9 https://extension.colostate.edu/topic-areas/people-predators/wolf-economics-8-012/

Such valuation examples have been used in several states to promote wolf protection and compensation to farmers for damage due to the presence of wolves. Wyoming paid about $170,000 in 2018 for livestock killed or injured by wolves, which is typical for western states. The Livestock Indemnity Program of the USDA Farm Services Agency reimburses 75% of the value of killed livestock.

As with many other species, it is very difficult to define the value of the wolf as a species or as an individual, and no study captures 100% of the values in planetary or local contexts. Nevertheless, Reads aims to define the intrinsic value to natural capital of various 'flagship' species that could be killed due to anthropogenic activities.

An alternative is to estimate the replacement cost, although this approach might not provide a technically correct measure of environmental value, which is properly measured by the maximum amount of money a person is willing to pay or allocate to ensure the survival of a particular species.

The legislation of some countries establishes penalties for illegal hunting or trafficking of species for which each individual is assigned a specific value. This approach forms the basis for damage compensation, which is sometimes extremely high to avoid illegal practices or low if based on fines applied for illegal hunting (e.g., this fine in Decree 1272, 2016 in Colombia is less than 1 USD per individual).

Reads can be used by the practitioner to incorporate a responsible ecological value for each individual of each specie. In the absence of more accurate data, the Reads tool uses published data provided by the Ministry of Environment in Spain as part of the default proxy valuation database for environmental damages, which determines a generic environmental value per individual depending on its protection status.

5.4.4.2 Modulation

Modulators for impacts on ecosystem services shall account for those characteristics beyond the monetary valuation and are designed to capture the following features:

1. **Abundance and livelihood dependence:** The local capacity of the ecosystem to deliver provisioning services, the accessibility of these provisioning services by local communities, and their reliance on them for meeting basic needs and/or as sources of income. If an environmental impact causes damage to the only available ecosystem service or services that are key for the subsistence of local communities, the impact significance is increased accordingly to reflect this exposure.
2. **Biodiversity and genetic materials for provisioning purposes:** The biological diversity of an ecosystem, in terms of species richness and functional diversity, determines the capacity of the ecosystem to provide ecosystem services. Biodiversity represents gene pools that often satisfy genetic resources provisioning purposes, e.g., native breeds used for cultivation. Some ecosystems are home to endangered species, and environmental impacts on these might increase their vulnerability. This modulator is designed to simultaneously capture the role of biodiversity for ecosystems functioning and the sensitivity of specific ecosystems for safeguarding threatened biodiversity beyond the monetary valuation. Consequently, if an ecosystem is rich in biodiversity, the significance of environmental impacts within it should be higher. The same will occur if environmental impacts take place within an ecosystem where endangered species are found.
3. **Relevance of regulating services for environmental quality:** This attribute adjusts the values of environmental impacts on regulating ecosystem services depending on the role they play to provide benefits for local environmental quality and communities. Depending on the social-ecological context under which a project might take place, especially in relation to anthropogenic disturbances, certain regulating ecosystem services are more significant than others (e.g., erosion control is critical in areas with high risk of erosion, but less so in flat areas with little or no risk of erosion). Some are critical for maintaining local environmental quality (e.g., forested areas near industrial sites or cities). Therefore, this modulator reflects the diverse relevance that regulating ecosystem services might have for the environmental quality of different project locations.
4. **Cultural diversity:** The average valuation and the applicable intra-biome adjustments cannot capture the value of cultural ecosystem services in each specific location. This modulator aims to provide specific valuation criteria to assess impacts on cultural diversity, and the number of languages, religions, and ethnic groups present in each specific location are recommended for consideration as proxies for cultural diversity.

The value assigned to loss of individuals does not require any modulation since it already accounts for the ecological value of each specie.

The Biodiversity Guidance to accompany the Natural Capital Protocol, published by the Capitals Coalition, recognizes as good practice the approach suggested by this methodology to use modulation factors of the monetary values to calculate dimensionless "Impact Units." Biodiversity is incorporated by adjusting the ecosystem service values for specific biodiversity features, e.g., protected species abundance and threats (such as habitat loss and fragmentation).

5.4.4.3 Biodiversity valuation

Reads produces biodiversity inclusive natural capital assessments to avoid underestimating and mismanaging business impacts on biodiversity, both negative and positive, through the following:

- Recognition that higher levels of biodiversity generally result in greater quantity and quality of goods and services and greater resilience to change.
- Inclusion of specific biodiversity characteristics to assess the extent and condition of the ecosystems, including the number of species, the extinction risk of threatened species, the habitat status, and the protection categories.
- Consideration that impacts on ecosystem services, water resources, and climate are intrinsically linked to biodiversity – a direct valuation relationship is established between impacts on ecosystem services, water resources, and/or climate, as follows:
  - Ecosystem services: variable for three (3) provisioning and four (4) regulating services.
  - Water: variable for surface and groundwater resources.
  - Climate: fixed at the global level.

Reads recognizes that the biodiversity provides a wide range of values to people and society and is both an integral component of natural capital (assets derived from nature that give rise to ecosystem service flows) and an indicator of the resilience of natural capital stocks, such as soil and water.

The Reads approach quantifies impacts on biodiversity (including the environmental value of biodiversity) and defines an indicator to assess the extent and condition of ecosystems.

Quantification of impacts on biodiversity is a tecnical challenge but will play a critical role in the development of strategies towards the biodiversity net gain objectives. Reads suggest quantifying impacts on biodiversity as a portion of the overall impact on natural capital.

Reads assumes that one portion of the overall impact on natural capital can be considered as a direct impact on biodiversity and that a portion of impacts on Climate, Water and Ecosystems have direct consequences on biodiversity. The following sections present the discussion on the portion of impact on natural capital that should be considered as a direct impact on biodiversity for each of these impact category groups.

Biodiversity and climate change

Carbon costs for GHG emissions are estimated using "prevention costs", which are the costs to society for attaining climate policy targets. Carbon costs are based on the costs of measures to reduce GHG emissions up to a certain target. Therefore, these emissions cannot be allocated to "Human Health" or "Ecosystems", and it is difficult to discern to what extent policy makers consider human health or ecosystems when implementing climate policies.

However, the ReCiPe report[10] (Goedkoop *et al.* 2009) suggests a division between ecosystem impacts and human health impacts and their associated values used in the Environmental Prices Handbook. The shares of human health costs are then calculated in total damage costs. Research developed by Delft CE found that the share of human health in total pollution costs for CO_2 is around 80%, which is used in the estimate proposed by Reads, and the remaining 20% is assumed to generate impacts on ecosystems. This assumption is acknowledged as insufficiently robust and further research is required.

An alternative to this approach is to identify the carbon costs that are only based on the potential consequences on biodiversity. For example, estimates of marginal prevention costs of CO_2 or tipping points (emissions that could generate a biodiversity collapse) can be used to assess additional increased carbon costs (approximately 25%) (Dietz *et al.*, 2021).

Biodiversity and water resources

Assessing the potential consequences of water detraction on ecosystems in a water basin (downstream) is also challenging; however, the ecological and social risk is higher when water stress is higher.

The Water Risk Monetizer Tool by Trucost assigns an environmental value for each m^3 of water abstracted from a basin considering potential consequences on human health, domestic use, and environmental costs.

10 The name "ReCiPe" represents the 3 institutions that collaborated on the "recipe" for calculating lifecycle impact category indicators: RIVM and Radboud University, CML, and PRé.

The approach followed by Reads assumes that impacts on biodiversity represent a portion of the water value, and that the proportion increases with increasing water stress, as follows:

- 25% of the value if WRI[11] is Low
- 37.5% of the value if WRI is Medium-Low
- 50% of the value if WRI is Medium-High
- 62.5% of the value if WRI is High
- 75% of the value if WRI is Extremely High

Biodiversity and ecosystem services (BES)

According to the Biodiversity Guidance published by the Natural Capital Coalition (NCC), "Biodiversity plays an integral role, underpinning the goods and services that natural capital stocks generate. Biodiversity describes the variety of life and is the living component of what can be thought of as natural capital stocks. It plays an important role in the provision of the services we receive from nature. Biodiversity can refer to the level of genetic variation, the variety of species present, or the variety of groups of species or ecosystems. In general, more biodiversity equates to a higher quantity, quality, and resilience of ecosystems and the services they provide, which underpin the benefits to business and society. As such biodiversity can be an indicator of the condition and resilience of natural capital stocks. It also contributes benefits to business and society in its own right, for example through direct and intrinsic value of species, nature-based solutions, and by enriching other benefits such as nature-based recreation."

11 Water risk indicator based on the WRI Aqueduct Water Risk Framework.

Assessing impacts on biodiversity following the ecosystem services approach will not capture the full value provided by biodiversity, because some ecological functions and existence values are unknown. The hidden and missing values of biodiversity are diagrammed in Figure 5-8, developed by the NCC for the article "Biodiversity at the heart of accounting for natural capital" to show the relationship between biodiversity, ecosystem services, and natural capital.

This gap is covered in Reads by including services related to Maintaining nursery populations and habitats (including gene pool protection) and other biotic and abiotic characteristics that have non-use value.

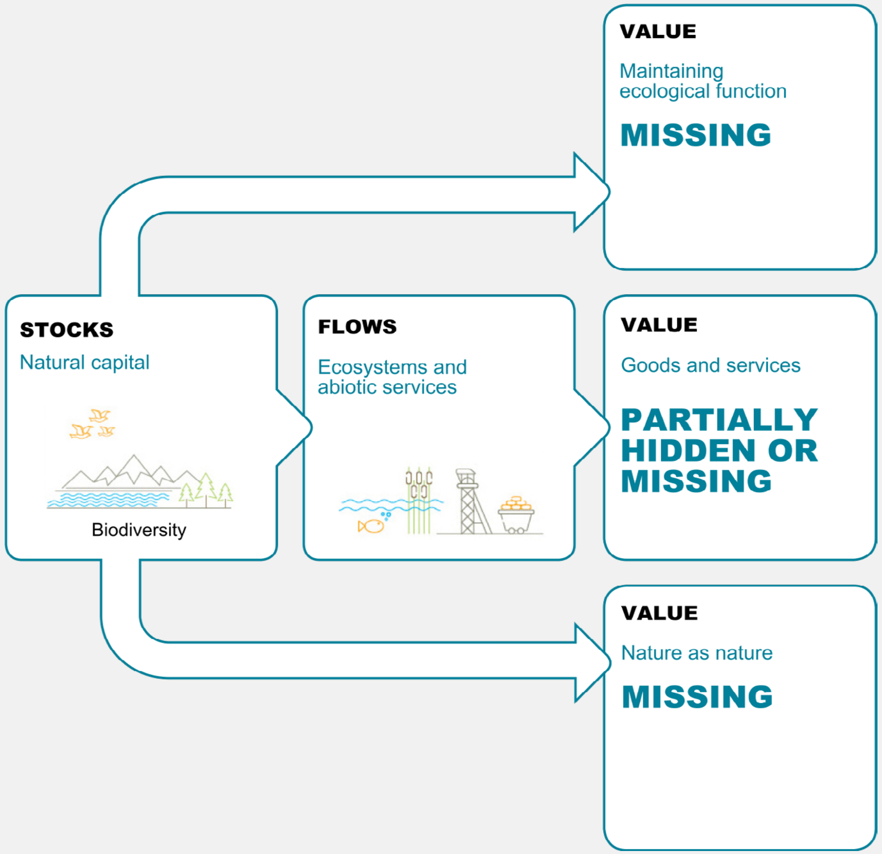

Figure 5-8 Hidden and Missing Values of Biodiversity (source: Natural Capital Coalition)

These two services, which are frequently missing in most valuation databases, are very specific to each location. If properly captured, they can be considered in Reads.

To estimate the portion of impacts on ecosystems that could have direct consequences on biodiversity, Reads correlates ecosystem services groups and biodiversity by assigning 100% when the service is fully related to biodiversity, 75% if the correlation is high, 50% if medium, and 25% if low.

These distributions (%) of biodiversity related to each ecosystem service group, Provisioning, Regulating and Cultural, are shown in Table 5-5.

Table 5-5 Distribution of Biodiversity per Ecosystem Services Group according to Reads

PROVISIONING	1	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes	
PROVISIONING	2	Cultivated terrestrial plants for materials or energy	
PROVISIONING	3	Plants cultivated in-situ aquaculture grown for nutritional purposes, materials or energy	
PROVISIONING	4	Reared animals for nutrition, materials or energy	
PROVISIONING	5	Reared aquatic animals for nutrition, materials or energy	
PROVISIONING	6	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	25%
PROVISIONING	7	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	25%
PROVISIONING	8	Genetic material from all biota (including seed, spore or gamete production)	50%
REGULATING	9	Mediation of nuisances, wastes or toxic substances of anthropogenic origin	
REGULATING	10	Regulation of baseline flows and extreme events	
REGULATING	11	Pollination (or "gamete" dispersal in a marine context), and seed dispersal	75%
REGULATING	12	Maintaining nursery populations and habitats (including gene pool protection)	100%
REGULATING	13	Pest and disease control	50%
REGULATING	14	Regulation of soil quality	
REGULATING	15	Regulation of the chemical condition of waters by living processes	25%
REGULATING	16	Atmospheric composition and conditions	
CULTURAL	17	Physical and experiential interactions with natural environments and with abiotic components	25%
CULTURAL	18	Intellectual and representative interactions with natural environments and with abiotic components	25%
CULTURAL	19	Spiritual, symbolic and other interactions with natural environments and with abiotic components	
CULTURAL	20	Other biotic and abiotic characteristics that have a non-use value	50%

5.5 Manage

5.5.1 Impacts management

Reads is designed to drive operational excellence and support decision-making by providing a set of metrics and indicators for improved impact management. As a result, Reads analyses the improvements (impact reductions) derived from applying the mitigation hierarchy (avoid, minimize, restore, and offset) to manage identified environmental impacts. This analysis helps to identify appropriate mitigation measures, compare mitigation alternatives (cost versus efficiency), and set and monitor impact reduction targets.

Conducting a Best Available Techniques (BAT, OECD 2020) assessment is effective for finding an appropriate solution that has the least environmental impact given a set of cost and benefit constraints. Reads supports this stepwise process as follows:

1. Identify impact mitigation options (avoid, reduce, restore, offset).
2. Assign overall performance, expressed as impact change (%) over the baseline, both for negative and positive impacts.
3. Perform cost-benefit appraisal: CAPEX, OPEX, and ABEX brought to NPVs.
4. Appraise KPIs / metrics and select the BAT.

This approach quantifies the environmental benefit (natural capital gain) of each mitigation measure. For each impact, the overall performance of each measure is projected and adjusted based on estimated or real data, where available.

As defined by the Cross-Sector Biodiversity Initiative (The Biodiversity Consultancy 2015), the mitigation hierarchy is 'the sequence of actions to anticipate and avoid impacts on biodiversity and ecosystem services (BES): minimize where avoidance is not possible, rehabilitate or restore when impacts occur, and offset where significant residual impacts remain.'

Reads is designed to drive operational excellence and support decision-making by providing a set of metrics and indicators for improved impact management.

Avoidance

Avoidance can be defined as 'Measures taken to anticipate and prevent adverse impacts before actions or decisions are taken that could lead to such impacts.'

In general, the Cross-Sector Biodiversity Initiative (CSBI) identifies and categorizes different approaches to avoidance through:

- Site selection (e.g., avoid impacting turtles nesting sites),
- Project design (e.g., avoid CO_2 emissions by using certified renewable energy for certain industrial processes), and
- Scheduling (e.g., avoid impacting narwhal migration periods).

Minimization

Minimization can be defined as 'Measures taken to reduce the duration, intensity, significance and/or extent of impacts (including direct, indirect, and cumulative impacts, as appropriate) that cannot be completely avoided, as far as is practically feasible.'

As described by CSBI, minimization actions can be divided into the following three major categories:

- Physical controls: Adapting the physical design of project infrastructure to reduce potential impacts, such as installing culverts on roads or bird flight diverters on transmission lines.
- Operational controls: Managing and regulating the actions of people associated with the project, including staff, contractors or (where feasible) project affected people and migrants. Operational controls can manage both direct impacts (e.g., soil spill minimization from drill pad construction) and indirect impacts (e.g., measures to reduce illegal hunting).
- Abatement controls: Taking steps to reduce levels of pollutants (e.g., emissions of dust, light, noise, gases, or liquids) that could negatively impact on the environment. Engineering for minimization may distinguish between designs that abate at the source (e.g., reduce the noise level generated) and abate at the receptor (e.g., install barriers to reduce noise transmission).

In Reads, minimization measures reduce BIUs and can be applied for certain periods with efficiencies that can change over time. Different measures per each impact driver are proposed based on industry good practices issued by the European Union for industrial activities.

Restoration

'Restoration' refers to actions taken to address the degraded or damaged BES of interest, such as species, habitats, or specific ecosystem services, due to project impacts that remain after implementing avoidance and minimization measures. Restoration goals in the mitigation hierarchy may relate to the site baseline prior to impacts.

In Reads, restoration activities result in an increase (recovery or gain) in natural capital that can be accounted for immediately or up to several years after operations cease, with the aim of achieving baseline (or better) conditions within a reasonable timeframe.

Offsets

The CSBI defines offsets as 'Measurable conservation outcomes, resulting from actions applied to areas not impacted by the project, that compensate for significant, adverse impacts of a project that cannot be avoided, minimized and/or restored. Where significant adverse impacts do remain, these can potentially be addressed via BES offsetting.'

The goal of offsetting BES is to achieve No Net Loss and preferably a Net Gain of BES in terms of species composition, habitat structure, ecosystem function, and human use and cultural values associated with biodiversity (Ecostar Natural Talents 2017).

According to CSBI, offsets may be divided into the following two groups:

- 'Restoration' offsets: Designed to remediate past damage to biodiversity and ecosystem services due to factors unrelated to the development project in question by making positive conservation management interventions, such as the rehabilitation or enhancement of biodiversity components (or even recreation of ecosystems and their associated biodiversity values) at suitable offset sites.
- 'Protection' or 'averted loss' offsets: Designed to protect BES in an area demonstrated to be under threat of imminent or projected loss (due to factors unrelated to the development project in question).

In Reads, offsets result in an increase (gain) in natural capital that can be accounted for immediately or up to several years after operations cease. This gain is quantified through the valuation of ecosystem services gains or CO_2 sequestration.

Offsets comply with the following Business and Biodiversity Offsets Programme (BBOP) principles (BBOP 2012):

1. **Adherence to the mitigation hierarchy:** A biodiversity offset is a commitment to compensate for significant residual adverse impacts on biodiversity identified after appropriate avoidance, minimisation and onsite rehabilitation measures have been taken according to the mitigation hierarchy. Reads prioritises the selection of mitigation measures to reduce the environmental impacts to the maximum extent.

2. **Limits to what can be offset:** Impacts cannot always be fully compensated for by a biodiversity offset if the affected biodiversity is irreplaceable or vulnerable. Through adjusted EEVs, Reads can help to quantify, in dimensionless units (IUs), the environmental impacts in a specific area for which the importance and the vulnerability of that specific site is understood.

3. **Landscape context:** A biodiversity offset should be designed and implemented in a landscape context to achieve the expected measurable conservation outcomes, accounting for available information on the full range of biological, social, and cultural values of biodiversity and supporting an ecosystem approach. Reads considers local transformation factors (availability, quality, social value) for the economic valuation.

4. **No net loss:** A biodiversity offset should be designed and implemented to achieve in situ (e.g., onsite or local), measurable conservation outcomes that can reasonably be expected to result in No Net Loss and preferably a Net Gain of biodiversity. Reads considers the value of the specific site through the Adjusted Environmental Economic Valuation.

5. **Additional conservation outcomes:** A biodiversity offset should achieve conservation outcomes above and beyond results that would have occurred if the offset had not taken place. Offset design and implementation should avoid displacing activities to other locations where biodiversity can be harmed. Reads helps to analyse the temporary evolution of applying the mitigation hierarchy (avoidance, mitigation, restoration, and offsetting).

6. **Stakeholder participation:** In areas affected by the project and by the biodiversity offset, the effective participation of stakeholders should be ensured in the biodiversity offsets decision-making, including their evaluation, selection, design, and implementation and monitoring. Reads is designed to provide critical information to enable Repsol decision-makers to select alternatives related to environmental impacts and operational costs and to present the actions to stakeholders and affected groups.

7. **Equity:** A biodiversity offset should be designed and implemented in an equitable manner, which means sharing with stakeholders the rights, responsibilities, risks, and rewards associated with a project and to ensure the offset is accomplished in a fair and balanced way, respecting legal and customary arrangements. Special consideration should be given to respecting both internationally and nationally recognised rights of indigenous peoples and local communities.

8. **Long-term outcomes:** The design and implementation of a biodiversity offset should be based on an adaptive management approach, incorporating monitoring and evaluation to secure outcomes that endure for as long as the duration of the project impacts and preferably in perpetuity. Reads represents the evolution of the company's impacts over time, enabling impacts monitoring as the company progresses toward an 'Environmental No Net Loss' target.

9. **Transparency:** The design and implementation of a biodiversity offset and the communication of its results to the public should be undertaken in a transparent and timely manner. Reads is designed to support management decisions in a defined approach across the entire business.

10. **Science and traditional knowledge:** The design and implementation of a biodiversity offset should be a documented process informed by sound science and appropriate consideration of traditional knowledge.

The BBOP indicates the following in their standard on biodiversity offsets: "Loss-gain metrics can be selected to include methods for calculating impacts on particular ecosystem services and gains (through the offset) in those ecosystem services." It also specifies that "Most methods used internationally in biodiversity offsets for calculating loss and gain use a combination of biodiversity components as proxies, rather than economic valuation. However, some methods of economic valuation are used, and the BBOP Cost Benefit Handbook suggests a range of tools that can help ensure that people are left at least as well off as a result of the project and offset, and preferably better off."

It should be noted that the standard approach to environmental economic valuation might be too inaccurate to quantify the proposed offset benefits in monetary terms, but it would be a very helpful tool for obtaining a screening value of the potential offsets and the spatial requirements (in hectares).

To assess and quantify the benefits of the offset, the same metrics used to estimate the environmental impacts should be applied. Impacts are both in EEVs and IUs. The monetary values used for this calculation will consider site-specific adjustments so that the process characteristics of the location under study as well as intra-biome characteristics are included. One challenge when designing an offset is whether to allow a temporal gap between development and offset gains. In site-specific adjustments, Reads considers the temporal loss, which is understood as the deficit in biodiversity that exists for a period that starts after negative impacts due to the development and extends to before an offset site is mature.

There are two potential applications for the valuation of offsets through the ecosystem service valuation approach:

- Identify potential offsets to compensate for an impact on biodiversity, and
- Obtain specific valuation of an already defined offset.

Offsetting is particularly important in fighting against climate change. In this context, Natural Climate Solutions (NCS, also called Nature Based Solutions) are defined as actions that conserve, restore, or improve the use or management of high carbon ecosystems (e.g., peatlands, forests, wetlands, grasslands, agricultural lands, and coastal ecosystems) while increasing carbon storage and avoiding GHG emissions. The IPIECA and the OGCI[12] state that NCS management offers a powerful set of options for companies to support the goals of the Paris Agreement, as it can deliver "more than one-third of the cost-effective climate change mitigation needed by 2030 to stabilize warming at well below 2°C." As described above, Reads allows for implementing the conservation mitigation hierarchy framework as recommended by IPIECA and OGCI for onsite NCS management, accounts for the production of ecosystem services, and calculates the potential CO_2 sequestration of a site according to the IPCC Tier 1 methodology.

12 International Petroleum Industry Environmental Conservation Association (IPIECA) and Oil & Gas Climate Initiative (OGCI)

5.6 Results

Reads provides a set of metrics and KPIs that can be used in a variety of ways, from informing stakeholders about material impacts to improving the decision-making process for new projects or operating assets.

5.6.1 Natural Capital report

A natural capital report (also referred to as the natural capital statement) provides stakeholders with a complete package of information on a company's natural capital risks and opportunities. It shows whether the company is sufficiently prepared for current/future risks and opportunities like climate change, water availability, biodiversity protection and others. Quantitative biophysical and monetary valuation data are used and can be run under different future scenarios.

This report is used to produce an environmental statement for internal use, both at the corporate level and for asset managers, and to communicate aggregated or focused results to stakeholders. The results inform an organisation's impact on natural capital in qualitative, quantitative, and monetary terms. These reports provide relevant information on the evolution of the impacts and the management actions required or taken to mitigate them.

In Reads, positive impacts (gains) and negative impacts (losses) in natural capital are considered to produce a balance based on EEVs and IUs. The net balance of units is expressed in net present value terms, which enables analysis of the impact on natural capital over time. This balance can be expressed in terms of totals or in terms of key indicators of a company's productive activity, such as industrial production or a company's various financial indicators (e.g., expenses, investments, profits).

Natural capital reports can be used to compare the impact results of different projects. The outcomes of these comparisons should reflect the impact magnitudes of each project combined with the sensitivities of the project locations. The overall results enable project comparisons regardless of activities or size.

Specific KPIs can be used for comparing projects within the same activity sector (e.g., energy generation projects). A key indicator for understanding the environmental footprint of a project is the overall project impact divided by the activity rate (e.g., Environmental valuation or Impact units per kWh generated). This KPI enables the comparison of projects of different sizes or magnitudes and projects using different technologies (i.e., generation using wind power vs.PV solar).

Reads uses production metrics (e.g., electricity generation [GWh] and product sales [kt]) and financial metrics that are consolidated in the company's financial statements, which are prepared in accordance with International Financial Reporting Standards (IFRS) as issued by the International Accounting Standards Board (IASB), such as capital expenditure (CAPEX), operating expenditure (OPEX) [k$], operating income [k$], and EBITDA [k$].

In the Reads tool, the Natural Capital report reflects the environmental impact of a company's portfolio by focusing on climate, water, BES, and human wellbeing. Financial and operational KPIs are also displayed. These impacts, in terms of BIUs, EEVs, and IUs, can be expressed in several ways, including but not limited to:

- Impact by year: annual and cumulative,
- Impact by category: climate, water, ecosystems, and human wellbeing – a separate chapter is proposed for BES,
- Impact by environmental aspect and impacts,
- Impact by activity,
- Impact by case (e.g., windfarm, refinery, combined cycle),
- Impact by infrastructure (e.g., roads, facilities, grids),
- Impact by operational metric, and
- Impact by financial metric.

In Reads, EEVs and IUs are always NPV-adjusted. The results of a natural capital report generated using Reads for a natural gas plant are provided in Figure 5-9 as an example.

These yearly NPVs are expressed in Impact Units (IUs). The graph represents the impacts in the construction, operation and decommissioning phase, including the generation of positive impacts from offset projects in the final stages of the asset's life cycle. The teal blue curve represents the accumulated impact over time.

The NPVs for each impact driver are compared in the lower graph. The quantitative results are tabulated in IUs per impact driver or environmental aspect and impact category.

Financial metrics, such as CAPEX, OPEX, income, and profit, are summarised in Figure 5-10 to obtain several impact intensity KPIs. Similarly, operational metrics (e.g. produced hydrocarbons (MBOE), power generation (GWh) are used to obtain impact intensity metrics).

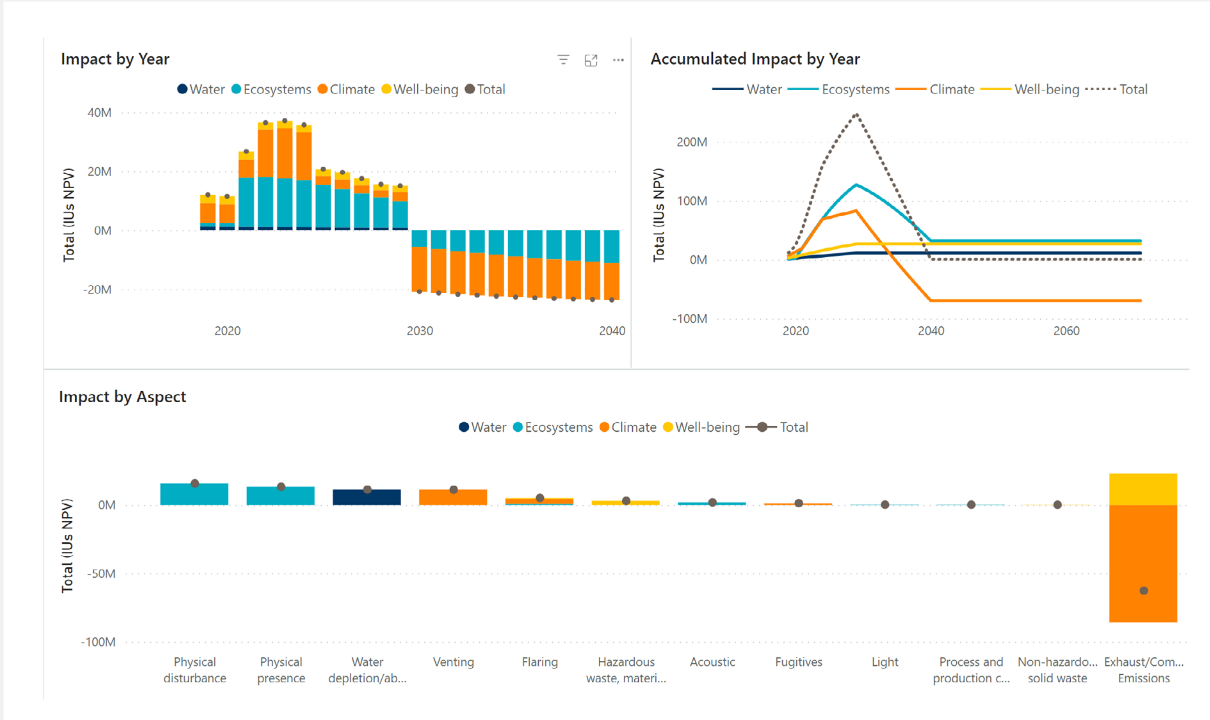

Figure 5-9 Impacts on Natural Capital over time for a Natural Gas Plant (Reads Natural Capital Report)

Financial Information (NPV)	KPIs (NPV)	
CAPEX (K$) 2,984,846	EEVs vs CAPEX 790.60	IUs vs CAPEX 772.09
OPEX (K$) 2,136,175	EEVs vs OPEX 1,104.69	IUs vs OPEX 1,078.82
TOTAL EXPENDITURE (K$) 5,121,021	EEVs vs TOTAL EXPENDITURE 460.81	IUs vs TOTAL EXPENDITURE 450.02
OPERATING INCOME (K$) 10,683,762	EEVs vs OPERATING INCOME 220.88	IUs vs OPERATING INCOME 215.71
EBITDA (K$) 3,797,846	EEVs vs EBITDA 621.36	IUs vs EBITDA 606.81

Figure 5-10 Financial Metrics in the Natural Capital Report

5.6.2 Mitigation Hierarchy report

Reads performs cost-benefit analyses (CBAs) of environmental mitigation measures to calculate their effectiveness and the financial return on natural capital. In this manner, Reads assesses whether a measure is cost-effective by comparing the cost of the measure with the social cost of the environmental damage avoided by implementing the measure.

It is important to emphasize that this approach should always be considered within a framework of operational excellence, always going beyond legal compliance, and always ensuring maximum protection of human health and the environment.

For example, if two Best Available Techniques are compared in terms of their benefits to business and society (e.g., improved air quality by reducing NO_X emissions), the cost-benefit ratio indicates which is the best investment overall if several alternative measures give positive results, the measure with the highest environment and/or wellbeing result is the measure that gives the best overall value with lower investment.

To accomplish this, the Reads tool includes a module that acts as a financial simulator that identifies which measures are most effective and allowing financial parameters, such as discount rates, to be changed for NPV calculations. In addition, this module includes a set of KPIs and metrics designed to relate the impact on natural capital to the company's financial and productive balance sheets, and to justify project alternatives based on ALARP or NEBA principles. This approach makes it possible to understand the Return on Investment (ROI) of a company's expenditure on protecting natural capital.

Through Reads, environmental costs and benefits associated with environmental mitigation measures are incorporated into decision-making processes. A ROI calculation enables the assessment of both the financial and environmental (external) costs and benefits associated with environmental mitigation measures and the assessment of the efficiencies of mitigation measures.

To determine which mitigation measures are most effective, a cost effectiveness ratio is calculated considering the total benefits to natural capital (expressed in BIUs, EEVs and IUs) versus the total costs (expressed in USD). This ratio is NPV-adjusted.

Environmental and social costs and benefits are discounted using a social discount rate, which is typically lower than financial discount rates. When considering the risks/opportunities to the environment or society that also represent risks to the asset or the company, the longer-term interests of the public should be considered. The lower discount rate has the effect of giving greater recognition to the external costs and benefits farther into the future and to ensure that excessive devaluation of long-lived assets, such as ecosystems or public infrastructure, does not occur.

The choice of discount rate can have a significant effect on the viability of the mitigation measures. Social discount rates are typically set between 3% and 5% to account for the trade-offs between future and current wellbeing. For decisions involving ethical considerations, such as indigenous cultural considerations, extreme poverty, or severe environmental degradation, rates may be set as low as 0% or below 0%, while impacts with immediate negative wellbeing costs or those that may put a strain on current resources/capacities may range higher (de Groot *et al.* 2010, Potschin & Haines-Young 2016).

As previously indicated, the values of environmental impacts are calculated in the Reads tool in USD of 2018 (base year). The effective values of specific environmental services or environmental costs (e.g., the cost of each emitted tonne of pollutant) could remain constant throughout the project duration, but an impact in the future (e.g., in 20 years) will be expressed in present values (i.e., shall have a lower discounted value). In the Reads approach, a 3% discount rate is recommended to adjust future environmental values in alignment with current research and policy standards, such as “Discounting and the Treatment of Uncertainty in Natural Resource Damage Assessment” (NOAA 1999) and “The Green Book: Central Government Guidance on Appraisal and Evaluation” (HM Treasury 2018).

The ROI calculator in Reads provides the NPV of project benefits (project revenues minus project costs) and the present value of environmental impacts (EEV and IUs). Mitigation measures are included as project costs. Default discount rates of 3% (environment) and 10% (project) can be modified to run different monetary scenarios.

Several inputs are required to run the ROI calculator, including:

- Project/asset economics that include CAPEX, OPEX [k$], operating income [k$], and EBITDA [k$] of the project, broken down by year,
- Mitigation measure economics that include CAPEX and OPEX of the measure, broken down by year,
- Timeline defined for the project and for implementing the measure, and
- Mitigation measure effectiveness, which is the % reduction in impact after the measure has been implemented. The % reduction is applied over the life of the measure and different % reductions can be defined for each year. If a measure affects more than one impact, the tool allows for assignment of a different % to each impact.

ROI outputs produce metrics and KPIs to analyze cost effectiveness (simulated scenarios), such as:

- Baseline impact (EEVs and IUs), no measure in place,
- Projected measure cost (CAPEX+OPEX) in USD,
- Simulated impact reduction (EEVs and IUs), indicating total reduction over baseline,
- Simulated measure effectiveness (%), indicating % reduction over baseline, and
- Simulated return of investment (EEVs/USD or IUS/USD), indicating benefits to society (e.g., improved air quality, expressed in EEVs/IUs) vs. costs of the measure (e.g., installation of a BAT for NO_x abatement, expressed in USD).

All results are NPV-adjusted. Results can be run for a single measure or for a selected group of measures. The Reads tool enables comparisons of baseline, current, and future scenarios.

The results of applying mitigation measures (1) and not applying other measures (2) are indicated in Figure 5-11, a summary of the mitigation results from a simulation report generated by Reads. The potential for each mitigation measure under consideration can be understood via this functionality. These results include the efficiency or amount of impact reduced expressed as a percentage (3), the mitigation cost (4), the NPV of the mitigation cost (using the 10% economic investment discount rate) (5), and the amount of reduced impact units (6) and the mitigation efficiency (impact reduced per each 1,000 USD spent) (7).

		3	4	5	6	7
	Mitigation Measures	Effectiveness %	Expenditure (k$)	Expenditure NPV (k$)	IUs Saved (NPV)	IUs vs Expenditure (NPV)
	Simulated					
2	Offset Agricultural to Rainforest Habitat (GHG Capture)		3,015.00	2,259.07	220,168,689.03	97,460.01
	Offset Agricultural to Rainforest Habitat (ES Generation)		3,015.00	2,259.07	110,217,473.08	48,788.94
	Gas Recovery - Venting Mngt. Program (LNG Plant)	100.00 %	3,620.00	4,757.84	11,180,548.62	2,349.92
	Off Spec/ Excess gas - Flaring Mngt. Program (LNG Plant)	75.00 %	4,750.00	6,195.49	3,875,563.59	625.55
	Applied					
1	LDAR - Fugitives Mngt. Program (LNG Plant)	98.92 %	1,195.00	942.65	81,726,476.24	86,698.29
	Low-NOx Burners (LNG Plant)	74.00 %	1,575.00	2,061.27	65,458,651.37	31,756.47
	Bird flapper/ Diverter (Power Line - Section 1)	70.00 %	1,800.00	1,980.00	24,719,496.44	12,484.59
	Habitat Restoration (Power Line - Section 1)	65.35 %	90.00	84.34	13,126,667.19	155,648.15

Figure 5-11 Summary of results for mitigation measures in a Reads Simulation Report

The results for all applied and simulated mitigation measures are summarised in Figure 5-12.

The Reads tool allows the user to select one or several mitigation measures, the applicable period of time, and the output of the simulation (IUs or EEVs).

The Reads tool summarises the results by comparing the case without mitigation (baseline) with the case incorporating applied measures (current) and simulated mitigation measures that could be applied (simulation), as shown in Figure 5-13.

The accumulated impacts for each mitigation scenario, baseline, current, and simulated, are shown in Figure 5-14 and Figure 5-15. This output is interactive by allowing the incorporation of financial or operational parameters, and the comparison of impact units versus chosen metrics, which in this case are in millions of produced barrels.

5.6.3 Biodiversity indicator

Following the recommendations of the International Framework for Natural Capital Accounting (SEEA), the British Standards Institution (BSI) Natural Capital Accounting for Organisations (BS 8632:2021), and the Standard in Biodiversity Assessment and Valuation (Align), Reads proposes a complementary biodiversity indicator to the monetary valuation that is based on the knowledge of the extent and condition of ecosystems that are potentially affected by the activity under assessment. By enabling a better understanding of activity impacts (pressures on ecosystems biodiversity), this indicator enables improved decision-making to protect and enhance biodiversity.

Mitigation Measures	Effectiveness %	Expenditure (k$)	Expenditure NPV (k$)	IUs Saved (NPV)	IUs vs Expenditure (NPV)
⊞ Simulated	87.50 %	14,400.00	15,471.47	345,442,274.31	22,327.70
⊞ Applied	77.07 %	4,660.00	5,068.26	185,031,291.25	36,507.86

Figure 5-12 Total results of applied and simulated mitigation measures of a Reads Simulation Report

	Baseline	Current	Simulation
Impact IUs (NPV)	517,193,130	332,161,839	-13,280,436
	Current vs Baseline	Simulation vs Current	Simulation vs Baseline
Impact IUs saving (NPV)	185,031,291	345,442,274	530,473,566
	Current (k$)	Simulation (k$)	Total (k$)
Measures Investment (NPV)	5,068.26	15,471.47	20,539.73
	Current vs Baseline	Simulation vs Current	Simulation vs Baseline
Measures Efficiency (%)	35.78 %	104.00 %	102.57 %
	Current vs Baseline	Simulation vs Current	Simulation vs Baseline
Measures ROI (IUs vs k$)	36,507.86	22,327.70	25,826.71

Figure 5-13 Report results comparing mitigation: baseline (without), current (applied) and potential (simulated)

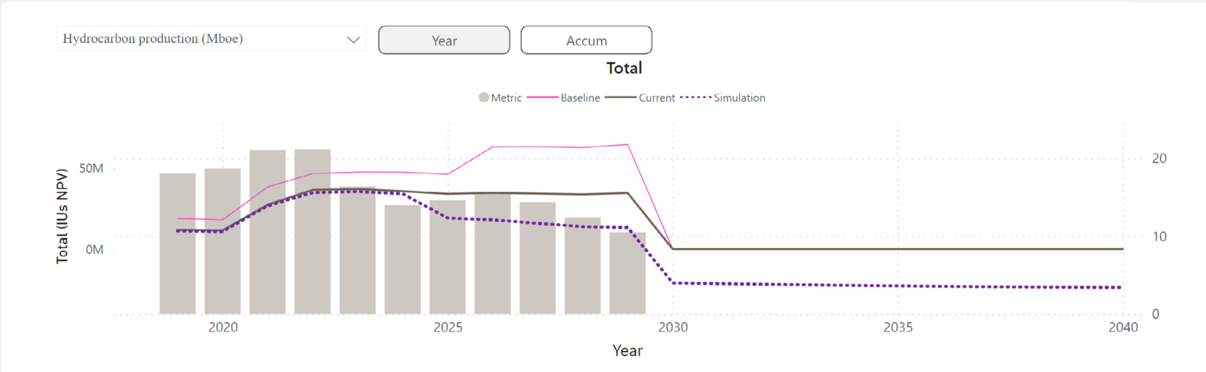

Figure 5-14 Interactive summary graph of accumulated impacts

Figure 5-15 Interactive summary graph of accumulated impacts by category

The biodiversity indicator is based on understanding changes in the ecosystems condition by assessing their capacity to provide ecosystem services. This approach assumes that the better the conservation status of an ecosystem, the greater its capacity to provide certain ecosystem services.

Several ecosystem services used in Reads have no or limited relationship with biodiversity (e.g., cultivated monospecific terrestrial plants grown for nutritional purposes). Consequently, these ecosystem services are not included in the biodiversity indicator since they are not considered representative of the ecosystems condition.

Biodiversity-related services considered in the biodiversity indicator are as follows:

- Wild plants (terrestrial and aquatic) for nutrition, materials, or energy
- Wild animals (terrestrial and aquatic) for nutrition, materials, or energy
- Genetic material from all biota (including seed, spore, or gamete production)
- Pollination (or gamete dispersal in a marine context) and seed dispersal
- Maintaining nursery populations and habitats (including gene pool protection)
- Pest and disease control
- Regulation of the chemical condition of waters by living processes
- Other biotic and abiotic characteristics that have a non-use value (considered in the definition of a cultural service)
- Regulation of soil quality
- Atmospheric composition and conditions

The biodiversity indicator measures the status of the ecosystems under consideration in terms of extent (area of influence) and condition (conservation status based on the capacity to provide biodiversity-related services), which are expressed in equivalent hectares (eq.ha) as follows:

- **Unit:** Equivalent Hectares (eq.ha)
- **Indicator:** Extension x Condition
  - **Extent:** Unit of area (hectares)
  - **Condition:** Capacity to provide certain Ecosystem services related to biodiversity at a given time expressed as a percentage
- **Formula:** Area (ha) x (Condition of the area / Baseline condition)

The indicator is calculated for a specific year (immediately prior to the assessment) and can be compared against the baseline condition or optimal site condition (pristine or best potential).

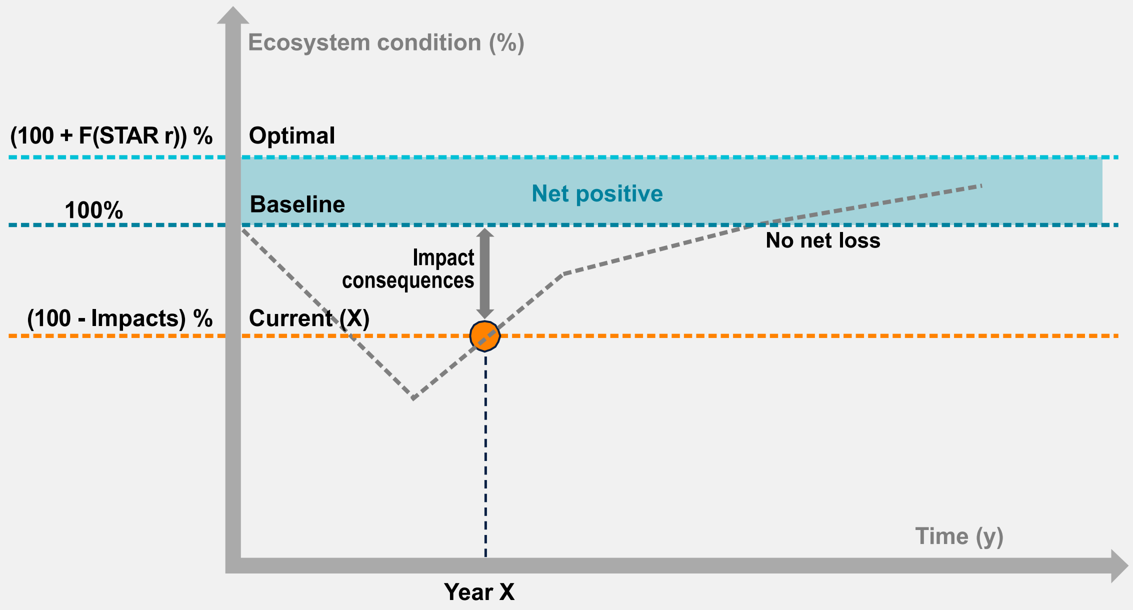

Figure 5-16 Optimal, Baseline (before project), and Current (during project) Ecosystem Condition

Extent

Reads considers an area of influence (AOI) defined as the surface across which impacts on local ecosystems are expected due to each project. The AOI includes land occupation as well as areas away from installations where effects above a threshold or damage level are expected (as those generated by noise, air emissions and wastewater discharges). The AOI is the overlap of all impact areas for all impact drivers. This area is project-specific and must be defined on a case-by-case basis.

It should be noted that one project may affect one or more ecosystems.

Ecosystem Condition

The Reads methodology assigns the baseline capacity to provide ecosystem services per hectare per year (USD/ha/year) based on the specific characteristics of the existing ecosystems in the project area. The proposed biodiversity indicator considers the ecosystems condition compared with the baseline and optimal (pristine) conditions, as illustrated in Figure 5-16.

Baseline: The initial (baseline) valuation of ecosystem services may be based on a review of available literature and/or specific surveys, among other sources. Once the baseline ecosystem services provision is calculated, the degradation (loss) and enhancement (gain) of ecosystem services due to project impacts are assessed while considering the implementation of the mitigation hierarchy: avoid-reduce-restore-offset.

Current: Reads values all predicted effects due to project impacts (pressures on ecosystems) -with or without implementation of mitigation measures- as changes in the provisioning capacity (loss/gain) of each affected ecosystem service, expressed in monetary terms (US dollars per hectare per year).

The baseline capacity (area of influence x baseline value of ecosystem services related to biodiversity) is reduced by the impact consequences during the year of assessment to define the current ecosystem capacity for a specific year (Year X). The change in ecosystem condition is expressed as a percentage: current condition divided by baseline condition multiplied by 100.

Optimal: The indicator is used to estimate the optimal capacity of an ecosystem (equal to or above baseline conditions). This optimal level is used as a reference to indicate whether the restoration of disturbed sites can be enhanced to reach ecological conditions above the baseline. Some project developments are planned in previously disturbed areas or areas with existing pressures or liabilities. A good restoration practice requires that disturbed sites are restored to baseline conditions or better. The optimal ecosystem condition is expressed as a percentage above the baseline and can be estimated using the threat or restore potential (i.e., applying the $STAR_R$ index).

The optimal condition can be defined based on ecological conditions, e.g., climate, soil, geographical region, net primary production, and ocean chemical and physical conditions. The provision of ecosystem services in the optimal condition could be obtained from existing valuation studies at locations with the same ecosystem type (biome) and the same ecological limiting factors.

To estimate the optimal condition, an alternative would be to use the ecosystem restoration potential based on the $STAR_R$ index.

The scientific basis for STAR is established by Mair *et al.* (2021). The metric bases its scores on data obtained from the IUCN Red List of Threatened Species. Further research is underway to extend the application of STAR to aquatic environments, to account for threats embodied in international trade, and to harness National Red List data for nationally threatened species. The STAR metric is available through the Integrated Biodiversity Assessment Tool (IBAT), a partnership of IUCN, BirdLife International, Conservation International, and UNEP-WCMC. The STAR metric is maintained under the authority of the IUCN Red List Committee.

Understood to represent the potential for a site to be restored, $STAR_R$ is a reasonable proxy for assessing how far the baseline condition is from the optimal ecosystem condition. The $STAR_R$ score sets values from 0 to 1000 as shown in Table 5-6.

The baseline condition of a location with a very low $STAR_R$ score should be considered optimal, that with a very high $STAR_R$ score is far from optimal, and the

Table 5-6 Relationship between $STAR_R$ scores and degree of restoration required

$STAR_R$ (score 0-1000)		Restoration required to obtain an Optimal Ecosystem
Very Low	0 - <0.1	Very Low
Low	0.1 - <1	Low
Medium	1 - <10	Medium
High	10 - <100	High
Very High	100 - 1,000	Very High

values of the ecosystem services between baseline and optimal could be increased more than 15 times (current location values should be multiplied by 15 to estimate the optimal ecosystem condition).

The escalation factor per biome and STAR$_R$ category (very low to very high) is calculated as the ratio between the percentile 10 value in the TEEB valuation database (TEEB 2012) and central value of each category (p30, p50, p70 and p90), as shown in Table 5-7.

Application to a case study

A new project development in a greenfield area of temperate forest will generate the following three (3) main impacts quantified for Year X of operations:

- Land occupation generating full reduction of all ecosystem services across 10ha.
- Noise generation affecting fauna within 40ha with a potential 25% reduction of the affected services (only wild animals and habitat maintenance services affected).
- Air emissions affecting all ecosystem services with 5% reduction of ecosystem services.

All ecosystem services in the baseline condition will generate a value of 1,750 USD/ha/year.

The AOI covers 100ha, of which 10ha comprise the occupied site and 90ha are affected by air emissions.

The Impact valuation process is outlined in Table 5-8 with the services present in the study area, their values, and the valuation of the impact consequences.

The baseline value of the 100ha corresponds to 175,000 USD.

During the year of assessment (Year X), the project impacts will reduce the overall value to 141,625 USD, representing 80.93% of baseline conditions (or a decrease in the baseline by 19.07%).

In this case, the biodiversity indicator for Year X would be -19.07 eq.ha, representing the gap between current conditions (due to the project) and the baseline condition (no net loss target).

It should be noted that if one or more impacts affect two or more ecosystems, the index shall be calculated independently for each ecosystem, expressing the impact/benefit balance for each ecosystem in eq.ha.

If the STAR$_R$ score for a temperate forest (in this case) is 5 (Medium restoration potential), the Reads methodology assumes that the optimal ecosystem condition could be 2.36 times the baseline condition. This escalation factor is defined as the difference between the baseline value and the percentile 90 (assumed as a

Table 5-7 Escalation factors to estimate ES provisioning capacity of the optimal ecosystem based on STAR$_R$ scores

Equivalence between TEEB 2012 and Reads Biomes		Escalation Factor (based on STAR$_R$ score)				
Biomes TEEB 2012	Biomes Reads	VL	L	M	H	VH
Oceans	Oceans	1.00	1.57	2.31	3.42	5.58
Coral reefs	Coral reefs	1.00	1.52	2.19	3.43	7.65
Costal systems	Coastal areas/Continental shelf sea Seagrass/Algae beds	1.00	1.08	1.14	1.18	1.22
Coastal wetlands	Estuaries Mangroves	1.00	1.59	2.61	5.15	15.27
Inland wetlands	Shrub and/or herbaceous vegetation, aquatic or regularly flooded	1.00	1.48	2.10	3.07	5.93
Fresh water lakes and Rivers	Inland waterbodies	1.00	1.20	1.41	1.70	2.26
Tropical forests	Tropical and subtropical forest	1.00	1.49	2.03	2.95	4.50
Temperate and boreal forest	Temperate boreal and Mediterranean forest	1.00	1.60	2.36	3.84	8.16
Woodlands	Shrub-covered areas Sparsely natural vegetated areas Terrestrial barren land	1.00	1.09	1.15	1.20	1.26
Grasslands	Grassland Tundra	1.00				
—	Artificial surfaces	1.00	1.00	1.00	1.00	1.00
—	Crops	1.00	1.00	1.00	1.00	1.00
—	Permanent snow and glaciers	1.00	1.00	1.00	1.00	1.00

proxy for optimal ecosystem condition) of the available valuation data for Temperate Forest in the TEEB valuation database. Consequently, the optimal ecosystem value would be 236% of the baseline value.

The potential for restoration in this example would be 155.07 eq.ha, representing the maximum potential gains if restoration achieves the optimal condition.

In this example, the project could achieve No Net Loss through project offsetting that provides a gain of 19.07 eq.ha (measured following the same approach as that followed to measure negative impacts) or by exceeding the required compensation to be Net Positive.

The $STAR_R$ score indicates that the project area might offer offsetting opportunities, not only through restoration of degraded habitat but also protecting endangered species. Offsets should be defined to maximize the benefits on biodiversity in the AOI or on other biodiversity features within the same project landscape / seascape following the offsetting principles defined in Section 5.4.4.3 and the “like for better” approach.

Table 5-8 Impact valuation of a new project in a greenfield area: Case study

	Ha	Damage	Wild plants	Wild animals	Pollination	Habitats/ Gene Pool	Soil regulation	Atmospheric conditions	**Total Impacts**
Ecosystem Services Values (**USD/ha/y**)			200	150	180	650	70	500	**1,750**
Impact 1: Occupied site	10	100%	2,000	1,500	1800	6,500	700	5,000	**17,500**
Impact 2: Noise	40	25%		1,500		6,500			**8,000**
Impact 3: Air emissions	90	5%	900	675	810	2,925	315	2,250	**7,875**
									33,375

Value per 1 ha	**1,750**
Value per 100 ha	**175,000**

Baseline:	**175,000**	100.00%
Reduction due to impacts:	**33,375**	**19.07%**
Value in year X:	**141,625**	80.93%

Indicator (Eq ha) -19.07

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