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# Perceived impacts of onshore wind power parks on ecosystem services in the High North: an EDA and sentiment analysis

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**ABSTRACT**

Despite the increasing popularity of wind power farms this kind of energy production has been contested, citing cultural, economic, and sometimes even environmental reasons – especially when such power farms are built in areas of significant environmental value and status, as is the case of several areas in the High North. One way to explore this conflict is through understanding the effects of such projects on local ecosystem services (e/s) – i.e., the direct and indirect benefits that ecosystems provide to support and sustain human livelihoods. This article discusses the perceived consequences on e/s after the development of a wind power farm in a Northern Norwegian context (High North), at the area of Kvitfjell/Raudfjell on the island of Kvaløya. Following a mixed-methods approach, combining exploratory data analysis (EDA) with thematic and sentiment analysis, the article presents a recent survey among various actors and stakeholders in the examined area to explore how they perceived the effects of the newly constructed wind power farm on e/s. Our results illustrate that a significant portion of the respondents maintained a critical and even apprehensive attitude on the wind farm development, although some positive economic impacts to the local community were also acknowledged.

## Introduction

The development of wind power farms has gained increasing popularity over the last years since it has been typically being promoted as an efficient solution to green power generation, capable of supplementing local grids, or in the case of larger farms in supporting national and international electricity markets. In many cases however, and especially in onshore wind farm deployments, this kind of energy production has been contested, citing cultural, economic, and sometimes even environmental reasons – especially when such power farms encroach in areas with particular environmental characteristics and status, as is the case of several areas in the High North[1].

[1] The High North includes Arctic and sub-Arctic regions that are not only characterized by unique environmental conditions, but also hold significant geopolitical, economic, and environmental importance due to natural resources, strategic location, and vulnerability to climate change.

A useful tool to explore the effect of wind power farm development on society is through the lens of ecosystem services (e/s) – i.e., the direct and indirect benefits that ecosystems provide to support and sustain human livelihoods. The term e/s typically includes four categories: provisioning, regulating, supporting, and cultural services. Provisioning services relate to all the material or energy outputs from an ecosystem (including food, forage, fiber, fresh water, and other resources). Regulating services are the benefits obtained through moderation or control of ecosystem processes (including regulation of local climate, air, or soil quality; carbon sequestration; flood, erosion, or disease control; and pollination). Supporting services help maintain fundamental ecosystem processes (e.g., habitat for plants and wildlife, or the maintenance of genetic and biological diversity). Finally, cultural services are all the non-material benefits that ecosystems provide to human societies and culture, (including opportunities for recreation, tourism, aesthetic or artistic appreciation, and spirituality).

This article discusses the perceived consequences on e/s after the development of a wind power farm in a north Norwegian context (High North). The area being investigated is in the Kvitfjell/Raudfjell on the island of Kvaløya that is part of the Tromsø municipality, located in Troms and Finnmark County in north Norway. The article presents a recent survey among various actors and stakeholders from the examined area to explore how they perceived the effects of the newly constructed wind power farm on e/s. Our results illustrate that a significant majority of respondents maintained a critical and even apprehensive attitude on the wind farm development, although some positive economic impacts to the local community were also acknowledged.

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## Study area and context

Located near Tromsø in northern Norway (Figure 1), the onshore wind power project in Kvitfjell/Raudfjell exemplifies the collaborative efforts between public and private sectors to drive forward the transition towards renewable energy sources. The authorization for the Kvitfjell Wind Farm’s development was granted in 2001, while the final concession for Raudfjell Wind Farm was approved by the Oil and Energy Ministry of Norway in 2015. It was Prime Capital AG, a German infrastructure developer company that had acquired the two companies, Tromsø Vind AS and Raudfjell Vind AS, that were the initial owners of the Kvitfjell and Raudfjell wind power projects, collectively known at the time as Project Northern Lights. The project reached financial close in October 2017 and stood as the largest onshore renewable energy endeavor in Europe at the time.

There was notably an amendment to the concessions, entailing a modification of the access route to the project site that was resolved through consultation with local stakeholders, including Norwegian Water Resources and Energy Directorate, and the Ministry of Oil and Energy. The development of the wind farm, specifically the construction of internal roads within the facility, commenced in October 2017 and turbine transportation started in July 2019. The first deployment tests of the wind farm started in 2020 and it has been operational since 2021.

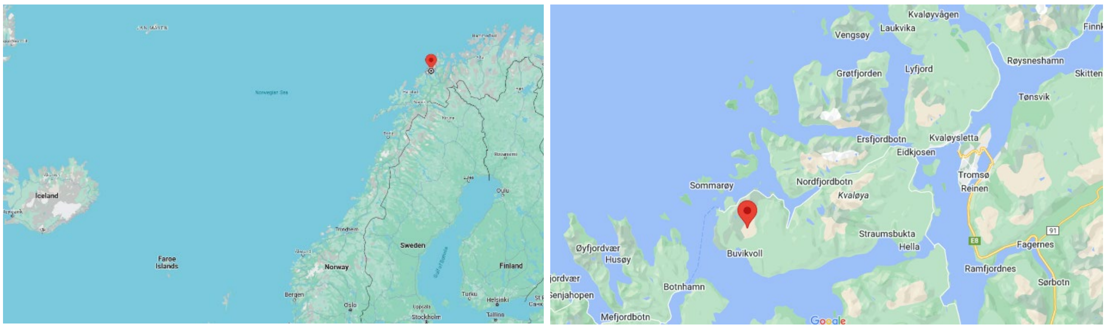


Figure 1. Kvitfjell/Raudfjell wind power farms (Source: Google maps)

The Kvitfjell and Raudfjell wind farm collectively generates approximately 780 GWh of electricity annually, equivalent to the power consumption of approximately 48 000 households per year. Comprising 67 Siemens Gamesa turbines, each with a total height of 150 meters, a rotor diameter of 130 meter and boasting a 4.3 MW installed capacity, the wind farm operates under a long-term maintenance agreement with Siemens Gamesa Renewable Energy. Accessible via a 55 km network of gravel roads, the wind farm is linked to Arva AS's 132 kV grid. The turbines were placed in ways that allow accessibility to the region, with newly constructed roads facilitating pedestrian, cycling, and skiing activities – although, the access road remains closed off with a barrier, and the secondary roads are not plowed during winter months.

After the deployment of the wind farm, reindeer herding remains active in the area while designated trails and ski tracks are still maintained. In periods of inclement weather conditions visitors are urged to exercise particularly caution since snow and ice may pose hazards from turbine blades or other structures, while several safety signage is in place since maintaining a safe distance from turbines is essential to mitigate risks associated with turbine operations.

It is worth noting that the wind farm deployment, especially when it comes to onshore sites, has received a significant amount of criticism in Norway. The skepticism usually relates to cultural, spiritual, and aesthetic values that can relate to the site. In many cases it also has to do with usage rights – e.g., several mountain areas in north Norway have been used by the Sami as winter grazing areas for reindeers.

**The Interplay between (onshore) wind power and ecosystem services**

The expansion of wind farms to onshore sites can be a good solution in mitigating climate change and helping with the transition towards sustainable energy systems (Ortega-Izquierdo and del Rio, 2020). However, it has also faced concerns about its potential impacts on ecosystem services (e/s) and therefore on its effects on human well-being and ecosystem functioning (Wang and Wang, 2015), especially when considering mountains regions that can typically favor more complex interactions among e/s (Mengist *et al.*, 2020b).

Ecosystem services play a critical role in supporting human well-being and socio-economic development, while they also reflect all the benefits that humans obtain from ecosystems, ranging from the provision of clean water to the regulation of climate (Daily, 1997). They are typically classified into four main categories: provisioning, regulating, cultural, and supporting services. Provisioning services include the tangible benefits that ecosystems provide, typically those that are essential for meeting basic human needs and ensuring food security (Millennium Ecosystem

Assessment, 2005; Poppy *et al.*, 2014) – e.g., food, feed, water, and raw materials. Regulating services encompass the regulation of environmental processes and help to mitigate natural disasters and enhance resilience to environmental changes (Millennium Ecosystem Assessment, 2005; Mengist *et al.*, 2020), including dimensions on climate regulation, flood control, water purification, and disease regulation. Cultural services refer to the non-material benefits that humans derive from ecosystems and contribute to human health and quality of life by providing recreational opportunities, spiritual values, and cultural identity [Daniel *et al.*, 2012; Chan *et al.*, 2012). Finally, supporting services are those that are fundamental to the production of all other ecosystem services; they help maintain the ecological processes that underpin all other ecosystem services, ensuring the continued provision of benefits to society - e.g., including soil formation, nutrient cycling, and primary production (Daily and Matson, 2009).

Overall, e/s cover a plethora of dimensions that relate to different element of human well-being and therefore their assessment requires a combination of biophysical, economic, and social methods in order to capture and valuate the full range of benefits and values provided by the ecosystems. Biophysical assessments involve measuring and quantifying ecosystem structures and functions, such as carbon sequestration rates or water filtration capacity (de Groot *et al.*, 2010). Economic valuation methods, such as contingent valuation and hedonic pricing, assign monetary values to ecosystem services based on people's willingness to pay or willingness to accept compensation for changes in ecosystem conditions (Costanza *et al.*, 1997). Social assessments involve stakeholder engagement and participatory approaches to understand the cultural and social dimensions of ecosystem services, including indigenous and local knowledge systems (Pascual *et al.*, 2014).

There have been many studies that identified both perceived and actual impacts of onshore wind farm deployment. For example, the study by BiGGAR Economics (2012) discussed the economic effects of onshore wind deployment at local, regional, and national levels, along with projections on potential impacts. Another study by Regeneris Consulting (2014) examines the economic implications of wind farm development on the visitor economy, focusing on local impact areas and factors influencing visitor reactions to wind farms in Wales. Jensen *et al.* (2018) analyzed the impact of onshore and offshore wind turbines on property prices for nearby single-family homes. Sargsyan (2019) investigated the methodological differences in economic analysis of wind power projects, highlighting the external impacts of wind farms on landscape quality, wildlife, and air quality, where the results show varying welfare effects based on the type of wind farm.

The main concerns on the effects of wind power farms to e/s typically concentrate on issues of biodiversity, carbon sequestration and climate regulation, water resource management, and the impact on recreational and cultural values, although there has been an increasing focus on wildlife impacts (Bispo *et al.*, 2019). When it comes to biodiversity, onshore wind farms have the potential to modify local biodiversity patterns due to different kinds of disturbance and habitat fragmentation, although well-planned wind farm siting can minimize the negative impacts while enhance certain ecosystem services (Bennun *et al.*, 2021). Onshore wind power farms can also play a significant role in mitigating climate change by reducing greenhouse gas emissions associated with electricity generation (BMU, 2008). Moreover, these installations can coexist with ecosystems that sequester carbon, such as forests and grasslands, thereby contributing to climate regulation. Provisioning services may also be affected by land-use changes associated with wind farm development (Armstrong *et al.*, 2014), while regulating services, including climate regulation and pollination, may experience disruptions due to changes in land cover and microclimatic conditions induced by wind farms (Tosh *et al.*, 2014; Wang *et al.*, 2015). On the other hand, supporting services, which support fundamental ecosystem functioning, may also be subject to disturbances from construction activities and habitat fragmentation (Scholl and Nopp-Mayr, 2021). Additionally, the cultural significance of landscapes may be compromised by visual and noise disturbances caused by wind turbines, impacting recreational and aesthetic values (Devine-Wright and Howes, 2010).

Understanding these interlinkages is essential for devising effective strategies to mitigate negative impacts and enhance synergies between onshore wind power and ecosystem services as well as in identifying proper ways to address these shortcomings. For instance, landscape planning approaches integrating ecosystem service considerations can optimize wind farm siting to minimize adverse effects on biodiversity and ecosystem functions (Pozoukidou *et al.*, 2021), while stakeholder engagement and participatory approaches are essential for fostering social acceptance and addressing local concerns regarding wind power development (Giordono *et al.*, 2018).

It is worth noting that despite growing research interest, several knowledge gaps persist in comprehensively assessing the ecosystem service implications of onshore wind power. Further development of standardized methodologies for assessing e/s impacts across spatial and temporal scales is crucial in facilitating comparative analyses and informed decision-making (Haines-Young and Potschin, 2018). Furthermore, there is limited research exploring the cumulative effects of multiple wind farms on ecosystem services, especially in ecologically sensitive regions (Drewitt and Langston, 2006). Overall, the interplay between onshore wind power and e/s underscores the need for holistic and interdisciplinary approaches to sustainable energy planning and management. By integrating ecosystem service considerations into policy formulation and project implementation, stakeholders can synergistically harness the benefits of renewable energy while safeguarding vital ecosystem functions and services. This article specifically addresses that inquiry.

**Data collection**

The distribution of an online survey to local stakeholders proved to be a fruitful endeavor, yielding valuable insights and feedback. The survey was conducted in the winter of 2023, where a common hyperlink was distributed among the participants that directed them to the survey website. While the initial intend was to have a random and diverse sample of local stakeholders, time and budget considerations necessitated a shift towards purposeful sampling, although every effort was made to still involve a diverse group of local stakeholders.

The online survey commenced with 77 potential participants, out of which 51 successfully completed it. Consequently, the ensuing findings and perspectives pertain to those who completed the survey (n=51). Beyond the numerical data, the comments section emerged as a particularly rich source of information, providing nuanced perspectives and detailed feedback on various aspects of the survey's topics. These insights offer a deeper understanding of the stakeholders' concerns, preferences, and suggestions, enriching our understanding of their needs and priorities.

The questionnaire and all related communication were in Norwegian. After receiving the responses, the authors translated the questions and the additional commends in English. At the beginning the questionnaire had a short introduction describing the project goals and the concept of ecosystem services. The following sections addressed participants' background and knowledge of the area, and participants were encouraged to share more details if they deemed to be helpful. Then the two main sections of the questionnaire followed, where the survey utilized a Likert scale to measure respondents' attitudes and opinions with respect to ecosystem services in the region – before the deployment of the wind power farm and then the effects of its establishment.

There can be several different ways to incorporate e/s in a questionnaire, with the primary objective in this instance being the creation of a survey instrument that would be simple to understand - even for respondents who were never exposed to the concept of e/s and have a streamlined structure that would facilitate swift responses. Therefore, the selection of ecosystem services that were included in the questionnaire was informed by desk research and pre-survey consultation with local experts in the research project team. The result was 16 ecosystem services covering the four main categories of provisioning, regulating, supporting, and cultural. The online questionnaire concluded with questions on personal impacts and in addition invited participants to suggest other possible effects and in general provide any comments.

In analyzing the responses, patterns and themes began to emerge from the comments sections, shedding light on key issues and areas of interest within the community. These insights serve to inform decision-making processes, guiding future strategies and initiatives aimed at addressing the identified concerns. Additionally, the qualitative nature of the comments allows for a more nuanced interpretation of the data, providing context and depth to the quantitative findings. This is particularly evident on the sentiment analysis part of the article that provides deep insights on how respondents answered and approached the questionnaire. This holistic approach to data analysis ensures a comprehensive understanding of the stakeholders' perspectives, enabling more informed and effective decision-making.

**Integrated Insights: Combining Quantitative and Qualitative Findings**

All questions had two parts – one where the respondents were asked to grade different pre-given options on a Likert scale, and another, optional, part where they could write – either commenting on the options and providing their own or providing other insights that they deemed to be relevant for the question. This section presents the combined answers for each question, thus reflecting a mixed methods approach, where quantitative and qualitative aspects of an issue are explored.

*Addressing respondents' roles and knowledge of the study area*

All responses (n=51) that were received were part of the analysis since in all cases respondents completed the questionnaire process. With regards to their connection to the area, respondents were allowed to self-identify in various ways and had the option to choose several categories. Hikers, hunters/fishermen, and residents were the top three categories with 66%, 46%, and 46% positive responses accordingly. Berry pickers followed with 38% and then landowners with 28% and local administrators with 14%. Others received much smaller percentages (Figure 2).

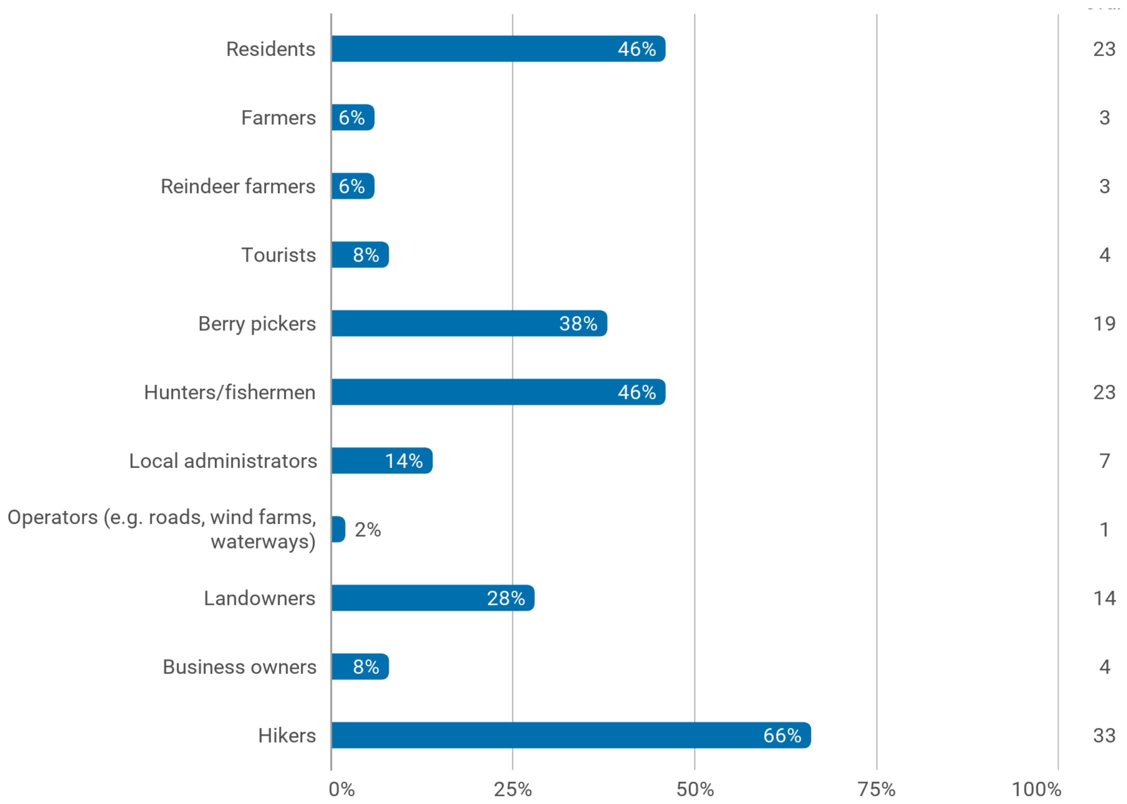


Figure 2. Connection of respondents to the area.

The question further allowed for optional comments and a small portion of respondents (9) identified themselves on their own as long-term residents and neighbors in the area, people who like to use the area for hiking or biking, local businesspeople, as well as people working in local public institutions and administrative support personnel.

When asked to report on their familiarity with the Kvitfjell/Raudfjell area on a scale of 1 – 7, where 1 signified no familiarity while 7 was very high familiarity, the vast majority reported an overall very high knowledge with the area (Figure 3).

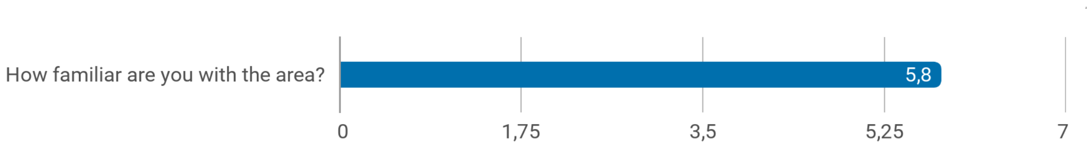


Figure 3. Overall familiarity with the Kvitfjell/Raudfjell area.

Again, the question further allowed for optional comments and 69% (35) of the respondents identified themselves on their own as long-term residents and neighbors in the area, people who like to use the area for hiking or biking, local businesspeople, as well as people working in local public institutions and administrative support personnel.

*Exploring respondents' e/s perceptions and potential impacts from Kvitfjell/Raudfjell wind farm deployment*

Respondents were asked to identify the importance of various e/s through the question "To what extent do you think the area is important for the following ecosystem services?". The pre-selected list of e/s was provided, and they had to choose from a 1 – 7 Likert scale, where 1 was "very unimportant", and 7 was "very important". The provided list of e/s was randomly changing each time and respondents were also given the opportunity to select "Don't know" if they wished. In overall, biodiversity, recreation, fresh waters, water regulation, and aesthetic values were among the top choices. Services such as tourism, education, climate regulation, erosion, and energy followed, while less identified e/s included medicinal services, spiritual value, and fiber/timber production (Figure 4).

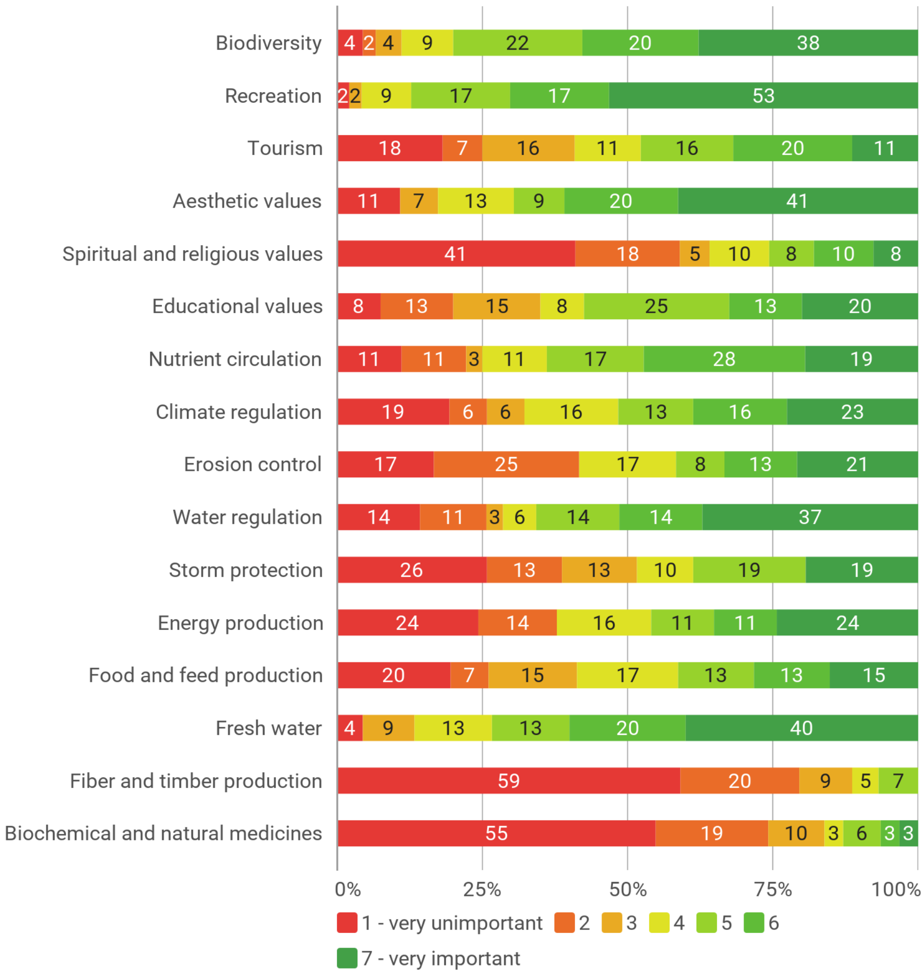


Figure 4. Perceived importance of the Kvitfjell/Raudfjell area for selected ecosystem services.

Likewise, respondents were allowed to provide additional e/s that they thought could be relevant for the case and they were either missing from the pre-selected e/s list or they felt there should receive more attention. In total, 8% (4) provided additional inputs, ranging from clarification on usage of the area as a mostly grazing land and a place popular for hiking and biking. One of the respondents specifically commented on the high value of freshwater services relating to the lake Elvedalsvatnet and its catchment area, which includes parts of the wind farm area, and is essential for the water supply in the Sommarøy/Brensholmen villages.

The development of the Kvitfjell/Raudfjell wind farm had received a lot of attention in the local media and among several stakeholders, so it was not a surprise that many of the respondents reported good knowledge on the case (Figure 5).

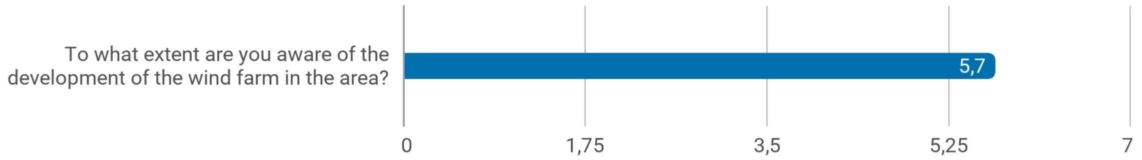


Figure 5. Knowledge on the Kvitfjell/Raudfjell wind farm deployment.

The next question directly explored the perceived impact of the Kvitfjell/Raudfjell wind farm deployment on the e/s, through the question "To what extent have the following ecosystem services been impacted by the establishment of the wind farm?". Not surprisingly, the responses reflect on the question prior to the last one, where certain e/s were identified as more important than others. Those e/s were now acknowledged as particularly negatively affected – e.g., biodiversity, aesthetics, recreation (Figure 6).

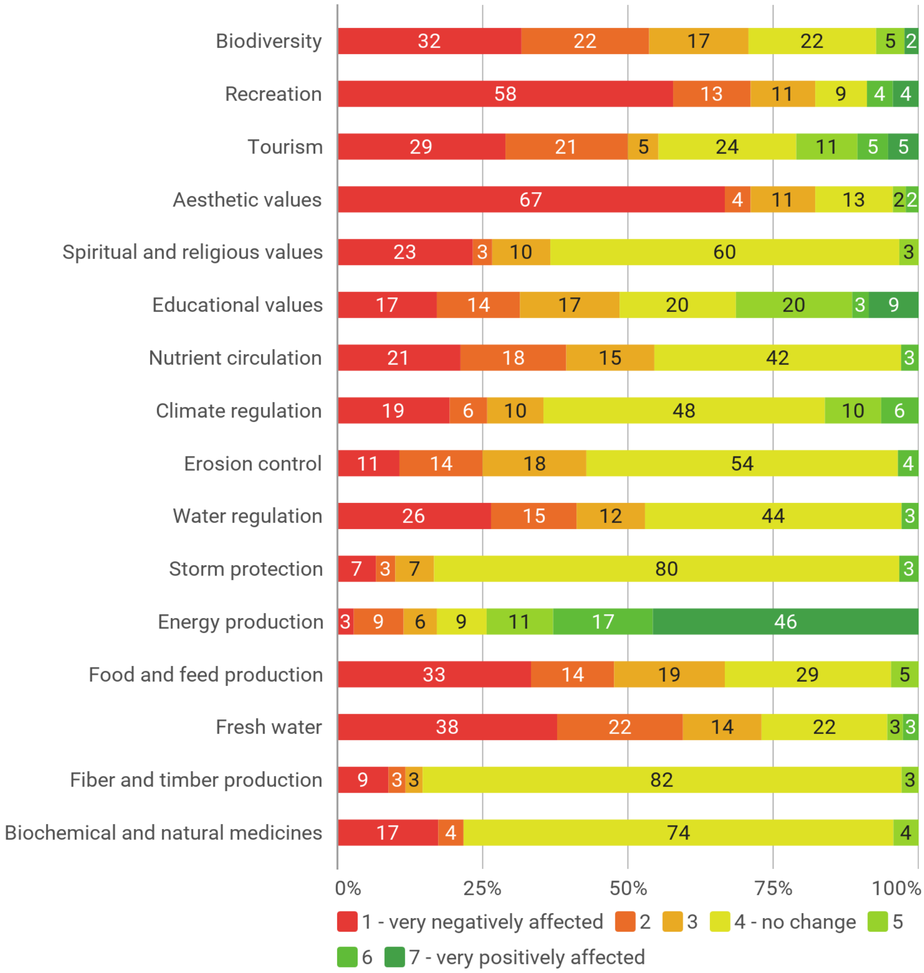


Figure 6. Perceived impact of Kvitfjell/Raudfjell wind farm development to e/s in the area.

*Potential personal impacts of the Kvitfjell/Raudfjell wind farm deployment*

The last question explored the direct impact of the Kvitfjell/Raudfjell wind farm development on individuals, by asking “To what extent are you directly affected by the development of the wind farm?”. The answers again were on a 1 – 7 Likert scale, where 1 was “Very negatively affected”, 4 was “not affected”, and 7 was “very positively affected”. The answers overall follow the already established pattern, where recreational dimensions are negatively affected, while on the other hand professional and business operations show to have mostly no effect (Figure 7).

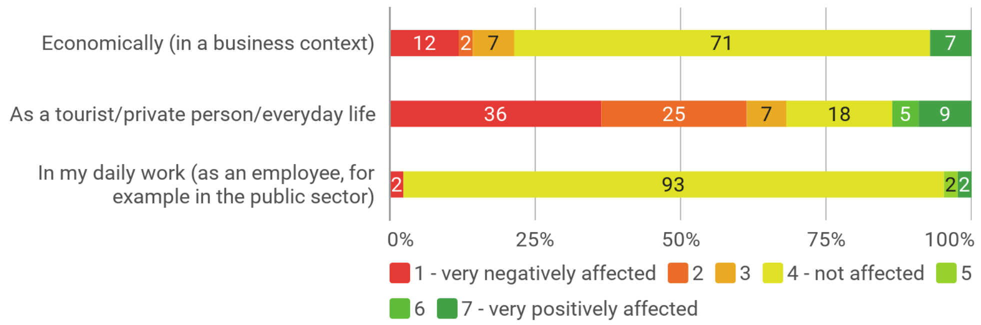


Figure 7. Perceived direct effects of the Kvitfjell/Raudfjell wind farm development.

*Qualitative insights*

There were in addition four more sections, spread throughout the questionnaire, where respondents were given the opportunity to not just choose an option on the Likert scale, but also provide their own insights in text. It was not obligatory to provide written material and thus the response rate greatly varied. The first, second, and fourth of these sections received relatively small attention from respondents: the first section was under the question "To what extent have the following ecosystem services been affected by the establishment of the wind farm?" where were in total only 14% (7) contributed with additional text, while the second section was under the question "To what extent are you directly affected as a business operator, private individual, or in other work by the development of the wind farm in Kvitfjell Raudfjell on Kvaløya in Tromsø municipality?", were respondents' written contribution was even less – only 10% (5). The fourth section was at the end of the questionnaire where respondents were given one last opportunity to write how they perceived the Kvitfjell/Raudfjell wind farm deployment in the region and provide any last additional feedback. There were no further instructions in this section, so it was up to them to choose if they would focus on e/s impacts or follow a different angle – e.g., economic impacts, societal, etc., if they chose to answer. There were 16% (8) respondents that contributed to this section, sometimes with additional insights on the perceived potential impacts and other times with comments on the general characteristics of the study area. The relatively small size of respondents in these three sections restricted the possibilities for any statistical analysis to avoid issues like overfitting and poor generalization. However, the thematic analysis of these responses shows that overall, most of the respondents commented that the development of the Kvitfjell/Raudfjell wind farm had mainly negative effects – most notably, noise and shadow casting, although some of the respondents registered with a rather positive view – e.g., the wind farm eliminates the necessity for heavy reliance on polluting diesel generators. Some of the comments relate to the perceived effects focusing on possible contamination issues (water supply) and adverse effects to local animal husbandry (reindeer). Several respondents wrote that hiking has been significantly affected due to increased traffic, noise, shadow casting, and the area had overall withered. Concerns also included biodiversity issues, specifically avian life in the area, as well as land and water issues (landscape), while some of the respondents also expressed concerns on issues of pollution (oil and plastic).

It was the third section of the qualitative part though that received significantly more feedback - 76% (39) of the respondents provided additional text, following the question "Can you imagine other possible challenges and opportunities that arise between ecosystem services in the area and the establishment of the wind farm?". The high participation on this section may relate to its positioning in the questionnaire (roughly at the middle) or the framing and type of this question that naturally generates prompts. Due to the larger number of respondents the approach in analyzing this question was expanded to include sentiment analysis - an AI technique that involves using natural language processing (NLP), text analysis, and computational linguistics to identify and extract subjective information from text. This technique is commonly used to determine the sentiment expressed in a piece of text, such as whether it is positive, negative, or neutral (Das *et al.*, 2023).

Although there is no one-size-fits-all approach in determining a sample size in sentiment analysis, aiming for larger labeled examples is a good starting point, with more data typically leading to better performance, especially for complex or nuanced sentiment analysis tasks. In this case the analysis employed a Lexicon-Based Approach (VADER), based on predefined lists of words associated with positive or negative sentiments. This method can work with smaller datasets, although their accuracy may be limited by the comprehensiveness and applicability of the lexicon to the specific application domain.

For each response the sentiment analysis calculated four scores: positive score (ranging from 0 to 1) indicates the proportion of the text that contains positive sentiment -i.e., a higher positive score means the text has a stronger positive sentiment; negative score (ranging from 0 to 1) indicates the proportion of the text that contains negative sentiment -i.e., a higher negative score means the text has a stronger negative sentiment; neutral score (ranging from 0 to 1) indicates the proportion of the text that is neutral, meaning it doesn't convey a strong positive or negative sentiment – i.e., a higher neutral score means a larger portion of the text is neutral; compound score (ranging from -1 to 1) is a normalized, weighted composite score that combines the positive, negative, and neutral scores into a single value: negative values indicate overall negative sentiment (closer to -1 means more negative), positive values indicate overall positive sentiment (closer to +1 means more positive), and near zero values close to 0 indicate a more neutral or mixed sentiment.

The answers defined the examined corpus that was preprocessed – an approach that applied a series of routines to the corpus, including transformation (apply lowercase transformations), tokenization (a method of breaking the text into smaller components), normalization (apply stemming and lemmatization to words), filtering (to remove or keep certain words), N-grams Range (creates n-grams from tokens), and POS Tagger (runs part-of-speech tagging on tokens). The first result was a Word Cloud, displaying tokens in the corpus, their size denoting the word frequency (Figure 8).


Figure 8. Word cloud after preprocessing corpus.

The next stage was the actual sentiment analysis (VADER) to predict the sentiment for each document in the corpus – in this case, each answer counts as a different document. This approach relied on the lexicon-and rule-based Vader sentiment modules from NLTK (Hutto and Gilbert, 2014), where each case received four scores: positive, negative, neutral, compound (Table 1).

The results were merged by k-means (i.e., merge documents with the same polarity into one line) and clustered by rows to create a clustered visualization where similar documents are grouped together. Thus, ensuing to a heat map with the compound score for each clustering (Figure 9). The map clearly shows the widespread neutral scores that have a significant effect on the calculation of the compound scores.

| Document | positive | negative | neutral | compound |
|---|---|---|---|---|
| **1** | 0 | 0.151 | 0.849 | -0.4943 |
| **2** | 0 | 0.692 | 0.308 | -0.6705 |
| **3** | 0.051 | 0 | 0.949 | 0.25 |
| **4** | 0.024 | 0.053 | 0.924 | -0.3867 |
| **5** | 0 | 0 | 1 | 0 |
| **6** | 0.098 | 0.413 | 0.489 | -0.7783 |
| **7** | 0 | 0.086 | 0.914 | -0.5574 |
| **8** | 0.257 | 0.128 | 0.615 | 0.3182 |
| **9** | 0.132 | 0.021 | 0.847 | 0.7178 |
| **10** | 0.176 | 0.088 | 0.735 | 0.4215 |
| **11** | 0 | 0.214 | 0.786 | -0.7845 |
| **12** | 0 | 0 | 1 | 0 |
| **13** | 0 | 0 | 1 | 0 |
| **14** | 0.025 | 0.063 | 0.912 | -0.4019 |
| **15** | 0.387 | 0 | 0.613 | 0.802 |
| **16** | 0 | 0 | 1 | 0 |
| **17** | 0 | 0.078 | 0.922 | -0.1531 |
| **18** | 0 | 0.21 | 0.79 | -0.6204 |
| **19** | 0 | 0.141 | 0.859 | -0.4215 |
| **20** | 0 | 0.552 | 0.448 | -0.5719 |
| **21** | 0.052 | 0.06 | 0.888 | -0.0772 |
| **22** | 0 | 0.148 | 0.852 | -0.3818 |
| **23** | 0 | 0 | 1 | 0 |
| **24** | 0 | 0 | 1 | 0 |
| **25** | 0.089 | 0.066 | 0.845 | -0.2263 |
| **26** | 0 | 0.179 | 0.821 | -0.5719 |
| **27** | 0 | 0 | 1 | 0 |
| **28** | 0 | 0 | 1 | 0 |
| **29** | 0.395 | 0 | 0.605 | 0.9393 |
| **30** | 0.189 | 0.181 | 0.63 | 0.0258 |
| **31** | 0.049 | 0 | 0.951 | 0.3619 |
| **32** | 0.096 | 0.071 | 0.833 | 0.2023 |
| **33** | 0.072 | 0.094 | 0.834 | -0.1336 |
| **34** | 0.08 | 0 | 0.92 | 0.2732 |
| **35** | 0.105 | 0 | 0.895 | 0.6124 |
| **36** | 0.105 | 0.036 | 0.859 | 0.34 |
| **37** | 0.149 | 0 | 0.851 | 0.8396 |
| **38** | 0 | 0 | 1 | 0 |

Table 1. Individual sentiment scoring

The sentiment analysis reveals a complex mix of sentiments with a notable lean towards neutrality and negative sentiments. The majority of comments have high neutral scores, indicating that many participants provided responses that were factual or lacked strong emotional content. Negative sentiment scores appear frequently and are often significant, with several comments showing high negative scores (e.g., 0.692) and strongly negative compound scores (e.g., -0.7845), suggesting concerns or perceived challenges related to the topic. Positive sentiments are present but generally lower and less frequent, with the highest positive score being 0.395. The compound scores, which aggregate overall sentiment, vary widely but tend towards neutrality or mild negativity, with a few strongly negative values indicating notable apprehension. However, there are also some positive compound scores, with the highest being 0.9393, showing that a few participants see potential opportunities or positive outcomes. Overall, the responses reflect a nuanced view with a slight tendency towards negative perceptions, highlighting both concerns and some optimism regarding the interaction between ecosystem services and wind farm development.

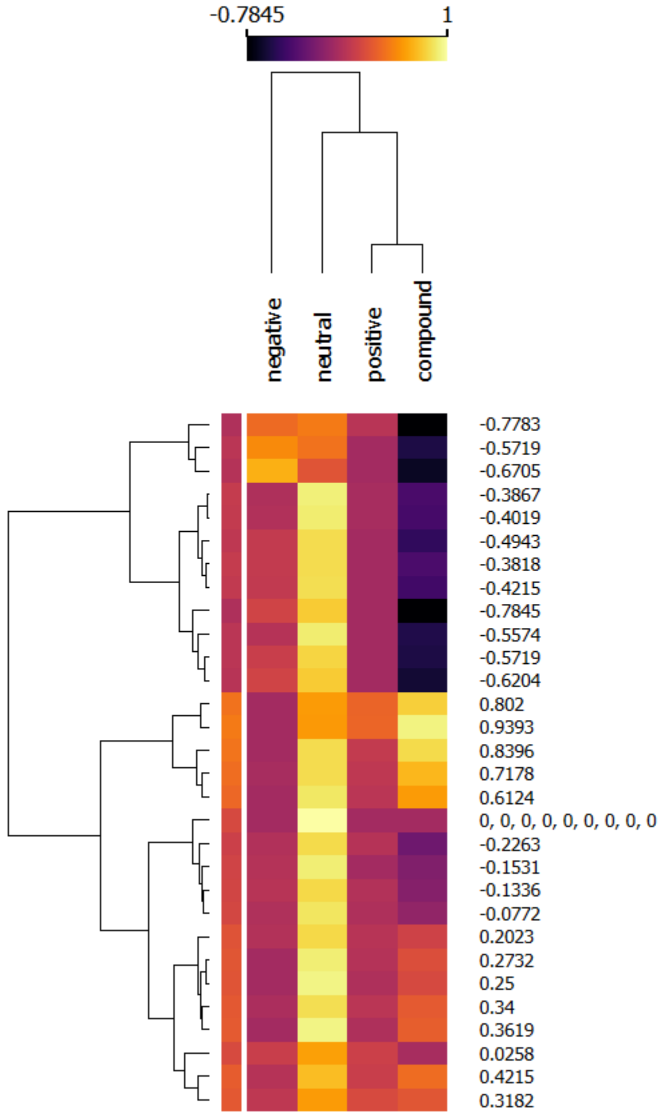


Figure 9. Heat map with compound scores for the clusters.

When it comes to the binary of positive-negative sentiments, the negative scores are generally higher. However, as already revealed, the relatively high proportion of neutral sentiment scores appears to significantly affect the compound score (Figure 10).

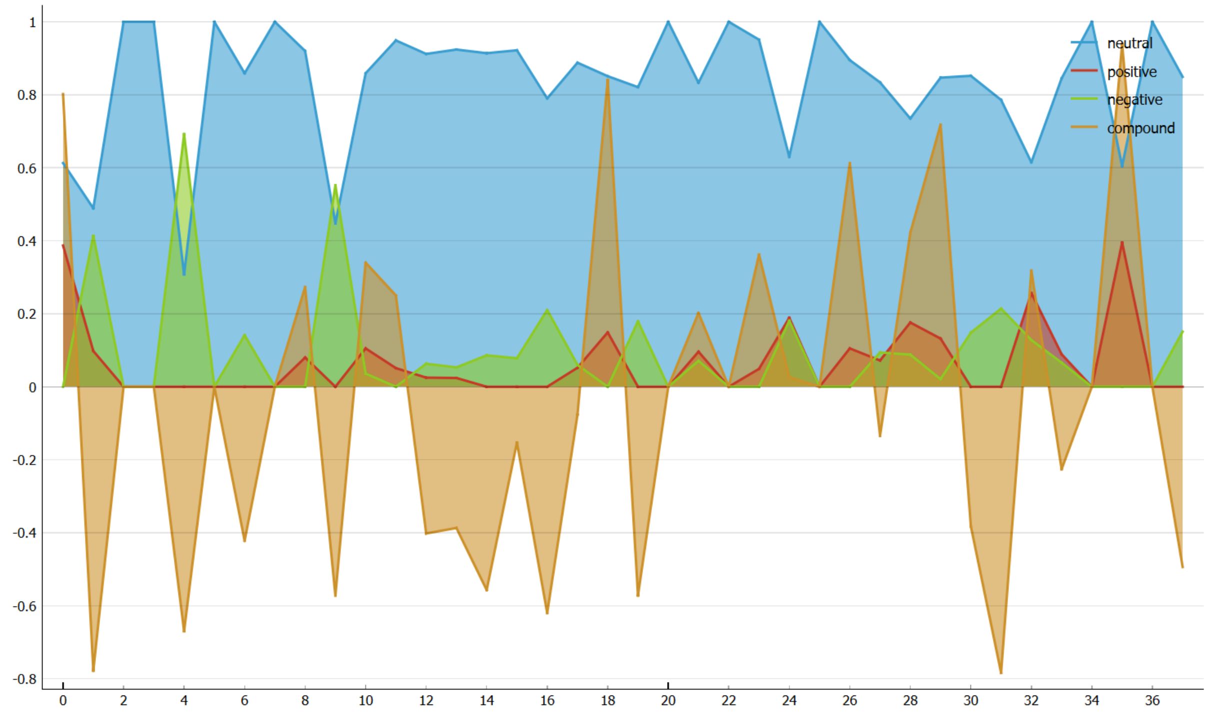


Figure 10. Sentiment scores in the examined corpus.

The effect of neutral sentiment is more profound when considering how the scoring range is distributed across the whole corpus (Figure 11).

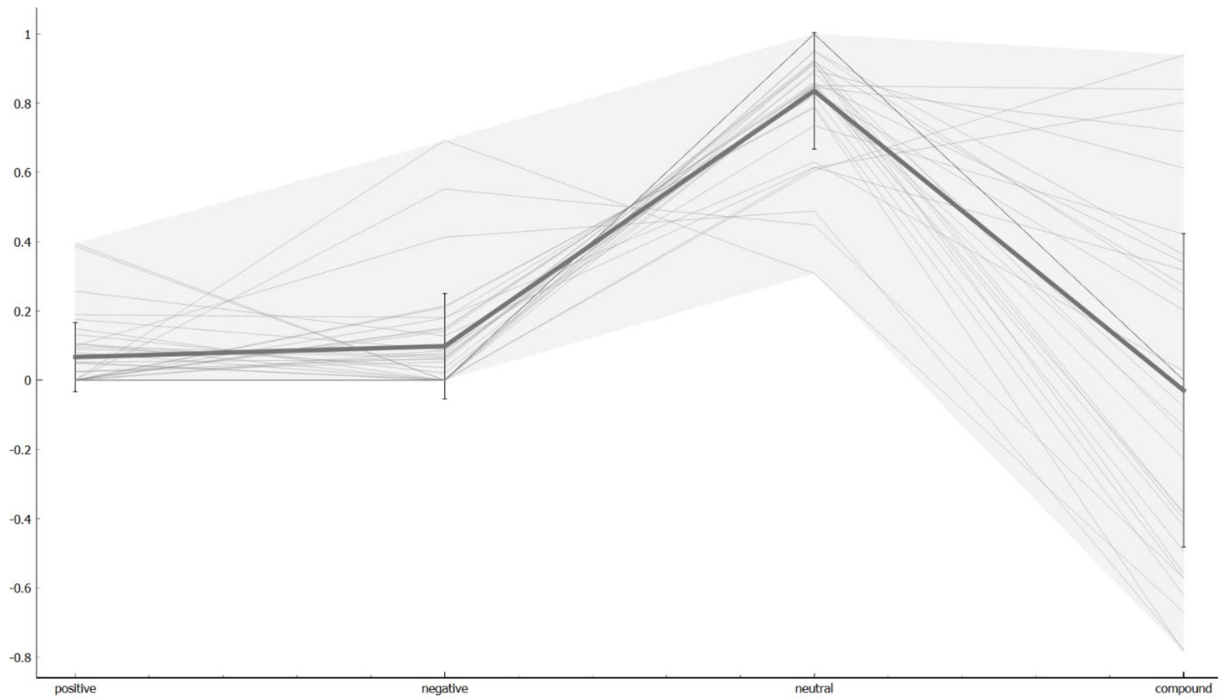


Figure 11. Sentiment scoring range, mean, and error bars.

The bold line in Figure 10 reflects the mean value for each score per document in the corpus, the grey area is the range of data points between 10th and 90th percentile, and the vertical error bars show the standard deviation of each attribute. In general, the sentiment appears to be hesitantly neutral (weakly negative) since the several negative statements were at the end counterbalanced by some positive and many neutral statements.

**Discussion**

The questionnaire explored socio-cultural and economic valuations on e/s with the purpose of collecting insights into how respondents perceived ecosystem's tangible and intangible services and benefits to society. Many of the e/s that were perceived as most important were later corroborated in more details in the following open questions – e.g., biodiversity dimensions with regards to avian life, or recreation opportunities with hiking routes. Overall, the responses align with expectations based on existing literature, though conducting the survey just one year after the full deployment of the power farm may have influenced the results. The negative feedback and overall apprehension that is registered in the survey is consistent with recent findings, especially when considering cases that involve areas of special environmental status, as is the case of several areas in the High North, and one can argue, the area of Kvitfjell/Raudfjell on Kvaløya island. This kind of apprehension is particularly evident on the multiple-choice questions that also gave respondents the opportunity to identify the most relevant e/s and those mostly affected by the power farm development.

The open-ended questions enabled deeper insights into these perceptions, predominantly concerning usage issues but also touching upon ownership. For example, one respondent commented: "After the development, the area is far less attractive in general for recreational purposes. This can reduce the value of properties that are or can be used for residential or leisure purposes […] the area has lost much of its value as a tourist destination". When it comes to ownership structures, one respondent commented: "In my experience, wind turbines add resources to Norway at a macro level, but their unclear ownership structures, a lack of local benefits [create major disadvantages]. It is also paradoxical that this is located in an area with significant tourism … these are industrial facilities that should be located in industrial areas primarily, with elements of local ownership.". However, several respondents commented on positive effects, mainly relating to direct and indirect economic impacts of the wind farm development. Those effects related to direct payments, as one respondents commented: "They buy services locally for a lot of money - everyone who works in the skilled trades knows that", while others pointed out that the wind farm will generate tax money for the community – for example, "It is positive that development is also taking place in this area in terms of business, energy production and tax revenues for the municipality". Interestingly, neutral responses or responses that had a balanced approach were very prominent, as also illustrated by the semantic analysis. For instance one of the respondents argued for positive benefits to the area due to the road construction, but also challenges due to ice hazards from the turbine blades: "Opportunity: well, an approximately 30 km road system has now been established in one of the finest mountain areas on the outer side of Kvaløya in Tromsø municipality and the road is an opportunity to get out into the terrain quickly and high up with e.g. electric bikes and will make the terrain much more accessible during the summer months. Challenge: as soon as the temperature drops below freezing, falling ice from the wind turbine blades will be a serious problem and in practice from October to early May, this area will be inaccessible to most hikers/skiers and those who hunt/ice fish. Ice throwing has been observed and documented by photos. If you look at the map, the potential ice throw will constitute a large area from each individual turbine and thus the

Raudfjell/Kvitfjell area is in practice inaccessible to most people who do not want to take risks by moving in an area exposed to ice fall."

The sentiment analysis reveals a complex mix of sentiments, with a notable lean towards neutrality and negative sentiments. The majority of comments exhibit high neutral scores, indicating that many participants provided factual responses or lacked strong emotional content. Negative sentiment scores appear frequently and are often significant, with several comments displaying high negative scores (e.g., 0.692) and strongly negative compound scores (e.g., -0.7845). This suggests considerable concerns or perceived challenges associated with the topic. Positive sentiments, although present, are generally lower and less frequent. The compound scores, which aggregate overall sentiment, vary widely but tend towards neutrality or mild negativity, with several strongly negative values indicating notable apprehension. However, some positive compound scores indicate that a few participants recognize potential opportunities or positive outcomes. Overall, the findings from the sentiment analysis reflect a nuanced perspective with a slight tendency towards negative perceptions, highlighting both significant concerns and some optimism regarding the interaction between ecosystem services and wind farm development.

Taking everything into account, it becomes evident that several of the respondents showed various degrees of apprehension to the wind farm deployment, something that is notably reflected in the multiple-choice questions; although, those who took the time to respond to the open-ended questions also exhibit a slight tendency towards negative perceptions as well, as revealed by the sentiment analysis. This underscores the importance of addressing stakeholder concerns comprehensively while also communicating the potential benefits to achieve a balanced and informed dialogue about wind farm projects. Increased civil society engagement and consulting, and, when possible, by adopting co-creation principles can help promote mutual trust among the various stakeholder parties –e.g., a Multi Actor Platform (MAP) in the early stages of the perception of the project could help better inform local stakeholders and allow them to not only express their concerns but also propose alternatives for the actual project implementation. In a similar way, an early MAP could also allow for the construction company and the project initiators to properly communicate the project and provide reliable information on its effects in the local environment and communities, as well as establish a roadmap to strengthen any positive impacts and alleviate any negative ones.

*Limitations and suggestions for further research*

Despite our efforts for a wide as possible distribution of the questionnaire, the sample size is limited. In addition, the online platform that was used for the deployment of the questionnaire produced one common hyperlink that was distributed, therefore making possible to either further distribute the questionnaire or resubmit answers – although we have no indications that either took place. Finally, the anonymity of the survey does not allow confirming the actual role and connection the respondents had with the region. Also note that the survey was conducted just one year after the Kvitfjell/Raudfjell wind farm deployment therefore the questions relate to the perceived potential and not actual impacts. In that respect it could be useful to update the survey after some years of operations.

Future research should focus in expanding the sample size and setting routines and protocols that assure feedback from diverse stakeholder groups in the area. The mixed methods approach that we followed in this article has a lot of potential, although the sentiment analysis performs best on large texts that follow a standardized structure, therefore proper adjustments should also be considered when asking open-ended questions. Additionally, longitudinal, and comparative studies will enhance the robustness and generalizability of the findings. Addressing these areas will not only advance the theoretical understanding but also pave the way for practical applications and innovative solutions that will also better inform policymakers.

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