UDC 504.03/.06
DOI: 10.17238/issn2221-2698.2017.28.77

Critical evaluation of the Roan wind farm (part of the Fosen wind project) from an impact assessment standpoint

© **Aleksey I. Patonia**, MSc in Sustainable Development, MSc in International Management (Oil and Gas). Tel.: +375295214912. E-mail: aip4@st-andrews.ac.uk; alex.patonia@online.liverpool.ac.uk
University of St. Andrews / University of Liverpool, United Kingdom.

Abstract. The paper views the Roan wind farm, which is a part of the Fosen Vind Project — the biggest planned onshore wind farm in Europe — from an impact assessment standpoint. Using the traditional stages of the impact assessment (such as screening, scoping and identification of the baseline conditions and crucial impacts), the research implements the 'traffic light system' to assess the magnitude of the core effects of the project on different dimensions — i.e. society and nature. Even though the previously conducted assessment describes the project as an extremely successful one with huge potential of generating sustainable energy, the current analysis reveals some of its greatest shortcomings. Social and wildlife aspects are its major drawbacks: the construction site is on the grounds used for the summer grazing by the Saami reindeers and the height and number of turbines significantly threatens migrating birds. Thus, even though the project happens to be economically attractive, it is a rather controversial undertaking when viewed from social and natural perspectives. The paper thus presents many solutions for the minimization of these negative impacts.

Keywords: *Roan wind farm, Fosen Vind Project, impact assessment, reindeer herding*

***Abbreviations, acronyms and abridgements used in the article*:**

Directive 2014/52/EU — Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU of the assessment of the effects of certain public and private projects on the environment.
EEA — European Economic Area
HFSE — high-frequency sound emitters
EIA — environmental impact assessment
HVC — high-voltage cable
Planning and Building Act — Planning and Building Act of 27 June 2008 No. 71 relating to planning and processing of building applications
SDG — Sustainable Development Goal

Introduction

The Fosen Vind Project commenced in 2016 by the Nordic Wind Power, Statkraft and TrønderEnergi is expected to become the largest onshore wind power undertaking in Europe, capable of doubling the wind segment in Norway's energy mix after the estimated time of its commissioning in 2020[1]. The Roan wind farm is the second largest farm of the six separate wind parks of the project, and the first to be constructed by 2018[2]. Planned by Statkraft[3] to be placed in the

[1] Statkraft. The Fosen Vind Project. URL: http://statkraft.com/about-statkraft/Projects/norway/fosen/# (Accessed: 20 October 2016).
[2] TrønderEnergi. Alternative for 1000 MW vindkraft I Midt-Norge utredes videre/ Alternative for 1000 MW wind farm in Central Norway is still under discussion URL: https://tronderenergi.no/aktuelt/alternativ-for-1000-mw-vindkraft-i-midt-norge-utredes-videre (Accessed: 21 October 2016).
[3] Statkraft. The Roan wind farm. URL: http://www.statkraft.com/globalassets/1-statkraft-public/1-about-statkraft/projects/norway/fosen/faktaark-roan-vindpark-uk.pdf (Accessed: 21 October 2016).

Roan municipality of Sør-Trøndelag County, the wind park aims to provide cheap renewable energy to the nearby settlements as well as the national grid, which coincides with the UN Sustainable Development Goal (SDG) 7 [4].

Commercially, the undertaking is assumed to be a great success: it will be possible to generate electricity at the lowest cost in Europe due to the geographic conditions, enabling the average yearly full load to reach 3500 hours[5]. As per the investors, the local communities will also greatly benefit from reduced electricity costs, improved ecology and infrastructure[6]. However, as the statistical evidence of Wang, Wang and Smith [1, Wang S., Smith P.] shows, the impact of most of the large-scale energy projects usually tends to bear not only socio-economic benefits and advantages, but also challenges and concerns.

This paper aims at conducting critical evaluation of the key effects of the Roan wind farm from an impact assessment standpoint. It emphasizes the major impact categories indicated by the Norwegian legislation and environmental organizations and applies them for the analysis of the effects of the wind project. The paper estimates the magnitude of those effects and identifies the most significant positive and negative impacts. Finally, it represents some suggestions for the mitigation of the adversities and augmentation of the advantages.

Project background, screening and scoping

1. Project background

By placing the project in Roan, the investors aim at reaching the maximum load of turbines, subject to the regional geographic conditions — i.e. an extremely high number of windy days[7]. This argumentation explains the decision of the Fosen Vind (2016) to install many high-power turbines in the same region — 71 turbines with the total capacity of 255.6 MW — i.e. approximately one quarter of the total project capacity (1000 MW). That is why the unique geographic features are assumed to make the wind farm capable of providing electricity for 42.5 thousand households[8].

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[4] United Nations. Sustainable development goals URL: http://www.un.org/sustainabledevelopment/sustainable -development-goals/ (Accessed: 02 November 2016).

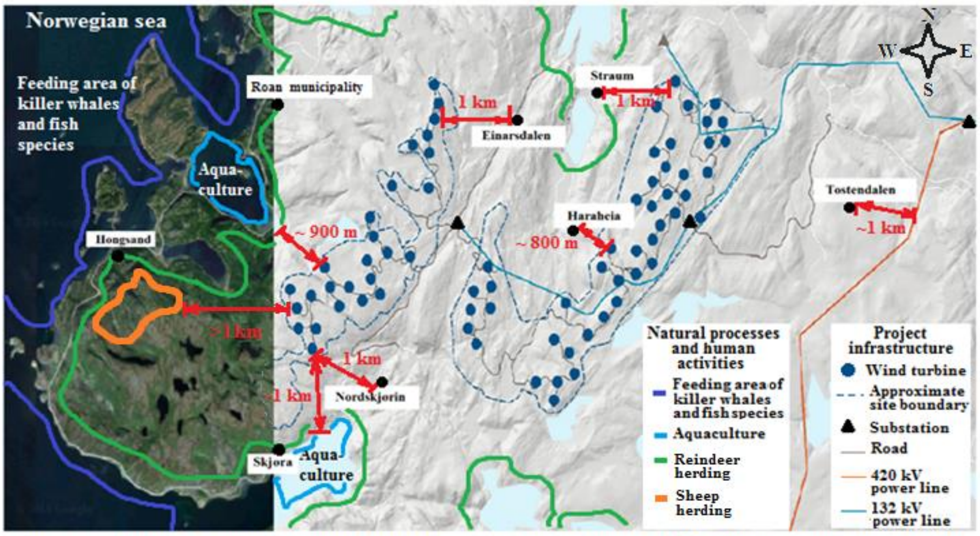
[5] Norwea. Europe's biggest and cheapest onshore wind project URL: http://www.norwea.no/nyheter-1/europe%E2%80%99s-biggest-and-cheapest-onshore-wind-project.aspx?PID=1162&Action=1 (Accessed: 21 October 2016).

[6] TrønderEnergi. Alternative for 1000 MW vindkraft I Midt-Norge utredes videre/ Alternative for 1000 MW wind farm in Central Norway is still under discussion URL: https://tronderenergi.no/aktuelt/alternativ-for-1000-mw-vindkraft-i-midt-norge-utredes-videre (Accessed: 21 October 2016)

[7] Statkraft. The Roan wind farm URL: http://www.statkraft.com/globalassets/1-statkraft-public/1-about-statkraft/projects/norway/fosen/faktaark-roan-vindpark-uk.pdf (Accessed: 21 October 2016).

[8] Statkraft. The Roan wind farm URL: http://www.statkraft.com/globalassets/1-statkraft-public/1-about-statkraft/projects/norway/fosen/faktaark-roan-vindpark-uk.pdf (Accessed: 21 October 2016).

At the same time, the permanent population of the municipality is only about 1000 people living in small settlements scattered around its territory[9]. Additionally, there is no major industrial activity in the region — instead, the population engages in fishing, fish farming and seasonal agriculture (primarily reindeer and sheep herding)[10]. None of the activities requires significant electricity supplies, meaning that the power produced by the wind farm will mostly be supplied to the national grid — i.e., it will not foster any local industrial development[11].



Sources: Author's superposition of the data provided by Statkraft (2015), Nordic Centre for Spatial Development (2015), Vongraven and Bisther (2014), Hansen (2015)

Fig.1 The Roan wind farm: Project infrastructure, natural processes and human activities

Considering low population density and specifics of the area's economic activities, the investors' decision seems to be well-reasoned. At the same time, due to the scale and complexity of the undertaking it will have remarkable *short-term* and *long-term* repercussions (see Fig.1). As we see from Fig. 1, the wind park will occupy substantial territory used for reindeer herding by the Sami. Some of the wind turbines will be placed in the relative vicinity (800 m — 1 km) of the settlements, fish farms and sheep husbandry areas. The fish farms, in their turn, are close to the open sea — i.e. habitat of marine fauna. Thus, apart from the wind farm itself, installation of 71 turbines, 3 substations, construction of 70 km of new roads, and laying of dozens of metres of high-voltage cables (HVCs) — the activities planned by Statkraft (2015) — will significantly affect the area.

[9] Roan municipality. En rundtur i Roan/ An overview of Roan municipality URL: https://www.roan.kommune.no /om-roan/en-rundtur-i-roan/ (Accessed: 25 October 2016).
[10] Nordic Centre for Spatial Development. Reindeer herding area in the Nordic countries URL:http://www.nordregio.se/Templates/NordRegio/Pages/MapPage.aspx?id=3619&epslanguage=en (Accessed: 24 October 2016).
[11] Roan municipality. En rundtur i Roan/ An overview of Roan municipality URL: https://www.roan.komm une.no/om-roan/en-rundtur-i-roan/ (Accessed: 25 October 2016).

2. Screening and scoping

In Norway, the legal issues of environmental impact assessment (EIA) for the objects related to the onshore energy infrastructure are regulated by the Planning and Building Act of 27 June 2008 No. 71 [2, Pettersson M., Ek K., Soderholm K., Soderholm P]. Additionally, being a signatory of the European Economic Area (EEA) agreement, Norway must follow the provisions of the EU's Environmental Impact Assessment Directive (Directive 2014/52/EU) which is integrated into the country's legal system [3, Bang G., Gullberg A.T.]

According to the Planning and Building Act[12], all wind projects with more than one wind turbine and capacity over 10 MW must undergo EIA. That is why, taking into consideration the scale of the project (see II.1. Project background), the *screening* stage of its implementation will detect the necessity to conduct EIA. In compliance with both the Planning and Building Act and the Directive 2014/52/EU, the *scoping* phase should include the following categories: (i) population and human health; (ii) biodiversity; (iii) land, soil, water, air and climate; (iv) material assets, cultural heritage and landscape. [13,14]

However, focusing primarily on *environmental* aspects the Norwegian and EU EIA-related regulations do not completely cover the remaining pillars of the sustainability tripod — i.e. *society* and *economy* [4, Blewitt J]. Thus, upon reviewing the best impact assessment practices represented by Ali [5, Ali M.] and Holder [6, Holder J.] and consultations with local branches of international NGOs (Greenpeace Norway[15] and Friends of the Earth Norway[16]), additional categories were added. This allowed the major impacts to be grouped into two main clusters: 'Society' and 'Biodiversity'. These clusters are analysed in terms of each impact's magnitude through the 'Traffic Light' colour code of the NATO Reporting and Tracking System[17].

Here, the magnitude of each *predicted* effect is identified and marked with 'red' if negative, 'green' — if positive, and 'yellow' — if it has medium influence or both positive and negative impacts (Table 1.):

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[12] HMKN Government.Planning and Building Act of 27 June 2008 No. 71 URL: https://www.regjeringen.no /en/dokumenter/planning-building-act/id570450/ (Accessed: 27 October 2016).
[13] Ibid.
[14] European Parliament. Directive 2014/52/EU URL: http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32 014L0052 (Accessed: 06 October 2016).
[15] Gulowsen, T. (truls.gulowsen@greenpeace.org), 24 October 2016. Re: *Fosen Vind Project.* Email to Greenpeace Norway (info.no@greenpeace.org).
[16] Bjerkli, K. (kb@naturvernforbundet.no), 26 October 2016. Re: *Fosen Vind Project*. Email to the Friends of the Earth Norway (naturvern@naturvernforbundet.no).
[17] NATO (2011) NATO Reporting and Tracking System URL: https://jadl.act.nato.int/NATO/data/NATO/lm_data/lm_ 12820/902/objects/il_0_file_34273/TTP%201%20draft%20110106.pdf (Accessed: 27 October 2016)

Table 1

Main impacts of the Roan wind farm

Impact categories		Baseline conditions	Local effects: Short-term (construction)	Local effects: Long-term	Regional effects: Short-term (construction)	Regional effects: Long-term	Global effects: Short-term (const.)	Global effects: Long-term
Society	Population & human health[18]	Low population density[19] One of the best health indicators in Norway [7, Rehn, T.A., pp. 209–216]	Construction noise may cause temporary health disturbances (e.g. insomnia) [8, Kageyama, T., pp. 53–61]	Turbine noise and shadow flickering may deteriorate health)[8]	No major impacts			
Society	Human activities[5]	Low unemployment rate and active reindeer breeding[20] Fish farming & sheep breeding — in the vicinity[21,]	Limited reindeer herding due to construction [9, Skarn, pp. 1527–1540]	Decreased reindeer herding due to landscape fragmentation etc. [9]	No major impacts	Cumulative adversities resulting in changed reindeer migration in Scandinavia[8]	No major impact	
Society	Energy output & infrastructure [6, Holder, J.]	Low energy needs, but high energy price[22] Few number of roads[23] Minor automobile and air traffic, but high maritime traffic[24]	Less complicated traffic due to the road construction[25]	Greater supply and lower energy prices[26] Significant infrastructure development — increased traffic[27]	No major impacts	Potentially decreased energy prices[28] Greater road development in Norway and Scandinavia[29]	No major impacts	

[20] Roan municipality. En rundtur i Roan/ An overview of Roan municipality URL: https://www.roan.kommune.no/om-roan/en-rundtur-i-roan/ (Accessed: 25 October 2016).
[21] Ibid.
[22] Nordic Centre for Spatial Development. Reindeer herding area in the Nordic countries URL:http://www.nordregio.se/Templates/NordRegio/Pages/MapPage.aspx?id=3619&epslanguage=en (Accessed: 24 October 2016).
[23] Ibid.
[24] Ibid
[25] Statkraft. The Fosen Vind Project URL: http://statkraft.com/about-statkraft/Projects/norway/fosen/# (Accessed: 20 October 2016).
[26] Ibid.
[27] Ibid.
[28] European Parliament. Directive 2014/52/EU URL: http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0052 (Accessed: 06 October 2016).
[29] Statkraft. The Fosen Vind Project URL: http://statkraft.com/about-statkraft/Projects/norway/fosen/# (Accessed: 20 October 2016).

	Culture & heritage[30]	No historical objects within site boundary, but some possible birdwatching [10, Haavik, A. & Dale, S., pp. 69–80] The Roan church — i.e. the nearest cultural object within 2.5 km from the turbines[31]	No major impacts	Potentially decreased value of bird-watching area [10]	No major impacts		
Nature & biodiversity	Soil and landscape[32]	The area is not arable — thin layers of soil (mostly rocks)[33] The area is mostly tree-less with the ground covered with lichens and moss [10]	Construction reduces soil and lichens [11, Reichenberg, L., Johnsson, F., Odenberger, M.] Construction disintegrates the landscape [11]	HVCs reduce the growth rate of lichens and moss [12, Urech, M., Elcher, B. & Siegenthaler, J., pp. 327–334] Roads fragment the landscape [8]	Cumulative soil and lichens' adversities due to construction of the other farms [8]	Cumulative effects hampering lichens growth and causing fragmentation [13, Vistnes, I.I. & Nellemann, C., pp. 215–224]	No major impacts
	Water[35]	Almost complete absence of underground aquifers because of the rocks[36] Several shallow lakes with fish[37]	No major impacts	Turbine noise may disturb lake fish [14, Dooling, R.J., Leek, M.R. & Popper, A., pp. 29–37]	No major impacts		
	Air[38]	Significant number of migrating birds with low number of bat species[39]	No major impacts	Potential bird collisions [15, Croft, S., Budgey, R., Pitchford, J.W. & Wood, A.J., pp.50–71]	No major impacts	Potential threat for bird migration [16, Marques, A.T, pp. 40–52]	No major impacts

[30] Roan municipality (2016) En rundtur i Roan / An overview of Roan municipality URL: https://www.roan.kommune.no/om-roan/en-rundtur-i-roan/ (Accessed: 25 October 2016).
[31] Ibid.
[32] HMKN Government (2008) Planning and Building Act of 27 June 2008 No. 71 URL: https://www.regjeringen.no/en/dokumenter/planning-building-act/id570450/ (Accessed: 27 October 2016).
[35] Ibid.
[36] Nordic Centre for Spatial Development (2015) Reindeer herding area in the Nordic countries URL:http://www.nordregio.se/Templates/NordRegio/Pages/MapPage.aspx?id=3619&epslanguage=en (Accessed: 24 October 2016)
[37] Ibid.
[38] HMKN Government (2008) Planning and Building Act of 27 June 2008 No. 71 URL: https://www.regjeringen.no/en/dokumenter/planning-building-act/id570450/ (Accessed: 27 October 2016).
[39] World Bird Database (2016) Sør Trøndelag URL: http://avibase.bsc-eoc.org/checklist.jsp?region=NOst (Accessed: 31 October 2016).

	Climate[40]	Good climate indicators — low CO_2 emissions due to the electricity being used from the grid (hydropower and minor fossil use)[41]	No major impacts	Lower CO_2 emissions in the Roan municipality[42]	No major impacts	The Fosen Vind Project completion may turn Norwegian energy mix fossil-free[43]	No major impact	Contribution to the global CO_2 reduction[44]

As we see, some of the areas such as e.g. health and cultural dimensions or water-related domain do not have significant negative impacts, whereas others — e.g. those related to soil, air or human activities bear remarkable adversities. In contrast, the effects on infrastructure, green energy output and climate are solely positive. Nevertheless, we can see that infrastructure development negatively influences reindeer herding because of HVCs on lichens and the impact of roadbuilding on reindeer pastures. Similarly, the turbines pose a threat to birds. Thus, due to the significant scale and timeframe of these effects they should be viewed in detail.

Crucial impacts

1. Infrastructure development and reindeer herding

According to Sorkhabi et al [17, pp. 359–370] building wind farms and infrastructure (i.e. roads and HVCs) is more cost-efficient in rocky areas than in regions with soil due to the use of fewer building materials. However, despite being obviously economical, both activities lead not only to destruction of lichens and moss on the ground (i.e. reindeer fodder), but also to significant landscape fragmentation [13, Vistnes I.I. & Nellemann C., pp. 215–224]. Additionally, long-term exposure of moss and lichens to electromagnetic radiation of the HVCs decreases their growth rate, which negatively affects reindeer diet [12, Urech M., Elcher B. & Siegenthaler J., pp. 327–334]. In the opinion of Skarin et al [9, pp. 1527–1540] even a small-scale wind farm construction accompanied by road-building and power line laying leads to landscape discontinuity, which, in turn, has 'a clear negative impact on reindeer habitat selection' due to the 'road avoidance instinct' which prevents the reindeer from moving through such areas. On the example of the Kiruna wind farm in Sweden Pettersson et al [2, Pettersson M., Ek K., Soderholm K., Soderholm P] show the decrease of reindeer herding in the area caused by this factor, which provoked negative repercussions in the nearby regions. Considering the larger scale of the Fosen Vind Project, cumulative adversities

[40] HMKN Government. Planning and Building Act of 27 June 2008 No. 71 URL: https://www.regjeringen.no/en/dokumenter/planning-building-act/id570450/ (Accessed: 27 October 2016).
[41] Roan municipality. En rundtur i Roan/ An overview of Roan municipality URL: https://www.roan.kom mune.no/om-roan/en-rundtur-i-roan/ (Accessed: 25 October 2016).
[42] Statkraft. The Roan wind farm URL: http://www.statkraft.com/globalassets/1-statkraft-public/1-about-statkraft/projects/norway/fosen/faktaark-roan-vindpark-uk.pdf (Accessed: 21 October 2016).
[43] Fosen Vind. Roan vindpark URL: http://fosenvind.mynewsdesk.com/documents/nyhetsbrev-roan-vindpark-number-2-2016-58096 (Accessed: 21 October 2016).
[44] Statkraft. The Roan wind farm URL: http://www.statkraft.com/globalassets/1-statkraft-public/1-about-statkraft/projects/norway/fosen/faktaark-roan-vindpark-uk.pdf (Accessed: 21 October 2016).

of this effect launched in the Roan wind farm may potentially change reindeer migration patterns in Scandinavia.

Similarly, Urech, Elcher and Siegenthaler [12, p. 327] provide empirical evidence that *Cladonia stellaris, Flavocentraria nivalis* and *Cladonia ragniferina* — the core lichens in reindeer diet — show ‘substantially reduced growth rate’ after prolonged exposure to electromagnetic radiation. Such exposure is more significant in large-scale projects, which, as in the case of the Havøygavlen wind farm in Norway, can cause changes in reindeer diets and force them to move to richer pastures to avoid starvation [11, Reichenberg L., Johnsson F., Odenberger M.]. Thus, the combined magnitude of emissions of the Roan HVCs and the other Fosen farms alongside the fragmented landscape may potentially disrupt the habitat of Norwegian reindeer.

2. Wind turbines and bird migration

According to Barrett [18, pp. 270–277], 11 out of 344 officially registered bird species of Sør-Trøndelag County are globally threatened. Out of those vulnerable species the World Bird Database[45] mentions two endangered ones — steppe eagle (*Aquila nipalensis*) and yellow-breasted bunting (*Embezia aureola*). The nine remaining ones and at least half of all the species present in the County are assumed to be migratory, which means they are prone to seasonal movement along the territory of Norway crossing the Roan municipality several times a year [18].

Based on the example of wind farms in Middle Sweden Hipkiss, Moss and Hörnfeldt [19, pp. 444–446] show that migrating and predatory species are most prone to collision with turbines, with the eagles (*Accipitridae*) family bearing the highest risk. Similar statistical evidence from the USA provided by Loss, Will and Marra [20, pp. 201–209] shows the death toll of migratory birds to be ‘between 140,000 and 328,000’ cases per year. According to Croft et al [15, pp. 50–71], the collision risk increases with the number of turbines. Thus, considering the extreme scale (71 turbines) and height (more than 117 m) of the project, we might assume significant danger to the migratory species of Roan after the farm’s commissioning.

Discussion

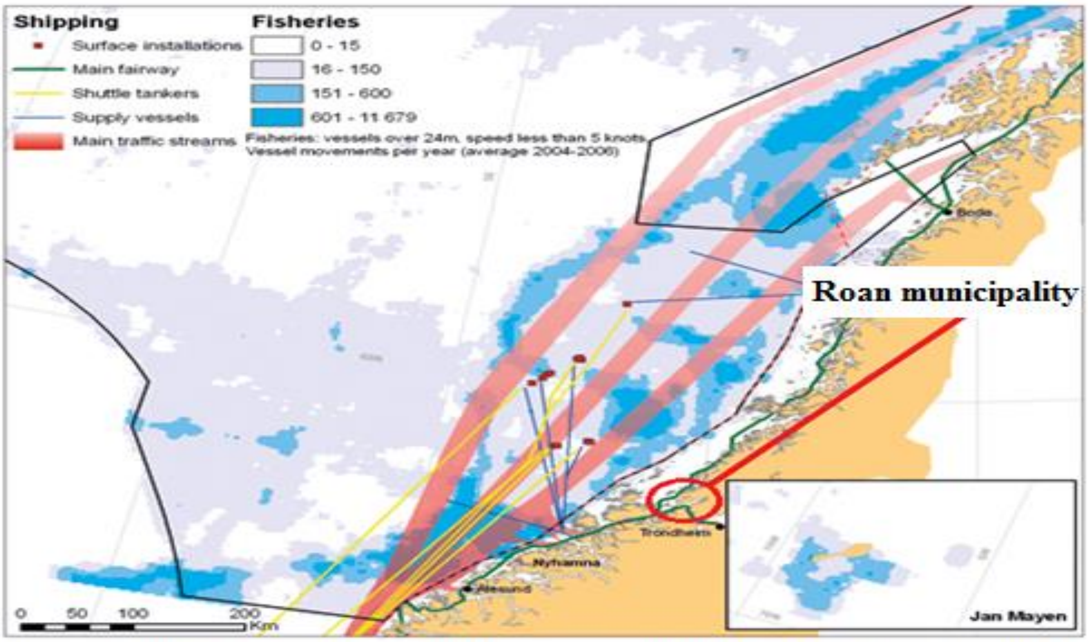
As we saw, although the population of Roan is sparse and the area almost treeless, the most significant troubles caused by the development of infrastructure and wind turbines per se relate to traditional human activity (reindeer herding) and wildlife (migrating birds). In such circumstances, the mitigation mechanism should not only decrease the negative effects of the project, but also preserve (and potentially augment) its positive affects — low-cost, carbon-free ener-

[45] World Bird Database. Sør Trøndelag URL: http://avibase.bsc-eoc.org/checklist.jsp?region=NOst (Accessed: 31 October 2016).

gy production, which coincides with SDG 7. The comparative research of similar Northern European cases conducted by Pettersson et al [2] shows two solutions to these challenges available at the current level of technological development: physical relocation of the wind farm and use of special mitigation tools.

In the opinion of Sorkhabi et al [17], to minimize negative effects, wind farms should be placed in areas far from population and wildlife with minimal human activity. That is why Haavik and Dale [10, pp. 69–80] explain the decision to move the Havøygavlen wind farm several kilometres to Northern Norway so that no important reindeer grazing areas and bird migration routes would be disturbed, despite this resulting in lower annual power load due to lesser wind magnitude. Alternatively, Pettersson et al [2] while providing the example of the Lillgrund wind park of Sweden, comment on higher capital costs associated with moving the farm offshore to preserve wind magnitude while avoiding problems related to bird collision and land-use.

Fig.2. Marine traffic along the coast of Norway



Sources: Author's indications on the map provided by the Nordic Centre for Spatial Development (2015)

Nevertheless, apart from increased costs, moving the Roan wind farm offshore might potentially interfere with aquaculture and marine traffic in the Norwegian Sea (see Fig.1 and Fig.2), with such interference going against national legislation (HMKN Government, 2009)[46].

Additionally, Bergstrom et al [21, Bergstrom L., pp. 1–12] provide empirical evidence of the negative effect of noise on the Atlantic cod (*Gadus morhua*) and herring (*Clupea harengus*) — the

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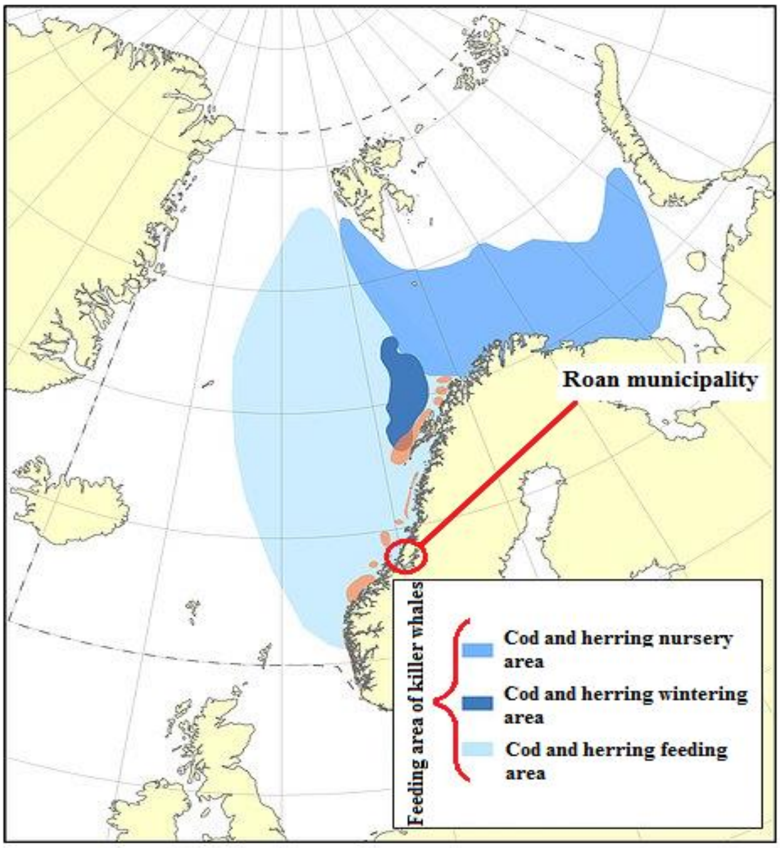
[46] HMKN Government. Integrated Management of the Marine Environment of the Norwegian Sea — Report No. 37 to the Storting (2008–2009) URL: https://www.regjeringen.no/contentassets/1b48042315f24b0182c3467f6f324d 73 /en-gb/pdfs/stm200820090037000en_pdfs.pdf (Accessed: 27 October 2016).

main food sources for the endangered killer whales (*Orcinus orca*), who, according to Samarra and Miller [22, pp. 963–971], are also distracted by anthropogenic noises. Given the presence of these species in Roan's coastal waters (see Fig.1 and Fig.3), going offshore seems to be problematic also for the fishing industry.



Source: Author's indications on the map provided by the Nordic Cantre for Spatial Development (2015)

Fig.3 Cod, herring and killer whales in the Norwegian waters

Alternatively, special mitigation measures can alleviate the negative effects of the wind turbines themselves and their infrastructure. For example, as Pekkarinen, Kumpula and Tahvonen [23, pp. 256–271] show, in the case of the Kittilä wind farm located on the reindeer grazing areas of the Finnish Lapland, the adverse effects of the landscape fragmentation and decreased lichens' growth rate were addressed by the supplementary feeding of the cattle. Similarly, Bang and Gullberg [3] mention installation of high-frequency sound-emitters (HFSE) and painting turbines pink, whereas Paula et al [24, pp. 202–208] indicate the use of dogs by the local population among the most successful factors in lowering the bird- and bat-collision incidence associated with the Näsudden wind farm of Sweden. If applied to the Roan wind farm, these measures will incur comparatively lower expenditures than would actual relocation.

Naturally, the solution that does not presuppose physical relocation is the most cost-efficient. However, it does not mean that it is flawless. On the contrary, the use of reindeer pastures raises the question of the violation of the rights of the indigenous peoples (Sami) to use their land, which is not legally secured [23]. Thus, the real sustainable solution might be in developing new types of wind turbines with greater productivity or lesser need for excessive infrastructure.

Conclusion

This paper provides critical evaluation of the Roan wind park from an impact assessment standpoint. Being a large-scale farm that is a part of the bigger Fosen Vind Project, it seeks to provide the cheapest wind-generated electricity in Europe. Due to the significant scope of the project's effects on each element of the sustainability triad — i.e. social, economic and environmental dimensions — implementation of the traditional EIA assessment categories envisaged in the Norwegian and EU legislative acts would not generate the complex picture. Thus, the inclusion of additional indicators and the "traffic light" colour code analysis helped to identify the most significant positive and negative impacts.

Apart from the long-term benefits of additional infrastructure development and relatively stable carbon free energy (the UN SDG 7), the Roan wind farm will most probably cause significant adverse changes to the reindeer and bird migration routes. As the paper reveals, the project-related infrastructure — i.e. roads and HVCs — hamper the reindeer migration. Similarly, the rotating turbine blades pose threats to migrating bird species.

The subsequent analysis of similar projects revealed two possibilities to alleviate the identified adversities. Relocation of the Roan wind farm to the areas far from human activities and fragile wildlife (e.g. offshore) or the use of special mitigation tools (HFSE, dogs or supplementary fodder) could help to find the acceptable cost-benefit balance. However, neither solution is flawless — offshore placement raises similar wildlife and industry concerns, whereas mitigation tools do not solve the problems of land use by the indigenous population. Thus, even though the investors might choose either approach to address identified challenges without termination of the project, some new technological solution needs to be applied to make the Roan wind farm more sustainable from an impact assessment standpoint.

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