Project description

PART 1: Knowledge needs

1.1 Background

Norway's abundant water supply makes it one of Europe most important producers of renewable energy. Tall mountains and high precipitations provide ideal conditions for hydropower, which has been much developed during the last century into a network of infrastructures now accounting for 97% of the electricity production in mainland. At the same time EEA Countries are expected to increase their share of renewable energy to 20% by 2020 (Directive 2009/28/EC), and Norway is asked to contribute to Europe's transition to a renewable energy system by serving as a "Green Battery" through pumped-storage hydropower. Norway has also a large potential in wind power, which is now developed mainly in coastal areas, but it is expected to expand into inland mountains by 2020.

Most of the large hydropower reservoirs are located in alpine areas, which also host the last remaining population of wild mountain reindeer *Rangifer t. tarandus* in Europe. The species is best known for its large herds and spatial requirements, as it is capable of the longest migrations among terrestrial animals. During the last century "the development of infrastructures, primarily roads, railways and power development, has contributed to a fragmentation of the population" (Rep. Norw. Parliament nr. 21, 2004-5) into 23 isolated sub-populations by blocking migration routes followed for thousands of years [1]. The ongoing development of infrastructures is further fragmenting sub-populations into smaller, isolated nuclei, whose vulnerability to climate change, habitat loss and stochastic events is rapidly increasing. To reverse this trend Norway, who has national and international responsibility for the species' conservation (Bern Convention, Annex III), uplifted wild reindeer to "species of special national value", and decreed to move from population-level management to an area-based, multilevel regional management model spanning large mountain regions encompassing the species' spatial requirements[2]. This is being implemented through the establishment of two European Wild Reindeer Regions and 10 National Wild Reindeer Areas, to be managed through dedicated, research-based Action Plans.

A major opportunity for defragmenting wild reindeer habitat is provided by the upcoming relicensing process to which most hydropower plants will be committed to in the next decades. Nowadays, the license to build new hydropower plants or wind farms can be granted following Environmental Impact Assessment, EIA, ensuring sustainability. However, most of the 277 hydropower plants situated in wild reindeer areas were constructed in the '50-'70ies, before the Norwegian Parliament adopted the first legislation on EIA (1990). To counter the lack of focus on ecosystems effects, within 2022 the licenses for hydropower plants and other energy-related infrastructures will be subjected to a revision of terms aimed at increasing focus on sustainability. Laws and regulations specify that EIA should focus on spatial scales relevant for reindeer, and that the developer shall…"remedy environmental damages caused as a result of the water regulation" [3, 4, 29].While aquatic ecosystems - and in particular salmon - are in the spotlight when discussing mitigation measures for hydropower, this will be the first opportunity to discuss large-scale mitigation and defragmentation possibilities for terrestrial ecosystems, which so far have been underestimated and overlooked. The recent availability of high-resolution movement data from GPS has unequivocally shown the magnitude of wild reindeer population fragmentation caused by the web of infrastructures, thus highlighting the urgent need to mitigate long-term effects of habitat loss and fragmentation on populations. Thus, the upcoming relicensing process is now faced with ecological, technical, economic and socio-political challenges of reversing ongoing fragmentation of Wild Reindeer Areas while accommodating a greater supply of renewable energy, in a multi-use landscape.

From an ecological and technical perspective, although it is well-known that infrastructure development is blocking migrations with detrimental effects on populations worldwide [5,6], no tools are available to concretely guide EIA. Thus, it is first needed to acquire a deep understanding of multi-scale effects of the network of hydropower-related infrastructures on long-term reindeer population viability. The major scientific challenges are to disentangle interacting effects of the network of coexisting infrastructures (e.g. hydropower, roads, tourist resorts) on reindeer space use, and to link them to long-term population viability in light of changes in climate. Second, there is a need for reliable tools to assist EIA and sustainable development with respect to hydropower and other infrastructures. The proposed project aims at translating state-of-the-art ecological information into cutting-edge, user-friendly simulation tools to predict the efficacy of land development, mitigations and compensation options on reindeer. This challenging task requires an interdisciplinary collaboration among ecologists, mathematicians, and software developers.

From a socio-economic perspective, there is a need for early-stage user involvement and dialogue processes involving industries, local experts and stakeholders. Wild reindeer share their habitat with multiple user groups with different social and economic interests, cultural background, and opinions regarding future development. Conservation interests therefore often conflict with development plans. Thus, there is an urgent need to secure public engagement, and to perform scoping processes to facilitate the reconciliation of contrasting social and economic interests, and to identify a set of socially accepted and cost-efficient mitigation and land development options.

Finally, the success of the process leading to increased sustainability of the renewable energy system is highly dependent upon substantial improvements in the legal and regulatory framework at the local, regional and national level. For instance, there appear to be inconsistencies between the large-scale, holistic perspective needed to assess impact of the network of hydropower and coexisting infrastructures on population fragmentation, and the narrow focus of the relicensing process, aimed at each hydropower plant independently [7, 8]. These regulatory gaps already fuelled a long history of conflicts between conservation and development, and now risk to undermine this opportunity to improve sustainability.

PART 2: The knowledge-building project

2. Objectives

We aim to predict the impact of the network of hydropower plants and coexisting infrastructures on wild reindeer conservation, and to assist the ecological and socio-political process of identifying concrete, cost-efficient and socially accepted options for increasing sustainability of the renewable-energy system in Norway under different land-development scenarios. This will be achieved through the following steps:

- Estimate nation-wide reindeer habitat suitability and barriers to movements; based on these, for each study area identify movement corridors and quantify a novel Habitat Functionality metric synthesizing the cumulative effects of infrastructures in terms of habitat loss and fragmentation (Fig.1); by predicting changes in these metrics following the development of infrastructures we will quantify the impact caused by hydropower to reindeer
- Involve users at an early stage and repeatedly throughout the project to maximize realism in model development, capacity building, and public engagement. Scoping processes will allow identifying a set of suggestions for realistic mitigation/compensation options
- Analytically simulate the effects of suggested mitigation options on corridors and habitat functionality, and rank them based on their ecological sustainability. Models and algorithms

will be implemented in a user-friendly, web-based simulation platform to make spatially-explicit environmental decision-making easier and more effective.
- Make an inventory of laws and regulations influencing multilevel reindeer governance with respect to renewable energy and suggest possibilities for improvements to ensure the actual and correct implementation of EIA and of mitigations
- Training courses, seminars, recommendations, and a Support Centre for reindeer-oriented impact assessment will grant dissemination and long-term applicability of the results

3. Frontiers of knowledge and technology

EIA is asked to quantify the impacts of a development on habitats and species, often with limited time and resources. Infrastructures cause both direct habitat loss (*e.g.* through area avoidance) and indirect habitat loss due to fragmentation of suitable ranges, which thus become inaccessible. However, quantifying the overall direct and indirect habitat loss and its population consequences is not straight-forward.

EIA often relies on *in situ* records of species' presence/absence. While this approach can be useful for stationary species, it is not suited for migratory ones, whose presence at a given place and time is determined by a complex web of parameters which need to be accounted for. A more robust alternative is to base EIA on probabilistic estimates of habitat quality, such as Habitat Suitability Maps [9]. Although this requires long-term projects on animal movement data, once developed these maps allow identifying suitable areas and extrapolating results to altered conditions. NINA has the privilege of owning an impressive dataset (270 wild reindeer monitored with GPS collars throughout Norway), and already produced a set of static Suitability Maps [10,11], and started quantifying responses to infrastructures [1,12]. Although these results represent a solid knowledge platform, their resolution is too coarse for EIA of specific infrastructures. Moreover, habitat suitability does not provide information on connectivity: a patch of suitable but not accessible habitat is, in fact, unusable.

Most of the approaches developed to estimate connectivity are based on Graph Theory [13], and operate on patchy representations of the landscape. Although recent developments allow estimating connectivity also in continuous landscapes, their simplistic assumptions (*i.e.* random- [15] or optimal animal movements - Least Cost Path [14]) do not allow representing movements in realistic ways. Movement ecology is now rapidly progressing, and the project owners recently organized a dedicated International Workshop, a Summer School, and are in the process of publishing a set of papers on a Special Issue in *J. Anim. Ecol.* (first:[16]). Within this framework the project owners, in collaboration with the Univ. Louvain, recently proposed an innovative algorithm (Randomized Shortest Path, RSP), to identify reindeer movement corridors with increased realism [17, 18]. RSP allows modelling the degree of plasticity in animal movements, thus predicting corridors closely matching observed GPS trajectories.

Notwithstanding parallel advances in habitat and connectivity studies, science still lacks tools to synthesise the cumulative effect of infrastructures, which cause simultaneously direct habitat loss and indirect habitat loss due to fragmentation. The project aims at further building on ongoing collaborations to develop a novel, synthetic metric of Habitat Functionality quantifying simultaneously the total loss of habitat due to infrastructure. The project also aims at pushing forward the frontiers of technology by implementing the new algorithms into cutting-edge, web-based, user-friendly platforms, to make spatially-explicit environmental decision-making more easy and effective (ARIES [19]).

Such ecological/technological advances however would become applicable in Norway only when related to socio-economic structures and to the political regulatory framework. Thus, on the one side it is crucial to related suggested environmental improvement to public support, and techniques have been developed to facilitate dialogue and scoping processes [20]. On the other, it is needed to understand the regulatory situation influencing political reindeer governance both at the local, regional and national scale as well as between different sectorial interests. In multi-use landscapes, stakeholders having a wide range of interests and concerns create a significant policy challenge. Multi-level governance is a wide-ranging concept, but it captures the dynamics between several levels of decision-making and intertwined policy areas [21,22,23]. The concept encompasses both public and non-governmental strategies and actors, including the political-administrative framework and the scientific foundation for decisions, as well as requirements and guidelines underpinning the planning and licensing processes. These cross-sectorial processes need to fulfil multiple and often conflicting policy objectives and, thus, should be supported by robust and coherent regulatory frameworks. It is obvious, for example, that the spatial scale required to grant reindeer conservation does not match the narrow scale of the regulatory framework. We will identify governance gaps and suggest solutions to enable the process of increasing sustainability in renewable energy production.

4. Research tasks and scientific methods

The project is organized in five work packages. WP1-2 develop tools to quantify cumulative impact of hydropower on reindeer and to predict the effect of suggested mitigation options in a scenario approach. WP 3 assists model development through a participatory approach and suggests mitigation options whose efficacy is tested in WP2. WP4 suggests improvements in multi-governance aspects to support the process leading to increased sustainability. WP 5 ensures dissemination and provides concrete support to reindeer-oriented impact assessment.

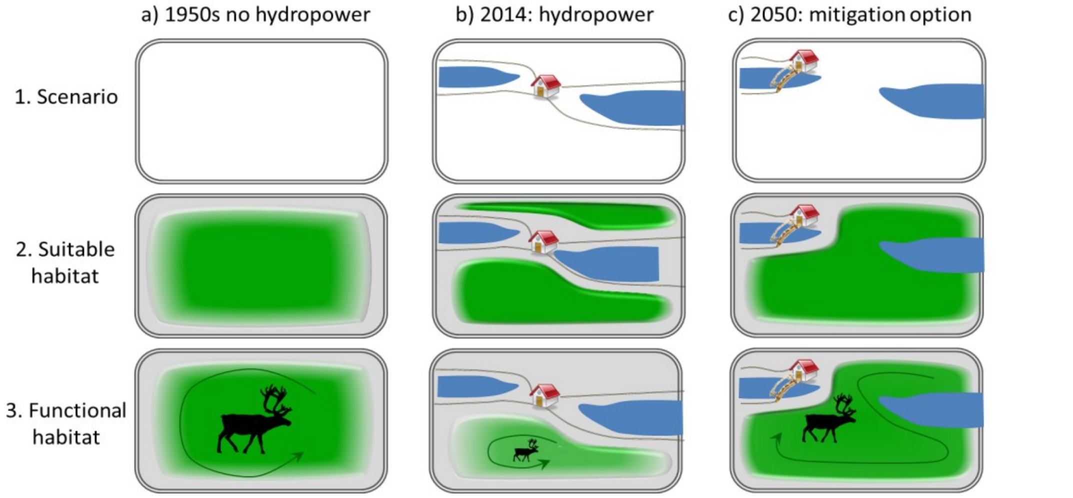

Fig 1. Imagine a hypothetical reindeer area in 1950, delimited only by a road (1.a). Reindeer experience high friction to movements in the roads' proximity (grey) but are free to move across all suitable pastures in the central area (*i.e.* suitable habitat, 2, coincides with functional habitat. 3). By 2014 two hydropower reservoirs have been built, encircled by tourist trails leading to a tourist resort (case b). In this case, traditional Habitat Suitability Models would indicate suitable habitat both above and below the infrastructures (2), ignoring the inaccessibility of the upper patch to reindeer. The novel *Habitat Functionality Metrics* that we will develop, on the contrary, would identify both the lack of functionality of the upper habitat patch, and the decreased functionality of the lower patch, due to its decreased carrying capacity (3). Such metric would also allow predicting spatially-explicit effects of possible mitigation measures (e.g. relocation of cabin, case c) on habitat functionality. This, together with maps illustrating the predicted location of movement corridors under different mitigation scenarios, will help to identify in a spatially-explicit way the most sustainable and cost-efficient interventions, within a dialogue with users and actors of the governance framework

WP1: Habitat suitability and fragmentation: state of the art *(Lead: Panzacchi M, NINA)*
WP1 provides the basic information needed for project development by gathering state-of-the-art experiences worldwide, and conducting analyses on which WP2 will build upon.
Question 1.1: *How can we assess reindeer habitat preferences and disentangle interacting effects of hydropower plants and other infrastructures?*

Activity 1.1: Organize an "International Workshop on Migratory Species and Sustainable Energy Production" within the 14th Arctic Ungulate Conference, Røros 2015
Activity 1.2: Produce national, dynamic Habitat Suitability Models, HSM, to estimate reindeer preferences with respect vegetation, habitat productivity (e.g. NDVI), weather (*e.g.* snow depth, icing), topography and infrastructures. HSM compare characteristics at used *vs.* available locations. A newly-developed, state-of-the-art Spatial Database for Animal Movements will perform the preliminary data processing steps needed for HSM analyses (http://postrack.nina.no/ [24]). This will facilitate the use of time-series for the construction of dynamic HSM using Conditional Logistic Regression, CLR as described in [11]
Deliverables 1.1: *(i)* Habitat preference maps; *(ii)* Paper: "Historical development of wild reindeer habitat connectivity and suitability" (Panzacchi et al – ecological journal)

Q. 1.2: *To which degree different landscape features and infrastructures facilitate, hamper, or represent barriers to reindeer movements?*
A 1.3: Perform Step Selection Functions [25] to quantify the degree to which different features (e.g. power lines, reservoirs, tourist trails) hamper reindeer steps. We will compare landscape features traversed by each step to paired alternatives, as in A.1.2 with a step-based approach.
D 1.2: *(i)* Friction Maps quantifying reindeer barriers and friction to movements in Norway; *(ii)* 2 papers: "Simultaneous estimation of re-distribution kernels and step selection" (Lele et al. statistic. journal); "Seasonal changes in landscape friction: transient connectivity windows for reindeer movements" (Van Moorter et al., ecol. j.)

WP2: Predictive tools for Corridors & Habitat Functionality (*Lead: van Moorter, NINA*)
WP2 builds on WP1 to develop a novel, synthetic metric of Habitat Functionality, quantifying simultaneously the total habitat loss and fragmentation produced by a given set and spatial configuration of infrastructures. By forecasting past and future changes in the infrastructure network in a scenario approach, the metric will allow to estimate cumulative changes in functionality due to past infrastructure development, and to rank suggested mitigation or compensation options or proposed land development in terms of ecological sustainability. Furthermore, we will produce probabilistic maps identifying movement/migration corridors in the past/present/future, to be used to assist the identification of the location for mitigation measures. Models and algorithms produced will be integrated in a user-friendly platform to be used by professionals for future EIA, and to predict and visualize the effect of changes in the infrastructure network on reindeer in a scenario approach. WP2 will be conducted in close collaboration with the Post-doc, who will develop the mathematical foundation for the functionality metric, and lead 2-3 scientific articles.

Q 2.1: *How can we produce a novel, synthetic metric of Habitat Functionality, and how can it be used to identify the most effective mitigation options?*
A 2.1: First we need to quantify the cost of moving between each pair of landscape units, and we would do this using *Randomised Shortest Path* (RSP [17]) algorithms operating on Friction Maps (D.1.2). This operation requires developing a large stack of Cost Maps - one for each pair of landscape units, and demands the development of specific mathematical approaches allowing for the algorithms to operate on saturated graphs and ease the computations. For each unit we would then divide HSM (D.1.1) by the Cost Maps and combine results across the stack of maps, to obtain the Habitat Functionality Metric.
A 2.2: Forecast changes in Hab. Functionality under scenarios of infrastructure development and climate change. This will be done by simulating spatially-explicit changes in existing infrastructure (e.g. simulating construction of new roads) and weather (e.g. deep snow cover) and iteratively re-calculating Hab. Functionality.
D 2.1: *(i)* Quantification of changes in Functionality following different land development plans or suggested mitigation /compensation options (see WP3), for each case study (Setesdal,

Nordfjella, Snøhetta); *(ii)* 3 papers: "A new synthetic metric of Habitat Functionality" (Van Moorter et al., ecol. j.); "Forecasting changes in reindeer habitat functionality due to infrastructures development to identify cost-efficient mitigation actions" (Panzacchi et al., ecol. j.); "Developments in the theory of Randomized Shortest Path applied to a complete graph" (Kivimäki et al., mathematical j.)

Q 2.2: *How can we identify probabilistically the location of movement/migration corridors, and how can we forecast their past/future changes caused by infrastructure development?*
A 2.3: In each study area we will predict corridors by using RSP operating on friction maps as described in [18]. Mathematical developments in the RSP algorithm will allow identifying paths more closely representing the observed trajectories.
A 2.4: As for A. 2.2, we will predict changes in movement corridors following changes in the spatial configuration of infrastructures in a simulation approach
D 2.2: *(i)* Maps showing changes in movement/migration corridors caused by the construction of infrastructures, and forecasting possible changes following the implementation of different mitigation options; *(ii) 3* papers: "Forecasting infrastructure-related changes in reindeer hab. functionality and connectivity to identify mitigation actions" (Van Moorter et al., ecol. j.); "Implications of orthogonal costs and weights in RSP" (Kivimäki et al., math. j.); "Estimating transition costs in RSP using landscape characteristics and trajectories" (Saerens et al math. j)

Q 2.3: *How can the simulation tools be used by land managers, planners and industries to support EIA and the identification of land development and mitigation options?*
A 2.5 - D 2.3: Models and algorithms developed in A.2.1-4 will be integrated in user-friendly and possibly open source and web-based platforms. There technical solutions will be defined based on project development. A likely possibility is to build upon the existing ARIES platform [19]; alternatively, Q-GIS plugins may be considered.

WP3 – User Involvement and new arenas for dialogue *(Lead: O Strand, NINA)*
WP3 develops in close contact with industries and stakeholders from the three study areas, where hydroelectric installations and coexisting infrastructures caused detrimental effects on wild reindeer. WP3 will maximize participation, realism and relevance for the models to be developed in WP1-2, will suggest mitigation measures whose efficacy will be assessed in WP2, and will set the basis for the governance analyses in WP4.

Q 3.1: *How do industries and stakeholders - with in-depth knowledge of hydropower plants and study areas – perceive the models? Can they provide input to improve model realism?*
A 3.1: Establish ad-hoc work-teams by building on the project owners' active collaboration with stakeholder groups and participation to Steering Boards for Wild Reindeer Management Areas. As the interaction with user-groups is particularly developed in Setesdal, the experiences gathered in this area will be used to structure dialogue-platforms in other areas. Through a series of iterative meetings, the teams will support model development in WP1-2 by providing data and confronting results with local knowledge, in a <u>Companion Modelling -</u> ComMod approach [26]. ComMod is a scientific posture funded on the idea that analytical models and simulations for decision support are merely intermediary objects facilitating our collective understanding of reality. By discussing around concrete models, maps and results, ComMod will allow to co-ordinate among actors by crossing disciplines boundaries, and will serve as "reality-check" to maximize relevance and applicability.

Q 3.2: *Can users suggest a set of realistic mitigation / compensation measures? Which societal costs and benefits will be associated to each proposed measure?*
A 3.2: We will initiate a series of <u>dialogue workshops</u> where participants will suggest a set of possible mitigation and compensation options in multi-use landscapes through structured <u>scoping processes</u>. Such processes build on Adaptive Environmental Assessment and

Management [27], and have been used in dialogue processes for EIA and scoping processes related to energy production (*e.g.* [20, 28]). The process starts with a holistic view and scopes down by identifying drivers and focal issues. Drivers and issues are then combined in cause-effects charts which are the basis for recommendations on future mitigation and management needs. The dialogues will minimize conflict potential by focusing on transparent information about both reindeer ecology and stakeholders needs, in a spatially-explicit context. Such solution-oriented approach allows identifying possible areas for sustainable development or for mitigations yielding the highest benefit / cost ratio, and it is thus expected to minimize conflict potential.
D 3.1: Matrix of suggested mitigation option and associated expected benefits, disadvantages, and costs to each user in terms of economy, access rights, lost opportunities etc.

WP4 – Science-policy interface – the regulatory challenge *(Lead: A Ruud, SINTEF)*
WP4 closely links to WP3 and aims at exploring the adequateness of the regulatory framework from a multigovernance perspective in assessing the prevailing capacity of supporting a revision of renewable energy system aimed at increasing sustainability.

Q 4.1: *Is the legal and regulatory framework adequate to support reindeer-oriented EIA?*
A 4.1: Make an inventory of relevant laws, regulations and formal practices related to the relicensing process of hydropower in order to identify the feasibility of conducting complex, multi-scale processes related to impact assessments. In particular, we will explore: *(i)* whether the spatial scales of the relicensing process is relevant for assessing impact to reindeer; *(ii)* the relationship between current governance practices and international agreements. These activities will be conducted through document analyses and informant interviews with representatives of policy decision-makers, public administration, industries and NGOs.

Q 4.2: *Is the regulatory framework adequate to support mitigation measures?*
A. 4.2: Despite the existence of formal regulatory procedures, the actual efforts to identify and implement mitigations depend on whether political commitments are implemented through appropriate policy tools and institutional arrangements. We will: *(i)* discuss whether the goals set by the legal and regulatory framework in terms of damage mitigation are applicable given the prevailing energy installations; *(ii)* assess the appropriateness of regulations regarding the distribution of costs and responsibilities for mitigation/compensation among stakeholders; *(ii)* discuss how the priority given to wild reindeer in the relicensing process is actually managed by the public regulatory agencies (e.g. NVE, Norwegian Environment Agency).

Q.4.3: *Which strategies and stances do energy companies adopt in the revision process?*
A.4.3: The strategies adopted with respect to the initiation of the revision processes and mitigation procedures need to be assessed. We will discuss: *(i)* whether the energy companies take a reactive or proactive stance; *(ii)* whether they have the necessary tools / resources for implementing mitigation measures; *(ii)* whether they create alliances with local / regional stakeholders to enable more comprehensive solutions.
D 4.1: *(i)* paper: "Improved reindeer governance in hydropower regions – how to reconcile different concerns?" (Ruud et al, socio-pol. journal)

WP5: Dissemination, guidance and support *(Lead: M Panzacchi, NINA)*
WP5 disseminates project results, and provides concrete support for industries, managers and decision-makers, also through the plan of Villreinsenter (www.villrein.no) to host an online SharePoint to distribute the material produced. Moreover, the Villreinsenter and Villreinråd are assessing the possibility of organizing a Support Centre for Reindeer Impact Assessment, and Villreinsenter has dedicated a 20% position to work towards this goal.
A 5.1: Synthesize the acquired knowledge in guidelines and recommendations

D 5.1: Two booklets: *(i)* "Assessing and mitigating impacts of Renewable Energy installations on Wild Reindeer: ecological, social & regulatory dimensions"; (ii) "Reindeer - Infrastructures Handbook: Conflict Prevention, Mitigation, Compensation & Monitoring". Recommendations will be provided in an Adaptive Management framework
D 5.2: Web-based Map Archive on an online SharePoint hosted by Villreinsenter
A 5.4: National Seminar: Reindeer & Renewable Energy. The seminar will present project results to industries, stakeholders, managers, decision-makers and politicians
A 5.5: Organize 1-day Impact-Assessment Training Course to train professionals from relevant sectors on the use of the web-based simulation tool developed in WP2.

5. Organisation and project plan

The project will be coordinated in NINA by Dr Panzacchi, a researcher with solid experience in habitat modeling, reindeer ecology, species conservation, and leadership of science-policy projects. NINA hosts cutting-edge skills in movement modeling (van Moorter, WP2), well-established experience in wild reindeer research and management (Strand, WP3), and broad expertise in participatory dialogue processes and scenario development (Thomassen, WP3). Renowned research partners with proven skills within topics relevant to the project (see Cvs) will contribute substantially to WP1-2. Prof Saeren, the proposed post-doc Dr. Kivimäki and Prof Lele and Prof Fryxell will provide invaluable support for modeling and algorithm development, and Prof Villa will assist model implementation in ARIES. Dr Ruud is a lead scientist from SINTEF with long experience in hydro- and wind-power related environmental policy, and is thus an ideal leader for leading WP4. The project involves a comprehensive and impressive constellation of industries (Sira Kvina Kraftselskap), Directorates (Norwegian Water Resources & Energy Directorate - NVE, Norwegian Environment Agency, Environment Directorate), Consultancies (Siri Bøthun Naturforvaltning), Consortia of stakeholders and landowners (Setesdal Wild Reindeer Group), and reindeer centres (Norwegian Wild Reindeer Center South) and management boards (Villreinrådet), all directly involved in reindeer–infrastructure conflicts (see also WP5). Most of these partners have a long history of collaboration with the project owners, and each will contribute to WP 3-5 as specified in the attached CVs and letters.

6. Key milestones

The project will start with an international workshop to be planned at the AUC conference in Røros, Aug 2015. We will then start preparing data and framework for model development in WP1, which will be discussed at the first meeting aimed at user involvement (WP3) in autumn 2015. Similar meetings will be organized throughout the project to confront model results and obtain a list of suggested mitigations - by mid-2017. Both Hab. suitability and Friction maps (WP1) would be ready by early-2017. WP2 will further build on these and deliver a Functionality Metric and movement corridors by summer 2017. Afterwards, simulations will be performed to assess efficacy of mitigations until the end of 2018. In the meanwhile, WP2 will develop a platform for simulation tools – ready by the end of the project. WP4 will develop parallel to all other activities. WP5 will produce guidelines during the second part of the project, concluding with a seminar.

PART 3: Project impact

Importance for national knowledge base

Norway has to grant wild reindeer conservation while revising/expanding the renewable energy system (and likely, in the future, other infrastructures) in mountain areas. Hence, it urgently needs tools to tackle reindeer-oriented EIA, and to increase focus on sustainable development. This concept is stated in the partners' internal strategies (see attached letters), e.g. strategic plan for FoU- activities - Norw.Env.Agency; [3, 4]; Regional Land Management Plans for wild reindeer (Rep.Norw.Parliament nr. 21, 2004-5). The project will provide such tools to be used both for the upcoming relicensing process of hydropower - both in terms of ecology and governance - and for future reindeer-oriented sustainable development and EIA. The collaboration with renowned researchers worldwide in a range of disciplines will ensure further development of cutting-edge expertise within the NINA research team, which is already a central node for reindeer research in Norway, and it is at the forefront in movement ecology internationally (see 2.3). NINA is also a centre of expertise within environmental consultancy, and the project would reinforce this position. The collaboration with the Norw.Env.Agency, which has developed capacity on the systemic side of EIA, will ensure strong long-term competence building in relevant areas. Finally, the collaboration with SINTEF-Energy will grant expansion of the knowledge base in energy-related multilevel governance. The project provides a unique opportunity to strengthen the integration between partners in science, management and industries, thus granting multiscale competence building. A skilled post-doc candidate will bringing new cutting-edge competences and will further enlarge the research network and visibility of Norwegian research.

Relevance for Norwegian industry

The project is expected to substantially advance reindeer-related EIA processes by introducing science-based, flexible and user-friendly simulation approaches, to aid the identification of mitigation options and sustainable solutions for land development, and improve environmental policy. This will allow hydropower industries to reduce the existing major conflicts with reindeer conservation, and to facilitate the current relicensing process. These goals conform to the internal strategies of the government, management authorities and industries, oriented towards increased sustainability [3, 4]. Importantly, the project will also allow the industries to single out the most sustainable and cost-efficient solutions for future land development options or changes in management strategies, thus increasing their social support and feasibility potential. On an international perspective, increased sustainability would increase the Norwegian attractiveness in the renewable energy market in a European context (e.g. Green Battery).

PART 4: Other aspects

Other socio-economic benefits

Norway is at the forefront in environmental research and in the know-how related to renewable energy production. Further research within these fields will consolidate this position and strengthen Norway's international attractiveness. On a national perspective, the improvement of governance dynamics would lead to a more efficient implementation of the legislation and to a reduced level of conflict between development and conservation.

Dissemination and communication of results

The project will produce a set of 10 papers to be submitted to high ranking referee-based scholarly journals (see part 2.4), and a set of popularized versions of these and a number of conference contributions. WP5 will ensure the development of guidelines, handbooks and recommendations aimed at industries, managers and stakeholders, and their dissemination through on-line Share Points. Villreinsenter and Villreinråd are establishing a Support Centre for Reindeer Impact Assessment, which will be crucial for ensuring the long term dissemination of relevant information. Finally, a series of workshops within the work-groups (WP3), with the international community (WP1) and with relevant stakeholders (WP5) will ensure local, national and international communication of results.

References

[1] Panzacchi M et al (2013a) Learning from the past... Landsc Ecol 28:847–859. **[2]** Kaltenborn et al (2014) Public perceptions.. J Env Plan Manag. **[3]** NVE/Miljødirektoratet (2013). Vannkraftkonsesjoner som kan revideres innen 2022. Sørensen J. **[4]** Olje-og energidepartementet (2012). Retningslinjer for revisjon... Y0116B. **[5]** Harris G et al (2009) Global decline in aggregated migrations.. End. Species Res. 7:55–76. **[6]** Vors LS, Boyce MS. (2009) Global declines of caribou and reindeer. Glob Chan Biol 5:2626–33. **[7]** Knutsen & Ruud (2011) Changing currents …SINTEF report. **[8]** Angel (2011) Frå kraft versus natur til miljøvenleg energi?. CEDREN Rapport 3. **[9]** Manly BF et al (2002) Resource Selection... Kluwer Academic Publisher. **[10]** Panzacchi M et al (2011) Searching for the fundamental niche... 13th Arctic Ungulate Conference, Yellowknife. **[11]** Panzacchi et al. under revision, Ecography. **[12]** Panzacchi M et al (2013b) A road in the middle... Rangifer. 33:15–26. **[13]** Urban DL et al (2009) Graph models ... Ecol Letters, 12: 260–73. **[14]** Pinto N, Keitt TH (2009) Beyond the Least-cost Path... LandscEcol, 24, 253–266. **[15]** McRae B et al (2008) Using Circuit Theory ... Ecology, 89, 2712–2724. **[16]** Beyer H et al (2014) «You shall not pass!» JAnimEcol, Special Issue. **[17]** Saerens M et al (2009) Randomized shortest-path. NeurComput 21, 2363–2404. **[18]** Panzacchi et al, under rev. J Anim Ecol **[19]** ARIES www.ariesonline.org. **[20]** Kaltenborn BP et al (2012) Island futures. Futures 44: 328-337. **[21]** Hooghe L et al (2003) Unraveling the Central State, but How? Am Politic Sc Rev, 97: 233-243. **[22]** Pierre J Peter BG (2005) Governing Complex Societies. Palgrave Macmillan. **[23]** Bache, 2004, Multi-level Governance, Oxford University Press. **[24]** Urbano F et al (2014) Spatial database... Springer, Berlin. **[25]** Forester JD et al (2009) Accounting for animal movement... Ecology, 90, 3554–65. **[26]** Étienne M (2014) Companion modelling. Éditions Quæ Versailles **[27]** Holling CS (1978). Adaptive environmental assessment.. John Wiley & Sons. **[28]** Thomassen J (2012) OPTIPOL-NINA Rapport 907. [29] Naturmangfoldloven § 10,11