Renewable Energy Projects: Local Impacts and Sustainability (RELEASE)

Meeting the EU's and Norway's ambitious renewable energy targets will have significant local consequences. Policymakers must make decisions that balance the consequences for the economy, the society, and the environment. RELEASE develops knowledge that assists them in such decision-making, while simultaneously providing new theoretical and empirical contributions to real options theory, social theory, restoration ecology, and local sustainable development.

1. Relevance relative to the call for proposals

Sogn and Fjordane University College's (HiSF) Renewable Energy Programme has, since its 2008 start-up, developed into a strong national player in interdisciplinary research and education on renewable energy. It conducts interdisciplinary research by applying theories from economics, sociology, political science, planning, and ecology. Currently the programme includes 75 bachelor students, five PhD students, two full-time research positions, and two professors.

The programme's success has been ensured by the active involvement of regional power utilities and financial institutions. These partners have contributed with substantial funding and have participated in research and teaching. Furthermore, HiSF is a partner in the Centre for Sustainable Energy Studies (CenSES), which was granted the status Centre for Environment-friendly Energy Research in 2011 by the Research Council of Norway. CenSES includes 11 excellent national research groups and organizes a PhD school that coordinates and strengthens the education of CenSES' PhD candidates. HiSF is now well positioned to broaden and strengthen its programme by including an interdisciplinary master programme in renewable energy and to be granted the status Norwegian Centre of Expertise (NCE). RELEASE will be crucial in achieving these aims.

2. Background and status of knowledge

2.1. The project's assumptions, concepts, and objective

Meeting the EU's and Norway's ambitious renewable energy targets will have significant local consequences (EU, 2009; OED, 2012). Renewable energy production is up to 1000 times more spatially demanding than fossil energy production is, meaning that significant land areas must be reserved locally (Twidell and Weir, 2005).

On one hand, this demand creates opportunities for local value creation as these areas are often controlled by local landowners. In Norway, traditional utilities—owned by the state or local municipalities—have historically been responsible for investing in and operating power plants. Recently, new investor groups have emerged, including landowners investing in small-scale, decentralized power production (Bergek et al., 2013; Linnerud et al., 2012). EU and Norwegian policies will affect how these projects are organized and thus how risk and return are allocated between national, regional, and local investors.

On the other hand, renewable energy projects put tremendous pressure on local communities and the local environment. The projects will harm the natural environment, and therefore conflicts may arise between local stakeholders with competing interests. Furthermore, social acceptance of the projects will depend on project and investor characteristics. The European Commission considers the problem to be urgent: "*The current trend, in which nearly every [renewable] energy technology is disputed and its use or deployment delayed, raises serious problems for investors and puts energy system changes under risk*" (EC, 2011, our italics).

To balance these impacts, we choose the concept of “sustainable development” as our theoretical point of departure (Figure 1). The concept is often interpreted as consisting of three dimensions that should be balanced: economic, social, and environmental (e.g., UN, 2012; Rogers et al., 2008a; Munashinge and Shearer, 1995; WCED, 1987). Broadly speaking, these dimensions capture the aspirations for improved welfare, just distribution of welfare, and for leaving future generations with an unchanged natural resource base (Holden et al., 2013). Applied to local impacts of renewable energy projects, these dimensions can be interpreted as the aspirations to create economic value locally, to balance between local stakeholders these projects’ social impacts, and to mitigate local environmental impacts.

We do not try to capture all local impacts of a renewable energy project. Rather, we have for each of sustainable development’s three dimensions selected a research area in which HiSF has a professional record of accomplishment. We use *real options theory* to study how uncertainty concerning future energy policies affects what kinds of projects are developed and how they are organized and financed (section 2.2). We use *restoration ecology* to examine the negative impacts of renewable energy projects on the natural environment and how these can be mitigated at different stages in developing and implementing these projects. Again, we maintain focus on different impacts of project and investor types (section 2.4). Finally, we use *social theory* to study the distributional consequences—including both economic and environmental impacts—of different projects and ownership models. We examine whether such differences in distributional effects influence projects’ social acceptance (section 2.3).

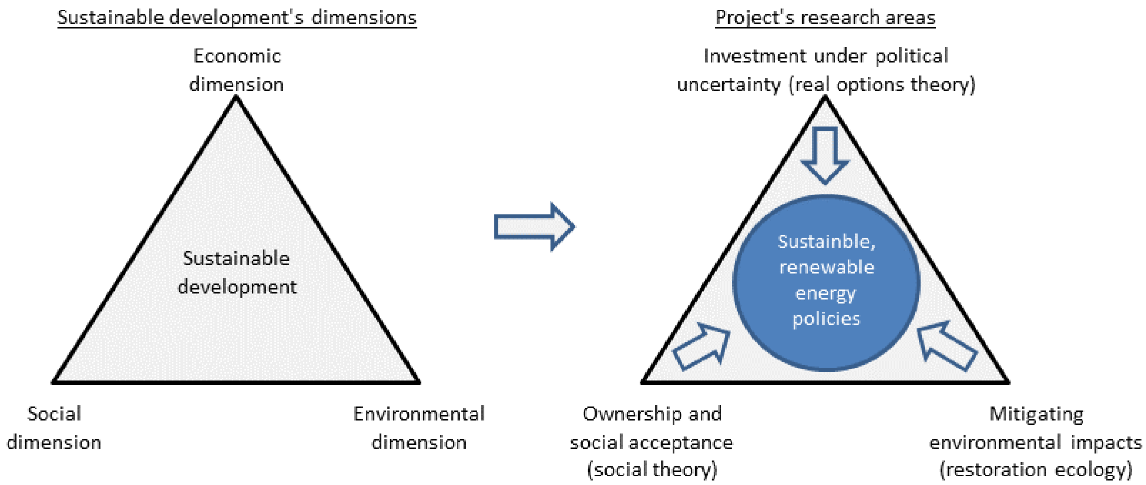

Figure 1: The project model

We will use Sogn and Fjordane County as a case to study local impacts. Norway’s power production is equal to 136 TWh, 96% of which is hydropower. One tenth of this production and one fifth of projects under consideration for a license to develop hydropower are in Sogn and Fjordane. Moreover, land-based wind power farms, decentralized fjord-heat energy installations, suppliers to the solar energy segment, and bioenergy plants are located here. Thus, we will have convenient access to renewable energy resources, plants, investors, local government, and other stakeholders.

The primary objective is (see grant application form for secondary objectives):

- To impart *new* knowledge of renewable energy projects’ impacts on local economies, local societies, and local environments in pursuing a sustainable energy policy.

2.2. Investing under policy uncertainty (real options theory)

Knowledge needs: Considerable uncertainty exists concerning EU and Norwegian renewable energy policy measures beyond 2020. As technologies mature, current support schemes may be terminated or revised to make them less generous or more market oriented. However, more ambitious renewable energy and/or climate targets may force society to use radically new technologies, resulting in more generous support schemes and/or in government's assuming more of the risk.

How this policy uncertainty is perceived and dealt with may vary across projects and investor types. Especially interesting is a new, emerging investor group—farmers, local community groups, and households without any experience in the power sector—who invest in small-scale, decentralized projects. Investors and financial institutions need information on how to respond optimally to policy uncertainty. And policymakers need information on the likely outcomes and social costs of their decisions.

Research questions: We will study how policy uncertainty affects investment decisions across investor groups and projects. Research questions are:

1. How should investors respond to policy uncertainties according to real options theory?
2. What characterizes different investor groups in renewable energy projects in Norway?
3. Do systematic differences exist across investor groups in how they perceive and act upon risk?
4. Can real options models be modified to reflect such differences?

Theory: Real options theory (Dixit and Pindyck, 1994) allows explicit modelling of different sources of uncertainty affecting projects' cash flows. Assuming investment expenditures are at least partly irreversible and that investments can be delayed, investors may value the opportunity to wait and thereby gain additional information about likely future conditions affecting the project. Hence, investors should invest now only if the value of immediate investment is greater than or equal to the expected value of postponing the investment decision.

The first theoretical real options studies to examine how uncertain policy conditions affect investment behaviour used investment tax incentives as an example (e.g., Mauer and Ott, 1995; Hasset and Metcalf, 1999). Recent studies have examined uncertainty with respect to future climate policy measures (e.g., Yang et al., 2008) and renewable energy support schemes (e.g., Fleten and Ringen, 2009; Boomsma et al., 2012).

A few empirical studies test whether firms time their investments as predicted by real options models (e.g., Moel and Tufano, 2002; Schatzki, 2003; Cunningham, 2006; Dunne and Mu, 2010). However, these studies examine only the effect of uncertain market conditions and not of uncertain policy conditions. Linnerud et al. (2012) have empirically tested the impact of policy uncertainty. They find that farmers without experience in the energy sector respond differently to policy uncertainty than do traditional utilities and other professional investors. This finding raises the question of whether the assumptions underlying real options theory are less realistic for some groups of investors than for others, a question that has so far not been dealt with in the real options literature. The bounded rationality theory (Kahneman, 2011) provides a plausible explanation for why people may use simplified rules because they lack the cognitive ability or time to arrive at the optimal solution.

2.3. New ownership models and social acceptance (social theory)

Knowledge needs: Lack of local acceptance is a major barrier in developing new renewable energy projects (OED, 2012; EC, 2011). Current EU trends indicate a shift from the current centralized system, with its large-scale power plants, towards a system made up of more and smaller decentralized production units (EC, 2011). Thus, a need exists for more empirical research about how the emergence of new ownership models will make renewable energy projects more or less socially acceptable (Li et al., 2013; Walker and Devine-Wright, 2008).

Research questions: We will study how the social acceptance of renewable energy projects is affected by different ownership models. Research questions are:

5. What are the main forms of ownership models for renewable energy projects and how do they vary across types of renewable energy?
6. What are the distributional effects of different forms of ownership models?
7. To what extent do different types of ownership models create increased acceptance for new small-scale hydropower projects?
8. How do different types of ownership models create increased acceptance for new projects across types of renewable energy?

Theory: Substantial literature exists concerning barriers to increased renewable energy deployment (e.g., IPCC, 2012; Verbruggen et al., 2010; Margolis and Zuboy, 2006). The literature suggests that the following are the main barriers: financial, technical, institutional, economic, infrastructure, lack of information and awareness, and sociocultural (e.g., Martin and Rice, 2012; Painuly, 2001). Most of these studies focus on international and national barriers. Thus, less attention has been paid to *local* barriers to deploying renewable energy, particularly in developed countries (del Rio and Burguillo, 2009). In particular, knowledge is lacking concerning barriers related to local support and acceptance by affected individuals and their communities (Rygg, 2012; Musall and Kuik, 2011).

Such local barriers have often been referred to as "Not In My Backyard" (NIMBY) (Wolsink, 2007). Part of the NIMBY concept is the "proximity hypothesis", which states that people living closest to wind farms (for example) are most opposed to them. However, several studies contest this hypothesis and have in fact found the exact opposite; those living closest to wind farms are the most supportive of them (e.g., Warren et al., 2005). Moreover, critics of the NIMBY concept refer to empirical studies that suggest that local people tend to become more positive once a renewable energy source is installed their community (Gipe, 1995).

Devine-Wright (2005) argues that particular characteristics in the local community can play a more significant role in shaping support and acceptance than has generally been acknowledged in the literature. Ownership models, for example those characterized by some form of public participation in project development and/or by the intention to deliver local and collective benefits, are important in this respect (Warren and McFadyen, 2010; Rogers et al., 2008b; Walker et al., 2007a). To study ownership models and social acceptance, we will use *collective-action theory*, as it originally was developed by Olson (1965) and refined by Elster (2007), and *actor-network theory* (Latour, 1987; Law and Hassard, 1999).

2.4. Mitigating environmental impacts (restoration ecology)

Knowledge needs: Renewable energy projects degrade and damage ecosystems. Hence, there is a need for knowledge on how the ecosystems can be restored after such projects are implemented. Restoration ecology provides such knowledge that ultimately can help policymakers design policies that ensure that the negative impacts on ecosystems are minimized.

The need for such knowledge is particularly great in fragile, arctic-alpine areas, where many renewable energy developments take place. Environmental degradation is unfavourable in such areas because restoration of alpine ecosystems may require decades or even centuries (Jorgenson et al., 2010). Therefore, we must develop clear recommendations for renewable energy development, based on detailed knowledge of changes at a species level, and scale up those changes to predict broad-scale changes in patterns at community (vegetation) and landscape levels (Denny and Benedetti-Cecchi, 2012).This knowledge is crucial in ecosystem restoration services and, ultimately, in pursuing a sustainable energy policy.

Research questions: We will focus on how restoration proceeds in hydropower developments in alpine environments, paying particular attention to dispersal traits and conditions.

9. At the species level, we study the commonly occurring dwarf shrubs billberry (*Vaccinium myrtillus*) and crowberry (*Empetrum nigrum*) and ask the following question: How do populations of these key species differ between restored and reference sites?
10. At the community level, we compare previous predictions of restoration success of alpine spoil heaps (Rydgren et al., 2011), that is, has the species composition recovered within 6–9 years? Moreover, will particular traits enhance restoration potential?
11. At the landscape level, we ask: Using distribution modelling, can broad-scale restoration success be predicted from observed temporal and spatial dispersal patterns of *E. nigrum*?
12. What restoration ecology guidelines could be developed for various types of renewable energy developments in pursuing a sustainable energy policy?

Theory: Restoration ecology is the scientific study supporting the practice of ecological restoration, which is the practice of recovering degraded, damaged, or destroyed ecosystems by human intervention and action (SER, 2004). Demand for ecological restoration is rapidly increasing because of increased environmental degradation and anticipated future environmental change (Suding, 2011). Renewable energy developments impact natural environments locally and the impacts are particularly prominent in open alpine landscapes. An illustrative example is the creation of massive and conspicuous spoil heaps of surplus rocks from hydropower tunnel construction. Most restoration attempts so far have included seeding with commercial grass species that detrimentally affect local biodiversity (Mack et al., 2000). Sustainable development is incompatible with this kind of environmental degradation (Nellemann and Corcoran, 2010). Ecological restoration may provide more environment-friendly solutions.

Restoration aims at manipulating vegetation succession to a desired endpoint, that is, at assisting revegetation by local species (Walker et al., 2007b). However, the slowness of alpine successional processes makes restoration of alpine ecosystems particularly challenging and calls for methods that enable early prediction of the direction and rate of change. Crucial to such methods is precise assessment of successional rates, but such assessments require data on species composition recorded at two (or more) well-separated time points (Rydgren et al., 2011).

Studies evaluating restoration success often compare the species composition of restored vegetation with “natural” references. However, insight into how species’ spatial and temporal dispersal traits impact their establishment success will reveal the mechanics behind the patterns (Auestad et al., 2013; Hedberg et al., 2013). Furthermore, studies at finer levels of organisation can, for example, by focusing on the population dynamics (Menges, 2008) of key alpine plant species such as the dominant dwarf shrubs *V. myrtillus* and *E. nigrum*, pinpoint main bottlenecks for successful establishment in restoration sites (Colas et al., 2008).

3. Methodology and work packages (project plan)

The project will be organized as five work packages (Figure 2). HiSF researchers in WPs 1–4 will visit international partners for several months during the project period, and international partners will visit HiSF frequently during the project period (attached letters of intent).WPs 1–4 each includes a new PhD student taken up by CenSES’ PhD school or by one of the project partners’ institutions. For leaders and partners in the WPs, see section 4. For WP deliverables, see also section 6.

WP1: Local sustainable development

This WP has three parts. First, we will suggest indicators and threshold values for sustainable development’s main dimensions at a national level. This work will further our long-term commitment in this field (Holden, 2007; Holden and Linnerud, 2007; Holden et al., 2013). Second, we will suggest similar indicators and threshold values at a local level, particularly emphasizing production and use of renewable energy. Third, we will suggest policies for sustainable renewable energy projects. The last part draws on the results from WPs 2–4 and on the interaction with the user group in WP5.

Method: A workshop will take place shortly after the project commences. It will include all research partners and the user group. Holden will have a 6-month term at Oxford University to develop the WP and publish a book.

Deliverables: A book (Title: Policies for sustainable renewable energy projects) published at a level-2 publisher and five articles in peer-reviewed journals, for example: *Energy*; *Sustainable development*; *Renewable and Sustainable Energy Reviews*; *Energy Policy*; and *Renewable Energy*.

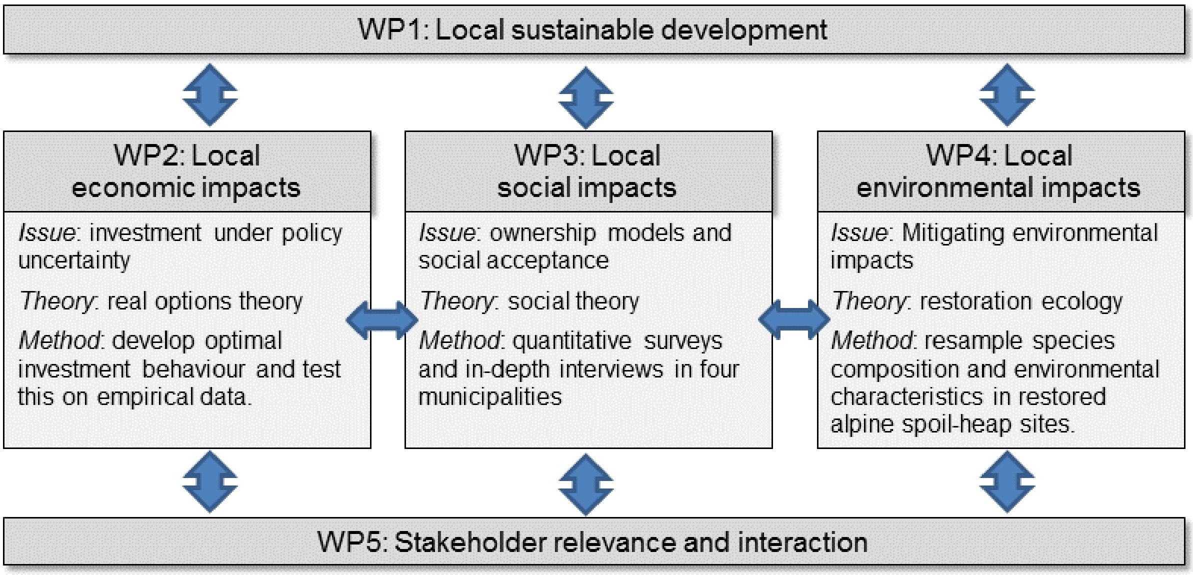

Figure 2: The project's work plan

WP2: Investing under policy uncertainty (real options theory)

Research questions: 1–4.

Method: We derive theoretical investment rules using dynamic programming to define the optimization problem, which is then solved analytically (e.g., Merton, 1976; McDonald and Siegel, 1986) or by using simulations (e.g., Longstaff and Schwartz, 2001). Uncertainty is modelled either as stochastic diffusion (e.g., geometric Brownian motions) or as jump processes (e.g., Poisson events). We test the theoretical models' predictions using discrete choice regressions. The data are gathered through interviews, surveys, and publicly available datasets. We will supplement these regressions with interviews and/or experiments in which investors' attitudes towards risk and their time preferences are tested more directly (Kahneman, 2011).

Deliverables: Four articles in peer-reviewed journals, for example: *Journal of Environmental Economics and Management*; *Environmental Resource Economics*; and *Journal of the Association of Environmental and Resource Economists*.

WP3: New ownership models and social acceptance (social theory)

Research questions: 5–8.

Method: We will use small-scale hydropower development as a case to study ownership models and social acceptance. There are three model types: development by traditional utilities owned by the municipality, development by professional small-scale private developers, and development by landowners. We will study acceptance in three developments within each model (i.e., there will be nine embedded cases). In each embedded case, we will perform in-depth interviews with key actors in the community. Key actors include political and administrative leaders in the municipality, representatives of developers, environmental organizations, and locals that otherwise will be affected by the development. The qualitative interview data will be analysed by applying the grounded theory method (Corbin and Strauss, 2007). Moreover, we will perform a questionnaire-based survey across the embedded cases. These quantitative data will be analysed by applying multivariate regression analysis. The interviews and survey will be supplemented by studies of articles in local newspapers to give further insight into community acceptance. Thus we will apply a methodological triangulation approach (Cohen et al., 2011).

Deliverables: Four articles in peer-reviewed journals, for example: *Energy*; *Energy Policy*; *Renewable and Sustainable Energy Reviews*; and *Renewable Energy*.

WP4: Mitigating environmental impacts (restoration ecology)

Research questions: 9–12.

Method: We will resample species composition and environmental characteristics in permanent plots in restored alpine spoil-heap sites and their undisturbed surroundings (Rydgren et al., 2011; Rydgren et al., 2013). These data will be subjected to ordination and calculation of successional rates (Rydgren et al., 2011). We will investigate the effect of dispersal traits on restoration success using data on all species' functional traits collected from literature and open databases (Bioflor, TRY, etc.). We will sample seed rain and seed bank in the permanent plots and germinate them in growth chambers. Appropriate modelling methods (e.g., linear mixed models) will be used. We will perform demographic censuses of populations of *V. myrtillus* (Hegland et al., 2010) in restored and reference plots, and will analyse data with matrix modelling and/or integral projection models (Metcalf et al., 2013). The spatial and temporal structure of spoil-heap populations of *E. nigrum* will be analysed using the methods of Boudreau et al. (2010).We will predict establishment success of *E. nigrum* at coarser spatial scales through distribution modelling (using MaxEnt; Phillips, 2011).

Deliverables: Five articles in international, peer-reviewed journals, for example: *Journal of Ecology*; *Journal of Vegetation Science*; *Restoration Ecology*; and *Ecological Engineering*.

WP5: Stakeholder relevance and interaction

Method: Research Council of Norway recommends that research ensure social relevance; thus, communication and interaction with private and public stakeholders are vital (RCN, 2012).

Activities: A number of activities will be conducted during the project. First, we will arrange a start-up workshop for all partners, including individual workshops for each WP. Second, we will arrange an open, international conference at the end of the project period, including a pre-conference for PhD students. Third, to ensure a continuous flow of knowledge between the user group and researchers, we will provide workshops to individual users that are tailored to their needs. Moreover, we will publish a bi-monthly newsletter on Sogn and Fjordane Science Park's website. Also, the project's PhDs will do yearly internships at individual users' facilities. Fourth, we will arrange yearly regional seminars open to users and other relevant stakeholders. Fifth, with users, we will continue the ongoing work to establish a renewable energy industrial cluster in Sogn and Fjordane. This work started in 2013 and will continue throughout the project period. HiSF will apply no later than 31 December 2017 for Norwegian Centre of Expertise (NCE) status.

Deliverables: Start-up workshop with project partners in 2015, international conference in 2017, yearly regional seminars, yearly business internships, tailored workshops for individual users, bi-monthly web-based newsletter, and an NCE application by 2017.

4. Project organization (*CV attached, **Letter of intent attached)

The project will be managed by *Erling Holden** (professor at HiSF**). Holden was central in developing and raising financial support for HiSF's Renewable Energy Programme, which he has managed since it started in 2008. He was also central in assisting CenSES to receive FME status and is currently a member of CenSES' leader group. For more than 20 years, Holden has worked with issues related to energy and sustainable development, combining technology-oriented environmental studies, sociological and socio-psychological behavioural studies, and physical planning studies. Thus, Holden is well suited to handle the project's interdisciplinary ambitions.

Holden will lead WP1. He will work closely with *David Banister** (professor at Oxford University**), who has an established international reputation in research on energy, transport, and sustainable development. In particular, his work on analyses of sustainable policy packages and paths will contribute to this WP. The PhD student will be working with policies for sustainable renewable energy projects. This WP's result rests heavily on the economic, social, and environmental impacts of renewable energy projects. The WP's work will therefore include frequent close cooperation with WP 2–4's leaders and with the user group.

*Kristin Linnerud** (senior research fellow at CICERO**) will lead WP2. Linnerud has both professional and academic knowledge of the energy sector. Recently she has been the key person initiating and developing two research projects on investment under policy uncertainty, which are led by the Institute of Industrial Economics and Technology Management at NTNU (part of CenSES). Thus, she will be a link between these projects and RELEASE. Linnerud lives in Sogn and Fjordane and has earlier held positions at HiSF, and will therefore be able to contribute actively to develop competence at the university college level. She will work with *Johannes Idsø,* associate professor in economics at HiSF. He has worked with issues related to energy and regional economic development since 2008. The PhD student will have main responsibility for the empirical studies.

Bente Johnsen Rygg (assistant professor at HiSF) will lead WP3. Rygg is currently finishing her PhD in renewable energy at HiSF and NTNU: "Renewable Energy as a Community Concern: How Local Communities Face the Challenge of Increasing Use and Production of Renewable Energy". She will work with *Marianne Ryghaug** (professor at NTNU**) and *Karl Sperling** (assistant professor at Aalborg University**). Ryghaug, deputy director of CenSES, will contribute with knowledge on how public attitudes affect acceptance of renewable energy technologies. Sperling will contribute with knowledge on the relation between local ownership and local energy planning. The PhD, supervised by Ryghaug, will have main responsibility for gathering empirical data.

*Knut Rydgren** (professor at HiSF) will lead WP4. His main expertise is within the fields of vegetation-, population-, and restoration ecology. He will work with *Inger Auestad* (associate professor at HiSF), *Rune Halvorsen** (professor at University of Oslo**), *Joachim Töpper* (PhD student at HiSF), and *Eelke Jongejans** (assistant professor at Radboud University**). Auestad's expertise is within restoration ecology, with particular emphasis on grasslands, invasive species, and seed ecology. She will work on the field studies. Halvorsen, a highly reputed scientist, will contribute with knowledge on statistics modelling of data. Töpper will contribute on the statistical modelling, and will contribute with statistical analyses on WP2 and WP3. Jongejans, who is at the forefront of international research on population modelling, will contribute on how environmental drivers impact spatial population dynamics.

*Jøril Hovland** (project leader at Sogn and Fjordane Science Park**) will lead WP5. She has long experience in managing knowledge-building projects between researchers, local government, and business. She will have the main responsibility in the project to ensure continuous communication and interaction between researchers in WPs 1–4 and the project's user group.

The user group includes relevant stakeholders from business, government, and NGOs. Sogn og Fjordane Energi**, Sparebankstiftinga Sogn og Fjordane**, and Sogn og Fjordane County Council** contribute with funding. All other members of the user group (a total of 30) are listed in the attached letter of intent from Sogn and Fjordane Science Park.

*CenSES*** (Centre for Sustainable Energy Studies), represented by professor Asgeir Tomasgard at NTNU, will be an important partner in the project. Through its PhD school, CenSES gives access to relevant PhD programmes and supervisors. Moreover, CenSES gives possibilities for HiSF to develop new projects for the Norwegian Research Council and for the EU's Horizon 2020.

5. Key perspectives and compliance with strategic documents

Compliance with strategic documents: See attached endorsement letter from HiSF. *Relevance and benefit to society and the environment*: See sections 1 and 2.1. *Ethical perspectives*: Our external funders represent developers and financial institutions. To ensure a balanced examination of impacts of renewable energy projects, we will invite to workshops and seminars representatives from environmental NGOs, regulatory authorities, and non-professional, small-scale investors. *Gender issues*: Five women (three WP leaders) and seven men (two WP leaders) constitute the project group. We will encourage female applicants to the PhD positions.

6. Dissemination and communication of results

See grant application form.

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