Renewable Energy Potential of Greenland with emphasis on wind resource assessment

As consumption, of the expensive energy, in the remote Arctic area increases, the demand for alternative energy sources will grow. For Greenland, hydropower is the preferred renewable energy source, but the resource is limited and the investment costs are high, and this moves the focus to other sources, such as wind and solar power. The biggest barriers to implementing these sources are lack of knowledge about the resources and their geographical distribution. In this project, different sources and methods for wind resource assessment are studied, with a focus on their performance in the complex Arctic terrain of Greenland. The energy systems are studied to identify the potential use of renewable energy in the system. Finally, a short description of wind power development in Greenland and some recommendations for further development are provided. The power systems can be split into three categories, based on the type and existing energy source. Small village systems are supplied with diesel generators with limited heat utilization. These generator units have a relatively low efficiency (0.25 - 0.35) because of obsolete technology and low-load factors. To demonstrate the optimization potential for these village systems, the village Sarfannagwaq was selected for a detailed study of consumption, saving potential, and renewable energy potential. The saving potential for nonindustrial use was, with only small adjustments, 20% of total consumption, and depending on the definition of Profitable (required returns of investment), more can economically be saved by replacing outdated equipment. The renewable energy potential for both solar and wind was relatively high, with solar radiation above 1000 kWh/m²/year and mean wind speeds of 6.1 m/s at 10 MAG. For a 50 kWp PV installation the 25 year average production cost was estimated to be less than 0.83 DKK/kWh and for a 100kW wind turbine, installed at site 2 (South-west of Sarfannagwaq), the 20 year
average production cost was estimated to be 0.85 DKK/kWh. Compared to the 2013 cost of goods for the diesel generators of 2.29 DKK/kWh, there is room for system updates to obtain a high RE penetration. In the next category, named diesel cities, a large potential for waste-heat utilization was discovered, and in the city of focus, Nanortalik, updating the diesel generator unit, expanding the district heating grid, and implementing 500-1500 kW wind power were suggested. For the last category, named hydro cities, there is potential for other sources if or when the hydro resources are used up.

For wind resource estimation, various methods of monitoring and modeling of wind resources were studied with a focus on their use in complex Arctic areas. First, the existing ground-based measurements (Climate stations) were studied to determine applicability for wind resource estimation, and for many of the stations, a high local effect, inhomogeneous time series, and deviance from the WMO guidelines were found. The next step was to design a dedicated wind monitoring system usable in the Arctic environment and to test it at different types of sites. The instrument test showed that even the highest quality of equipment failed in harsh climate. An extended test was planned, but due to delays, the test result is not ready yet. Based on the measurements, 10 sites were evaluated, 4 in the Uummannaq district, 5 in Sisimiut district and 1 in the Nanortalik district. Only two of them have a verified resource above 6m/s, but one more has the potential. One of the sites, Nanortalik Dump 1601, was studied in more detail by estimating the inflow angle, BL stability and turbulence distribution. The site class was found to be IEC class IIIS due to raised turbulence levels in some sectors. For wind resource modeling, two types of models were evaluated; micro- and mesoscale models. The validation work showed that the microscale models performed relatively well within a 500m range of the reference site, depending on terrain and metrological conditions. The mesoscale models WRF and Polar WRF were validated against 14 measurement points in an 800x800km domain, and a detailed study of the 3D flow field in a complex fjord system was done. Furthermore, the modeled wind speed distribution was compared to satellite based ocean wind observations. The mesoscale work showed that the surface data available, especially the sea ice concentration and the surface elevation, need to be improved to obtain optimal model performance throughout the domain. In the last part of the thesis, some suggestions for how wind power can be successfully developed in Greenland are given, together with the experiences gained from the test turbine. The main conclusion in this part is that a high-quality preliminary study (level 1) of available data, such as ocean wind, reanalysis data, inferred pictures of katabatic flow pattern, and station observation, together with good models is the key to a good site selection. To estimate project feasibility, detailed studies of infrastructure, raw materials, and wind resources are needed.

Since the unsuccessful introduction of commercial wind turbines in 1983-1986, wind power has not been a part of public systems, but technological development and the fact that verified resources now are available might open the way for Greenlandic wind power. There are still some model problems that need to be solved before a reliable resource map for all Greenland can be made, but with this project, Greenlandic wind power has come one step closer.

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Telonemia, a new protist phylum with affinity to chromist lineages
Recent molecular investigations of marine samples taken from different environments, including tropical, temperate and polar areas, as well as deep thermal vents, have revealed an unexpectedly high diversity of protists, some of them forming deep-branching clades within important lineages, such as the alveolates and heterokonts. Using the same approach on coastal samples, we have identified a novel group of protist small subunit (SSU) rDNA sequences that do not correspond to any phylogenetic group previously identified. Comparison with other sequences obtained from cultures of heterotrophic protists showed that the environmental sequences grouped together with Telonema, a genus known since 1913 but of uncertain taxonomic affinity. Phylogenetic analyses using four genes (SSU, Hsp90, alpha-tubulin and beta-tubulin), and accounting for gamma- and covarion-distributed substitution rates, revealed Telonema as a distinct group of species branching off close to chromist lineages. Consistent with these gene trees, Telonema possesses ultrastructures revealing both the distinctness of the group and the evolutionary affinity to chromist groups. Altogether, the data suggest that Telonema constitutes a new eukaryotic phylum, here defined as Telonemia, possibly representing a key clade for the understanding of the early evolution of bikont protist groups, such as the proposed chromalveolate supergroup.
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**Design af bæredygtige energisystemer i Grønland**

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