Description of the project for the general public

Increasing global energy demands are caused by rapid industrialization and population growth and therefore the acceleration of fossil fuel depletion and carbon emissions attracts attention to renewable energy sources. One of the least popular types of renewable energy sources is one associated with the presence of different liquid solutions in the environment. Differences in dissolved species concentration between two solutions can be used to generate useful energy by applying the controlled process of mixing of a pure solvent and its solution (or mixing of two solutions with different concentrations) through the passage of a solvent through a semi-permeable membrane. The flow of solvent occurs from a region of a high solvent concentration to the region of the low concentration and is known as osmosis. It results in the pressure difference between both its sides (the osmotic pressure). The observed increased pressure and amount of components on one side of the semi-preamble membrane can be subsequently used to obtain useful energy. The most common liquid solutions available in nature are these of water as a solvent with salts as the dissolved species. The natural mixing of the low salt concentration river water with the salty sea (or ocean) water occurs in the water estuaries. Assuming the mean salinity of the ocean water as 35 g/l and negligible salinity of the freshwater it was found that the osmotic pressure can then attain a value of 2.7 MPa. The useful energy can be obtained not only by mixing the river and ocean/seawater but also from, e.g., the seawater and the concentrated community waste sewage water, the seawater and the concentrated salty water received from the reverse osmosis, the sewage water coming from industry or the geothermal water of high salt content and the cleaned community sewage water or the groundwater with the low dissolved species concentration.

One of the most promising ways of extracting power from a difference of salt concentrations in solutions is the ***Pressure-Retarded Osmosis*** (PRO). It is based on applying the constant pressure difference between two solutions, e.g., water solutions with different salt concentrations. This results in a flow of the pure water across the semi-permeable membrane from the dilute and low-pressure solution to the high salt concentration pressurized solution and retaining the solute (dissolved salt). Due to applying the higher pressure to the concentrated solution (but less than the osmotic one), the water transport is partly retarded. The transport of water from the low-pressure diluted solution to the high-pressure concentrated solution results in the pressurization of the volume of transported water. This pressurized volume of the water can be subsequently used to run a turbine and finally generate electrical power.

The concept of generating useful energy by the mixing of low-saline and high-saline water using natural solutions existing the nature with the rejection of the exploited solutions back to the environment, i.e., using ***the open-cycle*** of the solution flow, attracted the attention of the researchers and resulted in building the first experimental hydro-osmotic power plant operating on the PRO in Tofte (Norway) in 2009 which was run by Statkraft Company till 2013. Since that time, several PRO-related pilot plants were constructed or are under construction worldwide. It was found that the performance of the power plants based on PRO and operating in an open cycle is limited by many factors (access as well as limited salinity of the seawater and flow of the river water, physical phenomena and operation of the semi-permeable membranes, etc.). Therefore, another concept based ***on the closed-cycle*** approach has been proposed in which the mixing process of associated with the generation of useful energy is followed by regeneration of the dissolved species concentration using, e.g., thermal energy. The working fluid can be replaced with by some synthetic solutions which have more advantageous properties and contribute to much higher power densities from membranes. For the regeneration of the solutions, low-grade heat sources such as solar energy, geothermal energy from shallow wells, biomass heat or the heat coming from industrial processes or power plants can be used. However, the application of closed cycles with alternative working media requires studies related to both analyses of membrane transport phenomena and the improvement of their efficiency. Tools (models & methods) needed for these investigations will be developed in this project.

The first result of the project will be a new complex and detailed micro-macroscopic model of solvent flow through the membrane (i.e., accounting for the membrane microstructure, transient and non-isothermal solvent flow, solvent flow interaction with flows of the low- and high-concentration fluids on both membrane sides). The model can subsequently be used to design, test and optimize the performance of the new membranes to be applied for the energy conversion in the future closed cycles. The second important result of the project will be working out a method for analysis of different ***closed-cycle*** PRO systems and for optimization of these systems from point of their energy conversion efficiency. The method may allow for carrying out a comparison of different configurations of the ***closed-cycle*** system and tailoring their specific configuration to the source of the renewable or waste energy available.