RegiOpt Conceptual Planner - Identifying Possible Energy Network Solutions for Regions

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Energy production systems are changing in its structure all over the world. The shift from fossil resources which are point sources to renewables is also forcing new ways of energy transformation. Because renewable resources are area dependent harvesting, logistics and also usage in small scale power plants are key areas of renewable based energy networks.

Regions are in the focus for the provision of energy carries like wood, cellulosic material and energy crops. Different regions have a variable setup of resource availability. RegiOpt tries to simulate possible energy network solutions based on the local conditions of every problem definition. The idea is to combine two proven tools to a single user friendly program. RegiOpt – Conceptual Planner (RegiOpt-CP) is a web based program which is intended to be used by regional actors and decision makers. It offers the possibility to get on a simple way an optimal energy technology structure based on PNS optimization. In addition the optimal solution is evaluated automatically with the SPI method and the results present the ecological footprint information. A continuous adjustment and variation of calculation values improves the capability of RegiOpt-CP for calculating a set of different scenarios which might be applicable for the specific region.

Because of the fact that not every technology can be used in each region and a huge set of technology options exists on the market, RegiOpt-CP offers objective technology network solutions to decision makers.

1. Introduction

Renewable resources for energy utilization are becoming more and more important. The substitution of fossil resources to reduce carbon dioxide emissions is a major challenge all over the world. Due to the fact that renewable resources are area dependent (e.g. biomass needs area to be grown and harvested) regions come into the role of energy carriers producers. Thus the development potential for regions is of public interest. In terms of renewable resource based energy provision there can not only be one specific successor technology substituting the fossil based ones. It is rather a combination of different technologies, linked in a mature network, utilizing several resources. Regions differ considerably in their structures like e.g in the availability of resources. For this reason every single region might need a specifically designed technology network for its energy provision.

To achieve those individually adjusted networks for regions the software RegiOpt-CP has been developed. A first basic concept has already been described by Kettl et al. in 2011, now the application is already near completion. It is a simplified decision making tool for optimizing sustainable energy structures at a regional level. In several projects during the last years of research there was one approach to create and evaluate technology networks (e.g. Birnstingl et al., 2011; Robeischl et al., 2012). In a first step the network itself was developed with the help of the Process Network Synthesis,

PNS (Fiedler et al., 1995). Out of a given maximum structure, which parameters are strongly linked to the basic conditions such as available resources in a region, an optimal solution could be found. This result of the p-graph method represented the technology network with the highest profit for a region. In a next step scenarios were run through and a setup of possible structures with different revenue of the solutions could be collected. After PNS optimization the ecological assessment was carried out. The technology network with all in- and outputs provided the data for the Sustainable Process Index, SPI (Krotscheck and Narodoslawsky, 1996). In the end the results of both tools were brought together and an overall solution with high profit and low ecological footprint could be described.

2. Methodology

The main idea was to combine PNS and SPI to a single application. The overall goal is to use the regional resource potential in the most economic and ecological way. The target user group comprises regional development experts and planners e.g. decision makers. RegiOpt-CP can be handled without any specific background knowledge as all necessary calculations for the optimization and evaluation are carried out in the background by the program itself. The user just needs to answer questions, asked by an online survey. The questionnaire is prepared to fit for the target user group and provides default values to help filling in the required information if some parameters are not known to the user. All calculated values needed for the PNS optimization are listed at the bottom of each page of the questionnaire. Optimization and evaluation result in graphs, figures, tables and text and create a solid basis for decisions.

The economical optimization is achieved with Process Network Synthesis (Halasz et al., 2010) and these results are ecologically evaluated by the Sustainable Process Index (Sandholzer et al., 2005).

2.1 Process Network Synthesis (PNS)

PNS uses the p-graph method and works through energy and material flows. Available raw materials are turned into feasible products and services, while in- and outputs are unequivocally given by each implemented technology. Time dependencies like resource availability (e.g. harvesting of renewable resources) as well as product or service demand (e.g. varying heat demand for district heating over the year) are part of the optimization. The necessary input includes mass and energy balances, investment and operating costs for the technologies considered, costs for resources and utilities, prices for products and services as well as constraints regarding resource supply and product/service demand.

In the case of RegiOpt-CP there is an already given maximum structure with default values in the background. With help of the user input this structure is adapted by adapting values or, if necessary, deleting some branches (e.g. if there is a resource not available in the region). In the end of the questionnaire this structure, linking resources and demands with different technologies, is the starting point for the optimization resulting in an optimal solution structure representing the most economical network.

2.2 Sustainable Process Index (SPI)

The Sustainable Process Index (SPI) was developed by Krotscheck and Narodoslawsky in the year 1996 and is part of the ecological footprint family. The SPI represents as a result the area which is required to embed all human activities needed to supply products or services into the ecosphere, following strict sustainability criteria. Based on life cycle input (LCI) data from a life cycle assessment (LCA) study, SPI can be used to cover the life cycle impact assessment (LCIA) part. LCA studies are standardized and described by the ISO norm 14040 (ISO, 2006).

2.3 Methodology interaction

Both methodologies are interconnected and work invisible to the user (see Figure 1). The user is guided through a web based survey which is intended to gather input data which is needed to start a PNS optimization. The survey is focused on regional specific data to get information about available productive areas, existing energy supply and demand situations. Based on the survey data and a pre-defined PNS maximum structure the so called PNS optimal structure is generated. It includes all material and energy flows as well as all costs and prices of the suggested technology network. In the next step the SPI evaluation is done automatically with the values out of the Optimization and results in

an Ecological Footprint. The SPI results allow analysing ecological impacts according to land use, renewable, non-renewable and, fossil resource provision as well as emissions to water, air and soil.
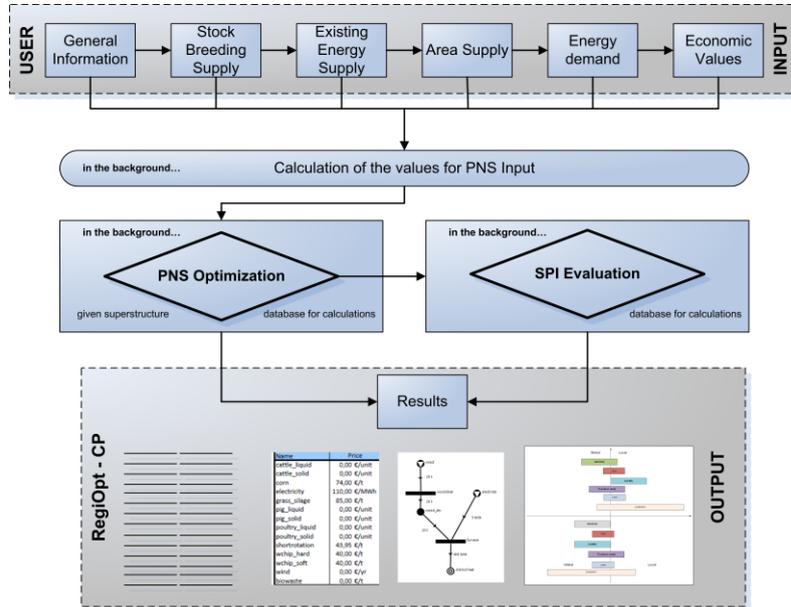
Figure 1: Schematic representation of RegiOpt – CP with its main functional parts

3. Functionality

Using RegiOpt-CP is simple and somehow self-explaining. It is mainly a questionnaire guiding the user through six input pages wherein all data and information are collected that are in a second step needed for background calculations done by the program without any notice of the user. Figure 2 has its focus on the questionnaire which is a data and information collector for the evaluations. The results are again visible for the user and offer a broad range to work with.
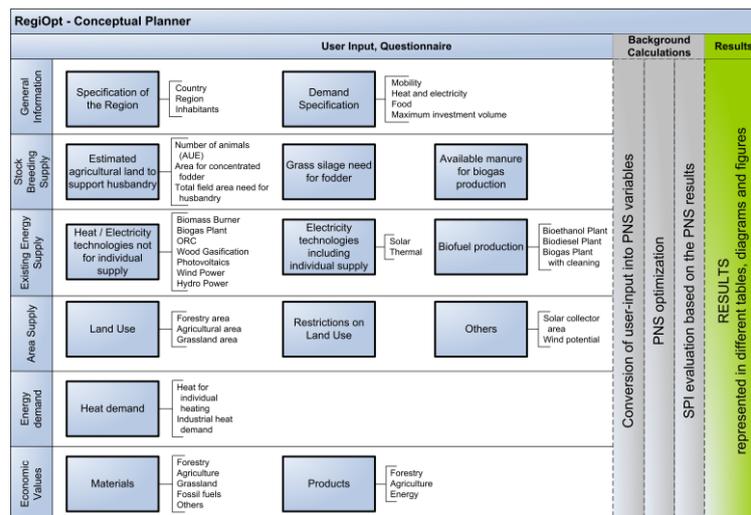
Figure 2: Data and Information Collection with the help of RegiOpt – CP questionnaire

3.1 General Information

In the beginning the user defines the project itself. Within this page main information about the structure of the region and the demands can be obtained. For example the country attribution defines the SPI value of the electricity that the system needs for the processes, because in every country the electricity mix and thus the impact on the ecological footprint differs (IEA, 2012). The SPI value itself depends on the different sources that the electricity is produced from.

The number of inhabitants is used in order to calculate the total amount of electricity need, meat and vegetarian food consumption and living space in the specific region. The demand specification is used to calculate this numbers in detail. RegiOpt - CP compares the demand for food with the existing potential to supply meat and vegetarian food and determines import of food to the region if necessary. The fact that high meat consumption means high environmental pressure may add to global inequalities and certain problems, therefore a warning is provided for sensitization.

These are so called ethical warnings that can be found all over the RegiOpt - CP as soon as there might appear an ethical conflict driven by the input parameters. These warnings are denoted by a separate button with an 'e' on it. There is an 'i' button as well where the user can find by mouse-over general information like default values or explanations what is meant by the developers in a certain case.

There is as well a possibility to set a limit of investment costs the user wants to spend for the project. As new energy systems are costly this function is implemented to avoid that a solution is offered that might exceed the regional financial capacities.

3.2 Existing Energy Supply

RegiOpt-CP takes into account, if some existing energy facilities based on renewable resources already cover some energy needs in the region. Therefore it is important to know the capacities of these technologies to consider the total amount. The existing technologies are not depicted in the optimal structure in the end, they just minimize the demand. The input page includes some well known technologies to produce heat, electricity and biofuels. The input is flexible and can be based on the input or output side of each technology.

3.3 Stock Breeding Supply

These data are required to determine the necessary agricultural area to support husbandry in the region as well as the degree of self-sufficiency in vegetable and meat production. The values are also used to estimate manure flows for possible biogas production.

3.4 Area Supply

For optimizing a region with RegiOpt–CP the starting point is the area that a region has on its disposal. The total area can be divided into three main categories; forestry, agricultural land and grassland. For each it is essential to define the area that is available to use the grown resources for energy provision. The restrictions on land use can be e.g. that some forestry area is needed for pulp and paper industry, for timber or for already existing energy technologies. Agricultural area can be reduced e.g. for growing vegetables or the fodder production to feed the animal needed to support the meat demand. There is a list of crops presented for the optimization process. Grassland area might be reduced e.g. if there is an existing biogas plant that runs on grass silage. To find out the solar thermal and photovoltaic potential the available area is asked as well. For wind energy the limiting factor is the wind power potential and the investment volume defined. RegiOpt–CP does not attach any area to wind power generation.

In this section it is possible for the user to add new materials and to define the lower heating value for unspecified oil seed and unspecified biomass for burning, for ethanol or for biogas production.

3.5 Energy Demand

This page is needed to get data about the heat demand, both for industrial and individual heating. The electricity demand given in RegiOpt–CP is calculated for all inhabitants of the region, but does not take industrial demand into account.

3.6 Economic Values

This page includes cost and price parameters of the different raw materials and products. Default values are based on the Austrian situation in the year 2011. The prices for crops include the costs for agricultural production (machinery, fertilizers and pesticides). Transport costs cover the transportation

from the farm to any plant. The transport costs for manure for biogas production are automatically included double for the calculation, because the costs of the return transport of the biogas manure to the field are also taken into account. Electricity is taken from the national grid. The ecological impact is calculated according to the national distribution of supplying technologies. The payback period for all technologies that are part of the optimization process is set to 10 years, except for photovoltaic and solar thermal where the period is 25 years.

4. Results

After the last input page of the questionnaire the user can see the results for his region. It is not only a list of numbers; RegiOpt-CP offers several diagrams for interpreting the results as well as a fully drawn structure. With the help of the input data given by the user a business as usual scenario is calculated to compare the optimized structure with the situation in the user's region at the moment. With that the improvement that can be achieved with an optimized technology network gets obvious. Due to the amount of results and their different representation forms (diagrams, tables and figures), a navigation bar will help users to find their way through. Aim of the navigation bar is to guide the user from results which are directly related to the structure, to more advanced results which connect the optimization and evaluation results in the regional context.

4.1 Tables
There are two tables within the result section that show the cumulated PNS optimization results (total revenue of the solution, cost of materials, revenue of products and total investment costs) as well as results of the SPI evaluation (ecological footprint in m² / service unit, share of products).

4.2 Technology Network
The optimal PNS structure is represented as an automatically drawn figure that can be exported and adapted by the user. Raw materials, intermediate products, technologies and end products are indicated by different symbols which are linked with related flows.

4.3 Region Comparison
In the focus of region comparison results are the comparison of the overall economic and ecological improvement compared to BAU (see Figure 3).
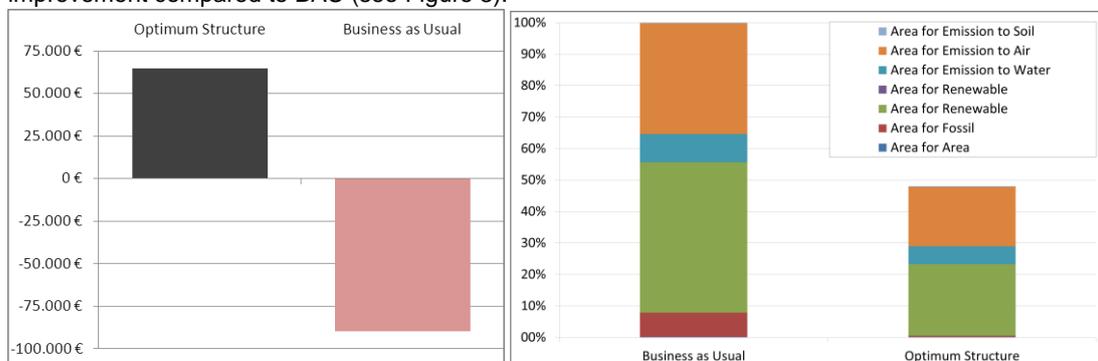
Figure 3: Regional comparison – Economic (left) and ecological (right) results within one year

Additionally the Ecological Footprint is divided by its 7 partial areas defined by the SPI methodology. Users are able to see life cycle Footprint information and the share between resource impacts (e.g. fossil and renewable), land occupation and emissions into air, water and soil.

4.4 Global – Local
According the SPI evaluation out of the PNS optimized structure, the SPI footprint of the region is presented in context to the regional information available. The user gets a diagram within the SPI values are presented in percentage and the position of the bar for each sector indicates which amount is produced locally and what has to be imported from outside. The diagram covers a business as usual (BAU) part as well which includes electricity, heat, biofuel, food (excl. meat) and meat production. On

the right hand side, the so called local part, the SPI impact caused by regional available production is shown. The opposite left side (global part) represents imports which are needed (assumed as fossil imports) as the region is not providing these services by itself. After PNS optimization a shift might happen from global to local SPI footprints caused by more activities within the region. Nevertheless it is important to keep in mind that due to reduced fossil imports the overall SPI value after optimization can be lower compared to BAU. With this way of representation, it should be visualized how the optimized structure can contribute from the ecological point of view, to reduce the ecological footprint. In the same way a diagram is given for the economic distribution between global and local production to highlight the economic improvement for the regional economy.

4.5 Energy Comparison

Finally some more detailed diagrams are presented related especially to electricity, heat and mobility. Because RegiOpt-CP does only propose an optimized energy technology network, the relation between BAU and PNS optimal structure is described in more detail.

5. Conclusions

RegiOpt – CP is a user friendly online - tool that shows how a regional energy technology network can look like. The user has to go through a questionnaire, but default values are always available if some specific data are unknown. After answering the self-explaining questions a total set of input parameters for an optimization is generated. With the help of PNS and the p-graph method as well as the SPI the best solution structure is calculated in the background in between a few seconds. The optimized network covers demands by using technologies mainly based on renewable resources that come from the region itself. By changing input parameters scenarios can be generated and compared by the user. As there is the possibility to save several projects the data is always available for the user as soon as an account is created. The data are treated completely anonymous and are just used within RegiOpt–CP. The results offer several possibilities to see the economic and ecological benefit of the suggested optimal network compared to the business as usual in the analyzed region. With the given tables, graphs and figures it is possible to prepare a good argumentation base to initiate innovative projects in a region that will be both; economic and ecological feasible.

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