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RESYS-Tool – considering dependencies among energy technologies in designing regional energy autonomy

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Abstract

The RESYS tool is an instrument, which is designed to provide communities with a profound overview and analysis about their energy demand and about their energy potentials based on renewables. On this basis, the creation of an appropriate energy strategy can be made more easily. The tool incorporates a generic approach which can be applied to many municipalities.

In order to consider demand and supply over time and interdependencies among different energy technologies and available resources a model was developed, which helps optimizing the usage of technologies. Finally, the tool is designed to help finding a reasonable local energy strategy and understanding the impacts of certain actions.

1. Motivation

The elaboration of energy transition strategies for municipalities is a severe challenge for energy consultants, who are developing these strategies together with the local policy makers. To understand the interactions and connections between the various energy technologies and efficiency methods profound knowledge is required. The RESYS-Tool was developed in a co-operative research project[5] funded by the Austrian research promotion agency FFG. It is designed to evaluate the qualitative and quantitative impacts of different strategies and support the energy consultants to compare and select best fit strategies. A main goal of this tool is to display the connections by varying the input values (actual energy demand, goals for energy reduction, potential exploitation, utilization strategies) and to integrate the results in the various energy concepts.

2. Overall model and tool concept

The RESYS-Tool guides the user step by step to create a sustainable energy scenario for a municipality.

An energy scenario is designed by the following steps (see Figure 1):

1. Determination of the type of municipality:
   Only a few user inputs are required to determine the type of municipality. This is the base for soft facts and key-numbers to determine energy consumption and potentials, thus reducing the number of further input actions.

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2. Current energy demand:
   Default values derived from the municipality type and a few additional user-inputs are used to calculate the current energy demand.
3. Energy production:
   Based on the soft facts of the municipality the theoretical renewable energy resources and the amount of potential exploitation are calculated.
4. Analysis of energy consumption:
   Calculation of the allocation of energy to sectors (habitation, businesses, industries, mobility) and the usage of energy (hot water, space heating, process heating, electricity, mobility) and the hourly development of the energy demand help to analyse the local situation.
5. Goals:
   The user defines trends and goals in order to determine the future energy consumption and exploitation (future number of inhabitants, reductions measures).
6. Results:
   RESYS-Tool calculates the hourly development of energy production and compares it with the energy demand for current and future scenarios. The benchmarking of potential exploitation, energy mix and utilization strategies informs the user about the sustainability and possibilities for improvements.

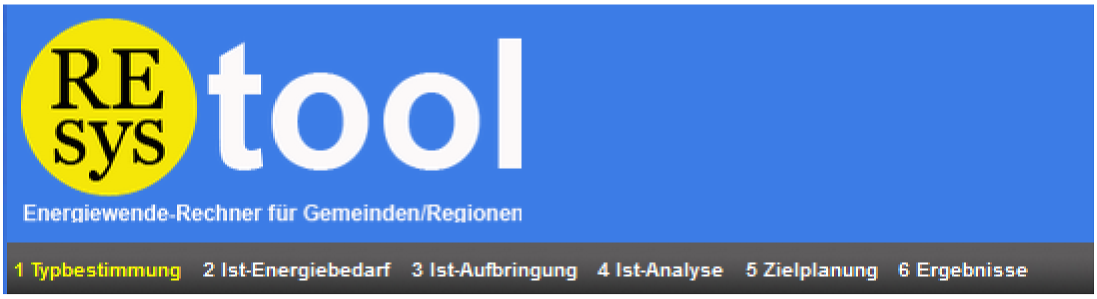

Figure 1: The tool bar of RESYS leads the user through modelling current and future energy scenarios.

3. Analysing the current energy demand

Frequently, the main problem is the lack of availability of all necessary information on energy use in the municipality. For some aspects, own surveys of a town or region may exist, in other cases even basic statistic data that could help to estimate energy demand might not be available. The RESYS-tool will help to analyse your municipality in short time (even if different levels of knowledge on energy use data are available) and sharpen the data as soon as you have more information.

3.1 Type of municipality

According to an analysis of 160 Austrian villages (Bußwald et.al, 2006), a set of municipality types, each with characteristic energy demand indicators and key figures like building quality, transport patterns etc., was developed: a town, a community with a higher amount of industrial and enterprise zones, a commune as a touristic centre, an agricultural municipality with the focus on land cultivation or on animal breeding, a local center (6.000 to 30.000 inhabitants) with infrastructure and administration or a community that is primarily a residence (often affluent suburban towns in the commuter belt).
The first step of working with RESYS tool the first step is to determine the municipal type. This can be done automatically based on some simple data readily available in any town: inhabitants, employees in

different sectors, beds in tourism, number of livestock, the electricity demand of the municipal administration and the areas of the community for buildings, forest and agriculture.
Based on this data the tool suggests a type of municipality, which can be modified manually. Some types can be combined (e.g. agricultural municipality with focus on animal breeding plus touristic community), some types (e.g. larger towns) not.

3.2 Energy demand simulation and analysis

Based on the type of municipality and some additional data input, RESYS tool estimates the **energy demand**.
The energy demand for heating, electricity and mobility will be divided into types of energy e.g. high temperature heat, steam, process energy below 100°C, hot water and space heating. The electricity is divided into the demand for air conditioning, cooling, IT, lighting, motors and so on. Additionally the total energy demand will be analysed in terms of user groups, dividing residential, business and infrastructure use. In the field of mobility results are separated in revenue passenger kilometres and tonne-kilometres of passenger cars, two wheel vehicles, trucks of different tonnage, tractors, busses, personal railway use, carriage of goods by train, ship, pipeline and flight, public and private aviation.

3.3 Sharpening data

Calculation will be more accurate if you add more specific data. Examples: The specific shares of passive houses, low energy houses and standard houses can be entered. Typical average energy indices can be modified for each house type (standard values proposed for the different municipality types). The number of employees in different sectors and the distribution of the working time of the enterprises (e.g. 10 hours from Monday to Friday or all the week 24 hours around the clock) can be entered to calculate the energy demand of business in accurately. Regarding infrastructure hospitals, indoor swimming pools, sewage plants and street lighting can be defined in detail if data is available.

4. Analysing the potential of renewable energy resources and current use

A central aspect for constructing sustainable energy concepts is to know the theoretical available energy resources.

All kinds of potential of solar energy, biomass, biogas and food production need land and space, which partly overlap. Thus they depend on each other. The immediate area consumption of wind water and geothermal plants is small and therefore it is neglected in RESYS.

Areas listed in Table 1 are the real potentials, which can be used by related technologies. The available areas have a constant unchangeable size. The way of the exploitation, however, can be varied by the user.

Area	*used for*	*Implementation*
roofs, facade areas	photovoltaic solar thermal plants	The available roof areas with different orientation and façade area is derived from special soft fact. The soft facts depend on the typ of municipality. It is up to the user to decide which amounts he would take for photovoltaic and solar thermal use. RESYS-Tool checks that the used areas do not exceed the total area. Based on climate parameters RESYS calculates the theoretical

		energy yield of the solar thermal and photovoltaic plants.
free areas	photovoltaic plants	Because of long distances, the solar thermal use is not suitable.
forest agricultural area	solid biomass biogas biofuels	The following biomasses are acquired. The energy potential is derived from typical soft facts. RESYS tool assumes that the food production areas are not affected by the energy production. Solid biomass: • forests • energy areas for miscantus, short-rotation plantation • straw (max. 60%, the rest remains on the field for humus formation) Biomass for biogas • non lignified energy plants • greening of corn field after harvesting • unused meadows • throw outs of vegetables Biofuels • oleiferous plants and corn from energy areas The amount of these areas come from User Input or can be imported from the statistical data of the Agrarmarkt Austria (AMA).
terrestrial heat	heat pumps	The user enters the type of ground (dry, wet, grit, clayey soil) and related key numbers lead to the theoretical potential of terrestrial heat.

Table 1: Calculation of the theoretical area potentials and their usage

The potential of biogas and solid biomass is expanded by biowaste from food production, park and garden maintenance. The amount of waste mainly depends on the number of inhabitants **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Theoretical Potential of Wind energy:

RESYS uses the results of the calculations performed within the study (Energiewerkstatt et. al 2012). The potential of each district of Austria was calculated depending on the size of the wind turbine. The theoretical potential of the municipality is the potential of the district multiplied by the proportion of the areas of the municipality and the district.

Theoretical Potential of Waterpower and Geothermal Energy:

The user has to enter the values of the remaining potential.

5. From the Current to the Future Exploitation

Actual exploitation:

The already exploited potentials are acquired by entering the annual energy yields or by entering the power of water or wind energy plants. For biogas or biomass CHP's and boilers the user enters the electrical or thermal power. For the calculation the input of the area of the solar thermal collector is necessary and the power in kWp is required for photovoltaic.

Future goals of exploitation:

The user can exploit the renewable resource for wind, solar and water power up to the limit of their theoretical potential. For biomass and biogas it is possible to exceed the theoretical potential, because additional biomass can be imported. However, RESYS-Tool informs the user that the import of biomass may cause harms to nature and restrict the food production.

Costs:

In order to give the user a feeling of the costs of the additional future energy plants, RESYS calculates them by using default key values.

6. Interaction between weather conditions, energy demand, energy production and their hourly progress

The regional climate and the profile of the energy use are the main influence factors for the energy demand, the usage of energy production technologies especially the useable energy yields of solar and wind power plants.

In order to model the interaction between energy demand and energy production in a realistic manner, RESYS-Tool uses several built-in simulations, which calculate in hourly steps. The following simulations work with regional climate data and demand profiles with hourly values.

- building simulation:
  It calculates the demand for heating and cooling energy demand of various building types (residential and non-residential passive house, low energy house, standard house)
- Simulation of solar thermal plats:
  It calculates the energy yield for hot water, space heating and low temperatur process heat with different demand profiles
- Simulation of photovoltaic plants:
  It calculates the electricity yields of photovoltaic plants which are orientated toward E(ast), SE, S, SW and W, as well as facade plants.
- Wind powers:
  RESYS uses the www.windatlas.at results to calculate the characteristic energy yield of wind power plants (see chapter 4) and uses a profile which is typical for the Austrian average. The hour values of the energy yield are derived from the average of 3 years of the published energy yields of wind energy.
- Simulation of lighting:
  The electricity demand for lighting is simulated by overlapping the global irradiance, the user profile and an amount of permanent lighting, which depends on the sector.

RESYS-Tool needs hour values of temperature and global irradiance of an average year. The regional climate data are calculated in the following steps:

1. Finding the climate region of the municipality. Austria is divided in 7 climate regions.
2. Calculation of the monthly mean values of temperature and global irradiance with the algorithm described in ÖNORM 8110-5.
3. Calculation of the hour values by regarding the actual sun position and building in fluctuation which are characteristic for the municipality weather. The fluctuations are very important, because they influence the size of energy storage devices.

There are some profiles which cannot be derived from climate data. These are water power, the demand of hot water, process heat, fuels, common electricity and sectoral energy consumption, too. RESYS uses synthetic profiles of working hours (5 day week, two trick, permanent working). The basic profiles are interfered in order to get characteristic for the distribution of working hours in the municipality.

7. Interaction between energy production technologies

The aim of developing a future energy scenario is to satisfy the regional energy demand for electricity, heat and fuels by using renewable energy resource. RESYS regards all proven technologies and technologies in a pilot phase, such as BTL (=biomass to liquid to produced fuels from biomass).

Figure 2 shows the main interactions between the demands of electricity, heat and fuels as well as climate parameters and the usage of renewable energy production technologies.

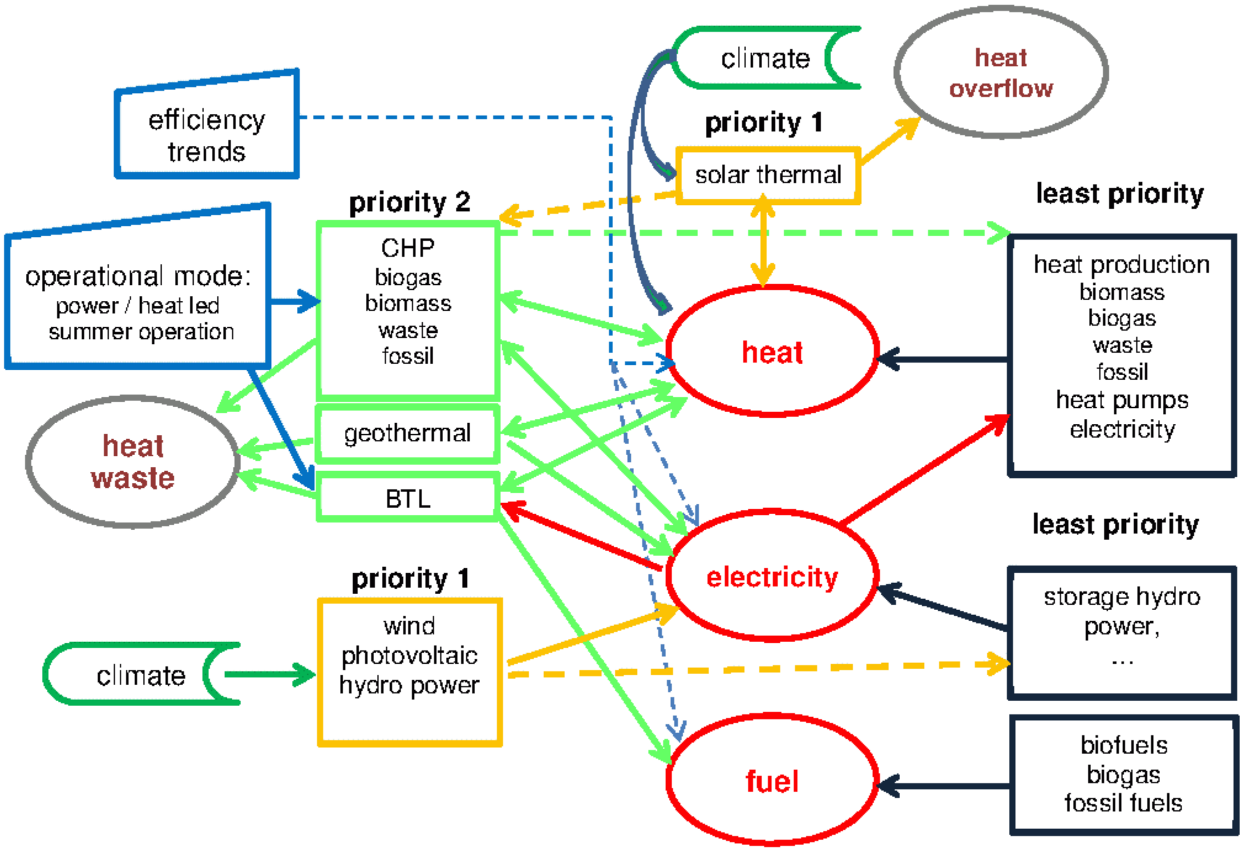

Figure 2: Interactions between the demands of electricity, heat and fuels as well as climate parameters and the usage of renewable energy production technologies. This diagram is simplified, RESYS differentiates between low temperature, steam and high temperature heat, related with certain technologies.

Important example of interactions which are treated in RESYS:

- By enlarging the area of the collector of a solar thermal plant, the coverage rate of low temperature heat increases. With the increasing amount of solar heat the digestible heat from the heat source of priority 2 (CHP's, BTL) becomes smaller and is repressed into the main heating time in winter
- A special challenge is the modelling of combine heat an electricity and heat and fuel production methods in order to achieve an high level of efficiency, it is important that all the produced heat can be used. If this is not successful, produced heat becomes waste and with it also biomass is wasted.
- BTL, biogas and solar plants and boiler need some electricity, which has to be produced from other power plants.

There are also some interactions which are not illustrated in Figure 2 – e.g. solar thermal plants and photovoltaic plant and somewhere also biomass can use the same areas. If one of these techniques increases, the potentials of the others decrease.

8. Hierarchy of energy production technologies

Storage hydro power plants and biomass need a special treatment, as the energy potential is included in a stored form and can be used at any time. Biomass can be exploited in CHP's (heat and electricity) and BTL plants (heat and fuel) or in boilers (only heat). The user can decide on the technologies and their amounts of use and also determines the operating modes (conducted by heat or electricity and fuel-output respectivly). RESYS also offers the opportunity to shut down a part or all biomass plants outside of the user-defined heating season. In order to raise exploitation efficiency of biomass it is important to go for combined heat and electricity or heat and fuels and to use the heat in an efficient way. Solar, wind and river power plants do not cause any direct resource costs and cannot store their energy. So they have a higher priority than biomass or biogas plants.

Completing our reflection, there are heat production technologies, which can be started at any time: Heat pumps, which need electricty and boilers based on different fuels.

In order to resolve the interdependencies, RESYS defines a priority order of technologies for energy production (see Figure 2):

Priority 1: Technologies (almost) without operational costs respectievly without fuel: solar plants, photovoltaic, wind, river plants. Their energy output cannot be stored, thus must be used as soon as it is produced, otherwise it is lost.

Priority 2: Accessible technologies with combined heat and electricity or fuel output: CHPs, BTL plants, geothermal energy only require cheap primary ressources (cheap biomass, waste) and therefore have a higher priority than the last priority technologies.

Last priority: heat pumps, boilers. Storage power plants. In the first version RESYS only regards (pumped) storage hydro power stations. In later versions electrochemical storage und power to gas storage will be implemented.

The priorty order of the energy technologies is demonstrated by an example of low temperature heat: A part of the regioal heat consumers have a solar thermal plant and take all the heat that is produced by the sun as much as they demand. The remaining demand is allocated by user interaction to the priorty 1 techniques (CHPs, BTL, geothermal energy) and the user also defines their operational parameters. RESYS then calculates with the built-in simulation the energy yields and the remaining energy demand, which at last has to be produced by the last priority techniques, which are allocated by the user to heat pumps and all kinds of boilers. The discribed methode is used to simulate the current as well as future scenario.

Regarding the solar thermal energy certain boundary conditions are considered: The average solar heating system is not a static factor but it depends on the total collector area. Significant enlargement of the total collector area will lead to corresponding rise of the collector area per house hold, which leads to a lower collector efficiency and poorer potential use. The tool will notify users about such adverse effects in order to support orientation towards suitable and efficient energy strategies.

9. Strategies of producing useful energy and the demand of energy storage

The direct comparison between energy production and demand results in a certain required storage capacity over time to balance short term and seasonal deviations.

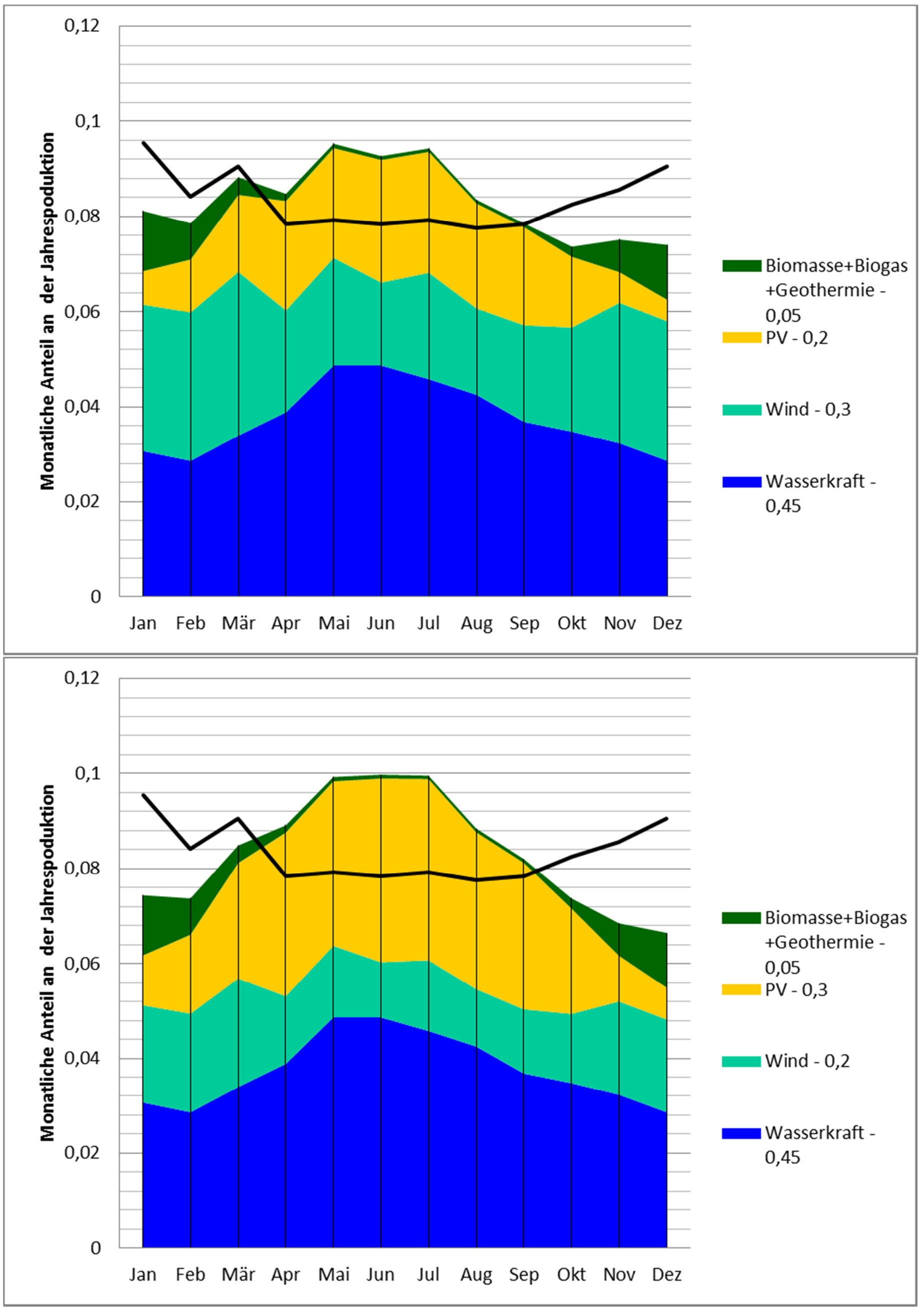

Figure 3: At the top: Renewable electricity mix for Austria consisting of 45% hydro power, 30% wind energy, 20% photovoltaic, 5% biomass. With a storage capacity of 5.8% of the yearly electricity demand (current capacity of pump storage systems) seasonal fluctuations can be balanced. At the bottom: If the wind energy contributes only 20% to the total demand while the share of photovoltaic increases, the storage capacity demand rises up to 50% (8.7 % of the yearly electricity demand). The solid black line represents the energy demand.

The RESYS tool is not designed to analyze and calculate prospective energy scenarios in detail by listing time resolved values of kWh but through the consideration of the factor time, complex interdependencies between energy technologies can be understood more easily. In addition it helps to identify energy savings. In detail the tool addresses the following issues:

- Consequences of the energy mix (wind energy, photovoltaic, hydro power, biomass) and reduction of demand for the short term and seasonal storage capacity demand
- The impact of the operating mode of biomass block heating stations and BTL plants in order to cover the demand of heat and electricity in winter. In addition the generation of lost heat will be identified.
- Through the usage of adequate meteorological data the influence of the weather can be simulated. As a result, even extreme weather situations can be considered.

Figure 2 shows the storage capacity demand for different compositions of the energy mix. If the generation of electricity exceeds the demand (in spring and summer) the storage system will be recharged. On the contrary, energy will be retrieved in times of high demand (fall and winter). Figure 2 shows that a high share of wind energy leads to a reduced storage capacity demand under Austrian climate conditions. By these diagrams users will be able to understand correlations and improve awareness.

Bigger storage hydro power stations are not configured for regional supply but to regulate the national energy balance. Therefore, RESYS assigns storage hydro power proportionally to the considered region by taking into account parameters like number of inhabitants and the potential for utilization of wind energy, photovoltaic and run-of-river power stations.

Amounts of energy, which cannot be balanced through the storage system, are marked as “Export” or “Import” energies. Depending on the population and employment density RESYS calculates how much “Import” energy is tolerable for a (urban) municipality respectively the amount of energy a (rural) region has to export in order to contribute a fair share towards a national energy transition.

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