Sustainable energy future for Austria

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Abstract

In many countries such as Austria the energy demand is mainly covered by fossil fuels. The negative impact on the climate and their decreasing availability brings up the need for a shift to a possible future energy system using solely renewable energy sources. The goal of the modelling is to compare and possibly match the energy demand of Austria with the long-term potentials of Austria's renewable energies. In different scenarios, possible ways of covering the energy demand should be visualised and analysed, taking into account the necessary use of biomass for food, for animal feed and for products.

To reach this goal, a static model of the demand in all different energy sectors versus all the various energy sources available per year was developed. Many parameters allowed one to change settings on both sides for the scenarios easily. We use a top-down modelling approach for the energy balance and apply bottom-up approach for functional modelling of the important parts of the system, due to high energy consumption, efficiency or trade-off potentials. Via the applied parameters it is possible to examine the effects of enforcing or reducing various energy supply and energy conversion technologies.

Our conclusion is that – against common opinion – it is possible to provide full coverage of Austria's energy demand by just using renewable energy sources, even with the still existing technologies. However, significant changes in the structure of buildings and in means of transportation are necessary. Introducing high construction standards leads to a definite reduction of heat losses. Room heating can then be done preferably by solar collectors, heat pumps and low-temperature district heating, reusing industrial waste heat wherever possible. The main part of biomass should be converted into CHP to process heat. The mobility structure has to change towards electrically driven technologies with much higher conversion efficiencies.

Keywords: sustainable energy system, renewable energy sources, energy systems model, efficient technologies.

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1 Introduction

These days, the topics climate change, high oil prices and rising food prices illustrate the dependence of many industrialised countries on fossil fuels mainly used as energy carriers. To mitigate the impacts of climate change, to increase national or regional value creation or the security of supply; the necessity for a sustainable energy system is discussed intensely by the science, by national and international policy makers and by economic and non economic stakeholders.

All the future scenarios of energy demand are based on actual demand, which developed as a result of cheap fossil resources and their broad availability. Extrapolation of the recent development to future trends leads to immense high-energy demand scenarios for the future which cannot be covered by renewable energy carriers. But in the long term, it is unavoidable to use renewable sources only.

This paper examines the opportunities of energy supply of the Austrian economy on a solar basis and shows up which changes have to be made to be able to meet the demand of the different sectors. With realistic available renewable energy potentials and foreseen technological improvements ways of possible full coverage of the energy demand are analysed in scenarios. The basis for this research is the Austrian energy balance. Fossil energy carriers are replaced by renewable energy forms and in a first step the insufficiencies are identified. Then the technological measures and required structural changes are implemented, which seem to be able to lead to a full coverage of the demand.

The results should point the reasonable development tracks which would be needed for a conversion to a solar based energy system. They should mark a possible vision of a sustainable energy future for Austria. Hence a specified time frame, costs or social acceptance are not considered. But they should be discussed on the basis of the results.

2 Methodology and approach

In course of the project a model was developed that provides the opportunity to analyse possible options of full coverage of Austria's energy demand solely by renewable resources. We used the modelling tool GABI, an object-oriented software tool that allows functional programming of process models. The objects can be taken out of databases or defined by the user. There exist different object categories, as the most important processes, flows and plans. The processes, which contain data of their input- and output-flows are positioned on the plans and then connected by the flows to process chains.

The model provides for the combination of different conversion technologies to cover the energy demand with the available potentials. "Distribution links" allow to reduce or enforce the use of certain technologies and to simulate the effects on the economy wide energy system. In sensitivity analyses the importance of the different "setscrews" then can be proved.

The basis of the modelling is the Austrian Energy Flow Diagram shown in figure 1 in a simplified version. Based on the energy demand in its qualities and quantities the energy supply chains that connect the demand with the required resources are visualised. The intermediate conversion technologies are combined to fundamental blocks. The flows on the left side of these technology blocks represent the transformed energy carriers. The outgoing flows indicate the amount of useful energy. The energy loss of the conversion technologies are not visualised to increase the clarity of the figure. They are visible from the difference between the in- and outputs. The resulting figure gives an overview of the Austrian energy conversion system, its connecting flows, the conversion efficiencies and the amounts and qualities of the energy demand.

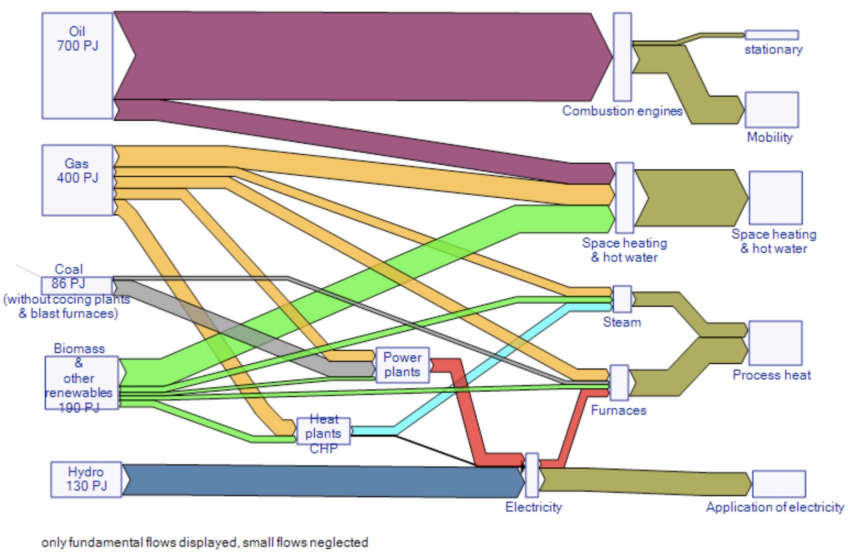

Figure 1: Austrian Energy Flow Diagram 2005 (simplified).

The now existing energy system is based on the use of mainly fossil resources. Mobility, space heating and process heat dominate the demand. For the electricity supply hydropower is yet the most important technology. The biggest losses occur in mobility followed by space heating.

3 Renewable energy potentials

The expert authority of the federal government in Austria for environmental protection and environmental control published a study on biogas in the transport sector in 2005 (Pölz and Salchenegger [1]). The study considers biogas substrates out of energy crops, excrement of the livestock production, sewage sludge and waste and reports a biogas potential of 54 PJ yearly. The potential of liquid agrofuels was studied by the Research and education institution “Biomass Logistic Technology” (BLT) Franzisco Josephinum and published by the

Austrian ministry of agriculture and forestry [2]. In the so-called biomass scenario a potential of 13 PJ yearly of biodiesel and bioethanol are obtained out of 200.000 ha cropland in the year 2020. These potential studies are based on specialised agricultural systems. Using integrated biorefinery systems a potential of about 180 PJ yearly seems achievable without any negative implication on the production of food and feed according to Amon *et al.* [3].

The Ministry of Agriculture and Forestry describes potentials of wooden biomass in the year 2020 of about 130 PJ [2]. In this study, black liquor, a by-product in the paper industry, is not considered. In 2005 about 22 PJ were produced and used as energy carrier in the paper industry. Together, a potential of 152 PJ can be concluded.

In 2002 the International Energy Agency (IEA) estimated the building integrated surface potentials with good solar yield for some selected IEA countries [4]. Austria offers about 140 km^2 on roofs and about 50 km^2 on facades with good solar yield. Dedicating 60% of the area to photovoltaic (PV) and 40% to solar heat and calculating 180 kWh/m^2*a as specific yield for PV and 400 kWh/m^2*a for solar heat results in 78 PJ electricity and 107 PJ low temperature heat. In this study the potentials of PV are based only on building integrated PV. Using also surfaces on other constructions would lead to a much higher potential.

The potential of hydropower is based on the technical economical potential of 56.100 GWh/a (200 PJ) indicated in different studies, i.e. Pöyry [5].

A study on the electricity potential using wind power in Austria in the year 2020 by Hantsch and Moidl [6] resulted in 26 PJ yearly. The study calculates an amount of about 1.000 possible plants. Taking this amount and assuming a mid to long-term average plant power of 4,5 MW leads to a potential of 34 PJ yearly. But also in wind power sector far better technologies are foreseen in the next decades, which would express a still higher potential.

Due to the limited potentials of renewable energy carriers the main issue of the transformation into a solar-based energy system is to use the existing potentials as efficient as possible. The priorities in this context examined in this study are the following: solar heat for space heating and hot water and in industry wherever possible. Wooden biomass should primarily be used in combined heat and power (CHP) plants to provide process heat or in industrial furnaces wherever possible.

A compilation of the respective potentials in Austria is shown in the following figure 2. The fossil energy carriers are removed and hence the supply side includes only renewable energies.

The size of the flows account for the amounts of energy potentials stated in selected studies. In the case of biogas, PV and wind, the squares and flows arising from it have different sizes. In these areas it seems possible to further increase the potentials as described.

A shortage of energy is clearly visible above all in the mobility and space heating areas. The potentials of biogas and liquid biofuels are not sufficient to cover the existing demand of the corresponding fossil energy carriers. Even

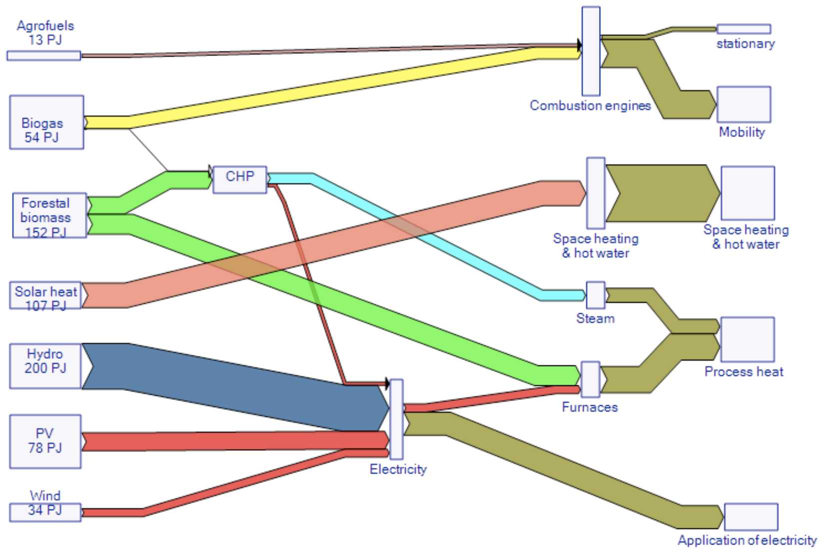

Figure 2: Solar and biogenic potentials.

dedicating all biogenic fuel potentials to the transport sector would not solve the problem.

Also in the area of space heating and warm water only by solar heat it is not possible to cover the existing demand. The forestal biomass, which is actually an energy carrier for space heating, is assigned to provide process heat, because there are little alternatives in industry imaginable. This way the process steam demand can be covered. The technical feasibility of using biomass in industrial furnaces has to be further analysed. In cases where this is not possible a substitution of electricity for fossil energy carriers represents a technical solution as this is already realised in parts of the metalworking or glass industry.

The electricity demand of stationary drives, of electrochemistry, of the households and for computing and illumination is combined in “application of electricity”, due to the exclusive use of this energy carrier. The potentials of electricity out of renewable sources are much higher than required for these applications, which allows one to supply also parts of the industrial furnaces and other areas of demand for electricity.

In the case of the hydropower potential, the framework directive in the field of water policy of the European Parliament has not been considered in the potential studies. But even with reduced realistic assumptions of 150 to 170 PJ per year a full coverage of electricity demand can be obtained.

4 Changes in the means of transport

As shown it is not possible to cover the existing energy demand for transportation just by a substitution of biofuels for fossil energy carriers. Hence it is necessary to work out realistic possibilities of structural changes that can lead to a full coverage in this area.

Electric drives offer much higher conversion efficiencies than combustion engines. Thus combustion engines should be substituted wherever possible. To ensure in modelling that electric drives are only used where this seems technologically possible (nowadays), the existing mobility demand is parted into long distance and local traffic (see figure 3). Furthermore we implemented the following assumptions regarding transport technologies: local traffic up to 50 kilometres is realised by electrically driven bicycles, scooters and cars. Local public transport is realised by subway, tramway and electrically driven buses. Distances below two kilometres are realised mostly by foot or by bike. Distances over 50 kilometres are realised by railway and private transport with biofuels and biogas. The individual long distance traffic is partly shifted to the railway. For the rest a supply with biogas and biofuels is assumed. Long distance transportation of cargo is mostly shifted to railway. The rest as well as short distance distribution of cargo is covered by biogas and biofuels.

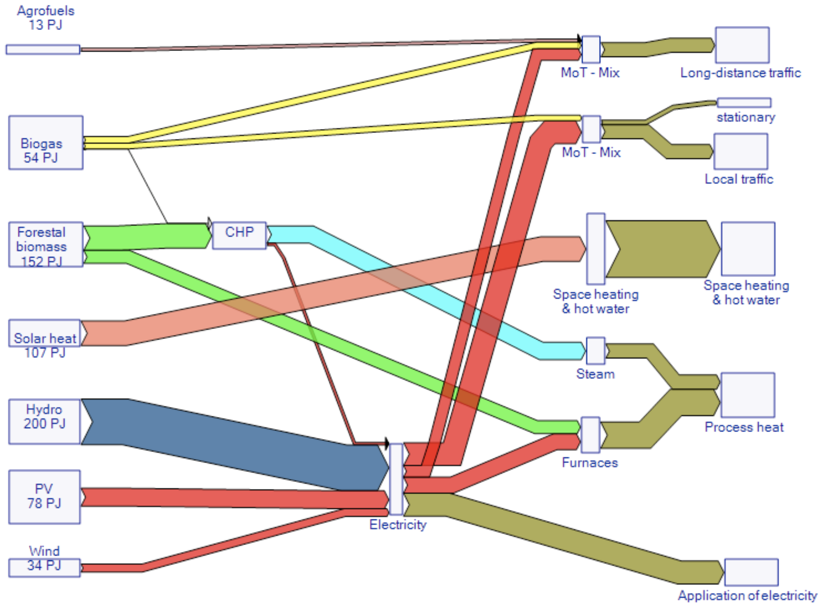

Figure 3: Changes in the means of transport.

These changes have great impact on the demand structures. The energy demand for local traffic is reduced drastically through the much better conversion efficiencies of electric drives. Long distance traffic overall the cargo transportation by train reduces the energy demand extraordinary and can then be covered by the potentials of electricity.

5 Changes in the space heating demand structure

In Austria the average heat demand of the existing residential buildings is 140 kWh/m^{2}a [7]. Considering the technological construction possibilities a significant reduction of the heat demand is possible. For the study we applied an average heat demand of about 50 kWh/m^{2}a over all buildings (including non residential). Furthermore we parted the heat and hot water demand into rural and urban regions to consider different technology options in different residential areas.

Covering the resulting demand would be possible with the following technological opportunities: In rural areas solar heat and heat pumps are used for space heating and hot water supply (low temperature heating). In urban regions the main part of the supply is realised via district heating including industrial waste heat. The rest is covered also by solar heat and heat pumps.

Figure 4 shows the reduced heat demand in the space heating and hot water supply. This demand can then be covered only by solar heat, heat pumps and district heating. The main part of the district heat derives from recovering

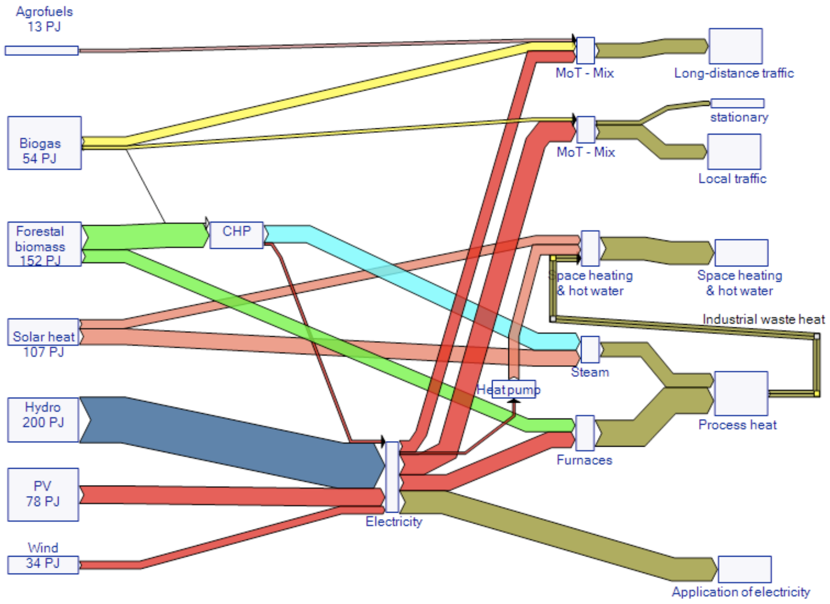

Figure 4: Full coverage by changed demand structures.

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industrial waste heat. The rest of district heat is supplied via forestal biomass in heating plants, but due to the small share in the sector it is not visualized in the figure.

6 Results

As a major pillar for a solar based energy system for Austria electricity has to become the basic energy carrier. The biggest potentials mainly in decentralised technologies would need a significant change of the power grid management. The major power supply would then come from decentralized small scale suppliers, the existing companies of the energy sector should then concentrate mainly on grid management, to compensate differences between supply and demand, instead of electricity supply with power stations.

Covering the energy demand in industry seems possible with the potentials of forestal biomass and by substituting fossil based melter furnaces by electric furnaces. The technological feasibility of this substitution has to be further analysed. Solar heat applications in industry should be pursued wherever possible.

The introduction of high construction standards will lead to a reduction of heat losses in buildings drastically. The resulting demand then can be covered by low temperature heating systems. In rural areas the potentials of solar heat and heat pumps allow full coverage with these technologies. In urban agglomerations district heating using preferably industrial waste heat and additionally solar heat and heat pumps can satisfy the demand.

In transport combustion engines are the dominating technology nowadays. The low efficiency of these engines leads to a high energy demand of mainly fossil fuels. Introducing electric drives and providing varying transport technologies for different distances allows a full coverage in transportation. Local traffic with mainly electric drives would allow covering the demand out of local supply. Long distance traffic has to shift partly to the railway. Parts of it can be covered by the potentials of biogas and liquid biofuels. Long distance cargo transportation has to shift significantly to the railway to make full coverage in transportation possible.

The displayed opportunities of a full coverage of the Austrian energy demand out of renewable sources should characterise the reasonable development paths obeying the realistic renewable potentials. They should mark a possible vision of a sustainable energy future for Austria without considerations on how the shift could be implemented.

Acknowledgements

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