Tyrol 2050 – Scenarios of a Fossil-Free Future

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Abstract

The presented study deals with energy scenarios for Tyrol/Austria, how energy systems in 2050 (buildings, production and mobility) could look like without fossil fuel use. For the building sector a course of the needed development is given. All available renewable energy carriers in Tyrol are needed and very high energy efficiency measures have to be taken to reach this goal. Four extreme scenarios and one mix-scenario were calculated. The extreme scenarios are dealing with primarily either electricity (I), hydrogen (II) or green-methane (III and IIIa) as future secondary energy carrier. The mix scenario (IV) is dealing with a more realistic mix of all these. Going for hydrogen and power to methane in an intense way, the electricity demand increases by far and large areas of PV fields on free land are needed.

Keywords: Energy Scenario, Tyrol, Fossil Free.

1. Introduction

The Austrian province of Tyrol intends to become energy autonomous until the year 2050. This means that all fossil energy carriers will have to be replaced by local available renewable energy. In the presented study the useable potential of local available renewable energy sources was evaluated and the future energy demand in 2050 under rigorous energy efficiency measures for the sectors buildings, mobility and production was estimated. Then the impact of different energy conversion technologies on the energy system was calculated. The whole project was accompanied by a stakeholder process in order to achieve a high acceptability in different political, industrial and environmental associations groups.

2. Scenarios and Basic boundary conditions

The energy sectors considered in this study were buildings, transport and production. The starting point was the official statistical data of the year 2016. Four extreme scenarios and one mix-scenario were calculated. The extreme scenarios are dealing with primarily either electricity (I), more hydrogen H2 (e.g. 40 % hydrogen-fuel cells in transportation) (II), or green-methane CH4 (III and IIIa) as future secondary energy carrier. The final mix scenario (IV) is dealing with a more realistic mix of all these.

The current energy flow of Tyrol was taken from official Austrian statistics for the year 2016. The potential of renewable energy carriers available in Tyrol were partly calculated and partly limited due to political restrictions. Hydro power, which is already one of the largest energy sources, was estimated to be increased by 50 %. This is still not the full technical potential, but seems to be today's maximum political feasible value. Solar energy was estimated to be mounted on 70 % of all roofs with more than 950 kWh/m²a solar irradiation. Thereby a distribution of 90 % to PV and 10 % to solar thermal collectors was assumed due to the price development of the two technologies in the last years. The potential of wood-biomass was derived by combining energetic biomass growing in Tyrol and saw residues from Tyrolian companies, even if the wood they used was originally imported.

Biogas, waste etc. was calculated according the available sewage systems and other availabilities. Wind energy is a pure political value. As there are no wind power plants so far in the highly touristic Tyrol installed, only 900 TJ (about 35 wind power plants with 2,5 MW each) were accepted by the stakeholders. Environmental heat for heat pumps was taken unlimited for ambient air and ground coupled systems, ground-water based systems were limited due to available aquifers in populated areas. Photovoltaics on open space is the reserve energy source, but as agricultural land and forest are needed for other purposes, only other land (maybe in the mountains above the tree line) can be used. Deep geothermal energy was not taken into considerations, as there is no major geothermal anomalies available.

Tab.1 sums up the energy flow in Tyrol for 2016 and the potentials of renewable energy sources. Hydro power dominates the potential of renewable energy carriers followed by solar and biomass. All the other reneweable energy sources are minor.

All renewables in their original state are called primary energy in the following.

Tab. 1 Primary energy used in 2016 and the available potential of renewable energy carriers in the province of Tyrol (Ebenbichler, Streicher et. al, 2018)

• Energy Used (2016), Potential (2050)	Use 2016 [TJ]	Potential 2050 [TJ]
Oil	37.314	
Natural Gas	12.788	
Coal	993	
Hydro Power	22.411	30.600
Solar		
Photovoltaics (Potential: 95% of useful roofs >950 kWh/m²a)	259	15.704
Solar thermal (Potential 5% of useful roofs)	891	2.161
Photovoltaics open space	0	not limited
Wood/residues	14.858	15.736
Waste	778	2.262
Wind	0	900
Biogas	401	
from biowaste and green plants		401
from bio fertilizers		549
from sewage gas		266
from energy plantations		0
Environmental heat	489	
Ground water		2.877
Ground coupled		not limited
Air		not limited
Deep geothermal	0	not used

3. Scenario Assumptions

Official statistical data available from 2016 was the starting value for the considerations. The following scenario assumptions were taken:

General

The demand of energy services was taken slightly rising with the population rate. This approach was heavily discussed in the accompanying stakeholder process especially by the environmental organisations. In the end it was agreed, that a reduction of energy services (less mobility, smaller area per person etc.) would make it easier for the energy transition but it would be difficult to “sell” this approach to the public. So taking this approach was staying on the safe (more difficult) side.

The study does not take into account seasonal energy storage or economics. Storage would need even more primary energy due to the storage efficiency. This aspect will be dealt with in a further study.

Trading of electricity is allowed I all scenarios as long as there is a yearly net balance of export/import.

Building sector:

The building sector was differentiated in 6 different building types (single family house (SFH), small and large multi family house (MFH), mixed use, commercial and other use) and 10 classes for the building age. For all buildings the 2016 baseline energy demand differentiated between space heating, domestic hot water and electricity for appliances was taken from previous studies (e.g. Pfeifer, 2017) that were based on a huge number of measured data. The following further assumptions for the scenarios were used:

- Population increase according to official values
- Increase of the useful building area per person from currently 46 to 48 m²/person.
- Starting from 2021 only passive houses for new buildings and a high standard for renovation is allowed. Both values are far better than the current national Austrian building code regulations. The equivalent deep renovation rate was estimated with 1.3 %/a, which corresponds to the historical renovation rate. The way of thinking behind that quite low number is that renovation takes place anyway when something is broken or at the end of life. Then it should be a very high quality renovation. Most of the cost are anyway costs (as the renovation has is done anyway) and only the additional costs for high quality renovation occur. The demolition rate and replacement by new buildings was estimated to be 0.3%.
- The same approach is taken for the exchange of oil and gas burners were an average lifetime of 30 years is assumed. They are replaced at the end of life, with
    - Scenario I, II: mainly heat pumps, minor parts with biomass burners, district heating for larger buildings and direct electric heating.
    - Scenario III, IIIa: all buildings using natural gas 2016 remain on the gas grid (2050 with P2G). The distribution of the rest is similar to the other scenarios.
    - Scenario IV: 5 % of buildings remain n the gas grid (P2G). The distribution of the rest is similar to the other scenarios.
- Starting with 2021 no oil and gas burners for new installations and boiler exchange are allowed.
- The seasonal performance factor (SPF) of the heat pumps is increasing from a current average value of 3 to 3.5 in 2050. Additionally biomass boilers and district heating systems are used.
- The district heating systems will be driven purely by renewables in 2050.
- 1%/a efficiency increase for electric appliances.

Mobility:

- No reduction of the mobility itself. No change in the modal split.
- Passenger und goods transport
- Inner Tyrolian, from/to Tyrol and passing Tyrol mobility is taken into account.
- Switch from fossil driven internal combustion engines driven vehicles depending on the scenario to
    - Scenario I: electric drives (including electrification of motorways for long distance goods transport),
    - Scenario II/IIIa: 40 % fuel cell with hydrogen (mainly goods transport)
    - Scenario III: internal combustion engine with green methane (power-to-gas)
    - (Scenario II to IV).

Production:

- Efficiency increase of 1%/a,
- Increase of production by 0.8 %/a,
- Replacement of fossil fuels by electricity, biomass hydrogen or green gas depending on the scenario.

4. Results

Fig. 1 shows the course of the final energy demand of the building sector including agriculture with the phase out of fossil fuels by 2050 for scenarios I and II. Even with the very high energetic level of new buildings and refurbishment, the final energy demand is only reduced by 32 % (65 % if solar thermal on site and environmental heat is taken as reduction). The additional electricity demand for the heat pumps is compensated by the efficiency increase of the household appliances. District heating stays constant in terms of final energy, this means a 32 % increase in heated area due to the demand reduction. Biomass is strongly reduced because it is needed for industrial processes high temperature heat.

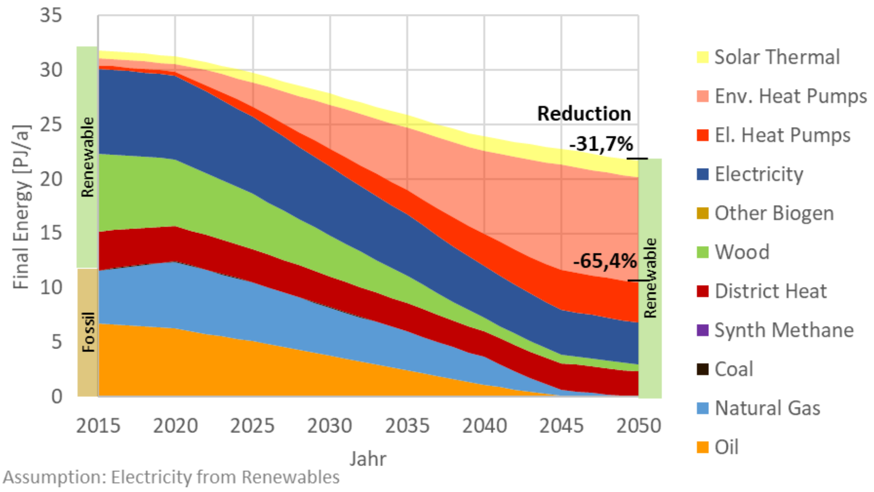

Fig. 1: Development Total Final Energy – all Buildings, (incl. Agriculture without Industry) scenario I&II (Ebenbichler, Streicher et. al, 2018)

Figs. 2 and 3 show the final energy demand distribution for the production and the mobility sector in the year 2016 and in 2050 for the different scenarios. For the production shown in Fig. 2 only a slight reduction of the final energy demand is achieved. This is due to the increase of production and a just little higher increase of efficiency. Nevertheless, there is a complete shift to renewable energies, which means a change in most of the production processes. In the scenario Electr (I) all processes that only need heat or electricity are shifted to electricity or heat pumps for low temperature heat, process that need originally wood are stayed with that and processes that need a flame or carbon are using either bio-coal or biofuels. In the scenarios Hydrogen (II) and CH4 &CH4 adapt (III/IIIA) more hydrogen respectively methan from P2G is used. The Mix scenario (IV) takes a bit of everything but still electricity in the majority.

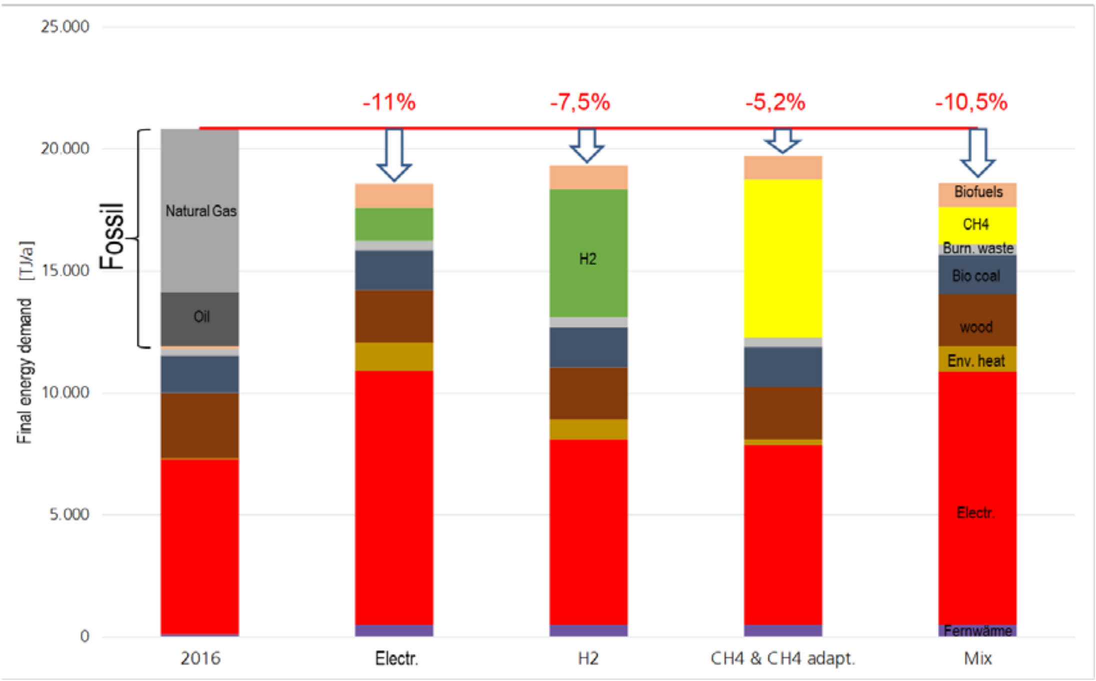

Fig. 2: Final energy demand production – baseline and all scenarios (Ebenbichler, Streicher et. al, 2018)

For the mobility sector the reults look quite diferent. There is a huge reduction of final energy demand for scenarios Electr (I), CH4 adapt (IIIa), H2 (II) and Mix (IV) of around 65 %. This is due to the low average efficiency of internal combustion engine driven cars of around 15% compared to the far higher efficiency of electric and fuel cell driven vehicles.

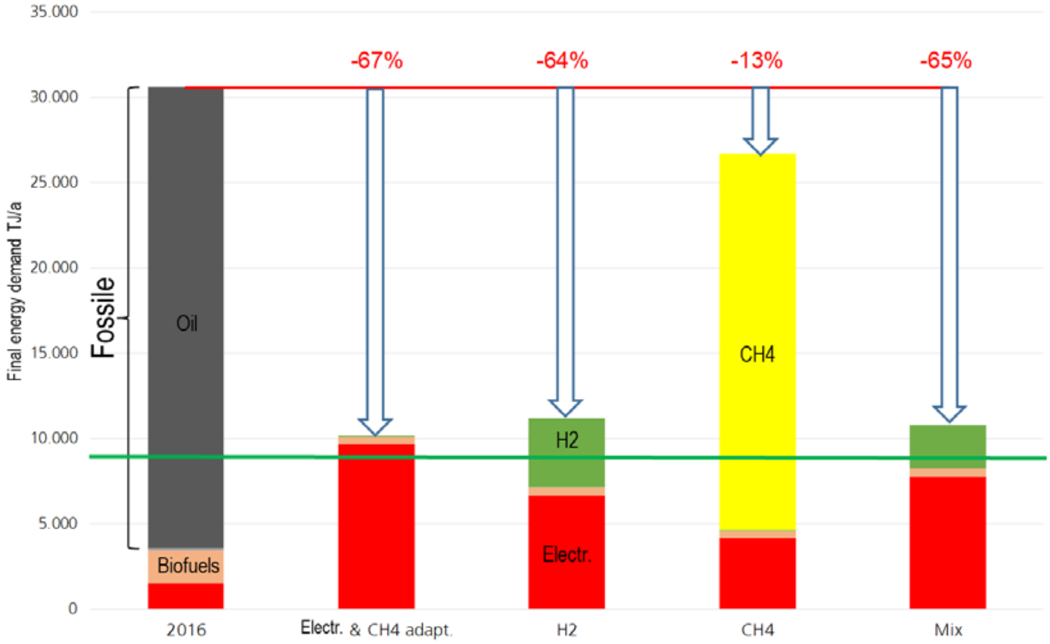

Fig. 3: Final energy demand mobility – baseline and all scenarios (Ebenbichler, Streicher et. al, 2018)

Tab. 2 shows the comparison of the 5 scenarios. Using power–to-methane and hydrogen increases the electricity demand (primary energy) significantly due to the efficiency in the production process, which is assumed to be 50 % for hydrogen production and 40 % for power-to methane (P2G). The highest primary energy demand occurs for Scenario III with bad efficiency for P2G and for internal combustion engine driven vehicles. This scenario should not be further discussed. The lowest demand occurs for the electricity scenario (scenario I) but it has to be admitted that seasonal energy storage was not in the model.

Tab. 2 Comparison of status 2005, 2016 and Scenarios I to IV (Ebenbichler, Streicher et. al, 2018)

	Primary Energy Input*	**Losses** Energy Input/ Final Energy	**Final Energy**	Distribution by Sectors			**Losses** Final Energy/ Useful Energy	**Useful Energy**
			Total	**Other (Buildings)**	**Production**	**Mobility**		
	[TJ]	**[TJ]**	**[TJ]**	**[%]**	**[%]**	**[%]**	**[TJ]**	**[TJ]**
2005	**101465**	14208	**87257**	42%	24%	34%		
2016	**100481**	13201	**87280**	41%	24%	35%	38125	**49122**
Sc. I	**67758**	13609	**54151**	47%	34%	19%	9834	**44278**
Sc. II	**78555**	22640	**55916**	45%	35%	20%	11600	
Sc. III	**147635**	74876	**72761**	36%	27%	37%	28527	
Sc. IIIa	**103546**	46908	**56640**	45%	35%	20%	12406	
Sc. IV	**73133**	18289	**54845**	46%	34%	20%	10567	

* Excluding electricity import-export, which is net zero in Tyrol.

In Fig. 4 the primary energy demand for the baseline and the different scenarios is plotted. Scenario I (Electr.) is already using up all potentials of renewable energy carriers. Therefor the open space of PV has to be used for the other scenarios to deliver the additional energy due to the efficiencies of hydrogen and power to methane production. As TJ are not understandable by politicians and many other decision makers, the additional PV open space demand was translated to football fields per community. To understand the problematic it should be noted that province of Tyrol has 12.640 km² and 279 communities, which are partly quite small or squeezed in deep valleys between mountains. So the average community size is 44.6 km², a football field has an area of about 7000 m² (0.007 km²). Taken this into account, scenario CH4 (III) along with scenarios H2 (II) and CH4 adapt (IIIa) seem to be quite unrealistic.

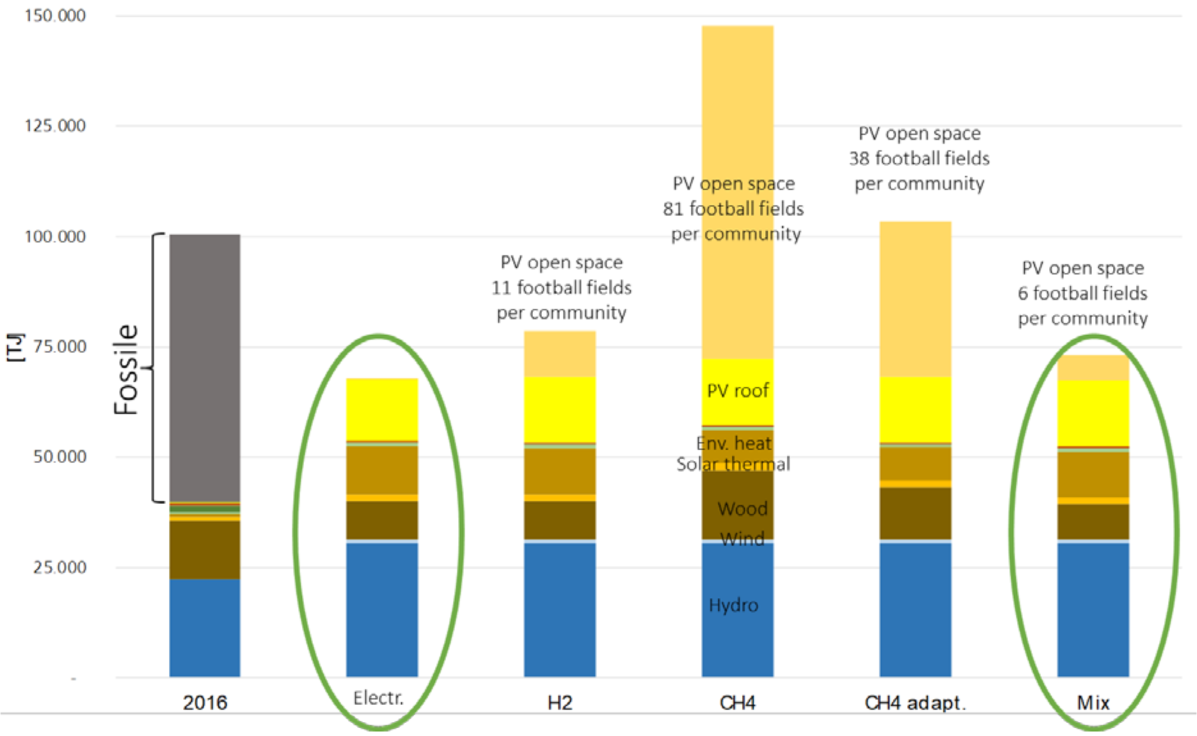

Fig. 4: Distribution of energy carriers – baseline and all scenarios (Ebenbichler, Streicher et. al, 2018)

Concluding it can be stated that the available renewable energy sources in Tyrol can theoretically cover the reduced demand of Tyrol in 2050, if all efficiency measures are implemented. How much of them can be used in reality depends on the political and economic boundary conditions and the acceptance by the people. All scenarios show, that electricity will play a dominant role in the future energy system. To cover the demand, the existing hydropower capacity has to be increased by 50%, the small potential of wind energy has to be fully used, nearly all feasible roofs have to be covered completely with PV or solar thermal plants and additionally free land is used for additional photovoltaic plants. Biomass (wood and biogas) will be used completely, partly in the energy system but also as raw material in industry (paper and pulp, polymers etc.).

5. Acknowledgments

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6. References

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