ACRP - Austrian Climate Research Program

Transitioning buildings to full reliance on renewable energy and assuring inclusive and affordable housing (Decarb_Inclusive)
www.eeg.tuwien.ac.at/decarb_inclusive

Interdisciplinary framework and constraints in housing transition. Working paper

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Project synopsis

The project Decarb_Inclusive focuses on transitioning buildings to full reliance on renewable energy, while assuring inclusive and affordable housing. It combines (1) techno-economic modelling of decorbonisation scenarios with (2) an analysis of possible effects on real estate prices and aspects of social inclusion, and (3) transdisciplinary research on policy options to implement social innovations. The active engagement of stakeholders and municipalities will ensure the targeting of policy makers and academia.

Table of contents

1 Introduction

1.1 Objective of this working paper

The objective of this working paper and WP 2 is to set up the framework, general outline and targets of the transition process of the building stock towards full reliance on renewable energy and at the same time assuring inclusive and affordable housing. We document and discuss the policy targets, challenges, controversies and framework conditions with implications on the transition pathways.

This framework will be further used to develop and analyse pathways towards full decarbonisation and assuring inclusive and affordable housing for the Austrian housing sector by effective policy interventions. For WP 3 especially the physical constraints but also the demographic and socio-economic context elaborated in this framework will be used to model scenarios for selected Climate Alliance municipalities and to discuss respective transition pathways. In WP 4 and in WP 6 information and data will be collected in interviews based on the results from this working paper and Structures of Housing Provision (SHPs) will be identified and outlined. For WP 5 this framework will provide indicators to evaluate possibilities and limits for social innovations regarding institutional prerequisites for Austrian housing policies.

1.2 Contents and structure of this paper

Section 2 addresses relevant policy targets and implications for the transition pathways regarding the transition of the building stock towards full reliance on renewable energy and at the same time assuring inclusive and affordable housing. Therefore, the Sustainable Development Goals and the Paris Agreement are discussed under the light of this work and the implementation of climate and energy policies for housing on a European-, national and federal level is discussed. The national implementation of policies regarding social inclusion and affordability is put into perspective with the European average and selected Member States. Housing promotion and laws are summarised. The section is completed with cross cutting policy targets and interdisciplinary issues.

Section 3 analyses the demographic and socio-economic context in Austria. The main data of interest deal with demographic trends, economic forecasts (short to long term), housing prices, living conditions of households, housing prices and ownership structures. The Austrian construction sector is analysed by means of consumer prices as well as market concentration and market structure. Furthermore, the regional building stock and population related data is analysed.

In Section 4 physical constraints regarding renewable energy potentials and energy efficiency are outlined with respect to the housing sector as relevant side-conditions for the case of Austria and the selected Climate Alliance –Municipalities. Renewable energy potentials including biomass, roof-top solar thermal and photovoltaic (PV), ambient heat and biomethane (green gas) are quantified and district heating scenarios are discussed. The working paper concludes with potentials and constraints of energy efficiency in the housing sector.

2 Policy targets, provisions and implications for the transition pathways

In this chapter, we document and discuss existing policy targets, provisions and their implications for the transition pathways of the building stock towards full reliance on renewable energy and at the same time assuring inclusive and affordable housing. In particular, this includes the Paris COP21 targets and sustainable development goals.

2.1 SDGs, international climate targets and COP21

By the beginning of 2016, the 17 Sustainable Development Goals (SDGs) officially came into force have, after being adopted at a UN Summit in September 2015. Following up the Millenium Development Goals, the SDGs can be regarded as the most comprehensive global framework to promote social and environmental sustainablility. As a follow-up of the Millenium Development Goals, the unique characteristic of the SDGs is the strive to find a way to combine combatting poverty and addressing social needs including education, health, social protection, and job opportunities with economic growth, while at the same time tackling climate change and environmental protection. Therefore, the environmental, the social and the economic sectors are viewed as interdependent. The targets are also differentiating industrialised and developing countries, in order to try to accommodate the different necessities and socio-economic and environmental realities.

Although the SDGs are not legally binding, countries are expected to take ownership and establish a national framework for achieving the 17 Goals. They also have primary responsibility for follow-up and review, at the national, regional and global levels, with regard to the progress made in implementing the Goals.

The SDGs consist of 17 different goals, of which 11 goals are relevant for the decarb_inclusive project:

- SDG 1 Fight poverty in all its forms (subgoals 1.4, 1.5, 1.b)
- SDG 6 Clean water and sanitation (subgoals 6.3, 6.b)
- SDG 7 Affordable and clean energy (subgoals 7.1, 7.2, 7.3)
- SDG 8 Decent work and economic growth (subgoal 8.4)
- SDG 9 Industry, innovation and infrastructure (subgoal 9.1)
- SDG 10 Reduced inequalities (subgoals 10.2, 10.3, 10.4)
- SDG 11 Sustainable cities and communities (subgoals 11.1, 11.2, 11.3, 11.7)
- SDG 12 Responsible consumption and production (subgoals 12.2, 12.3, 12.5, 12.8)
- SDG 13 Climate action (subgoals 13.1, 13.2, 13.3) (to outline the legally binding character of climate protection the target catalogue is acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.)
- SDG 15 Life on land (subgoal 15.1)
- SDG 16 Peace, justice and strong institutions (subgoals 16.7, 16.b)

Austria did not establish a national framework for achieving the SDGs so far as well as the government did not submit a progress report so far. Thereby, the country is in the group of the last European nations to do so, suggesting a certain lack of political will to implement the SDGs.

The most important source for climate-related policy targets was approved at COP 21 in Paris, on 12 December 2015, where it was decided to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise well below 2 degrees Celsius above pre-industrial levels within the 21 century and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

The national specific reduction targets are declared by so called NDCs (nationally determined contributions). The EU, including Austria, committed itself to a binding target of at least 40% domestic reduction in greenhouse gas emissions by 2030, compared to 1990.

2.2 Related energy policy provisions on EU level

Since 2002 the European Union has enacted several directives targeting at increasing the energy performance of the building sector to reach a deep decarbonisation. The most relevant ones are the energy performance of buildings directive (starting with the directive 2002/91/EC, being amended by the directive 2010/31/EU and most recently by the directive 2018/844/EU), the renewable energy directive (2009/28/EC, for which the Commission in 2016 has proposed a revision, the energy efficiency directive (2012/27/EU, for which the Commission 2016 has proposed a revision).

Important elements of the most recent energy performance of buildings directive are:

- “Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings.” The obligation to develop a long-term renovation strategy has already been part of the energy efficiency directive. However, only with the directive 2018/844/EU, the legislator stated unambiguously that these strategies have to target a decarbonised building stock by 2050, with realistic intermediate targets.
- The concept of “nearly zero energy buildings” was already introduced in 2010/31/EU, stating that all new buildings have to achieve this standard end of 2020 (and public buildings end of 2018). However, since the definition of “nearly zero energy buildings” remained somewhat vague and under the responsibility of each member state, the progress and ambition level of this new building standard differs strongly between member states (see e.g. Toleikyte et al., 2016).
- The directive foresees a “smart readiness indicator” of buildings, indicating that buildings should increasingly contribute in a “smart” way to the flexibility of the energy system, by providing options for demand response and an active participation in the energy markets.
- Optional building renovation passports are mentioned in the directive as well. They have the potential to support building owners in stepwise renovation of buildings targeting towards high energy performance and full reliance on renewable energy. The stepwise renovation process in contrast to a one-step building renovation has a major implication on affordability

2.3 Energy and policy targets and provisions

2.3.1 The Austrian climate and energy strategy

Within the framework of the EU-level energy provisions, the Ministry for Sustainability and Tourism published together with the Ministry for Transport, Innovation and Technology a climate- and energy strategy document in June 2018 with the aim to provide orientation for the path until 2030 and predictability for the government, the states, communities as well as economy and society. The strategy, especially its formulated targets will be the basis for the upcoming Integrated National Energy- and Climate Plan for Austria according to the Governance Provision (com(2016) 759final) which will be used for evaluation in 2023. The targets relevant for this project include:

- A 36% reduction in greenhouse gas emissions by 2030 compared to 2005 for the non-ETS sectors. Measurements have to result in reduced emissions of $36.4*10^6$ t CO_{2eq}. Focus of the linear target path between 2021 (!) and 2030 will be put on transport and buildings.
    - Through efforts in E-mobility and alternative drives as well as strong impulses for the expansion of public transport about $7.2*10^6$ t CO_{2eq} have to be saved which amounts to a reduction from $22.9*10^6$ t CO_{2eq} in 2016 to $15.7*10^6$ t CO_{2eq}. According to the strategy, this pathway is compliant with the target of a fossil free transportation in 2050.
    - In the housing sector a reduction from 8 in 2016 to 5 in 2030 is determined mainly through thermal renovation, no fossil fuel based heating in new buildings and a switch-over to efficient district heating and renewable energy in the existing building stock.
- The share of gross energy consumption from renewable sources has to be increased from about 34% to a range of 45-50% in 2030.
    - Fossil energy carriers have to be completely phased out until 2030 in terms of national electricity consumption while overall electricity consumption is expected to increase to cover additional demands for transport, buildings and industry.
    - A national heating strategy has to be formulated in which further expansion of bioenergy, solar thermal and ambient heat applications will be determined.
    - Natural gas will be substituted with renewable gas in terms of biomethane from biogenic residues, hydrogen and synthetic methane from renewable electricity.
    - The amount of biofuels that is blended with fossil transport fuels today is determined to stay constant until 2030.
- In terms of energy efficiency, the strategy aims for primary energy demand of 1.200 PJ by 2030, however with the plan to mitigate remaining inefficiencies (above 1.200 PJ !) through energy from renewable sources.

The Climate and Energy Strategy document furthermore lists 12 light house projects that have to be implemented in order to reach the stated targets. These projects include various activities regarding thermal renovation (e.g. “renovation check” for best practice renovation), renewable heat (e.g. changes in the construction law to prohibit installation of oil boilers in new buildings), rooftop PV-installation subsidies, renewable hydrogen and biomethane (e.g. facilitation of feed-in of biomethane into the national gas grid) and another try for the formulation of a bioeconomy strategy for 2019-Q1 followed by a bioeconomy plan.

2.3.2 Regional and local climate and energy targets and strategies

The Austrian climate targets on sub-national political levels are diversified and for both the regional level (Bundesländer) and the municipal level (Gemeinden) separate targets exist. Table 1 presents a summary of the climate targets for the nine Austrian federal states (Bundesländer), differentiating for climate targets and energy targets. Some of the federal states did not issue climate and energy targets separately. In these cases, both targets will be summarized in the same box, following the respective strategy papers.

Table 1: Regional Climate and Energy Targets

<table>
<tr><th>Federal state</th><th>Climate targets</th><th>Energy targets</th></tr>
<tr><td>Vienna</td><td colspan="2">Climate protection agreement 2020; main targets:
-21% GHG emissions compared to 1990
+3.000 GWh/a for heating and electricity out of renewable energy sources
Smart City Vienna; main targets:
2030: reaching a 20% share of renewable energy and -35% GHG emissions per capita compared to 1990
2050: reaching a 50% share of renewable energy, +40% energy efficiency and -80% GHG emissions per capita compared to 1990</td></tr>
<tr><td>Lower Austria</td><td colspan="2">KEP – climate and energy program 2020: defines a reduction potential of 0,6 mio tons of CO_2 equivalent
Main targets:
-16% CO_2 equivalent till 2020
-24% CO_2 equivalent till 2030
Increasing energy efficiency and promoting the expansion of renewable energy
Climate protection for future innovations and investments
Better quality of life and sustainable lifestyle</td></tr>
<tr><td>Upper Austria</td><td>Climate strategy: Many different climate protection projects to commit to Austria´s national target of -36% CO_2 equivalent compared to 2005</td><td>ENERGIELEITREGION OÖ 2050
Main targets:
Emission reduction target till 2030 ist between -25% to -33% compared to 2014
Increasing the share of renewable energy and efficiency measures in different sectors</td></tr>
<tr><td>Styria</td><td colspan="2">Climate protection plan Styria: defines a reduction target of -16% CO_2 equivalent till 2020 and -28% CO_2 equivalent till 2030 compared to 2005</td></tr>
</table>

	Main targets: • Increasing the share of renewable energy at least to 7,5 peta joule • Increasing the building renovation rate from 1% to 4% • Strengthening competitiveness and attractiveness for sustainable technologies and innovations	
Burgenland	-	Energy strategy 2020: reaching a 50% renewable energy share of final energy consumption till 2020 and energy autonomy over all sectors till 2050.
Carinthia	Climate strategy: Extensive analysis of different scenarios how to reach the international and national climate targets in Carinthia.	Energy master plan´s main targets: • Energy autonomy (heating and electricity) till 2025 • Energy autonomy (transport, mobility) till 2035
Salzburg	Climate and energy stategy; main targets: • 2020: -20% GHG emissions, 50% renewable energy share • 2030: -50% GHG emissions, 65% renewable energy share • 2040: -75% GHG emissions, 80% renewable energy share • 2050: climate neutral, energy autonomy and sustainable	
Tyrol	Climate strategy: Many different climate protection measures (without concrete numbers) are defined to commit to Austria´s national target of -36% CO_2 equivalent compared to 2005	Energy strategy; main targets: • reaching a 100% renewable energy share of final energy consumption till 2050 and a reduction of energy consumption down to 48.000 TJ/a
Vorarlberg	Energy autonomy 2020, main targets: • -18% CO_2 equivalent till 2020 compared to 2005 • -15% energy consuption till 2020 compared to 2005 • A permanent renovation rate of 3% • +35GWh electricity out of new photovoltaics The main future target is accomplishing energy autonomy till 2050	

Considering the municipal level, it will not be possible to describe the respective strategies in detail for all municipalities. Instead, membership in the three most important climate and energy related organisations or institutions for municipalities can be measured. These organisations work on topics to push climate and energy measures towards a more sustainable society, such as climate protection and adpatation, sustainable mobility, renewable energy and energy efficiency, energy autonomy, sustainable housing and living, sustainable life style.

Table 2: Most important climate and energy related organisations or institutions for municipalities in Austria

Oranisation/institution	Founded in	Amount of municipalities / percentage in Austria
Climate Alliance Austria	1990	977 / 46,6 %
e5 program	1998	217 / 10,3 %
Climate and energy modell regions	2009	91 modell regions with 772 municipalities / 36,8 %

2.3.3 Policy programmes and support schemes with impact on the energy transition of the housing sector

Housing-, energy-, and environment subsidies of the countries (Wohbauförderung, Energieförderung and Umweltförderung der Länder):

These support schemes are in place since 1982 with constant adaptation of the respective requirements. About 2.5 Mia Euro could be returned to private households to improve the thermal quality of their housing (0.7 Mia Euro) and to support efficient heating systems. The individual funding volume depends on the achieved thermal quality or efficiency of the new heating system. Cumulated final energy savings of about 24 PJ are expected based on the support schemes by 2020.

Energy taxes:

Fossil energy is taxed in Austria, with taxes on transport fuel since the beginning of the 20th century (Minaralölsteuer), later on heating oil, since 1995 on natural gas and electricity and since 2004 on solid fossil energy carriers. The taxes apply for households, transport, industry, services and agriculture. Underlying legal documents are the Elektrizitätsabgabegesetz, the Erdgasabgabegesetz and the Minarölsteuergesetz which include higher tax rates than recommended by the energy tax directive (RL 2003/96/EG). Income generated amount to about 5 Mia € in 2014, final energy savings are estimated with about 46 PJ until 2020.

Renovation offensive of the Austrian government (Sanierungsoffensive der Österreichischen Bundesregierung):

In 2009 this support scheme for private households and businesses started. Thermal renovation of private buildings or buildings used for operational purposes which are older than 20 years is eligible for renovation cheques for exterior walls, storey ceilings and window renewal. The funding rate is limited to 30% of the eligible costs and includes surcharges for the utilisation of insulation materials from renewable resources. In 2016 about 44 Mio € have been budgeted, 34 Mio € for private households and 10 Mio € for businesses. Estimated cumulated final energy savings amount to about 4 PJ in 2020.

2.4 Policy targets regarding social inclusion and affordability

For social inclusion and affordable housing, policy targets are not clearly set on the national level. According to the Austrian federalist system, housing is mostly managed on the municipal and regional level. As a result, national or international policy targets mostly have indirect effect. This section will therefore rather highlight the interplay of housing, social needs and social policies.

In European comparison, Austria is regarded as a country with a developed welfare state, governed by a corporatist governance setting, involving associations and representatives of employers and labour (Esping-Andersen 1990). As already pointed out in the seminal work of Esping-Andersen (1990, pp. 18-41), the Austrian institutional heritage is marked by conservatism, leading to the relative privilege for certain status groups, such as public servants. The Christian-democrat heritage (Huber und Stephens 2001) is characterised by a middle-class bias, with less universalistic traits as the social-democrat welfare regimes and a stronger focus on subsidiarity, i.e. the focus on families to solve social problems. In contrast to liberal welfare state regimes, the Austrian welfare regime has a higher grade of de-commodification, i.e. the provision of non-market services (Esping-Andersen 1990, pp. 21-27). Therefore, Austrian social policies tend towards public sector solutions, while liberal welfare states rather focus on market-based service provision with means tested social benefits: While the majority of the population is expected to rely on market-based services, the poor will be either provided with financial assistance or social services by the state. In order to qualify for public services, the poor have to prove their eligibility, on the one hand that they are poor enough considering income and/or wealth and on the other hand considering their willingness to integrate into the market. A means test has to be passed in order to qualify as 'deserving poor' (Dean 1991). In contrast to this liberal setting, conservative-corporatist welfare state regimes such as the Austrian tend towards service provision for both the poor and the middle class, albeit in a more socially stratifying way than social-democrat welfare state regimes (Esping-Andersen 1990).

Many of the above-mentioned traits can be observed in Austrian housing policies. Despite the high grade of decentralisation, regulatory policies have important common features. Compared to other international and European policy frameworks, Austrian housing policies are characterised by a considerable high degree of direct 'object subsidies', i.e. the focus of public spending rather on social housing is on financing the building of new housing facilities than on paying direct subsidies to the beneficiaries of social housing ('subject subsidies') or on indirect policies such as tax deductions for building companies (Mundt 2018).

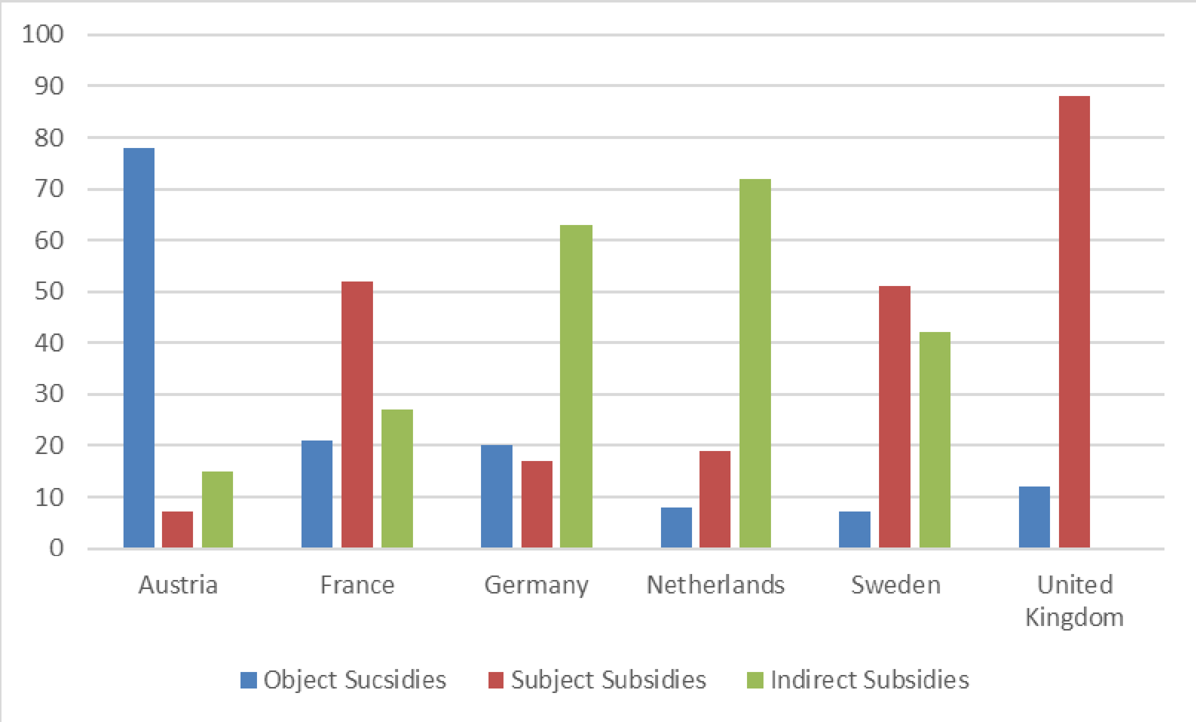

Figure 1: Public Spending on Housing, 2001, in % of total spending. Source: (Mundt und Amann 2009) p. 15

Figure 1 clearly indicates the peculiarity of Austrian housing policies to focus rather on object than on subject subsidies, in stark contrast to most other European countries. Especially if compared to the UK, the liberal focus on means-tested direct subsidies is very visibly differing from the Austrian universalist focus on object subsidies. Comparative evaluations of the social impact of object and subject subsidies (Mundt und Amann 2015; Gibb et al. 2014) found out that positive expectations derived from economic theory regarding the merits of subject subsidies did not meet empirical results. Due to a series of problems of market-based housing, the Austrian focus on object subsidies proved to be comparatively successful, despite non-preference by EU subsidy standards.

The housing sector has further peculiarities regarding governance which will be explained in section 2.4. General statistics on housing and its social effects reflect the effects of the above-mentioned characteristics. In addition, Austria's relatively low rate of urbanised housing (31.1% in 2016; EU-average: 41.2%; according to Eurostat 2018) also influences the structure of housing, especially regarding the comparably higher percentage of detached houses (cf. Figure 2).

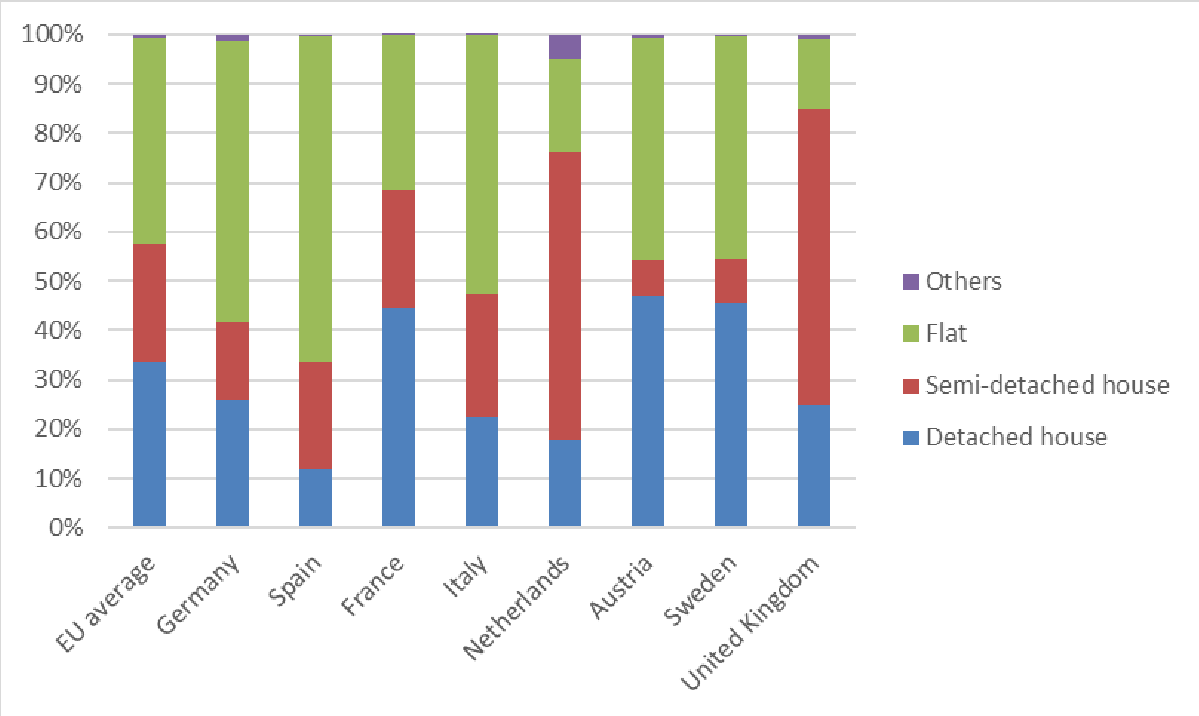

Figure 2: Housing by type of dwelling, 2016. Source: (Eurostat, 2018)

Figure 2 shows the types of dwellings in European comparison. Austria's percentage of flats is close to the European average percentage, while the proportion of semi-detached houses is below the average of EU member states and detached houses are more widespread than the EU average percentages.

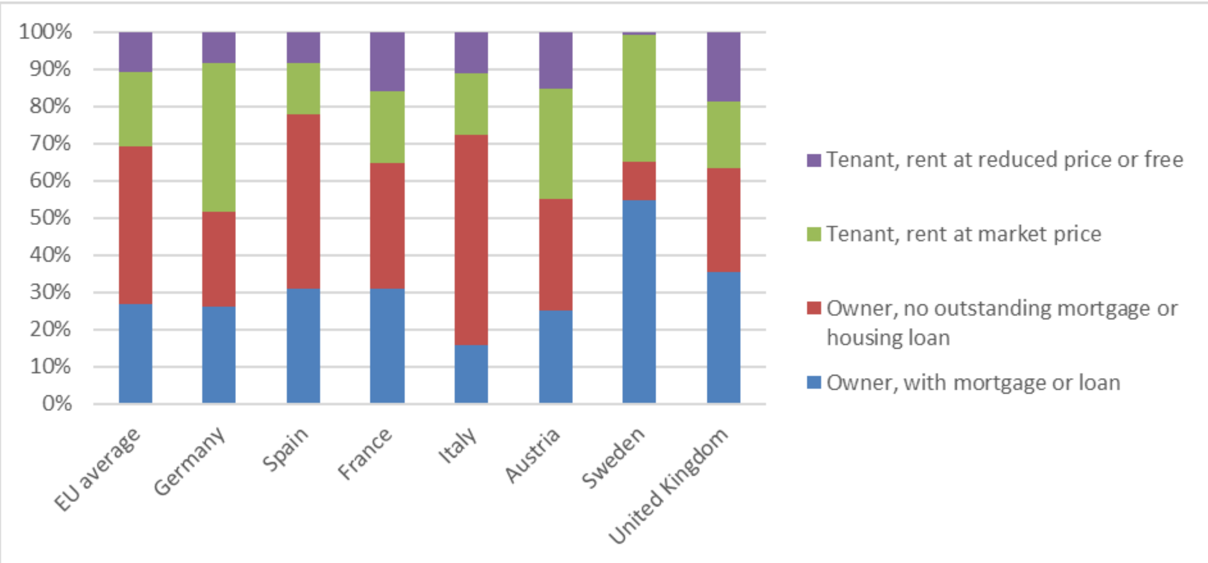

Figure 3: Housing ownership status, 2016. Source: (Eurostat, 2018)

Figure 3 shows the distribution of the population according to tenure status. It reveals that Austria has a higher percentage of tenants than the EU average, while owner occupation is less widespread than in most other EU member countries. The latter detail leads to slightly lower numbers of house owners with mortgages or loans, despite the fact that costs for loans decreased during the recent 10 years.

As shown in Figure 4, the interest rates of loans for house purchases decreased in Austria since 2003. This corresponds to a general development in the Euro area. A moderate decrease of interests rates of loans by around 1,5 percentage points between 2003 and 2005 was followed by a sharp increase, which peaked in October 2008 shortly after at the outbreak of the Financial and Economic Crisis. After a sharp drop until 2010 interest rates of loans decreased continuously and were in December 2018 slightly below 2%. This implies that households face a lower cost of borrowing to purchase housing. The reduction of interest loans does not automatically imply, however, that households have access to these loans. Especially in the wake of the Financial and Economic Crisis lending policies of banks could have become more strict.

Figure 4: Loan for house purchase, total, %. Source: (ECB, 2018)

Figure 5 shows the rate of severe housing deprivation for people earning less than 60% of median income (therefore defined as poor by EU standards) and the total population (poor and non-poor). Severe housing deprivation is defined as overcrowded housing, combined with other aspects of housing deprivation — such as the lack of a bath or a toilet, a leaking roof in the dwelling, or a dwelling considered as being too dark. The overcrowding rate is defined by the number of rooms available to the household, the household’s size, as well as its members’ ages and their family situation. Figure 6 reveals that Austria’s housing situation is slightly better than in the EU average, but worse than in many other European countries.

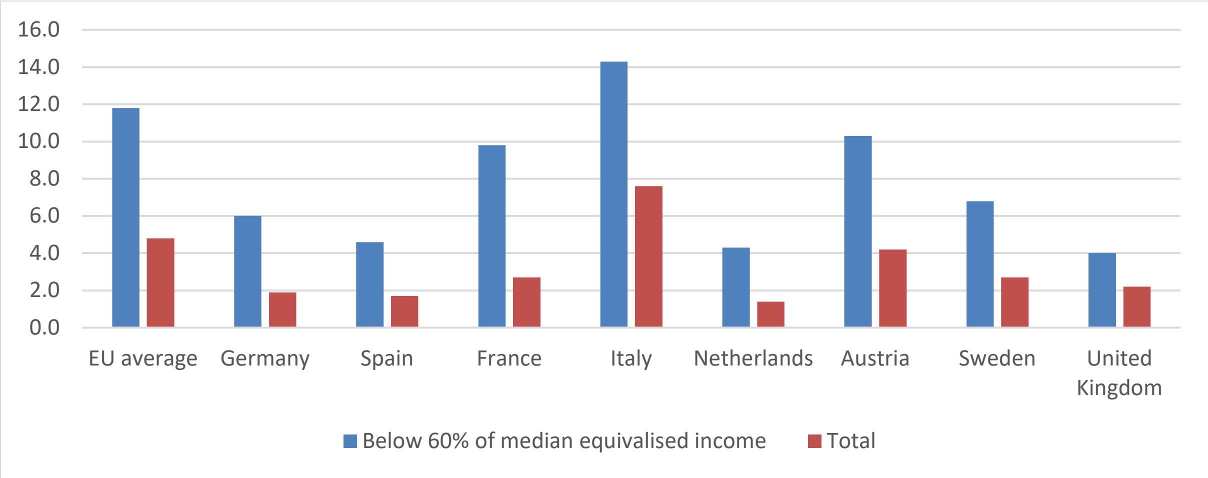

Figure 5: Severe housing deprivation, 2016. Source: (Eurostat, 2018)

Concerning affordability, the central indicator is the percentage of people having to spend more than 40% of their income on housing. Table 3 gives an overview on the situation in European countries and reveals a rather positive comparative picture of the Austrian housing market. 7.2% of Austrians have to pay more than 40% of their income for housing, compared to 11.1% of EU citizens having. A remarkable detail of the Austrian housing situation is that tenancy at market prices is much less responsible for the rate of housing cost overburden than in most other European countries. While an average of 28% of EU citizens has to pay more than 40% of their income on housing in rented flats, compared to only 15.6% of Austrians living in rented flats. Reasons for this will be explained below.

Table 3: Housing affordability, 2016. Source: (Eurostat, 2018)

	Total population	Owner occupied, with mortgage or loan	Owner occupied, no outstanding mortgage or housing loan	Tenant — rent at market price	Tenant — rent at reduced price or free
EU-28	11,1	5,4	6,4	28,0	*13,0*
Euro area (EA-19)	11,0	5,5	5,2	27,1	11,8
Belgium	9,5	2,4	1,3	35,4	11,9
Bulgaria	20,7	23,2	19,6	50,4	20,3
Czech Republic	9,5	6,0	5,2	29,3	10,6
Denmark	15,0	5,2	4,3	31,1	:
Germany	15,8	10,3	9,2	23,0	19,1
Estonia	4,9	3,0	3,6	28,5	6,4
Ireland	4,6	2,2	1,5	19,6	4,2
Greece	40,5	28,5	30,6	84,6	10,4
Spain	10,2	6,7	2,8	43,0	10,6
France	5,2	1,1	0,9	16,5	8,9
Croatia	6,4	1,8	5,9	45,2	7,7
Italy	9,6	4,6	3,6	32,2	12,7
Cyprus	3,1	2,5	0,2	18,1	0,6
Latvia	7,0	9,3	5,8	13,0	8,0
Lithuania	7,8	3,3	7,3	48,3	12,2
Luxembourg	9,5	1,6	1,6	33,8	22,3
Hungary	8,8	11,2	5,1	36,6	19,6
Malta	1,4	1,2	0,6	22,1	0,9
Netherlands	10,7	3,1	3,2	28,0	16,4
Austria	7,2	2,1	1,7	15,6	10,2
Poland	7,7	11,9	5,9	24,5	11,5
Portugal	7,5	4,4	2,9	31,9	5,4
Romania	14,4	32,5	13,7	36,3	19,2
Slovenia	5,7	7,7	2,8	29,0	7,7
Slovakia	7,7	15,1	5,7	13,9	17,6
Finland	4,4	1,4	2,1	14,6	8,2
Sweden	8,5	2,8	7,5	18,0	5,6
United Kingdom	12,3	4,8	4,3	35,4	16,2
Iceland (¹)	*6,3*	*4,6*	*2,1*	*16,9*	*12,8*
Norway	9,7	6,7	4,3	34,0	18,6
Switzerland	12,0	4,4	7,9	18,2	12,2
Former Yugoslav Republic of Macedonia	12,5	3,8	11,9	29,0	18,6
Serbia	28,2	31,4	25,7	68,3	33,8
Turkey (²)	10,5	14,1	1,5	36,1	1,9

Austria's relatively low grade of housing cost overburden for rented flats can be mainly explained by two factors: (1) Austrian renting laws are relatively strict and rigid concerning possibilities to raise prices and to terminate renting contracts (Mundt/Amann 2015), (2) Austrian renting subsidies tend to support the building of new affordable housing units (Streimelweger 2013). Figure 6 demonstrates the comparably high percentage of social rental dwellings in Austria. After the Netherlands, Austria had the second highest percentage of social housing in a recent OECD survey (del Pero et al. 2016).

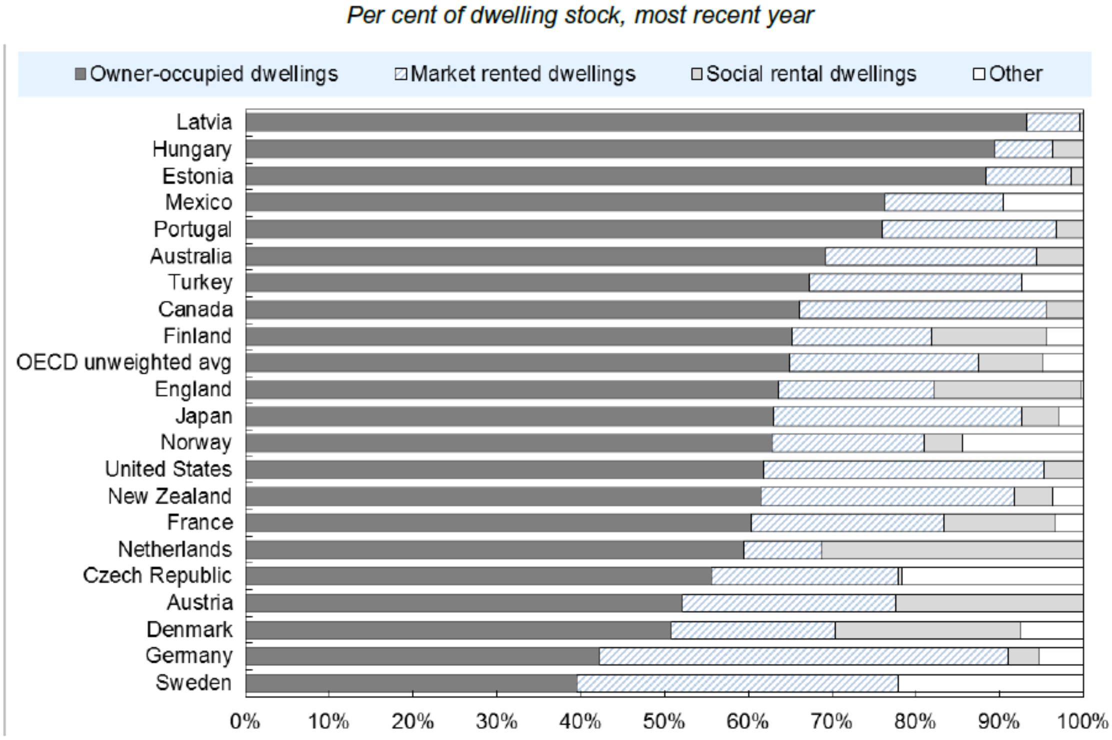

Figure 6: Housing tenure across OECD countries. Source: (del Pero et al. 2016)

The peculiarity of the Austrian social housing policies, to finance rather the building of new affordable housing units than to financially assist the deserving poor by means tested programs (subject subsidies) promoted a more stable situation of new buildings. Comparative analysis (Gibb et al. 2014; Streimelweger 2013) reveal that Austria was much less influenced by the real estate boom and bubble than countries such as Spain, where the private housing market was driven by a speculative boom and a successive bust phase.

While the further promotion of means tested social assistance for housing might help to promote some of the poor, who are often confronted with difficulties to get access to social housing, the Austrian solution of object subsidies also has advantages. The criteria to live in social housing units are in most cases not very strict, enabling important sections of the middle classes to live in these facilities too. Thereby, tendencies such as spatial stratification and polarisation are much less pronounced in Austria than in other comparable countries (Jäger 2003). A study on the situation in Austria's capital city Vienna confirmed the positive effects of object subsidies (Mundt und Amann 2009)

2.5 Housing related policy targets and provisions

Corresponding information for selected Climate Alliance –Municipalities will be added later in the project.

Structures of housing provision is a conceptual framework, which emphasises an institutional perspective on housing. The framework was developed by Michael Ball as an alternative within the critical political economic debate on rent theory (e.g. Ball 1981, 1985, 1986 and Ball/Harloe 1992). Without going into the details of this debate (cf. Haila 1990, Ward/Aalbers 2016), it is worth noting that Ball criticises neoclassical and Marxist rent theories, since they neglect the institutional setting of housing provision in general or key social relations. Consequently, he turns his focus towards social processes within an institutional[1] context, which provided distinct forms of housing. Therefore, it is necessary to take a closer look at the legal context and complexity of this subject matter. Housing policy is a general term, which covers rather diverse topics related to housing provision. In order to provide sufficient housing space the state disposes of multiple instruments. In this subchapter main elements of the Austrian housing policy are discussed by means of a legal contextualisation.

In general, the current Austrian government favours private property over other forms of tenure. This is clearly expressed by the current government's program (ÖVP/FPÖ 2017: 47). Nevertheless, this new focus is breaking with the tradition of the Austrian welfare state and its implications on housing provision (cf. section 2.4).

2.5.1 Housing Promotion (*Wohnbauförderung*)

The promotion of residential buildings has a long tradition in Austria. Whereas elements date back to the 19th century and the inter-war years, large-scale promotion of housing took off after the Second World War. In 1948 the *Wohnhaus- und Siedlungsfonds* (housing and settlement fond) created a broad financial basis, which was further secured by the *Wohnbauförderungsbeitrag* (1952 – housing promotion contribution) and the *Wohnbaubeiträge* (1954 – housing contribution Moreover, the federal government opted for a two-tier approach. On the one hand, it provided municipalities and limited-profit housing organisations with subsidies to construct rental housing. On the other hand, owner-occupiers were financially supported to refurbish or construct privately owned housing. In either case subsidies took the form of long-term, low-interest loans. The generated return flows (i.e. loan repayments) created a sustainable financial basis (Kunnert/Baumgartner 2012: 88-93, Wurm 2003, Streimelweger 2010).

Whereas in the beginning the federal government assumed the lead role in housing promotion and the federal states created complementary housing funds, the former increasingly delegated competences towards the latter. One milestone in this gradual process occurred in 1985, when the nine federal states became authorised to manage housing promotion. Another (and final stage) was implemented in the new millennium. Until 2008 the central government earmarked a share of its financial transfers for housing promotion. Since 2009 the federal states determine independently of the federal government the volume of housing promotion. With respect to the form of housing promotion it should be noted that especially in the 1990s there was a significant increase of annuity payments at the cost of loans. Streimelweger (2010) argues that this gradual retreat of the federal government is part of a structural shift in housing policy, which could jeopardise financial sustainability.

Without going into details concerning neither the financial basis nor the structural composition, Figure 7 shows that housing promotion in Austria fluctuated between 2.5 and 3 billion Euro during the 2006-2015 period. Only in 2005, 2016 and 2017 it was slightly below 2.5 billion Euro. Whereas until 2008 the federal government annually earmarked 1.8 billion Euro, the end of this policy did not coincide with a major drop in housing promotion. Nonetheless considering that construction costs for housing increased in the same period by almost 50% (Statistik Austria 2018a), it is safe to say that in real terms housing promotion decreased.

[1] From our reading of Ball's work, we conclude that his understanding of 'institutional' is close to Hodgson's definition of an institution: '[…] we may define institutions as systems of established and prevalent social rules that structure social interactions.' (Hodgson 2006: 2)

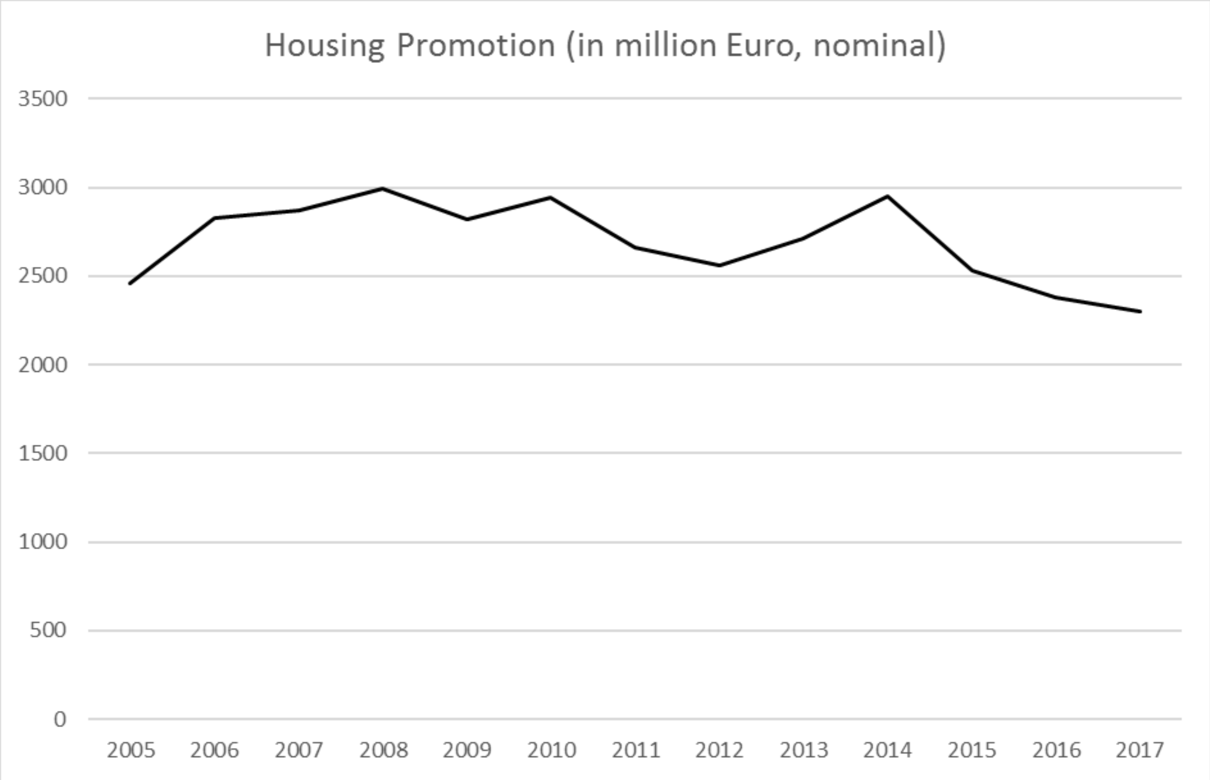

Figure 7: Housing Promotion in million Euro, nominal. Source: IIBW (multiple publications)

Since housing promotion is now a competency of the federal states, a regional level perspective should be considered. Figure 8 displays the diverse developments since 2005. Three broad groups can be classified. First, Vorarlberg, Tyrol and Salzburg[2] are three federal states, which managed to increase their spending on housing promotion. Second, Carinthia, Styria, Upper- and Lower-Austria more or less stabilised their spending on housing promotion. Third, Vienna and Burgenland display a clear decrease.

[2] The development of the housing promotion budget of Salzburg is peculiar, because it introduced in 2006 a new funding system (*Wohnbaufonds*). The cost of establishing this fund is also included in the data (IIBW 2007). Moreover, in the wake of a financial scandal concerning this fund, a new housing promoting system was introduced in 2015 (Amann/Mundt 2017).

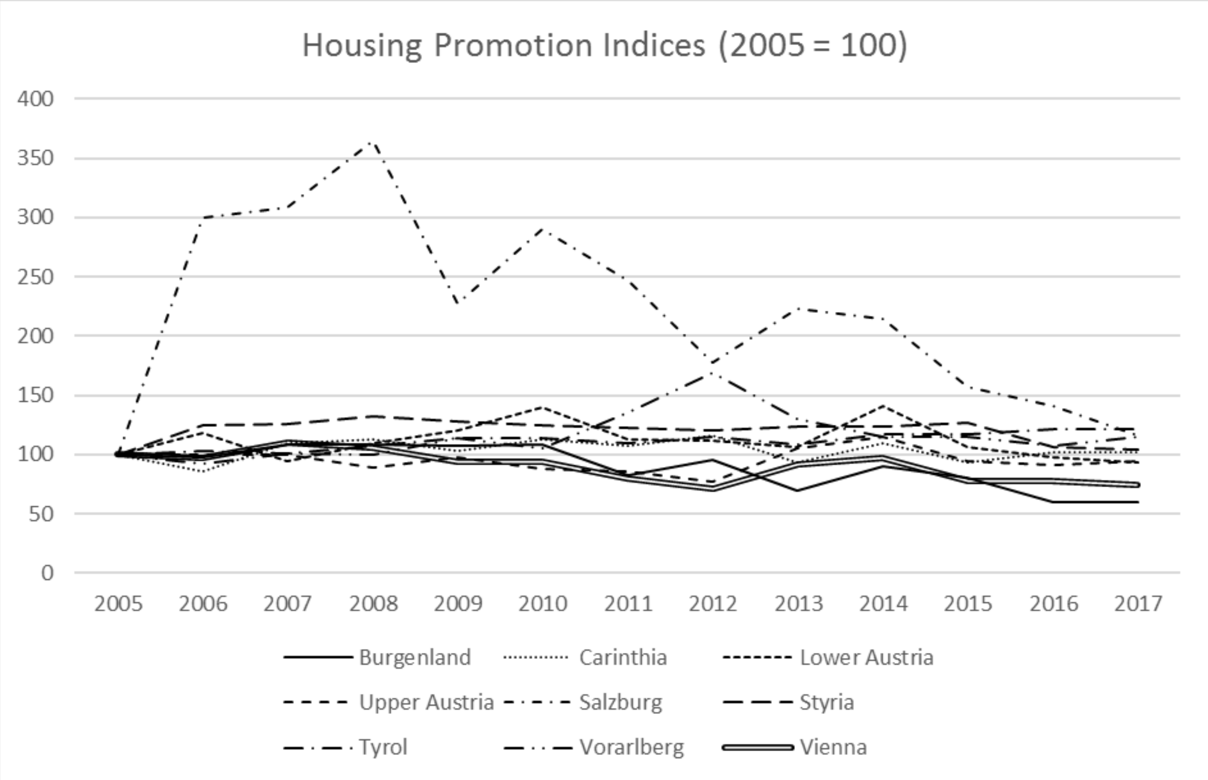

Figure 8: Housing Promotion Indices (nominal). Source: IIWB (multiple publications)

2.5.2 Limited-Profit Housing Law (*Wohnungsgemeinnützigkeitsgesetz*)

As previously indicated, limited-profit housing organisations emerged in the wake of the *Wohnbauförderungsbeitrages* (1952) and to which in general a price curbing effect is ascribed. Since these housing co-operatives do not focus on profit maximisation but instead have to contribute to housing welfare, it is assumed that rent levels are lower than on the private, unregulated rental market. These co-operatives are allowed to generate a limited amount of profit, which they have to reinvest in domestic housing projects. Moreover, rent levels are capped by economic rent, i.e. rents may not exceed production costs. The regulation of limited-profit housing aims at securing the supply of affordable and qualitative housing. Since limited-profit housing organisations offer a significant volume of total housing and are thus an alternative to private rental markets, they influence overall price level (Kunnert/Baumgartner 2012: 88, Wurm 2003, Bauer 2006, Streimelweger 2010).

Bauer (2006) points out that from a historic perspective the price curbing effect of low-profit housing organisations emerged not before the 1980s, when communal housing became less available. Whereas communal housing could offer subsidised rental prices, rental prices of low-profit housing organisations are defined through economic rent, i.e. the costs of production. She concludes that the main difference between the limited-profit and private housing sector is their price dynamics. In the long run, the rents of the limited-profit sector are bound by economic rent and thus less subject to change. These economic rents are mainly defined by the costs of financing, although construction costs and land prices cannot be neglected. It was not always the case, but the limited-profit housing organisations are important for social integration as they provide housing to a broad middle-class.

2.5.3 Tenancy Law (*Mietrechtsgesetz*)

The Tenancy Law, which entered into force in 1982, is an amendment to the Civil Law Code. Whereas tenancy regulations by the latter are non-binding, the Tenancy Law is binding when applicable. Since Limited-Profit Housing Law has already been discussed, this housing type is not further discussed here. The main pillars of the Tenancy Law are the regulation of time limits, the protection against dismissal and the regulation of rents. Nonetheless, it should be noted that the Tenancy Law does not cover all rental agreements (AK 2010, Mieterschutzverband 2012, Kunnert/Baumgartner 2012: 58-60)

The Tenancy Law defines three scopes of application (cf. Table 4): full-application, partial-application and non-application. Rental agreements for which the Tenancy Law does not apply are not subject to legal regulations with respect to rent level or to dismissal. Housing units, which are exempt from Tenancy Law regulation are for example one and two family houses with a rental agreement signed after 2001, asylums, secondary residences and holiday homes. The Tenancy Law is partially applicable for buildings with a building licence after 30 June 1953 and which were constructed without subsidies according to 1968 Housing Promotion Law, condominiums in buildings with a building licence after 9 May 1945. In addition, attic-extensions (*Dachbodenausbauten*) with a building licence after 2001 and annexes (*Zubauten*) licenced since 1 October 2006 are also partially subject to the Tenancy Law. With respect to these housing types the Tenancy Law regulates time limits and the termination of rental agreements. Rental objects, which are fully regulated by the Tenancy Law, include old buildings licenced before 1 July 1953, condominiums in buildings licences until 9 May 1945 and subsidised buildings according to the 1968 Housing Promotion Law. Besides time limits and the termination of rental agreements the Tenancy Law in these cases also regulates rent levels (AK 2010: 22-28, Mieterschutzverband 2012, Kunnert/Baumgartner 2012: 58-60).

Table 4: The applicability of the Tenancy Law (1982)

Housing Type	Rent Levels	Time Limits	Determination
Buildings licenced before 1-7-1953	V	V	V
Condominiums in buildings licenced before 10-5-1945	V	V	V
Promoted buildings (1968 Housing Promotion Law)	V	V	V
Buildings licenced since 1-7-1953	X	V	V
Condominiums in buildings licenced since 10-5-1945	X	V	V
Attic extensions licenced since 2002	X	V	V
Annexes licenced since 1-10-2006	X	V	V
Others (e.g. one and two family houses with a rental agreement signed after 2001, asylums, secondary residences and holiday homes)	X	X	X

3 Demographic and socio-economic context

The chapter will elaborate the demographic and socio-economic context in Austria. The main data of interest deal with demographic trends, economic forecasts (short to long term), living conditions of households, housing prices and ownership structures. The results build on existing studies, literature and data. In particular ÖROK-Regionalprognosen (2014), WIFO studies on the construction industry, Eurostat's SILC-database, EU energy poverty observatory (https://www.energypoverty.eu/) and Statistic Austria's data on housing offer valuable input. Corresponding data for selected Climate Alliance –Municipalities will be added later in the project.

3.1 Demographic trends

In Austria, the population grows slowly, but steadily during recent years, mainly triggered by migration. Between 1990 and 2010, the Austrian population grew from 7.77 million to 8.39 million. This steady growth is estimated to continue, so that in 2030, 9.0 million people are estimated to live in Austria, growing further to 9.4 million in 2060 (Statistik Austria, 2018). While this growth is stimulated by moderate growth rates of children under 2 years (by 2020, the number of children is expected to grow by 6%, compared to 2011), improving life expectancies are a major contribution to Austria's changing demography.

Table 5: Demographic Trends, Austria, 2011-2060. (Statistik Austria 2018)

	2011	2020	2030	2040	2050	2060
Total	8.420.900	8.713.178	9.000.007	9.205.647	9.330.904	9.378.251
0-2 years	235.253	249.315	250.497	245.524	251.109	255.861
3-5 years	238.568	249.334	255.488	249.430	252.335	258.497
6-9 years	325.030	329.493	344.195	339.082	337.561	346.274
10-13 years	337.958	328.689	346.082	348.503	341.792	348.306
14-17 years	379.920	340.328	347.961	357.980	350.859	352.385
18-29 years	1.287.455	1.251.133	1.165.130	1.194.759	1.209.476	1.194.231
30-54 years	3.135.529	3.001.544	2.890.757	2.851.436	2.789.186	2.800.292
55-64 years	994.746	1.244.386	1.237.676	1.113.301	1.164.835	1.115.234
65-79 years	1.072.328	1.227.662	1.522.677	1.687.509	1.536.290	1.602.728
80 years +	414.113	491.294	639.544	818.123	1.097.461	1.104.443

As Table 5 indicates, the highest growth rates in the Austrian population concern the age groups over 55 years. The fastest expected growth rates concern the 'young elderly population' (65-79 years), rising from 1.072.328 in 2011 to 1.602.728 in 2060 (49,5% growth) and the 'elderly population' (more than 80 years) with an expected rise from 414.113 in 2011 to 1.104.443 in 2060 (166,7% growth). One of the major challenges arising from the demographic shift will be to accommodate the special needs of an aging population for Austrian housing.

This will possibly lead to new demands for providing a combination of housing and care facilities, especially for the age group beyond 80 years.

Compared to the population, the number of households has tended to grow at a much faster pace, from 2.91 million in 1990 to 3.62 million households in 2010. This growth rate (25%) exceeds by far the population growth rate (10%), due to changing family and household patterns. The general trend are more smaller households, with single parents, non-married forms of partnership and one-person-households (currently 33% of all households, expected to grow up to 40% in the near future). Due to this trend, it can currently not be expected that the slightly shrinking age groups between 18 and 54 years will lead to less demand for housing. Nevertheless, it can be expected that their demand will rather shift towards smaller housing units. (Fassmann without year - https://www.gbv.at/Page/View/4403)

3.2 Construction sector analysis

Figure 9 displays the indicators of the Austrian construction industry and their development since the mid-1990s. During the last two decades both the turnover as well as the index for new work orders doubled. However, there are distinct phases of stagnation: One around the end of the 1990s and another in the immediate aftermath of the financial crisis of 2008. For the most part, this development is in line with the overall GDP growth of the Austrian economy.

Statistik Austria (2018a) also provides an index for actual production that is corrected for inflation. Until 2008 this production index developed similarly to turnover, work orders and GDP. Since then, however, actual production in the construction sector seems to be stagnating. Subsequently *real* economic growth of the construction industry was consistently negative from 2008 and 2015.

Despite growth in revenue and – to a lesser degree – in production since 1995, hours worked remain largely stable over the years. A close correspondence between hours worked and the number persons employed can be identified. In the year 2008, there is, however, a clear divergence: while hours worked increased, the number of persons employed was slightly falling. This can most likely be ascribed to the financial crisis.

In absolute number, the construction industry employs about almost three hundred thousand persons (287,944 in 2015). These figures do not include contractual or temporary workers (LeiharbeiterInnen). The year 2011 saw – in total - 81,000 contractual workers employed in Austria. Second only to manufacturing, the construction industry employs the largest share of these contractual workers with about 18 per cent. It should be noted that this form of atypical employment is especially sensitive to fluctuations in the business cycle. (Statistik Austria 2012: 57-58)

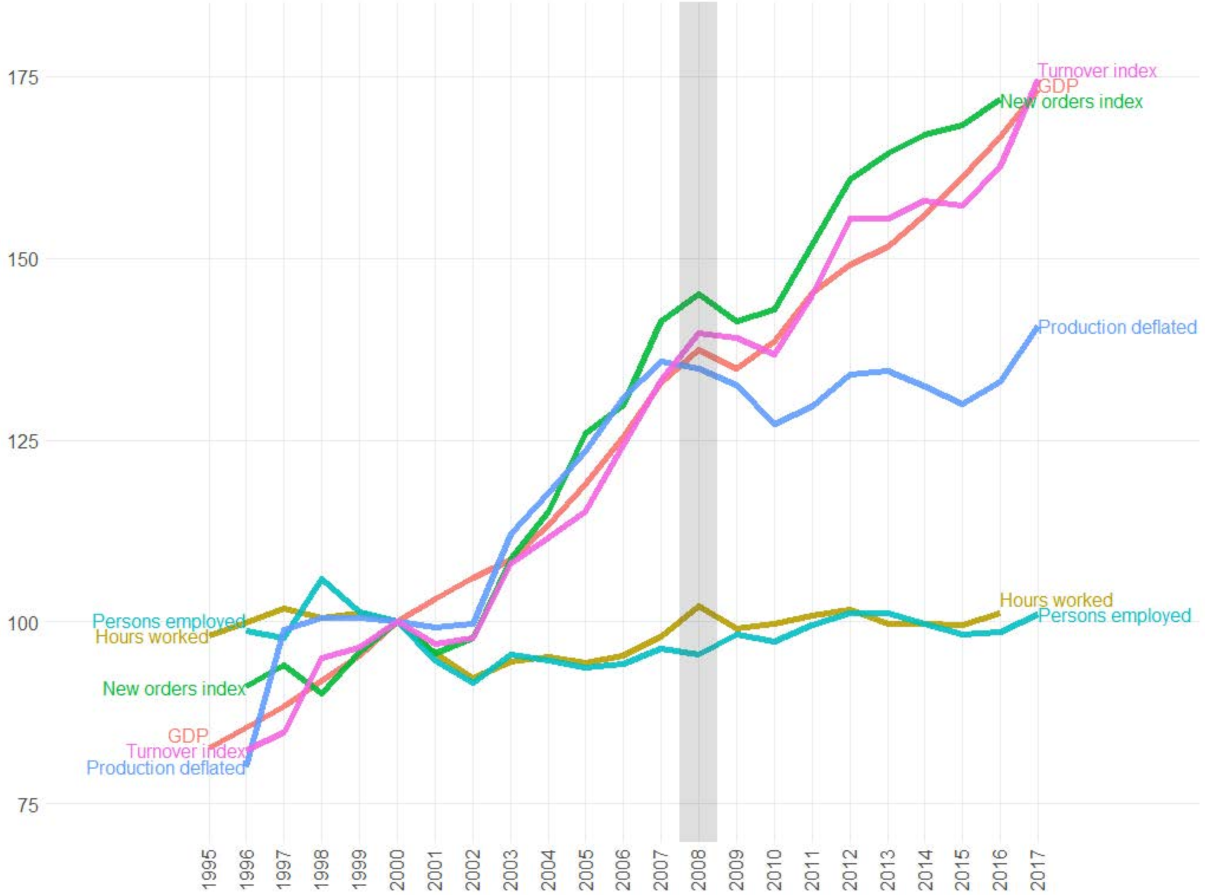

Figure 9: Key figures of the construction industry (2000 = 100); Source: (Statistik Austria 2018a)

Table 6 shows trends in construction costs, construction prices and overall consumer prices. Since the late 1990s, construction cost, i.e. a building company's cost for labour and material, rose faster than the prices charged for construction. Construction prices, in turn, increased slightly more *on average* than overall consumer prices, i.e. between 1997 and 2017 construction prices are up by 48%, while consumer prices are up by 44%. A closer look at these figures, however, reveals noteworthy variation. For example, in the period 1998-2005, consumer prices tended to rise faster. Since then construction prices started to spur, peaking in 2008 with an increase of 5%.

Table 6: Trends in construction costs and prices (2000 = 100); Source: (Statistik Austria 2018a, 2018e)

	1995	1997	1999	2000	2001	2003	2005	2007	2009	2011	2013	2015	2017
Construction prices	94	98	99	100	101	103	107	114	123	132	137	140	145
Consumer Price Index	-	96	98	100	103	106	111	115	119	125	131	134	138
Construction cost	90	94	98	100	102	106	114	125	132	139	145	149	155

In addition to these aggregate data, we employ firm-level data from the ORBIS database to draw a more complete picture of both the building construction and the real estate sector[3]. This allows us, for example, to measure market concentration using revenue and ownership data of individual firms. For 2015 we find that both sectors are relatively un-concentrated. For the sector *construction of buildings* the three largest enterprise groups control a combined market share of 37% (C3-ratio), the ten largest groups control 49% (C10-ratio), and another commonly employed tool to measure concentration, the HHI, indicates a relatively competitive sector with a value of 839.[4] In comparison, the *real estate* sector appears to be even less concentrated (C3 = 24%, C10 = 45% and HHI = 316).

Despite these low concentration figures, it should be kept in mind that there are still vast differences in terms of firm size and respective market shares. While numerous small and medium-sized enterprises operate in the construction sector, there are about twenty companies with revenues above the €100-million mark, for example subsidiaries associated with both the *Habau Group* and the *Strabag,* as well as the *Buwog AG* and the *Porr AG*. The latter is the largest company in the sector with sales amounting to more than 3 billion euro in 2015. Foreign capital plays an insignificant role in the construction sector – only about 5% of revenue is generated by firms owned by foreign corporations. A notable exception is the *Buwog AG* which is owned by *Vonovia SE*, one of the largest German real-estate enterprises. Quite in contrast, the case of GESIBA is of interest. As one of the larger players in the sector with a revenue of about €200 million in 2015, the GESIBA is owned by the City of Vienna.

The real estate sector presents a similar picture: There are about two dozen entities which generate revenues above €100 million. However, in contrast to building construction, both the role of foreign capital as well as the role of the state are more pronounced. On the one hand, an estimated 17% of total revenue is generated by firms controlled by foreign companies. On the other hand, the Austrian state is the largest player by revenue due to having the majority interest in entities such as the *Bundesimmobiliengesellschaft*. Regarding the ownership structures another aspect is quite striking: Among the largest entities there is also a comparatively high number of private foundations, for example the *Familie Benko Privatstiftung*, *Karl Wlaschek Privatstiftung* and the *Lugner-Söhne-Privatstiftung*.

3.3 Living conditions of households

The weighted mean total disposable yearly household income in Austria in 2016 was about 40,750 euro. In addition, Table 7 shows the weighted mean disposable income for four federal states and the three degrees of urbanisation. A test of differences brings significant differences forward. Except for Upper Austria, the weighted mean household income differs significantly from the Austrian level. Lower Austrian households display a higher value, whereas households in Vienna and Styria have lower figures. Only between Styria and Vienna there is no significant differences, otherwise the federal states differ significantly from each other. A similar observation is made with respect to the degrees of urbanisation. The weighted mean

[3] Specifically, we analyse companies that are classified as one of the following two NACE Rev. 2 categories: either the *construction of buildings* (41) or *real estate* activities (68). Of course, this approach is subject to limitations. Especially larger firms in our sample are active in a variety of areas and cannot be neatly restricted to one NACE category. The results must be treated with caution.

[4] The HHI (Herfindahl–Hirschman Index) is defined as the sum of the squared market shares of all independent companies within a given market. Hence, the HHI can range from 0 to 10,000. The US Justice Department (2018), for example, considers a market to be “moderately concentrated”, when the HHI is between 1,500 and 2,500 and “highly concentrated” when the HHI is above 2,500.

household income in densely populated areas is significantly lower than the overall Austrian level, whereas in thinly populated areas this number is significantly higher. Consequently, the differences between these regions are also significant.

Table 7: Disposable Household Income – Regional Analysis (EU-SILC data)

	n	Mean	Standard Deviation	Confidence Interval (95%)
Austria	6 000	40 751,76	30 551,56	± 773,06
Lower Austria	1 203	44 089,39	27 485,86	± 1 553,22
Upper Austria	1 018	41 474,13	26 077,78	± 1 601,96
Styria	817	38 477,14	24 051,05	± 1 649,22
Vienna	1 301	38 201,85	36 278,51	± 1 971,36
Densely populated	1 668	38 068,31	33 212,38	± 1 506,15
Intermediate populated	1 774	40 975,11	26 955,10	± 1 254,35
Thinly populated	2 358	43 069,83	30 542,77	± 1 232,80

Around half of Austrian households live in buildings with one or two dwellings. It comes as no surprise that in densely populated areas (e.g. Vienna) slightly over 10% of households live in such buildings, whereas in less densely populated areas it is the main form of housing stock (e.g. Lower Austria 73,90%, Upper Austria 62,18% and Styria 58,27%). Almost all of these buildings are non-detached houses (2632) or semi-detached houses (403). Only in Vienna a major share of buildings with 20 or more dwellings (41,20%) can be found. Around 60% of all Austrian buildings with dwellings were constructed between 1945 and 2000. Since 2000 another 17% was constructed. Minor regional differences can be observed, but only in Vienna the dwelling stock built before 1945 covers 34%.

Around 40% of all Austrian households are house owners, whereas another 10% own the dwelling they live in. In thinly populated areas the share of house owners increases to almost 64% and the share of dwelling owners decreases to 6%. This contrasts with the shares in densely populated areas, in which they are 10% and 16%, respectively. In 2016, 40% of house owning households paid mortgages, of which 47% were private (mainly bank) mortgages and 37% loans within federal state's housing promotion program. Almost 40% of households are tenants. These households either rent through the private market (16%), limited-profit organisations (15%) or municipalities (7%). The remainder households (11%) have another form of tenure status. 60% of households, which do not own their house/dwelling, have a permanent contract. This figure, however, drops drastically to 26%, if housing through municipalities and limited-profit organisations is not considered. Especially the impact of limited-profit organisations in intermediate and densely populated areas, where they house around 20% of all households, cannot be ignored. The impact of community housing is only significant for Vienna, where it covers housing needs of around 22% of Viennese households.

Table 8: Disposable Household Income – Tenure Status Analysis (EU-SILC Data)

	n	Mean	Standard Deviation	Confidence Interval (95%)
House Owner	2414	51 804,09	30 947,02	± 1234,54
Dwelling Owner	676	43 086,03	30 357,59	± 2288,49
Tenant (Community)	414	27 870,19	15 665,15	± 1509,00
Tenant (Limited-Profit)	909	34 154,72	18 554,23	± 1206,19
Tenant (other)	944	34 691,35	38 771,08	± 2473,31
Other	643	28 463,14	20 886,68	± 1614,43

In addition to a geographical analysis of household's tenure status, it also possible to combine income data with tenure status. Table 8 shows the basic data, which can be used for difference tests. It can be stated that the weighted mean disposable income of house owner households differs with 95% certainty from all the other tenure households. This holds also for households, which own their dwelling, i.e. flat. The weighted mean disposable income of households, which rent from communities, does not significantly differ from households with atypical tenure statues (i.e. the "Other" category in Table 8). Both household types' disposable incomes, however, is significantly lower than other tenant or owner households. The mean disposable income difference between households, which rent from limited-profit organisations, households, which mainly rent on private markets (i.e. the "Tenant (other)" category), does not differ significantly. It should come as no surprise that households, which own their house, have the highest mean disposable income. They are followed by households, which own their dwelling. Households, which rent from limited-profit organisations or through the private market, come in third, whereas tenants from community housing and households, which cover their housing need neither through ownership nor tenure, have the lowest mean disposable income.

3.4 Housing prices

Housing price developments can be analysed by means of the Residential Property Price Index (*Häuserpreisindex* - HPI) of Statistik Austria (2018c) or the Residential Property Price Index of the Austrian Federal Bank (OeNB 2018). The indices provided by Statistik Austria (2018c) cover the period 2010-2017 and distinguish between four subcategories as featured in Figure 4. Prices for residential property grew during this period between 40% and 50%. The lowest price increase can be observed within the subcategories New Residential Property and Existing Houses, whereas Existing Dwellings witnessed the highest increase. It can be assumed that price increases of New Residential Property are significantly influenced by the increase of construction costs, which added up to 14% during this period (cf. Figure 10). The gap between Existing Houses and Existing Dwellings reflects probably regional differences in demand, i.e. more densely populated areas are characterised by dwellings and less densely populated areas are characterised by houses.

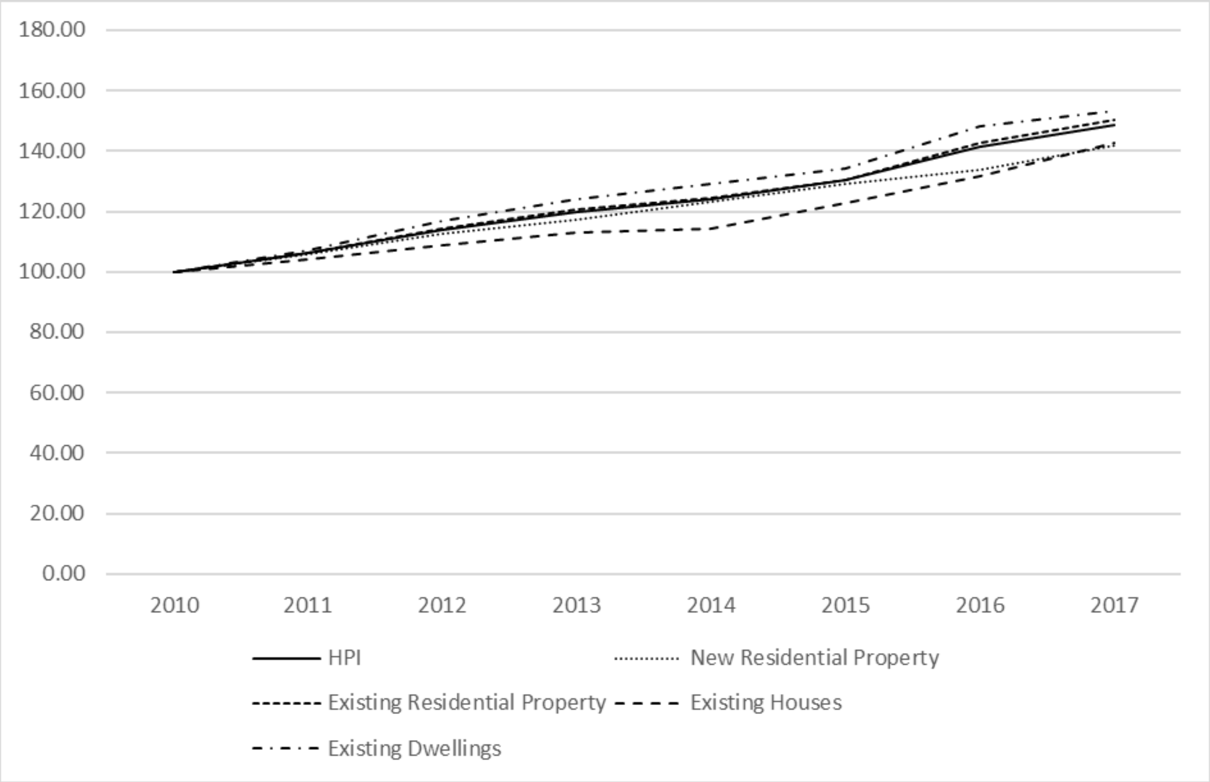

Figure 10 Residential property price indices (2010 = 100) (Statistik Austria 2018c)

Whereas the overall OeNB index displays a very similar trend as the HPI, it covers the period 2000-2017 and has slightly different subcategories. Since 2000 the overall price of residential property increased by 87%. This increase was much higher in Vienna (120%) than in the rest of Austria (75%). This price increase in Vienna was mainly driven by the developments of used condominiums' prices (+128%) and less by new condominiums (+90%) or single-family houses (+76%). A similar, but less pronounced development could be observed within the rest of Austria (single-family houses +54%, new condominiums +24% and used condominiums +92%). It is noteworthy, that the OeNB data do not indicate a price dip in the wake of the Financial and Economic Crisis (OeNB 2018).

Actual price levels for residential property are also provided by Statistik Austria (2018e), but these data cover only the years 2015-2017. In 2017 the Austrian median price was 1,458 euro/m² for houses, 2,812 euro/m² for dwellings and 86 euro/m² for building plots. Table 9 shows the spatial variance of these prices. An interesting aspect is that next to Vienna the western federal states have the highest prices. Only with respect to dwelling prices is the difference with the other federal states not that distinct.

Table 9: Median prices (€/m²) in 2017 (Statistik Austria 2018e)

	Houses	Dwellings	Building Plots
Burgenland	797	1,200	65
Carinthia	1,400	1,959	56
Lower Austria	1,265	2,250	83
Upper Austria	1,622	2,178	84
Salzburg	3,105	3,016	236
Styria	1,200	1,721	55
Tyrol	2,667	3,045	257
Vorarlberg	2,941	3,469	374
Vienna	3,750	3,598	676

Figure 11 displays the evolution of rents within Austria and four federal states. From 2005 the general level of rent prices did increase by 43,5%. This increase was the highest in Vienna (+49,5%), whereas in Upper Austria it was +38.9%. Vienna did not only experience the highest price increase, but has also the highest rent level (7,99 €/m²). Despite rent increases by around 43% rent levels in Lower Austria remain the lowest with 6,87 euro/m².

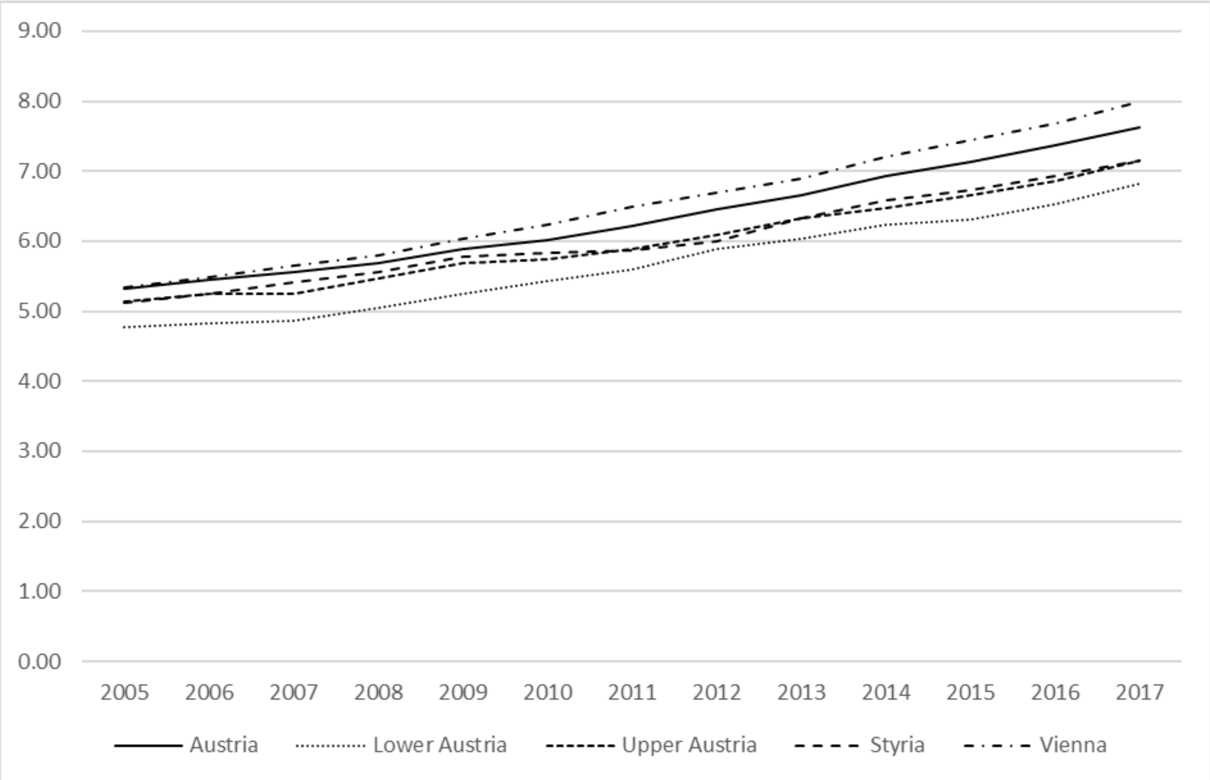

Figure 11 Rent prices (€/m², incl. overhead) (Statistik Austria 2018d)

3.5 Ownership structure

In a 10 year period Statistik Austria gathers a nation-wide people's, workplace and building and housing census. For the Census 2011, registry and administrative on a regional level was used for the first time for the bottom-up count of buildings and flats, their ownership structure, building types and other traits (Statistik Austria, 2013). Regional data can be downloaded individually on a NUTS-3 level as PDF-documents for the Census 2011 and Census 2001 (Statistik Austria, 2019). For a first overview and the framework discussion in this work package the agglomerated data on the legal basis for Austria and its federal states is illustrated, discussed and compared to the 2017 results of the yearly micro-census (Statistik Austria, 2018a).

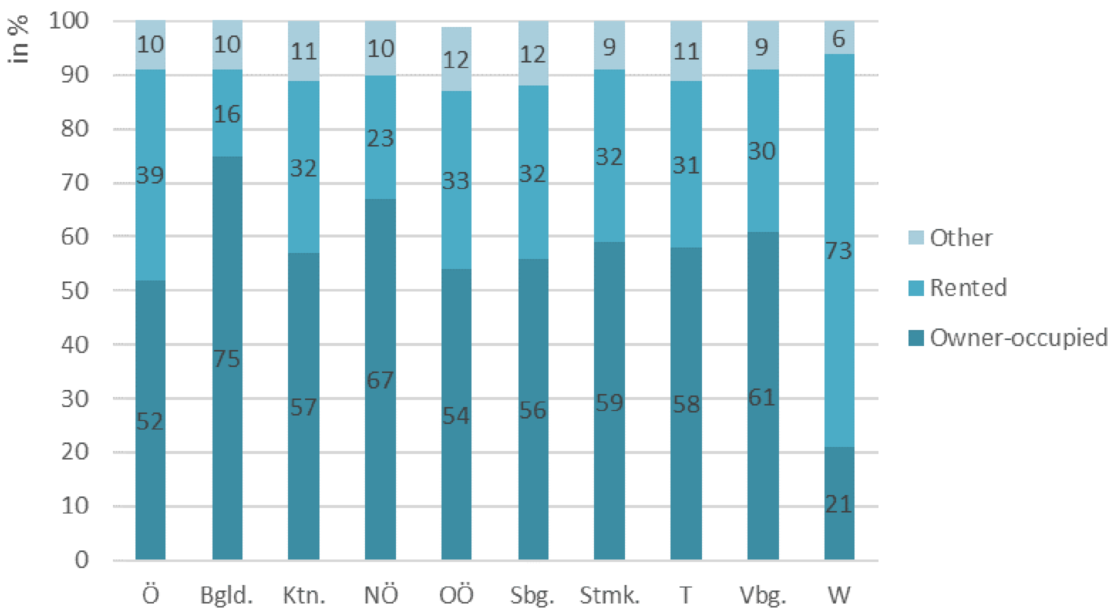

Figure 12: Percentage of owner-occupied and rented dwellings (main residences) by provinces. Source: Own Illustration based on (Statistik Austria, 2018a)

More than half of the Austrian dwellings are occupied by the owner of the flat (48% in 2017) or building while another 39% are dwellings rented from private persons, Gemeinde or Genossenschaft or other legal entities (43% in 2017). For another 10% other, free living conditions apply or they live in tied flats. In Figure 12 also the difference by provinces in this share are illustrated. While in Vienna only 21% of the dwellings are occupied by the owner and 73% are rented, in Burgenland this share is almost reverse.

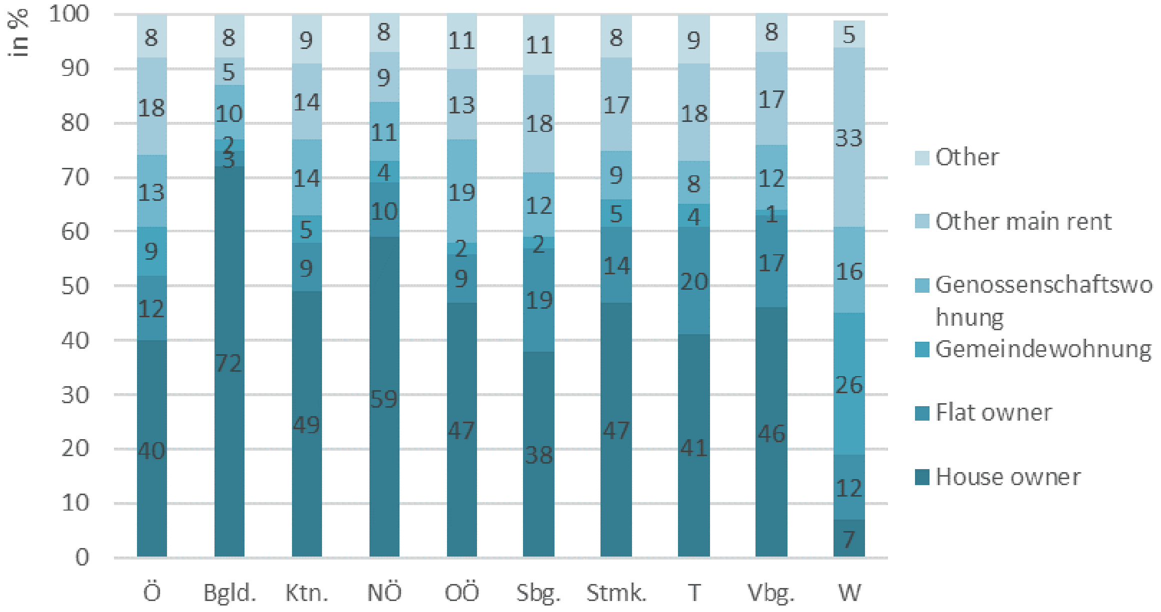

Figure 13: Tenure status of dwellings (main residences) by provinces. Source: Own Illustration based on (Statistik Austria, 2018a)

Illustrated in Figure 13, the lion share of the owner-occupied dwellings are house owners with 40% (37% in 2017), while 12% are flat owners (11% in 2017). Rented flats are 9% Gemeindewohnungen nation-wide with highest shares for Vienna (26% in 2011 & 23% in 2017) and lowest shares for Vorarlberg (1%), Genossenschaftswohnungen with 13% nation-wide (17% in 2017), other main rents (from private persons and other legal entities) with 18% and 10% in other living conditions. Upper Austria has the highest share in Genossenschaftwohnungen (19%) followed by Vienna (16%) and Corinthian (14%).

Next to the presented overall ownership structure on a provinces level also structures on a regional level can be derived to generate insights e.g. on national migration or urbanisation movements. Tenure status of dwellings by type of households (one-person household of different age groups, couples with/without children or more-family households) can be used to estimate investment decisions for renovation measurements.

3.6 Regional building stock and population related data

Population and housing data on municipal level

The national statistical bureau collects and provides population and building stock related data on the level of municipalities on the web portal ("Municipality in figures".) While the majority of the data need to be purchased, a subset (8 out of 55 datasheets is available free under http://www.statistik.at/blickgem/index.jsp.

These freely available data include:

- Development of the population of the municipality (as well as district ("Bezirk") and federal state) from 1869 to 2001 (roughly a datapoint every 10 years) and from 2002 onwards on an annual basis.
- Population per cohort groups and country of birth for 2018
- Population per highest level education for 2015
- Population per employment status and economic sector (ÖNACE) for the year 2015.

- Number of buildings per building type, number of buildings per construction period for the year 2011
- Number of apartments and main residences for 2011
- Number of main residences per owner ship status, number of main residences per apartment size, number of main residences per number of rooms for 2011.
- Number of households per household size, type of relationship status, number of children, etc. for the year 2011.
- Income and expenses of the municipal government from 2007 until 2016 and taxes per type for 2015 and 2016.
- Number of employers (and per company size) and employees per economic sector for 2011.

Regional population and housing forecast

ÖROK (https://www.oerok.gv.at/index.php?id=1152) provides an regional forecast of the population development per cohort group (http://www.oerok.gv.at/fileadmin/Bilder/2.Reiter-Raum_u._Region/2.Daten_und_Grundlagen/Bevoelkerungsprognosen/Prognose_2014/OEROK-Bevoelkerungsprognose_Tabellen_Web.xlsx), and the development of households per household size (http://www.oerok.gv.at/fileadmin/Bilder/2.Reiter-Raum_u._Region/2.Daten_und_Grundlagen/Bevoelkerungsprognosen/Prognose_2014_Teil_3/AnhangtabellenEndbericht.xlsx) on the regional level of districts ("Bezirke").

4 Physical constraints regarding renewable energy potentials and energy efficiency

In this chapter, we elaborate the potentials for renewable energy and energy efficiency with respect to the housing sector as relevant side-conditions for the case of Austria. This is done based on existing literature and decarbonisation scenarios. In particular for the case of biomass potentials, we take carefully discussed and balanced assumptions regarding the allocation of biomass potentials to different sectors into consideration (see e.g. the ACRP project BioTransform.at (Kalt et al, 2016), Stromzukunft 2030 (Resch et al, 2017) and further literature cited in part 1.1).

Therefore, we illustrate relevant renewable energy potentials as well as potentials for the decarbonisation for district heating and potentials of energy efficiency in the housing sector. Constraints and potentials regarding the fossil fuel phase-out in the mobility sector have not been addressed in WP2, while this sector includes important cross-cutting issues with the space-heating focus in this project.

Furthermore, Corresponding data for selected Climate Alliance –Municipalities will be added later in the project.

4.1 Renewable energy potentials

For the housing sector especially constraints regarding renewable energy potentials have to be considered. Biomass is currently used for bioenergy applications in a magnitude of about 245 PJ (about $2*10^7$ t) and 2030 potentials of 307 PJ-421 PJ are currently discussed based on various feedstock types. For roof-top solar thermal and PV the utilisable roof area for solar collectors has to be estimated. Lowest energy densities are discussed in the form of ambient heat. Coefficients of performances of ground-source heat pumps and air-source heat pumps are illustrated and a heat demand of about 41 PJ is expected to be supplied by heat pumps in 2050 (31% of the total gross floor area), which have to be driven by renewable electricity. For greening the gas grid, biomethane and renewable hydrogen potentials are outlined. Several studies report potentials for space heating in the range of about 4 PJ-52 PJ based on biomethane from biogenic residuals and strict constraints regarding gas-grid connection and the utilisation of biogas in other sectors with less options to phase out fossil fuels. The upcoming subsections illustrate the outlined potentials and their respective constraints in a greater detail.

4.1.1 Biomass

Current biomass utilisation:

Information and data on biomass production, consumption and respective streams in, to and from Austria is not collected and reported by a single dedicated authority in Austria but can be found in various statistics and official documents issued by governmental institutions. The Federal Ministry for Agriculture, Forestry, Environment and Water (BMLFUW) hosts a GIS-Database for a simplified access to the Integrated Administration and Control System (IACS) and its land utilisation data. Together with i.a. national production statistics, economic accounts for agriculture and forestry, supply balances, the Austrian forestry inventory and trade statistics the “Grüne Bericht” (BMLFUW, 2018) reports economic performance, property ratios and production volumes of the primary sector. In total agriculture and forestry accounted for 1.3 % of gross value added in 2016 with an estimated cumulative output in the magnitudes of about 10^7 t for various crops and in the same order of magnitude for primary forest resources.

Kalt et al, (2016) completed the picture on biomass streams in Austria by including additional statistical sources such as the national economic (production) statistics, international forestry statistics from FAOSTAT and foreign trade statistics from Eurostat as well as industry reports and expert estimates. Furthermore, they estimated cumulated values with and without water content for increased comparability. They found about $4*10^7$ t_{dry} biomass input into the Austrian economy in the report year 2011 of which 42% have been imported. Final use shares of 7% for human food, 18% for raw materials, 38% for energy use and 37% for animal feed are calculated. About $2*10^7$ t_{dry} flow into the wood processing industries which generates the main products for export (on dry tonne basis) such as paper and paperboard. While small shares of biomass for energy use originate from a diverse set including landfills, sewage plants, animal rendering and liquid (transport) biofuels, a main share (45%) relate to the wood processing industries (i.e. heat and power generation in auto-production plants, waste liquor utilisation in the paper industry, pellet production from sawmill residues and wood residues sold for energy generation). In summary, the work illustrates that the Austrian bioenergy sector is largely based on by-products and wastes, especially when considering that log wood and forest wood chips are by-products of stemwood sourcing for material uses.

According to (Statistik Austria, 2018b) domestic cross consumption of biomass for bioenergy in 2016 equalled about 245 PJ (about $2*10^7$ t) with a steady growth from about 6 % of total domestic cross consumption in 1970 to 17 % in 2012 and a stagnating phase thereafter. In 2016 about 22 PJ, mainly of biogas, wood residues and biogenic municipal solid waste have been used for power production in dedicated power plants while another 54 PJ of these resources have been deployed in heat- or combined heat and power plants. Large amounts of log wood (56 PJ) are used for residential heating as well as in the agricultural sector. Black liquor (25 PJ) and a smaller share of wood residues (5 PJ) are used for process heat purposes in the pulp and paper processing industry. Another 12 PJ of wood residues are furthermore converted to process heat in the wood processing industry, while residential heating uses 6 PJ of wood residues and 8 PJ of wood pellets and briquettes in 2016. Biermayr et al. (2018) estimate an installed capacity of 6.4 MW_{th} biomass boilers above 100 kW_{th} for process heat and district heating and about 0.3 MW_{th} biomass boilers for residential heating.

Biomass potentials:

How the current utilisation of biomass in Austria relates to its potential as well as potentially relevant future demand will be discussed based on the existent literature in the following paragraphs.

Current studies on biomass potentials often have a broad focus, assessing the global or European biomass potentials on a national or even on a regional level. Hoefnagels et al., (2017) started with (1) theoretical potentials based on theoretical production, (2) technical supply potentials indicating the upper technical boundary, (3) reduced by constraints like biomass management practices and sustainability concerns (sustainable/achievable potentials), (4) further reduced by demands for material uses (technical/realisable/sustainable potential) to (5) finally model supply potentials for bioenergy based on supply cost curves as well as logistic costs and GHG-emissions for trade. Biomass categories and potential definitions have been adopted from the Biomass Energy Europe (BEE) project which analysed and outlined the harmonisation needs of biomass resource assessments (Vis and van den Berg, 2010). The BioSustain study (Hoefnagels et al., 2017) calculated for Austria primary biomass for energy supply potential of 347 PJ for the year 2030 in the reference scenario with shares of 62% for forestry biomass, 27% agricultural products and 11% biogenic waste.

While the BioSustain study includes 23 different feedstocks, with updated wood resources potentials from the EUwood/EFSOS studies, spatial resolution only goes down to Member State level for the EU28. For the follow-up ESPON-Locate project the discussed potentials where clustered into three main types of biomass feedstock categories (forest residues, energy crops and organic wastes) have been again spatialized down to a NUTS-3 level using GIS-based land use analysis for arable land and an analysis for land used for forestry (Schremmer et al., 2018).

A similar methodology was applied in the Hotmaps-project. To be able to simulate space heating supply in the EU, renewable energy potentials including bioenergy potentials have been derived on the NUTS-3 level (and for forestry residues on a 100x100m-grid level). Therefore, potential estimates on the MS-level from the Biomass Policies-project (Elbersen et al., 2016) have been collected, and extended with residues from agricultural production and processes and effluents from livestock breeding, “while crops cultivated purposely for biofuel production have been excluded due to the prospective environmental impacts in terms of land use change, biodiversity losses and water resources depletion”. (Pezzutto et al., 2018) Statistics on land use and land cover in a georeferenced points format from the European Environment Agency (EEA, 1995) as well as from EUROSTAT, (2018) have been used. The open source dataset estimates the forestry residues potential with 68 PJ and livestock effluents with 2.9 PJ. Furthermore, agriculture resides have been estimated with 10.2 PJ for cereal straw, 4.9 PJ for grain maize and 0.6 PJ for rape and sunflower. The open-source database includes next to household waste estimates also waste water treatment plants and other energy intensive industrial sites to estimate waste heat potentials for energy efficiency measures. Compared to the BioSustain study, this database is based on significantly lower values for forestry residues, rape and sunflower and livestock effluents while excluding black liquor, forestry products (stem- and logwood), short rotation coppice, grassy biomass and other dedicated energy crops (such as sugarbeet, maize, wheat, barley).

The Austrian Biomass Association discusses expansion scenarios for biomass utilisation for energy purposes in 2030. They estimate, that the utilisation of residues from agricultural processes to be used energetically could increase from a vanishing amount today to 16.4 PJ. Therefore, up to 30% of currently used cereal-, rape seed and grain maize cropping surface has to be used to extract straw and corncobs as well as intermediate crop surfaces would have to be extended intensively. Woody non-forestry biomass (SRC and Miscanthus) could increase from 0.3 PJ in 2015 to 10.6 PJ in 2030. Organic waste and manure energy potentials are outlined with 1.6 PJ in 2015 and 8.6 PJ in 2030 based on a 10-fold increase of manure utilisation. Biomass from landscape conservation and grasslands are not used today but could add another 2.5 PJ if 5% of extensive- and 3% of pasture land is used. Dedicated bioenergy crops could furthermore double from 3.6 PJ in 2015 to 7.1 PJ in 2030. Largest shares of this expansion plan however are discussed for forestry biomass. While its utilisation for energy purposes is estimated with about $2.5*10^7$ solid m^3 in 2012, deployment of $3.1*10^7$ solid m^3 in 2030 are suggested mainly based on increased logging also in smaller forests. With the outlined expansion potentials (in total 95.4 PJ), the Biomass Association expects increased biomass for energy utilisation from 245 PJ in 2013 to 340 PJ in 2030 (ÖBV, 2015). In comparison with older potential estimates, Streicher et al., (2010) discuss sustainable biomass potentials of 307 PJ for 2050 while Christian et al., (2011) outline a potential of 421 PJ.

Potentially relevant demand:

In the Adoption of the Paris Agreement it was stipulated that the amount of greenhouse gas (GHG-) emissions will have to peak soon, after which rapid reductions will have to be achieved to reach the international target of economy-wide zero net-emissions in the second half of this century (UN/FCCC, 2015).

Prior to the Paris Agreement, the European Council had already decided on its 2030 climate and energy policy framework, which includes a European Union (EU)-wide reduction in domestic GHG-emissions by at least 40% in 2030 compared to 1990 (EUCO, 2014). Considering the leading role of the EU within the Paris framework as a "developed country party", let alone possible first-mover advantages with regard to the development of technological, societal and institutional innovations and solutions, targets for 2050 can and should be significantly more ambitious. Indeed it will be essential to phase out non-renewable fossil carbon across all sectors of the economy, whilst at the same time enhancing resource efficiency. (Schipfer, 2017)

Scenarios for the Austrian energy consumption illustrating a break in the current trend have been published as transition scenario for the ministry of environment (Krutzler et al., 2017). To provide a realistic opportunity to reach the outlined targets, this scenario proposes a cut of final energy consumption from about 1.090 PJ in 2015 to 900 PJ in 2030 and about 620 PJ in 2050 (gross inland consumption on average 30% higher). Largest efficiency gains are discussed within the 35 year timeframe for transport with about 270 PJ and households/buildings with 130 PJ. While 20% of final energy consumption in Austria have been covered by electricity in 2015, about 43% are envisaged in this scenario for 2050 especially due to an 8-fold increase of e-mobility. The renewable energy share of the gross final energy consumption (incl. conversion and other losses) is expected to increase from 33% in 2015 to 47% in 2030 and 94% in 2050. Biomass consumption is expected to decrease, especially in buildings (from about 70 PJ in 2015 to 40 PJ in 2050) and the transport sector (from about 30 PJ in 2015 to 20 PJ in 2050) due to overall efficiency gains and better isolation as well as a switch to electro mobility. Overall, gross domestic energy consumption from biomass is expected to reach the 2015 values of 240 PJ in 2030 with a medium-term decrease to about 210 PJ in 2030.

Possibly relevant future developments of space heating have been analysed in detail in the project Wärmezukunft (Kranzl et al., 2018). Building upon the discussed Transition scenario primary energy deployment of biomass in buildings (incl. district heating) decreases from 110 PJ in 2016 to 100 PJ in 2050. Decentral biomass heating is expected to decrease from 80 PJ in 2016 to 50 PJ in 2050 while for district heating a 7% expansion of bioenergy utilisation is expected before reaching starting levels again in 2050. Biomethane is discussed to be delivered via the natural gas grid from almost vanishing amounts today to about 20 PJ in 2050. Furthermore, for decentral biomass heating a shift in the utilised bioenergy carriers is outlined. While wood pellets are contributing about 13% of today's primary energy deployment for decentral biomass heating, this share is expected to increase to 34% in 2030 to up to 50% in 2050. Wood chips are discussed to double until 2030 while the utilisation of wood logs should decrease from 60 PJ (77%) today to 10 PJ (26%) in 2050.

The study Stromzukunft (Resch et al., 2017) discusses renewable energy deployment for electricity production in Austria. A high share of bioelectricity can be installed based on floating market premiums set administratively resulting in a production of about 20 PJ with 27% from biogas (also in the form of biomethane) and 73% solid biomass in 2050. Its underlying scenario assumes a gross domestic energy consumption from biomass of about 280 PJ in 2050 (Krutzler et al., 2016).

Bioenergy consumption in industrial processes is discussed to increase from about 50 PJ in 2015 to 70 PJ in 2050 in the discussed transition scenario. While biomass is mainly used for heat and electricity in the pulp and paper industry today, high temperatures and specific requirements of furnaces often limit the use of renewable energies to biomass or other secondary energy carriers. Sensfuß et al., (2018) discuss a doubling and tripling of bioenergy in the EU28 industry from about 840 PJ to 1.7-2.4 EJ in 2050 in their scenarios. In terms of a transformation towards a bioeconomy also novel biomaterials such as biobased polymers, lubricants, solvents, surfactants and bitumen have to be considered. The advanced biobased material scenarios from Schipfer et al., (2017) discuss an additional biomass demand of up to 40 PJ for Austria in 2050 for these products.

Discussion:

Biomass flows to, in and from Austria are clearly dominated (when calculated on dry weight basis) by wood and wood products today. The wood processing industry is furthermore the main single source for domestic bioenergy supply which plays a significant, thus stagnating role (since 2012) in the energy mix. Bioenergy is mainly used for space heating and to a lesser extent for process heat in the wood processing industry. Electricity from biomass is less common in Austria.

Various scenarios from academia estimate sustainable expansion potentials for domestically sourced biomass for energy of 25% and 71% in 2050 (Streicher et al., 2010; Christian et al., 2011) respectively 42% in 2030 (Hoefnagels et al., 2017) compared to 2016 values. At the same time and to hold a chance to comply with international climate goals, final energy consumption will have to be cut drastically through efficiency measures in all sectors. For space heating an improved building stock could result in slightly decreasing primary bioenergy demands, however with shifting shares from decentral- to district heating as well as to denser bioenergy carriers such as wood pellets and biomethane delivered via the natural gas grid. While biomass for electricity is expected to have a similar relevance in Austria in the upcoming decades as today, the demand for high temperatures and specific requirements of furnaces in industries could represent additional bioenergy deployment potentials.

By tapping only parts of the domestic biomass for energy expansion potentials, significant contributions to the energy transformation can be achieved assuming that overall energy consumption is reduced and a switch to more efficient bioenergy carriers is performed. Therefore, forest management especially from small forest owners has to be amplified while non-forestry woody biomass such as SRC has to be extended and practices for the energy conversion of agricultural residues have to be implemented. At the same time structural improvements of the affected regions are needed to prevent their simple exploitation and to ensure a positive impact on rural development.

Bioenergy contributions to phase out fossil fuels would be comparable to highly ambitious expansion campaigns for photovoltaics, wind and ambient heat due to their small shares today. This holds true especially on a medium-term until renewable electrification, energy storage and energy carriers such as methane and hydrogen from renewable electricity can take over functionalities only bioenergy can deliver today.

4.1.2 Roof-top

Among other alternatives, solar energy can be harvested to provide clean and renewable energy to end users. Besides regional differences in the annual solar radiation per plot area, the main key parameter, which determines the annual amount of energy that can be harvested, is the plot area, on which collectors are installed.

With respect to the installation size, we can distinguish between two different strategies. The first strategy is the installation of large central collector fields. The amount of energy harvested in such fields typically exceeds the energy needs of the close surrounding. Therefore, the energy – either heat from solar thermal collectors or electricity from PV modules – is fed into an energy transmission system (district heating network or electricity grid) and is supplied to customers.

An alternative route to the central large collector field approach is the installation of decentral fields in the direct surrounding of the energy users. The installation of roof top PV or solar thermal collectors is the typical case of this type of installation. Other types of installation, yet not as common, would be the installation of collectors on vertical building areas (façades) or the installation of collectors in the back (or front) yard of buildings.

In this chapter, we focus on the potential energy that could be harvested by roof top systems and compare the annual energy amount with the energy needs for space heating and domestic hot water (DWH) production. This is done for each municipality in Austria. Data developed in the Solargrids project (Müller et. al 2014) suggest that the ratio of roof top area of buildings to current energy needs of heat supply are in the range of 1.5 to about 3 m² per MWh energy. Densely populated areas with typically a larger share of multi-storey buildings are found in the lower end of this range, while municipalities with a large share of single family homes are found in the upper range. Since the latter situation is the predominate case in Austria, counted by the number of municipalities, the median value of this ratio is well above the mean value and lies at about 2.5 m²/MWh (Figure 14).

However, we have to consider that not the entire roof area typically can be used for collectors. This can either have technical restrictions, a certain share of the roof area doesn't have a favourable orientation, the shadows projected by surrounding objects (trees, buildings, elevations, etc.) would heavily reduce the specific solar yield, or solar technologies are unwanted for aesthetic reasons. Therefore besides the total roof area, a reduced area, which considers these barriers, has been calculated in the Solargrids projects (Müller et. al 2014). If considering these barriers, the available roof area drops from an average value of 2.25 m²/MWh to about 0.75 m²/MWh.

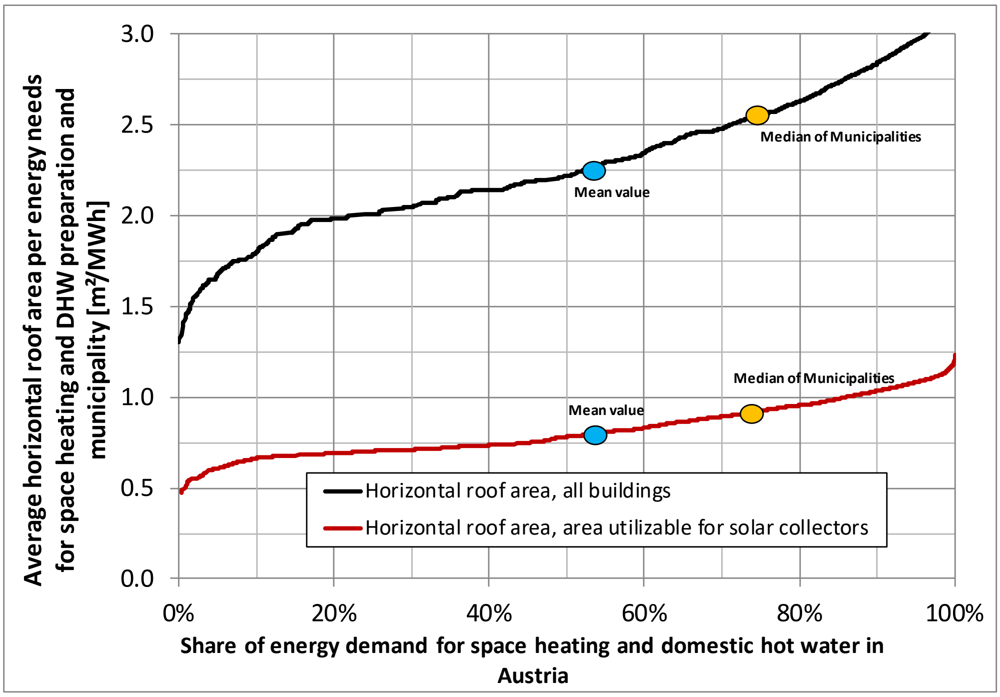

Figure 14: Roof top area of buildings per energy needs for space heating and domestic hot water preparation per municipality in Austria. Source: own illustration based on Müller et. al (2014).

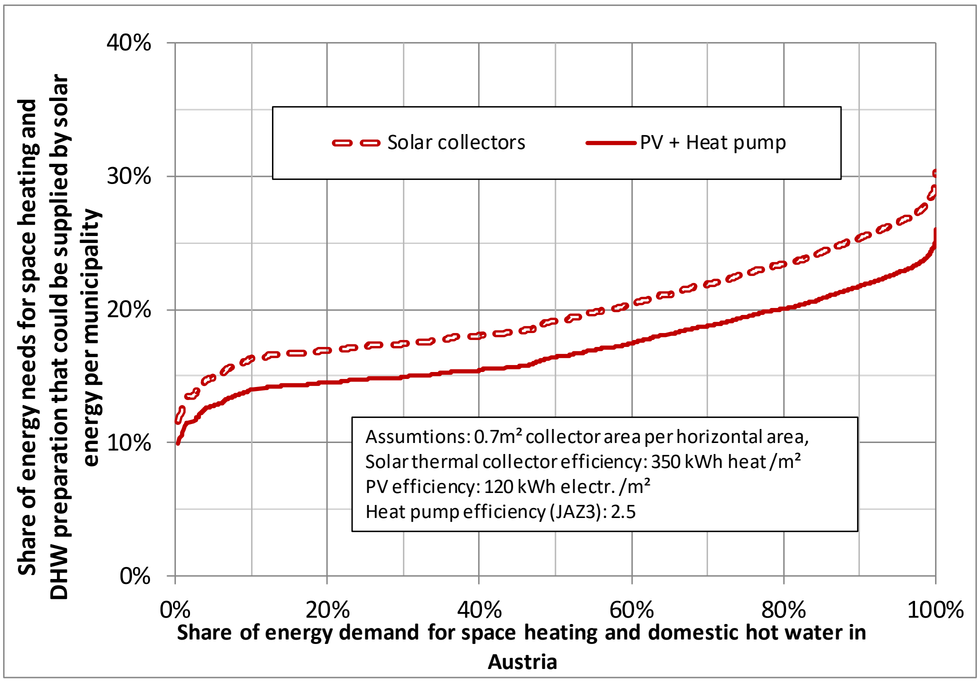

Figure 15: Share of energy needs for space heating and DHW preparation that could be supplied by solar technologies. Source: own illustration based on Müller et. al (2014).

4.1.3 Ambient heat

Ambient heat is a principally unlimited resource because it continuously gets renewed by the suns radiation or through geothermal activity. The limitations in tapping the potential of ambient heat lie in its low energy density and the limitations of the conversion technologies called heat pumps. The low energy density limits the potential for individual ambient heat technologies especially in urban areas where the available ground for ground source heat pumps is limited but also the potential for air source heat pumps is limited due to noise and distance restrictions. Limitations of the conversion technology refer to the achievable coefficient of performance of the heat pump under certain conditions. The coefficient of performance – the efficiency – is the ratio of energy output from the heat pump and energy input to run the heat pump and highly depends on the temperature difference of heat source and heat sink. Therefore the gainable ambient heat is limited on the one hand if the flow temperature of the heating system (=heat sink) is on a high level or on the other hand if the temperature level of the heat source is on a very low level. The former is the case mostly in older buildings with bad insulation and with heat radiator systems with high flow temperatures and the latter can be the case especially in winter time when air is the heat source and outdoor temperatures are rather low. Figure 16 shows coefficients of performance for different heat pump types for different heat source and heat sink temperatures. The figure clearly shows that the lower the heat sink temperature and the lower the difference to the heat source the higher is the achievable coefficient of performance.

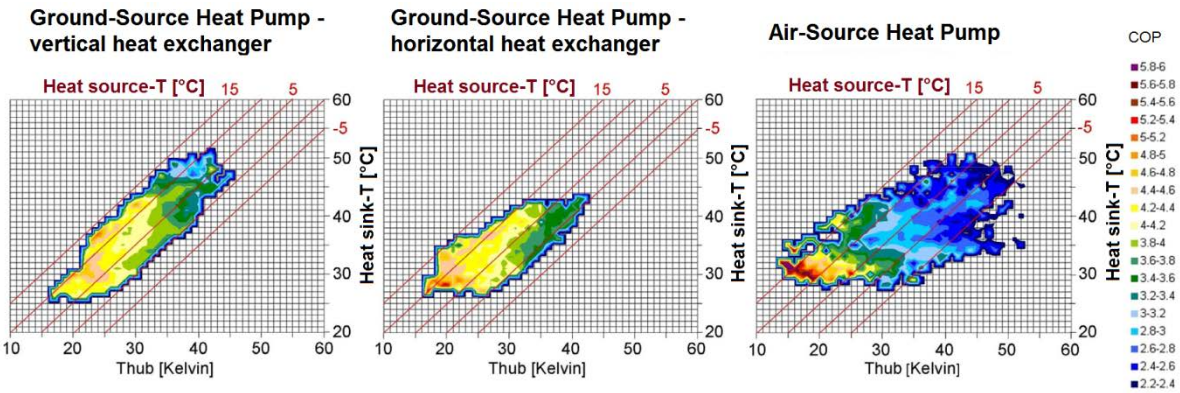

Figure 16: Measured coefficient of performance for different types of heat pumps for different heat source and heat sink temperatures. Source: Translated from Miara et. al (2011)

To illustrate the potential for ambient heat in Austria, Figure 17 shows achievable seasonal performance factor of an Air-Source Heat-Pump from Kranzl et. al (2018) considering typical flow temperatures of the heating systems in the current Austrian building stock. Demanding seasonal performance factor of at least 3, results in a potential of ambient heat provided by Air-Source Heat-Pumps of only 0.5 TWh. On the other hand in new or in deeply renovated buildings with heating systems with low flow temperatures heat pumps have a high potential especially in rural areas and are currently often the choice in new buildings resulting in more than 20 000 heat pumps installed annually in the recent years in Austria (Biermayr et al, 2018).

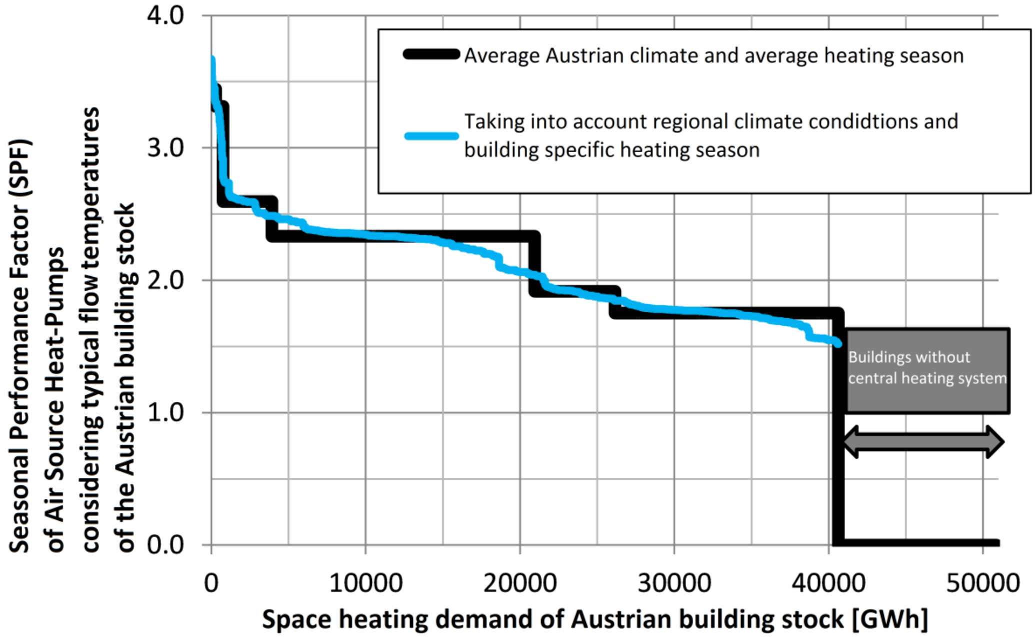

Figure 17: Seasonal Performance Factor (SPF) of Air-Source Heat-Pumps considering typical flow temperatures of heating systems in the Austrian building stock. Source: Translated from Kranzl et. al (2018)

Taking into account the characteristics of future buildings most studies see rising potentials for heat pumps. The Austrian heat pump roadmap (Hartl et al., 2016) provides three scenarios (high, medium and low) of the market development of the different types and sizes of heat pumps for space heating until 2030 with assumptions based on the results from (Müller et al., 2010).

The aggregated results for all sizes of heating HP are shown in Figure 18. In the medium and high scenario annual sales between 34 000 and 62 000 are expected for 2030, reflecting optimistic current trends and policies. Only in the low scenario where a continuous decline of the market is assumed the annual sales figures drop to around 9 500 until 2030.

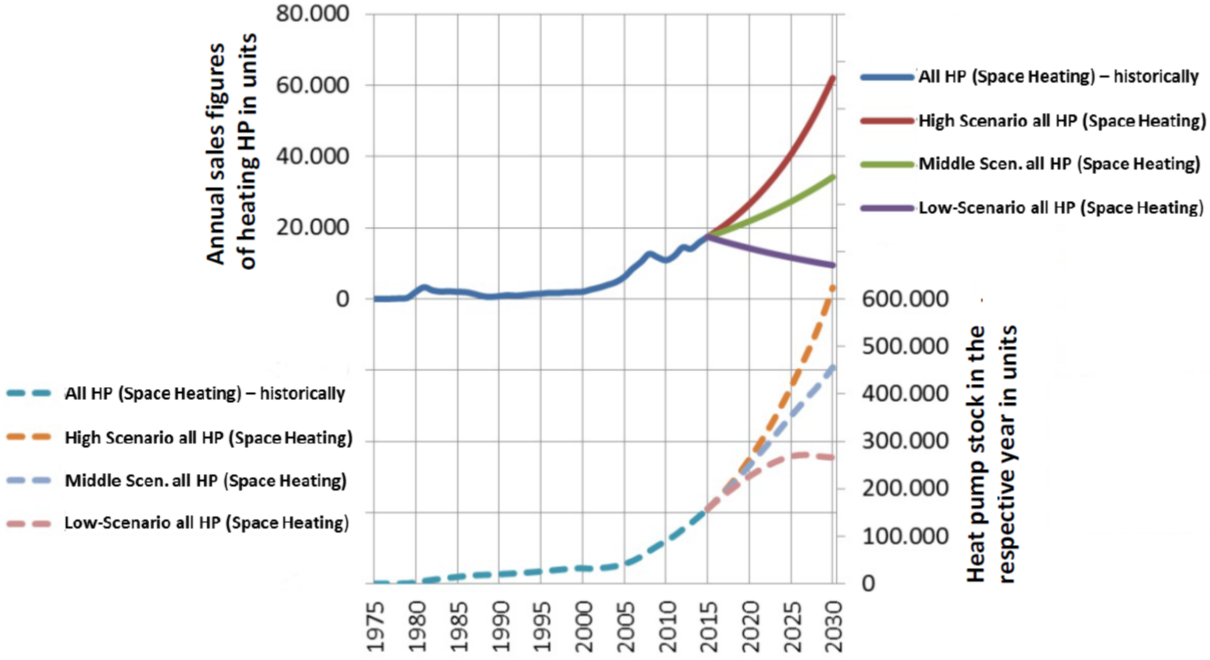

Figure 18: Annual sales figures of heating HP and heat pump stock according to the Austrian heat pump roadmap. Source: Translated from Hartl et. al (2016)

A newer estimation made in the project "Wärmezukunft 2050" (Kranzl et.al, 2018) is depicted in Figure 19. In this study a scenario of a highly decarbonised heating sector is shown resulting in a high potential for heat pumps supplying 15% of the total heated gross floor area in 2030 and 31% in 2050 resulting in a heat demand of 11.5 TWh (26% of the heat demand in 2050) supplied by heat pumps.

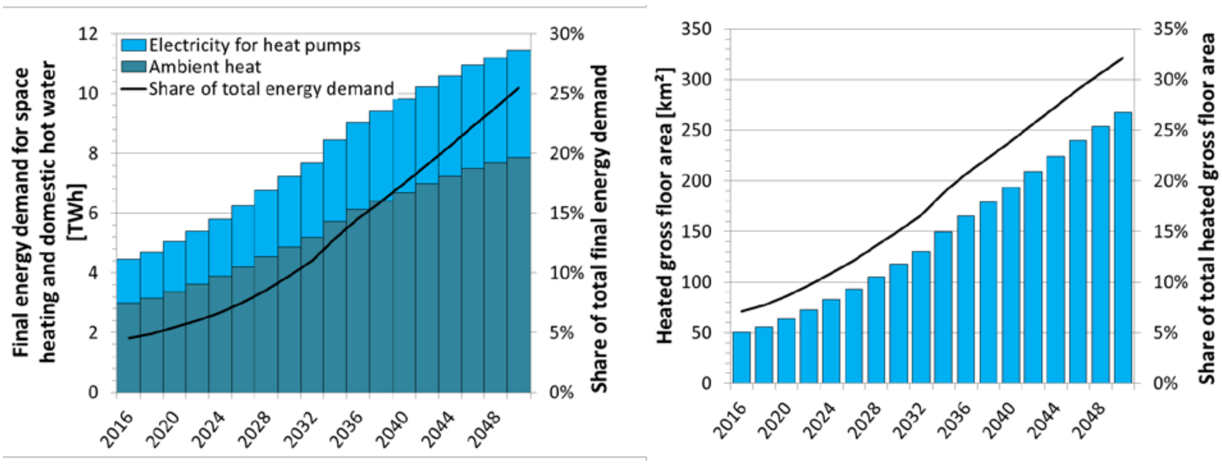

Figure 19: Final energy demand and gross floor area supplied by heat pumps according to the project "Wärmezukunft 2050" . Source: own illustration from Kranzl et al (2018)

The role of ambient heat in the transition to a decarbonized system is discussed controversially. On the one hand the electricity for driving the heat pump has to be renewable to contribute to the decarbonisation of the system which is often not the case right now and also the highest electricity demand for heat pumps usually occurs in times with high electricity demand leading to additional needed back-up capacities in a renewable energy system. On the other hand heat pumps add flexibility to the system due to the coupling to the electricity sector and can significantly increase efficiency and reduce CO_2 emissions when driven by renewable electricity and operating with high COP's as it is the case in good planned and implemented systems for new or deeply renovated buildings with low flow temperatures.

4.1.4 Green gas

In different renewable heating scenarios almost always a remaining gas demand is foreseen. For example in the “Wärmewende 2050” scenario (Kranzl et. al, 2018) a remaining demand of approx. 5855 GWh of final energy needs is supplied by gas. To fully decarbonize the heating system this remaining gas demand has to be provided by CO_2 neutral, renewable energy carriers like bio methane and regenerative hydrogen. In the following we assume that this green gas would consist of a mixture of 50% by volume of bio methane and 50% by volume of renewable hydrogen. This is a share that was typical for the gas provided from gasification of coal by the city of Vienna in the second half of the 19^{th} century or of the water gas used after the second half of the 20^{th} century. Due to a lower volume-specific upper heat value of hydrogen (H^o = 3.54 kWh/Nm³) compared to methane (H = 11.06 kWh/Nm³) this green gas would result in an upper heat value of 7.3 kWh/Nm³. Because the mentioned remaining gas demand of 5855 GWh refers to the lower heating value, the lower heat value of the assumed gas mixture of 6.48 kWh/Nm³ has to be corrected due to the higher ratio of upper to lower heat value of hydrogen compared to methane. This results in a lower heat value of the assumed gas mixture of 6.59 kWh/Nm³ with 25% of the energy coming from the hydrogen and the remaining 75% of the energy coming from the methane. Assuming this mixture, approximately 900 Mio. Nm³ of this renewable gas are needed (450 Nm³ CH4 and H2 each) to cover the remaining gas demand in the “Wärmewende” scenario of 5855 GWh (lower heat value of final energy needs).

Where this renewable gas could come from, was assessed in a study by the Energy Institute of the JKU (Tichler, 2017) where the potentials of bio methane from residuals in Austria until 2030 were calculated resulting in an overall potential of 14500 GWh. The total potentials and the proportions of the different residuals for the different federal states can be seen in Figure 20.

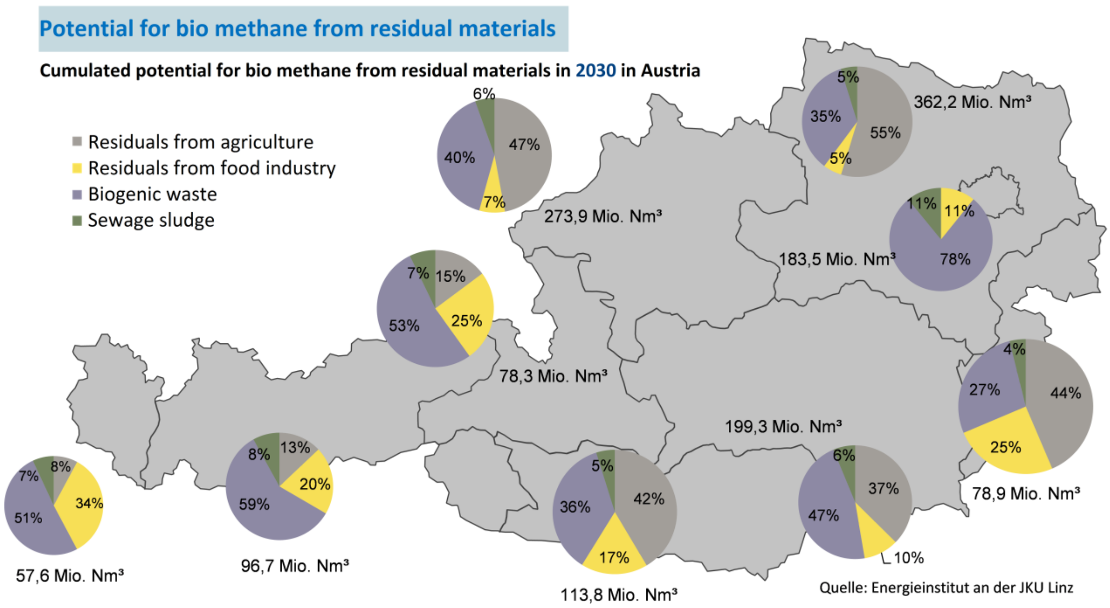

Figure 20: Potentials for bio methane from residual materials in Austria in 2030. Source: Translated from Tichler (2017)

Comparing these potentials with the heat demand from the “Wärmewende 2050” scenario in Kranzl et. al (2018) shows that around 30% of the overall bio-methane potential needs to be feed into the gas network to supply the remaining gas demand in buildings. In all federal states except from Vienna the remaining gas demand remains below 35% of the potential of renewable gas (Figure 21).

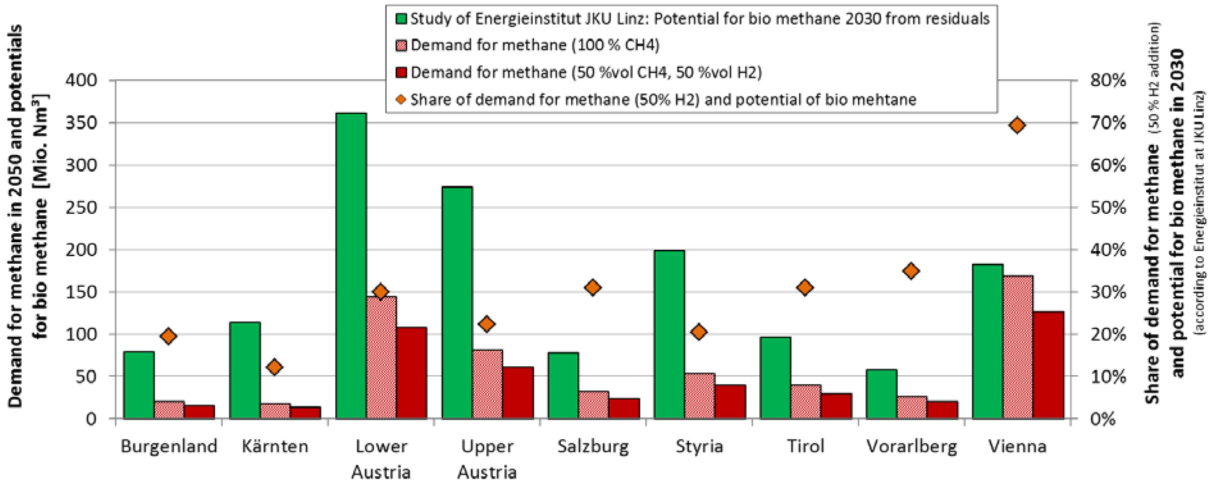

Figure 21: Comparison of potentials for bio methane from residual materials and demand for methane in the heating sector in Austria according to the Wärmewende 2050 scenario. Source: Translated from Kranzl et. al (2018)

It has to be pointed out that this is an optimistic study and other studies obtain lower potentials for bio-methane. The association „ARGE Kompost und Biogas” (Kompost & Biogas Verband Österreich, 2018) estimates the potentials for biogas that could be feed into the grid to around 750 Mio. Nm³ resulting in a share of 60% of the potential of bio-methane used for space heating purposes.

An even stricter analysis by the “DBI Gas- und Umwelttechnik GmbH“ (Müller-Syring and Hüttenrauch, 2012) focusing on the biogas potential from residuals on the one hand receives an overall potential for biogas of around 2800 Mio Nm³ which would be enough to supply the gas demand in 2050 according to the “Wärmewende” scenario in Kranzl et. al (2018) but on the other hand restricts the biogas potential that could be fed into the grid taking into account regional and seasonal aspects (not considering seasonal storage of bio-methane) to only 150 Mio Nm³, which would only last to supply one third of the remaining gas demand.

The different analysis show that the potential for bio-methane indeed is limited and that there may be other sectors with need for renewable gas which might be harder to decarbonize than the building sector.

4.2 Potentials for (decarbonised) district heating

District heating in general is seen as an important medium to decarbonize the heating sector especially in urban areas. This is because in densely populated areas there is often not enough potential for renewable heating sources due to their low heat densities or transportation issues. As discussed in the previous sections, available roof space for solar thermal heating may not be enough, the available underground may not be sufficient for ground-source heat pumps or distances and free space may not be sufficient to install air-source heat pumps, and also individual biomass boiler can only be used to a very limited extent in densely populated areas due to logistic (transportation and storage) and local air pollution reasons.

In these urban areas district heating allows the integration of renewable and excess energy sources which otherwise could not be tapped to a large extent by allowing central but also decentral feed in of heat sources and the distribution to various consumers for different purposes. The feasibility of district heating, however, highly depends on the amount of sold heat per meter of installed network compared to the cost of heat production. Therefore the higher the heat density of the supplied area and the higher the connection rate in a certain area the lower are the specific costs of infrastructure per unit of heat. This makes district heating interesting especially in densely populated areas.

The integration of renewable heating sources into a district heating network and the efficient distribution within an integrated system request certain features of a future network which are described in the concept of the fourth generation district heating system (Lund et. al, 2014) with the following main challenges:

- Supply low-temperature district heating
- Distribute heat in networks with low grid losses
- Recycle heat from low temperature sources and integration of renewable heat sources
- Be an integrated part of smart energy systems
- Ensure Institutional framework for suitable planning, cost an motivation structures

The potential for district heating therefore depends on various factors one of it being the current and future regional heat demand density. Figure 22 shows heat demand densities and prospective district heating supply areas in Austria according to the results of the Heat Roadmap Europe project (https://heatroadmap.eu/). They coincide with densely populated urban areas and are based on regional grouping of coherent and contiguous areas with a minimal heat demand density of 100 GJ/ha (2.8 GWh/km²) and annual heat demand higher than 10 TJ (2.8 GWh). Comparable results can be found in the toolbox (https://www.hotmaps.hevs.ch/map) of the hotmaps project (https://www.hotmaps-project.eu/) which are downloadable from their data repository (https://gitlab.com/hotmaps) and documented in Pezzutto et. al (2018).

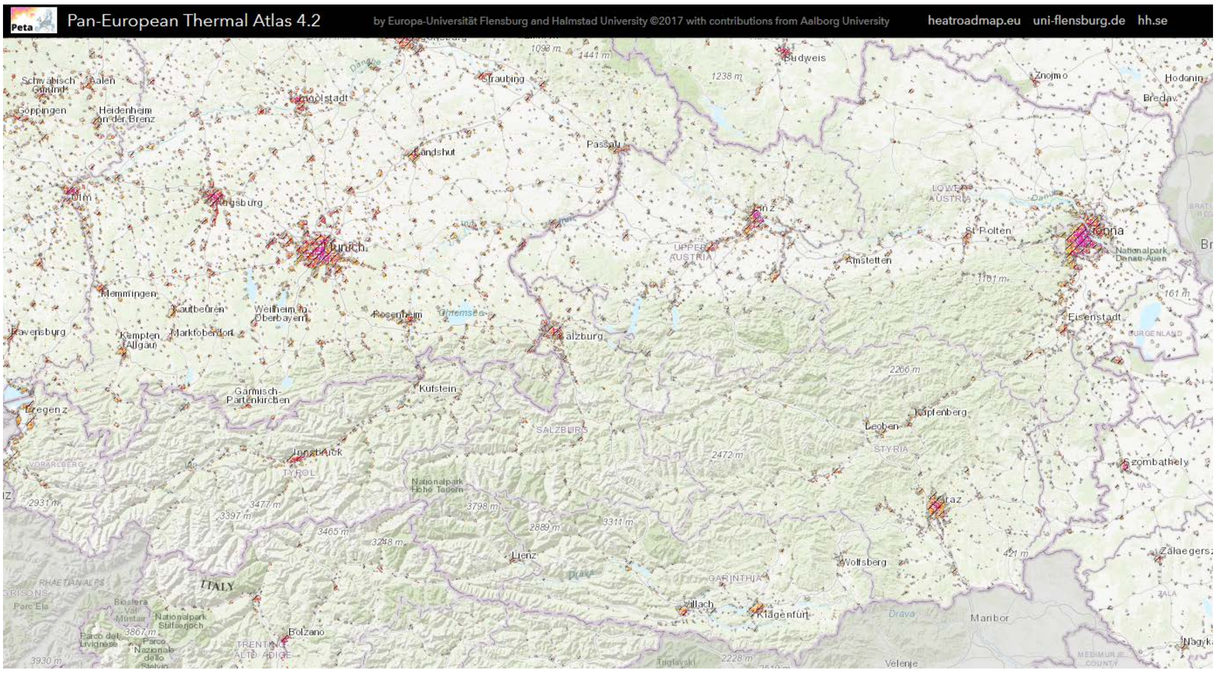

Figure 22: Prospective district heating supply areas in Austria (source: Snapshot of the PETA4 of the HRE4 Project, https://heatroadmap.eu/peta4/)

A heat density map for Austria but with a heat demand scenario until 2025 is available from the Comprehensive Assessment of the Potential for Efficient District Heating and Cooling and for High-Efficient Cogeneration in Austria[5] (Büchele et. al, 2015) in which the district heating potentials in 2025 in Austria were calculated. Figure 23 shows these potentials for different scenarios. In the base scenario there is an additional potential for district heating of more than 40 TWh with almost 20 TWh of it being efficient according to the definition in the Energy Efficiency Directive[6] (Directive 2012/27/EU). In the base scenario a connection rate of 90% of the heat demand within the areas classified as highly suitable for district heating is assumed. A connection rate of only 45% of the heat demand in these areas would reduce the additional district heating potential to 10 TWh with around 8 TWh being efficient. This illustrates the importance of a high connection rate in areas with sufficient heat density. However, it can be seen that also other factors like CO_2 price, price of fossil fuels and building efficiency significantly influence the potential for district heating.

[5] http://www.austrian-heatmap.gv.at/das-projekt/

[6] Efficient district heating refers to district heating that is supplied with at least 50% renewable or excess heat or with at least 75% combined produced heat.

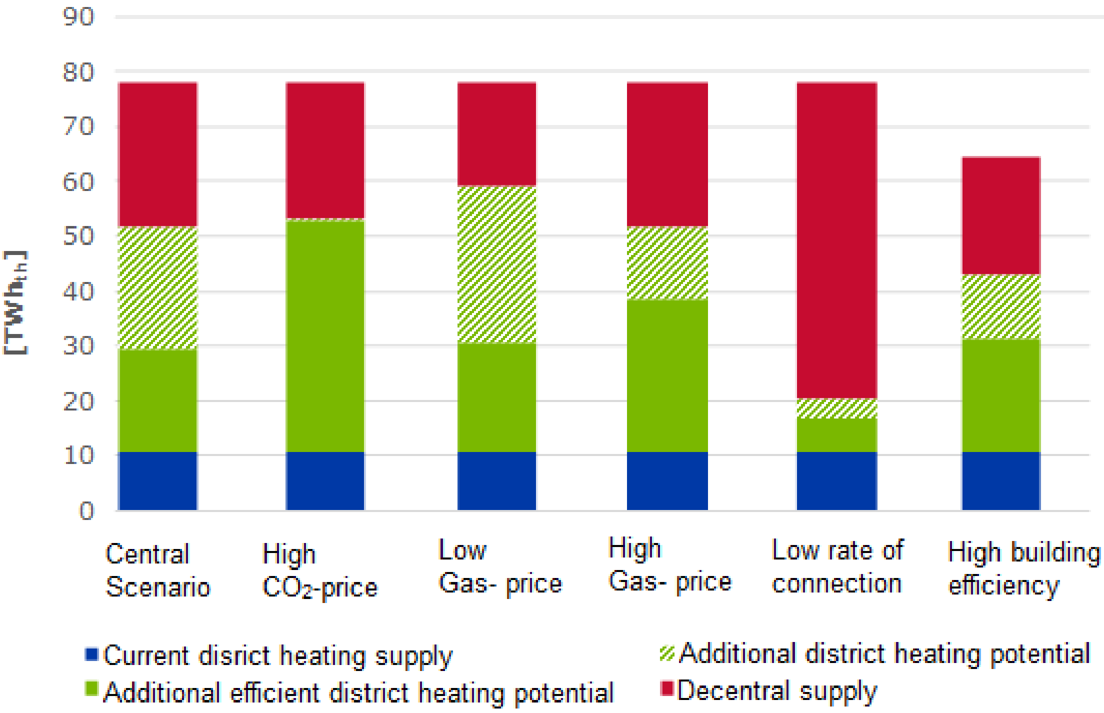

Figure 23: Potential for district heating in Austria until 2025 for different scenarios. Source: own illustration from Büchele et al (2015)

In the Wärmewende Scenario where a wide decarbonisation of the heating and power sector is assumed, district heating plays an important role as shown in Figure 24. Although the absolute heat demand supplied by district heating decreases from currently around 20 TWh to 12.5 TWh its share in the final energy demand increases from currently around 20% to 28% due to overall heat demand reduction through increased building efficiency. Looking at the gross floor area heated by district heating first an increase until the mid-2030's followed by a slight decrease can be seen resulting in around 25% of the heated gross floor area being supplied by district heating.

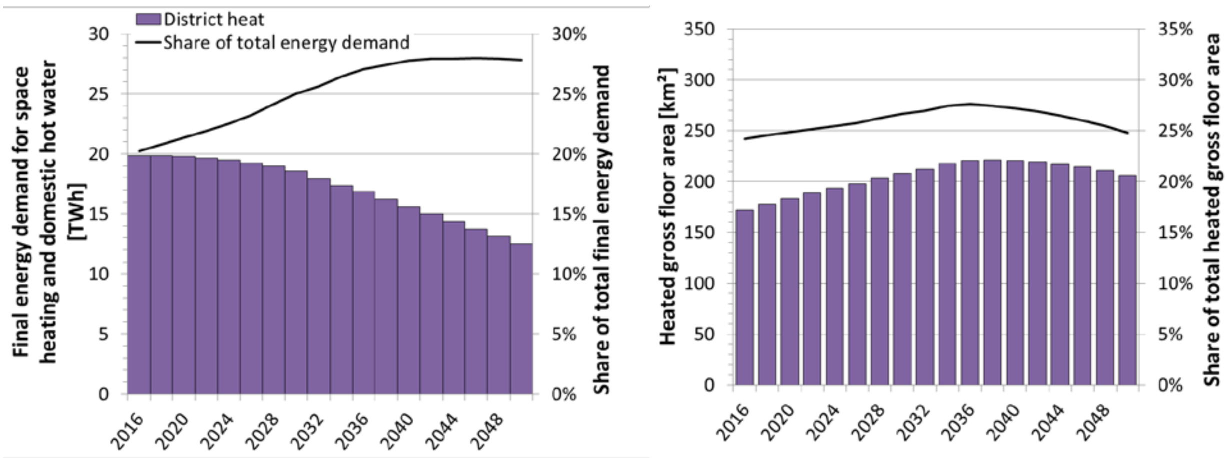

Figure 24: Final energy demand and gross floor area supplied by district heat. Source: own illustration of the "Wärmewende" Scenario in Kranzl et. al (2018)

All in all, district heating systems can not only allow the integration of renewable or excess heat sources into the heating sector but can also foster the integration of renewable power sources due to coupling of the heating and the power sector through power to heat technologies and the ability to store energy in district heating networks and heat storages. This will make district heating an important part in the transition towards a renewable energy system.

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