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Energy relevant aspects of building and future of Housing and Settlement-Structures in Austria

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Abstract

"Urban sprawl", "Embodied Energy in the building sector" and "Peak oil" are main topics in the field of policy on energy and climate as well as problem areas that communities and states are forced to deal with. The project ZERsiedelt has analysed causes and effects of urban sprawl by focusing on public support measures, embodied energy used for buildings and attached infrastructure and financial impacts on private households in consequence of rising energy prices. The consortium primary aimed at generating and enlarging knowledge as well as supporting public and political discussions.

ZERsiedelt reveales that still more than 5 billion Euros per year of public funding is allocated for extending and maintaining dispersed settlement structures. There is great significance of embodied energy in the Austrian housing sector as approximately 440 TWh of primary energy have been used for the construction of residential buildings and infrastructure since 1970. The project results further show that rising crude oil prices especially affect suburban and rural households. At a price of 200 $/bbl additional costs for direct energy consumption may reach above 5.000 € per year.

Keywords: Urban sprawl, Embodied Energy, Housing in Austria, Peak oil, ECSM

1. Introduction

Starting points for this study are the climate and energy policy-relevant topics “embodied energy”, “urban sprawl” and “peak oil”. Notably in the realm of embodied energy sound scientific balances are lacking that would be required for the construction of residential settlements and their maintenance. Simultaneously, it can be witnessed that in many Austrian regions the development of settlements is characterized by the emergence of clusters of single-family houses, low settlement density and high land-use, linked, inter alia, to road construction. Both in connection with the creation of residential settlements and technical and social infrastructure as well as in relation to the citizens´ mobility, this urban sprawl causes a higher energy usage.

In Austria, a large amount of public support measures exist, promoting the provision of housing development, individual mobility and the construction of technical and social infrastructure. Additionally, the public sector influences settlements through various land-use and development plans. However, so far the exact linkages between these framework conditions and the trend of urban sprawl have not been sufficiently analysed.

Potential future effects of urban sprawl could be, in addition to ecological ramifications, higher financial costs for private households. One project hypothesis states that the hundred of thousands Austrian households located in regions with widely sprawled single-family houses will be most affected by an energy (price) crisis as a consequence of peak oil. This is due to their higher mobility and the sometimes higher heat requirements of households in non-renovated houses.

Based on these assumptions and results, the project´s focus lies on answering the following questions:

- Why does urban sprawl exist, notably in Austria?
- How much energy consumption and which costs are caused by urban sprawl?
- How much energy is embedded in residential building?
- What kind of countermeasures can we take?

This paper presents results of the study ZERSiedelt which was conducted from 2009 to 2011 and funded by the Austrian Climate and Energy Fund. The full project publications are accessible at www.zersiedelt.at.

2. Why does urban sprawl exist?

To answer this question, we research the motives of individuals for the decision where to settle and we point out the main drivers. Furthermore, we describe the relationship of “environmentally counterproductive support measures” (ECSM) and the development of dispersed settlement structures. As ECSM we understand fiscal and regulatory support measures of public authorities for building dwellings, mobility or infrastructure (cf. OECD, 1998)[1] which foster urban sprawl. Therefore we analyse a set of ECSM and assess both the interrelation with urban sprawl and the extent of public financial support.

[1] OECD (1998) defines ECSM as “the benefits and costs of all kinds of financial supports and regulations that are put in place to enhance the competitiveness of certain products, processes or regions, and that, together with the prevailing taxation regime, (unintentionally) discriminate against sound environmental practices” and reasons: “Support removal has been identified as a potential „win-win“ policy in that it may benefit both the economy and the environment.”

2.1 Drivers of urban sprawl

Urban sprawl is a very complex phenomenon as it results from a variety of demographic, social, cultural, technological, economical and political factors. In literature, the question about causes and drivers of urban sprawl is not clearly answered[2]. But there is evidence in literature of a demand on housing in suburban/rural areas which is independent of public support measures – which leads to question whether urban sprawl results not at all from support measures but just from demand factors like the preference for owning a house in the outskirts, rising household incomes or population growth. Additionally there is evidence, that the often stated "dream of the own home in the outskirts" is not only driven by personal preferences (like size of dwelling, social environment, clean air, nature etc.) but is often the result of financial restrictions (housing preferences are not affordable in urban areas) or the lack of urban alternatives to satisfy individual fields of need.
To isolate the effects of different factors the causes and drivers are divided in "demand side" and "supply side" factors (fig 1). Apparently, public support measures mainly affect supply-side fields of needs as they influence the availability and the costs of housing options.

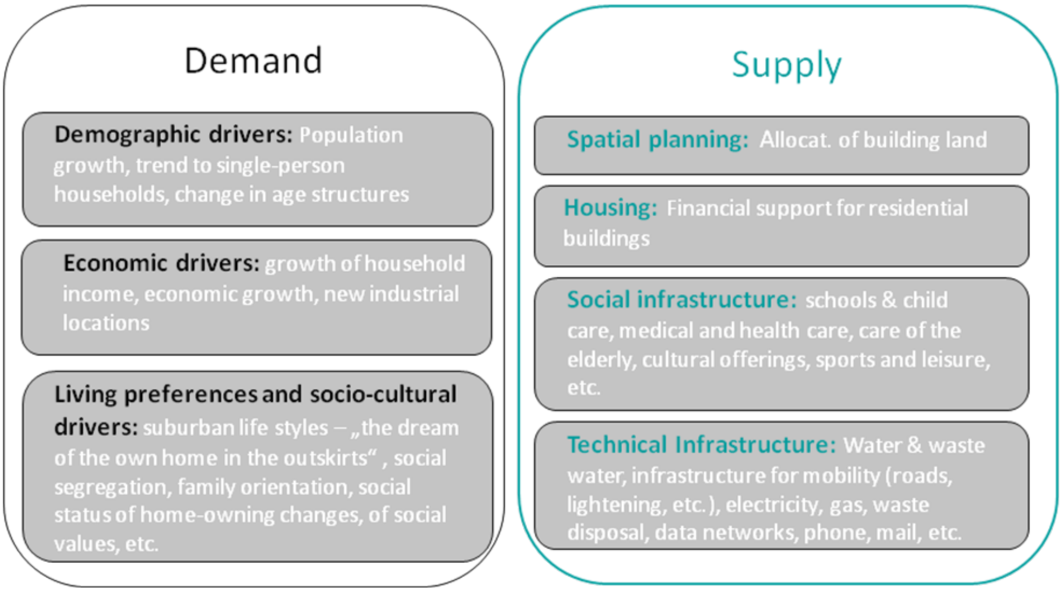

Fig. 1: Drivers of urban sprawl.

Systematic investigations show that there are two types of supply-side support measures: "Must have" support measures are necessary preconditions for housing – and hence also for urban sprawl. The main support measure in this context is the classification of new building land, as urban sprawl would not occure without new classifications outside dense settlement structures. Just as important are public support measures which supply technical infrastructure (roads, water and waste water management, electricity, natural gas, etc.) which are also widely relying on public authorities or funding, respectively.
On the other hand, public authorities also provide "nice to have" support measures which are not necessary but nevertheless often crucial for the decision to settle in dispersed settlement structures. Such measures mainly have impact on relative prices and hence make housing in these structures more attractive and affordable. The most important measures to name are residential building support ("Wohnbauförderung"), support measures for mobility and measures in the field of social infrastructure.
Fig 2 shows the set of support measures which is analysed. As we define urban sprawl per se as "environmentally counterproductive", the analysed measures are seen as ECSM.

[2] cf. Dollinger et al. (2009); Siedentop (2005); Tötzer et al. (2009)

Fig. 2: Fields of need (left) and ECSM (right) relevant for urban sprawl.

In this context, the role of the 2.359 municipalities in Austria has to be emphasised: In the legal system of Austria, the competence for many of the ECSM – especially for many "must have" support measures – lies in the hands of municipal authorities. As for the classification of new building land, this often leads to all the problems in the context of close contact and dependences of municipal politicians with their voters and the weakness or lacking of the co-ordinated regional planning on the level of the provinces or the federal state. Beyond that, municipalities decide about infrastructural investments like roads or (waste) water management which are then funded by other authorities, mainly the federal state. A third fact is a certain competition between municipalities for residents and the establishment of companies, as the funding structure of municipalities strongly depends on the number of inhabitants and tax revenues of companies.

2.2 Assessment of ECSM

To assess the ECSM, an evaluation system was developed. In this system, the relationship between the ECSM and urban sprawl is defined as a chain of effects in which every chain link can be assessed in a ten-point rating scheme:

- Interrelation 1: How important is the field of need (e.g. cheap mobility) for the decision to settle in dispersed structures?
- Interrelation 2: How strong is a field of need influenced by a certain ECSM?
- Interrelation = Interrelation 1 x Interrelation 2
- Public funding of the ECSM per annum

Fig 3 shows the result of the assessment. It clearly indicates that

- the ECSM "Zoning of new building land" not only has the strongest interrelation with urban sprawl but also provides the highest financial support for it. The reason is the fact that the increase of land value through classification as building land remains at the land's owner and hence has to be considered as an indirect subsidy;
- the ECSMs affecting technical infrastructure (shown in blue) also have very high interrelations and substantial financial support;
- the ECSM "residential building support" shows the third-highest financial public financial support;
- the ECMS s affecting mobility (shown in red) have less interrelation with urban sprawl.

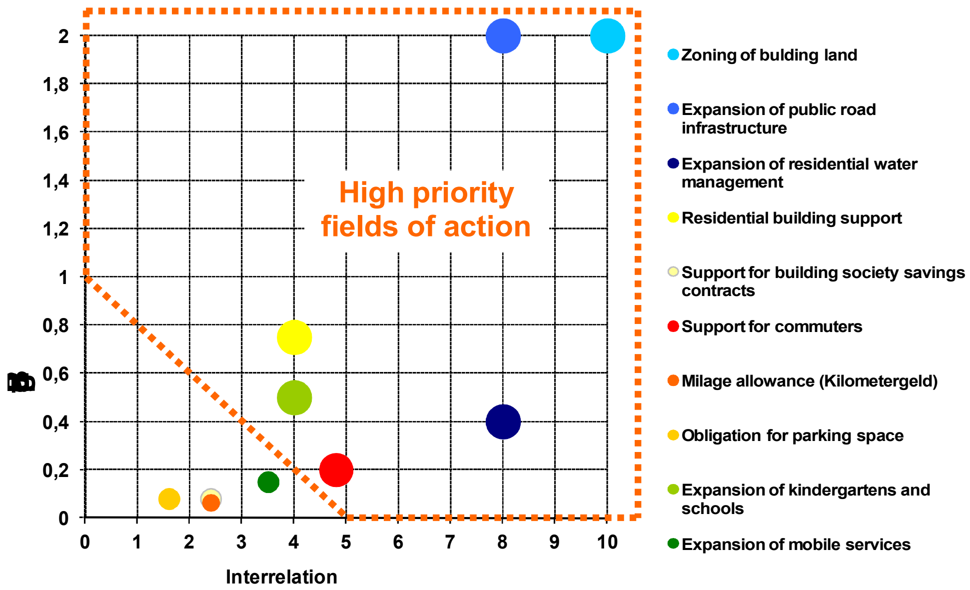

Fig. 3: Results of the assessment of ECSMs.

In consequence of the results, policy recommendations are drawn up for the most relevant ECSM, namely for ECSM with a high interrelation with and/or a high financial support for urban sprawl (as highlighted in Fig 3), see chapter 4.

3. Urban sprawl, peak oil and the effects on households

As a further research area we estimate additional costs for households in different settlement structures occurring from energy demand characteristics and estimates for rising energy prices. Starting point is the hypotheses, that households in dispersed settlement structures will be affected from high energy prices stronger than households in more dense structures.

3.1 Energy prices in the past – and the future?

Crude oil prices are still the main driver for energy prices, as prices for other energy used (like petrol/diesel, gas, electricity etc.) are fundamentally linked to crude oil, contractual coupled to crude oil prices or because of the substitutability of energy sources. Hence, assumptions for energy prices have to be orientated on crude oil prices.
The market for crude oil got very volatile in the past years, especially in terms of prices. For the future, the price of oil is supposed to get even higher and more volatile. The reasons may be seen in lacking or more difficult investments in oil developing and drilling (due to different reasons) and – first of all – in geological reasons ("peak oil"). Many publications, particularly the annually published World Energy Outlook of the International Energy Agency (IEA) forecast these developments. Remarkably, in the last years IEA reduced the projected production rates but almost annually increased the projected prices (fig. 4).

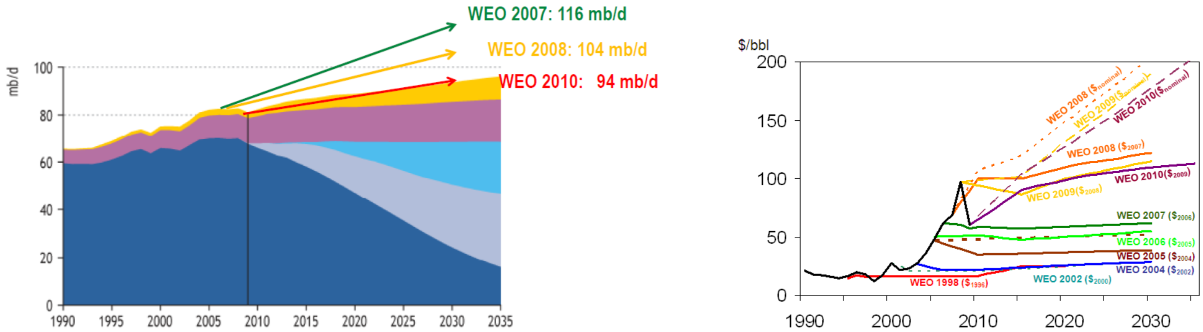

Fig. 4: Development of IEA-Scenarios in terms of production rate (left) and price (right). Source: Left: IEA (various years), own illustration. Right: Ludwig Bölkow Systemtechnik

Due to these projections it is reasonable to base a future (peak oil) scenario on a crude oil price of 200 \$. To assess the effect of crude oil prices on the prices of energy for Austrian households, the correlation between time series of these prices in the last years has to be analysed. In doing so for time series from 2002 to 2010 we found that

- there is a significantly high correlation between the prices for crude oil and oil products (petrol, diesel, heating oil) of $R^2 > 0,9$;
- the prices for natural gas lag about three months behind crude oil prices; considering this time lag, correlation is very high at $R^2 > 0,95$;
- for electricity, the correlation peaks at $R^2 < 0,8$ for a time lag of nine months whereat the actual effect is much lesser than for oil products or gas;
- for biomass no significant correlation can be observed.

Based on the results of the time series analysis the prices for different forms of energy demanded by households – except biomass[3] – at a crude oil price of 200 \$/bbl can be estimated. The estimations are shown in Table 1, including taxes and grid prices, but without considering time lags.

Table 1: Estimates for energy prices at 200 \$/bbl crude oil ant actual values for 70 \$/bbl (mid-2009)

	Price @ 200 \$/bbl (150 €/bbl) crude oil	**Price @ 70 \$/bbl (52 €/bbl) crude oil**
Motor fuel (petrol/diesel avg.)	2,00 € / Liter	1,06 € / Liter
Heating oil extra light	1,60 € / Liter	0,72 € / Liter
Natural gas (Austrian avg.)	10,5 Ct / kWh	6,5 Ct / kWh
Electricity (Austrian avg.)	26,4 Ct / kWh	18,0 Ct / kWh

3.2 Cost effects on households

For estimating the effects of higher energy prices on Austrian households we have to take into account their distribution in terms of their location (e.g. density of structure and population etc.) and their energy-related characteristics. In the scope of our investigations we describe different household typologies by "case studies", as there is not sufficient data to distinguish different typologies by combining statistical attributes. With respect to the most important energy-related cost factors – space heating, electricity and mobility – as well as to cover a wide

[3] Although no significant relation for biomass prices can be observed in the past (biomass prices increased at about the rate of the consumer price index – exception: pellets in 2006/07), this may not be the case in future.

range of household types we define six cases of "typical Austrian households" with "typical" parameters. The main characteristics of the six case studies are shown in Table 2[4].

Table 2: Estimates for energy prices at 200 $/bbl crude oil and actual values for 70 $/bbl (mid-2009)

Case #	**Situation**	**Persons in household**	**Size of dwelling**	**Condition of building**	**Heat demand**	**Heating system**	**Electricity consumption**	**Distance travelled by car**
		#	m²		kWh/m².a		kWh/a	km/a
1	urban single	1	60	100 y/o, unrefurbished	60	gas	1.290	3.000
2	outskirts couple	2	120	refurbished terraced house	60	gas	2.300	5.000
3	commuter belt family	3	150	partly refurb. single-family house	100	oil	3.310	18.000
4	suburban couple	2	150	low-energy house	40	heat pump	2.300	15.000
5	rural family	4	150	un-refurbished single-family house	170	oil	4.300	30.000
6	farmer family	4	150	un-refurbished farm-house	170	Wood (own prod.)	4.300	30.000

The results in terms of additional costs for the households at a (possible) crude oil price level of 200 $/bbl compared to a situation of medium energy prices mid-2009 (average crude oil price of 70 $/bbl then) are shown in fig 5. The additional costs comprise costs directly linked to the consumption of energy and fuels; costs for embodied energy in consumed goods and services are not included[5]. As the figure shows, the additional costs in the described case studies sum up to above 5.000 Euro per year (!) in case 5. The main cost drivers are:

- Type of heating fuel: The costs for space heating differ significantly depending on whether the household is heated by heating oil (cases 3 and 5) or not[6]. In comparison households heated by gas or electricity are much less affected by high oil prices. Due to the fact, that the wood used for space heating in case 6 is from own production, no price effect is considered.
- Car usage: As petrol/diesel prices are as strongly linked to crude oil prices as heating oil, the consumption of petrol/diesel is the strongest cost driver (non-oil heated cases 1, 2, 4 and 6) or the second strongest (oil-heated cases 3 and 5). The consumption is mainly determined by the distance travelled by car and therefore by the location of the household, family size, life style etc. This refers to an effect of dispersed structures which often induce high demand on motorised private transport.
  The second most determining factor is the specific fuel consumption, which is fixed in the case studies to an average of 7,2 liter / 100 km. Obviously, a higher specific consumption (bigger cars) or higher mileages would lead to even higher costs.
- Heat consumption: Also the amount of energy consumed for space heating determines additional costs. Therefore, a good condition of the building the household is located in is with a low heat demand an important prerequisite to avoid too high additional costs at high oil prices.

The results also show that the impact of electricity consumption and the resulting extra costs are comparatively lower.

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4 In addition, assumptions are made for further parameters (warm water consumption, efficiencies etc.). Data are derived from statistcs.

5 In addition, the addition, the results represent a "static" view on additional costs, as adaption measures or behavioural changes due to rising prices and the time lag between price developments are not considered.

6 In 2007/08, still 822.000 Austrian households were heated by heating oil.

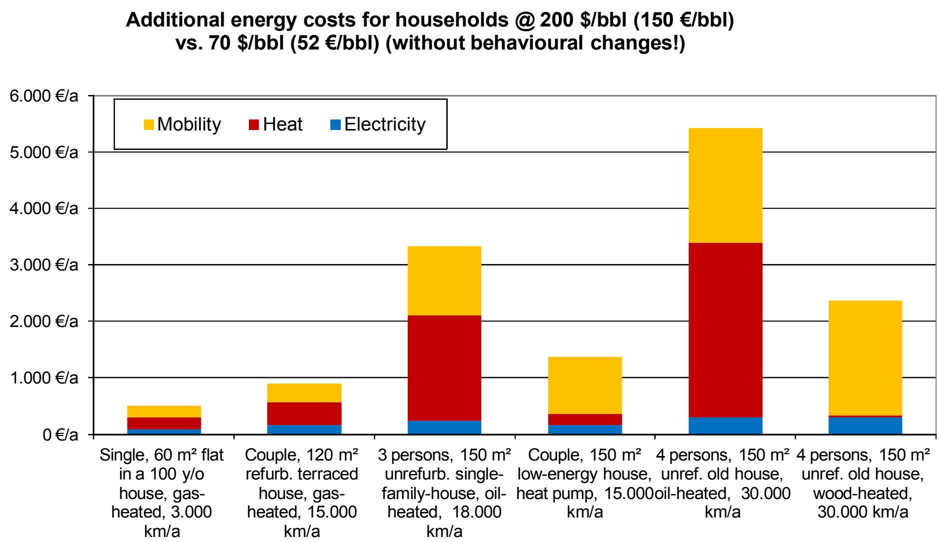

Fig. 5: Results for the case studies. Source: own illustration after Cerveny et al. (2011)

4. How much energy is embedded in residential building in Austria

4.1 Methods

For the construction periods 1970, 1990 and 2010, representative residential buildings and the required related infrastructure were modelized.

Table 3: Typology – Comparison of modelized residential buildings

	Single-family house, remote area	Single-family house, settlement area	Passive energy house, settlement area	Residential building, 3 storeys	Residential building, 7 storeys
Land area	1200 m2	800 m2	800 m²	10816 m2	3150 m2
Gross Floor Area/ residential unit	176 m2	176 m2	176 m²	100 m2	100 m2
Flats	1	1	1	132	54

Access roads and the respective shares of a collecting road, including power lines, shafts and building connections, are included as road infrastructure. Additionally, balconies (storey-buildings), patios (single-family houses), children playgrounds, fences, pathways and garages have been included as outdoor facilities.

For the modelling of the residential settlement and the calculation of the used primary energy and the CO_2 equivalent values the planning tool ArchiPhysik (Version 9.0.0.007) has been applied. It contains the building material database of IBO (Österreichisches Institut für Bauökologie). For the calculation of the energy required for transport and building processes, a proportional surcharge on the accumulated primary energy of the building materials has been added. For the additional inclusion of maintenance works, renewal cycles for a total useful life of 100 years were estimated: for buildings 50 %, streets/connections 200 %, outdoor facilities 300 % and garages 20 %.

To ensure the comparability of the different residential buildings, all building types have been standardized as 100 m2 heated gross floor area (GFA). The related infrastructure has been proportionally calculated as 100 m2 conditional GFA for each type.

For the extrapolation of the results on Austrian level, the data for embodied energy that accrue in the building of residential settlements were linear interpolated for the benchmark periods of 1970, 1990 and 2010. For the calculation of the energy balance, embodied energy data were multiplied with the annually created m² GFA.

4.2 Results on the level of individual residential building types

The modelling demonstrates that notably dispersed settlements require a huge amount of embodied energy and that this energy accrues in particular for the building of roads and wiring. In case of single-family houses located in scattered settlements, the energy demand for establishing the infrastructure is considerable higher than the energy demand for building the house. For multi-family houses (3 and 7 storeys), the respective values for road & infrastructure are basically similar. Small differences occur in regard to the use of energy for the construction of the houses.

Figure 6: Embodied energy required for the construction of residential buildings and the related infrastructure (without maintenance), standardized for 100 m2 GFA

If the energy demand for maintenance works and projections of embodied energy for a period of 100 years are included, the differences between the individual types of residential buildings are even more striking. The respective embodied energy values are: single-family house in dispersed settlement 1,178471 kWh; single-family house in residential settlement 702.331 kWh; 3-storey residential building 276.295 kWh; and 7-storey residential building 264.089 kWh. Multi-family houses (3 and 7 storeys) require less than 25% of the amount of embodied energy single-family houses in dispersed settlement need.

As in 1970, energy consumption for operation was very high, embodied energy for the building process amounted to only 7 to 19% of total energy usage. Till 2010, however, the proportion of embodied energy grew dramatically, accruing to almost 24 to 48% of total energy usage (50% for passive houses). Also in absolute terms the energy consumption of all building types were in 2010 considerably higher than in 1970. For single-family houses in dispersed settlements, the amount for embodied energy required for construction and operation is basically the same. Moreover, the total energy usage of passive single-family houses is higher than for multi-family houses. This is due to the higher development costs, as there exists no “passive road construction”.

A direct comparison of the energy consumption of single-family houses in settlement areas with multi-family houses (medium value of 3- and 7-storey buildings) shows a reduction of the total energy required for construction, and a shift (both absolute and relative) to embodied energy. The reason is twofold: First, the reduced energy demand for operation of both building types since 1970, second the increased proportion of embodied energy over time, caused by the application of complex building materials and the increased quality of heat insolation.

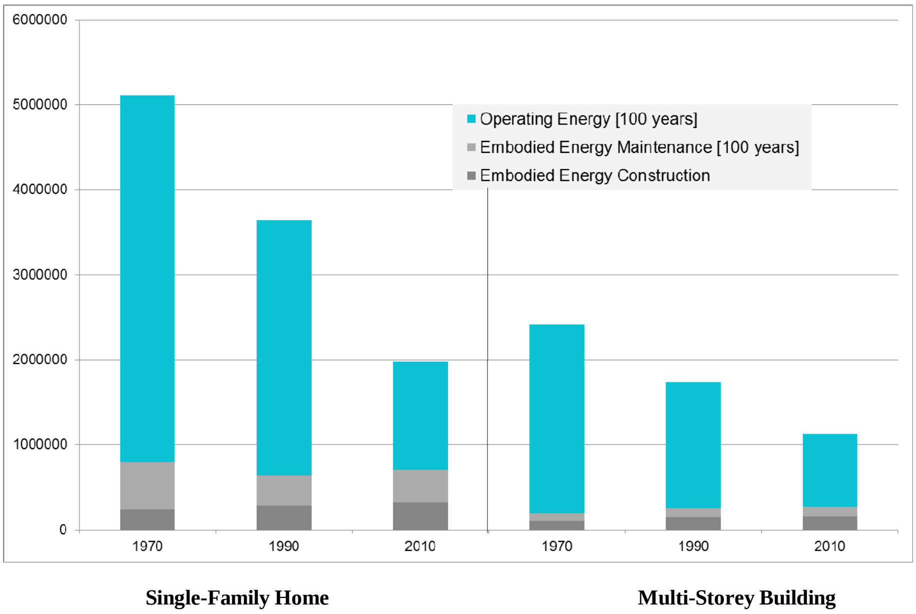

Fig. 7: Comparison single-family and multi-family house – Embodied energy for creation and maintenance, energy consumption during operation, each for 100 m2, 100 years usage period

4.3 Projection

The previously calculated embodied energy consumption data were extrapolated to allow estimates for the energy consumption of the newly created gross floor area (GFA) for the period 1970 to 2010. For instance, in 2010 the whole Austrian residential building sector was responsible for about 11.529 GWh of embodied energy. If the data for the years 1970 to 2009 were added, the overall result is 440 TWh embodied energy (85 mio. t CO_2 equivalents respectively). These values resemble more or less the current annual Austrian energy demand and the annual CO_2 emissions.

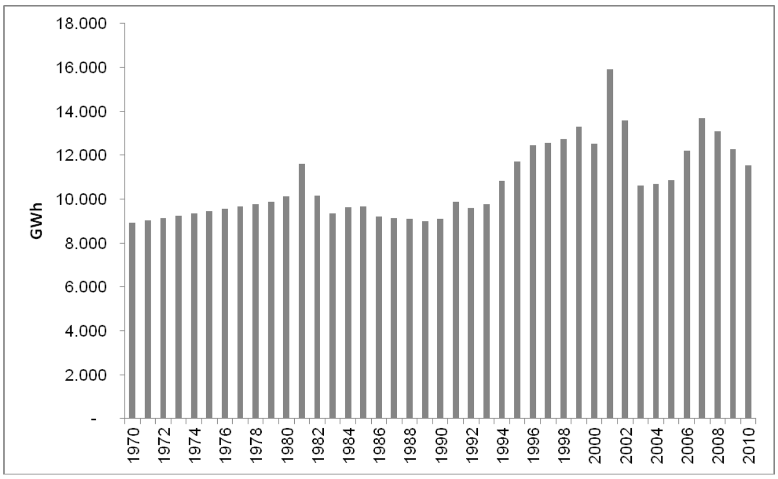

Fig. 8: Usage of embodied energy for newly constructed residential buildings in the years 1970 – 2010

It needs to be emphasized that the projection concerns only the first construction. If ongoing maintenance was included, the figures were (at least) twice as high.

4.4 Grey Energy Calculator

The Grey Energy Calculator, developed as part of the project ZERsiedelt, allows for individual comparisons between construction periods and building types, operating energy and embodied energy for various types of settlements. It can be reached at www.zersiedelt.at.

5. Policy recommendations

As the results show, extending and maintaining dispersed settlement structures in Austria still needs public spending of more than 5 billion Euros per year. Results also show that embodied energy must not be regarded as negligible in comparison to the buildings' energy demand for operation/maintenance. Also can rising crude oil prices become a threat for suburban and rural households: At a price of 200 $/bbl additional costs for direct energy consumption may reach above 5.000 € per year. These facts – in combination with other un-sustainable consequences of urban sprawl not in detail discussed in the study – demand for counter-measures. Therefore, recommendations are drawn up for the most relevant policy options addressing and governing relevant consequences of urban sprawl. The recommendations in general aim at a "greening" of settlement structures in Austria. As the general recommendations to curb urban sprawl developments and its negative effects we consider in brief:

- Re-thinking of competence allocation in the realm of reclassification of construction land for projects that surpass local and regional interests: shifting it from community to regional/provincial level, stimulating co-operation of communities.
- Competence for land-use planning and monitoring at federal level.
- Application of ecological, energetical and economical criteria for reclassification and infrastructure investments
- Linking competences for decision-making and financing, especially regarding reclassification and infrastructure investments
- Strengthening of the cost-by-cause-principle, especially for development costs of building land and infrastructure costs
- Reforms for public authorities to participate in the value growth through classification as building land, e.g. by taxation or by obligating land owner for compensation.
- Efforts to release classified building land, e.g. taxation etc.

Especially with respect to limit embodied energy we recommend:

- Amending homeownership regulations with the aim of the promotion of energetic renewals. Enabling the renewal of parts of a building and flats
- Inclusion of embodied energy criteria in public support measures for construction; promotion of construction of multi-storey buildings in areas that are in terms of infrastructure and traffic well developed
- Preference for conversion rather than new construction; permits and public support measures for energetic renovation of existing buildings
- Support for measures and criteria that ensure buildings and infrastructure are conceived for longer periods of usage (at least 100 years)
- Alignment of development fees for home owners to real costs for first construction and ongoing maintenance. No cross-subsidies paid by general public for single-family houses.

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