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The future of energy is solar

A. Present situation of energy consumption in Upper Austria

The gross inland energy consumption of Upper Austria is about 343 PJ, which is about a quarter of Austria´s overall gross inland energy consumption of 1,442 PJ (status in 2006). 27% of Upper Austria´s gross inland energy consumption is produced within the province.[1] For the same time period the total final energy consumption in Upper Austria is 231 PJ, that of all Austria 1,093 PJ [1]. Viewed roughly by sectors, 20% of the total final energy consumption are used in "private households, 25% in "transportation" and 42% in the production of goods.

Of these 42% (98 635 TJ) final energy the most prominent consumers are:

iron- and steel production	21%
chemicals and petrochemicals	19%
pulp and paper	20%

While private households with 48,907 TJ contribute "only" about 20% to the total final energy consumption, a closer look shows a strong link to transportation. A typical average Central European household consumes per year:

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[1] Statistics Austria, Energy statistics for Austria 1970 - 2006

- electricity ca. 3,000 – 4,000 kWh
- warm water heating ca. 3,000 – 5,000 kWh
- space heating ca. 3,000 kWh (passive house standards)– 30,000 kWh (existing buildings150 m²)
- individual car traffic 20,000 – 30,000 kWh (assumed: 30.000 km).

The total energy consumption of an average household in Upper Austria is about 70,000 kWh per year (assumptions: single family house; low insulation standard, with 2 cars travelling 30,000 km per year)
The most considerable factors driving energy consumption of such a household include the increase of living and utility space, the rise in residential units, the increase in appliances and the extent of their use, as well as the number of cars per household, whose design, size and mileage increase steadily.
The rebound-effect for both space heating and personal vehicles ranges between 10 and 30%.[2]

Only about half of total primary energy employed is available as effective energy (light, heat, motion, etc). Considering the basic structure of Upper Austria´s final energy consumption, these policy decisions are essential to influence the development of energy consumption substantially:

- promote an increase of energy efficiency
- implement energy standards for both, private, commercial and industrial buildings
- support alternative energy use for space heating
- foster alternative energy uses for industrial production processes and commercial services
- offer acceptable alternatives of transportation.

Upper Austria has committed itself to meet the following goals by 2030:

- 100% electricity from renewable energy sources
- no fossil fuels for space heating
- 39% reduction of the energy demand for space heating
- 41% reduction of fossil fuels in transportation
- 65% CO_2-reduction (base-line 1990)

Worldwide, the key problems and challenges to meet the energy demand of tomorrow are - with regional variations - rather similar. Besides biomass, hydropower and wind, solar energy – both solar thermal and photovoltaics – have a high potential and will have to play a key role in archiving these high goals (Figure 1).

[2] Schriefl, E. (2008): Steigender Energieverbrauch trotz verbesserter Energieeffizienz? Der "Rebound-Effekt" und andere verbrauchstreibende Faktoren. *In:* Forum Wissenschaft & Umwelt (Hrsg)(2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S.128-133.)

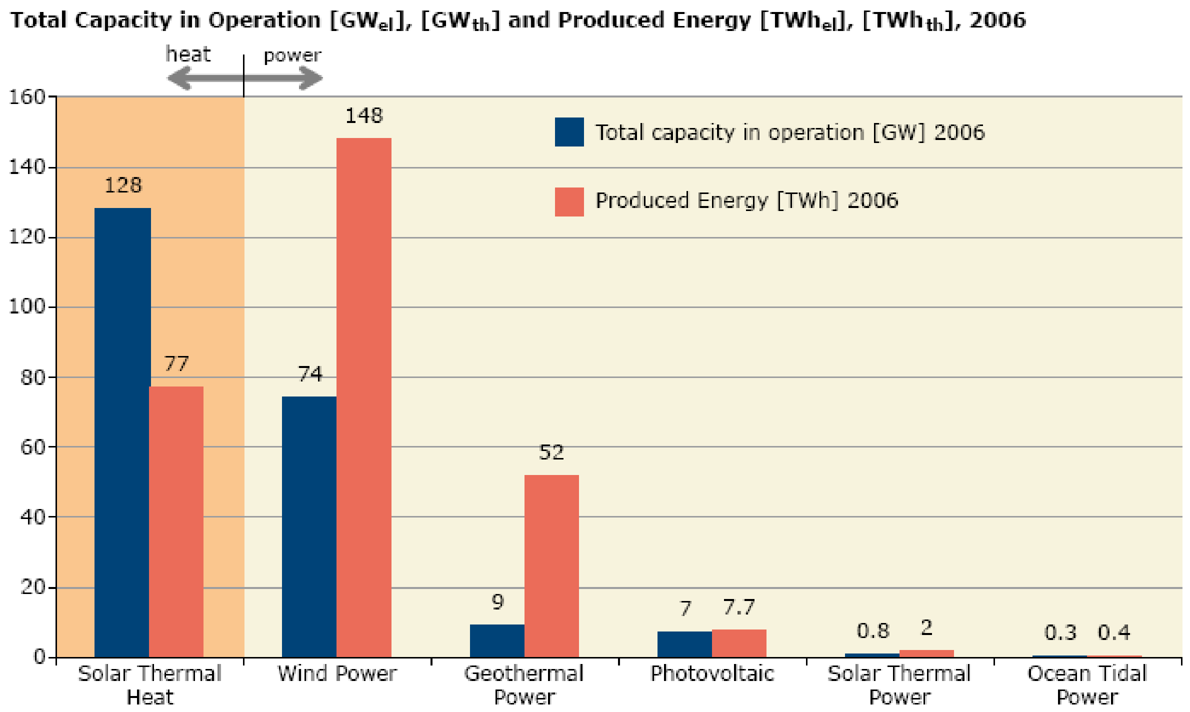

Figure 1 : Total capacity of renewable energy units in operation (GW_{el}, GW_{th}) and annual energy generated (TWh_{el}, TWh_{th}) in 2006. [3]

[3] Weiss, W., I. Bergmann and G. Faninger (2008): Solar Heat Worldwide. Markets and Contribution to the Energy Supply 2006. AEE INTEC, AEE - Institute for Sustainable Technologies, IEA Solar Heating and Cooling Program. Gleisdorf, Austria.

B. Recovery of solar energy

B.1. Thermal solar units

In a global context by the end of 2006, 182.5 million m² of thermal solar collectors were installed worldwide with a capacity of 127.8 GW_{th} in operation (Figure 2) : [3]

flat-plate and evacuated tube collectors	102.1 GW_{th}
unglazed plastic collectors	24.5 GW_{th}
air collectors	1.2 GW_{th}

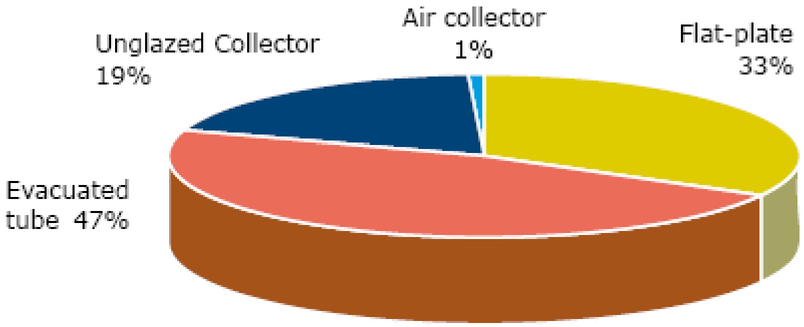

Figure 2: Distribution of the worldwide capacity of thermal solar collectors in 2006. [3]

The total capacity of thermal solar water collectors and the type of collectors varies between different countries. However, it is clear that flat-plate and evacuated tube collectors play a dominant and increasing role worldwide considering demands of space heating and industrial processes. The prominent role of unglazed plastic absorbers in the USA, Canada and Australia are primarily to attributes to pool heating. Unglazed collectors will gain a bigger role in commercial and industrial building ventilation, air heating and agricultural applications (Figure 3).

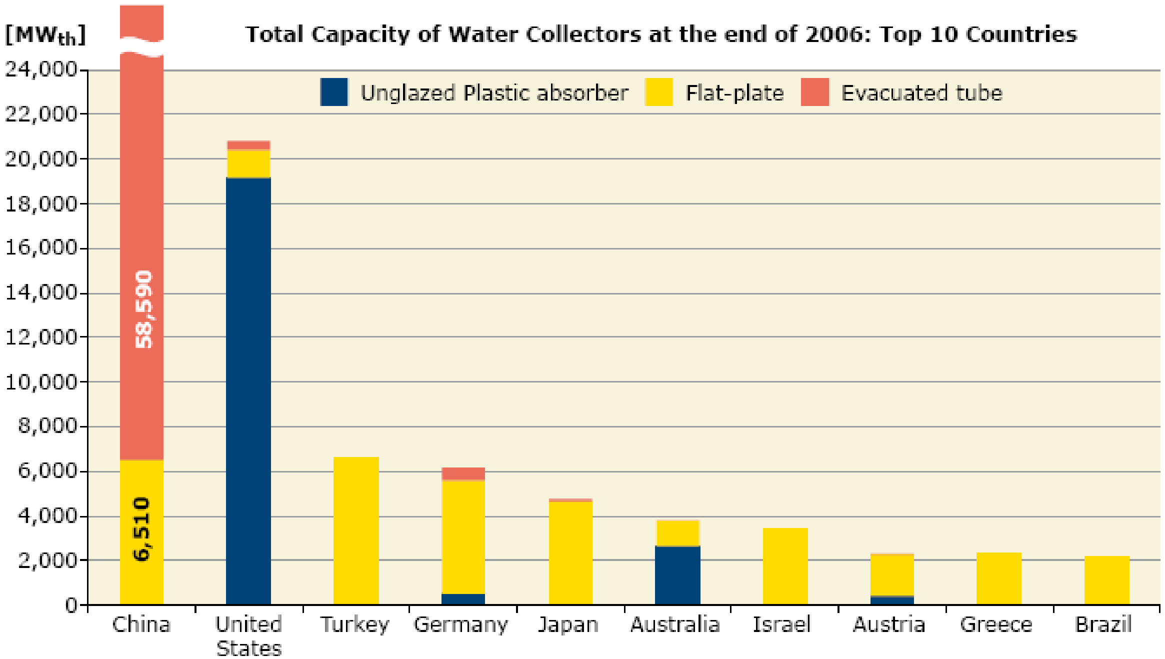

Figure 3 : Total capacity of water collectors (2006) [3]

In Austria, Germany and Switzerland 20% or more of the hot-water in single-family households is heated solar. Future development will have to target hot water heating for multifamily-houses, space-heating for households, hotels, as well as other commercial and industrial buildings and large-scale plants. A growing market will be solar-based air conditioning, cooling and industrial production uses (Figure 4).

The largest thermal solar units in Austria are currently at a district heating plant in Graz (3,600 m², since 2008), in a multi-family compound in Graz (2,446 m², since 2006), at the Liebenau Stadium in Graz (1,440 m²; since 2002); a local heat plant in Winklern, Carinthia (1,280 m²; since 2000,) and in Eibiswald, Styria (1,246 m²; since 1997), both combining biomass and solar.

The largest thermal solar unit produced in Austria and installed abroad is at the residential development "Ackermannboden" near the Olympia Park in Munich (3,000 m²; since 2008). In China, the swimming pool hall and the logistics centre of the Olympic Games 2008 in Peking is equipped with Austrian solar technique.[4]

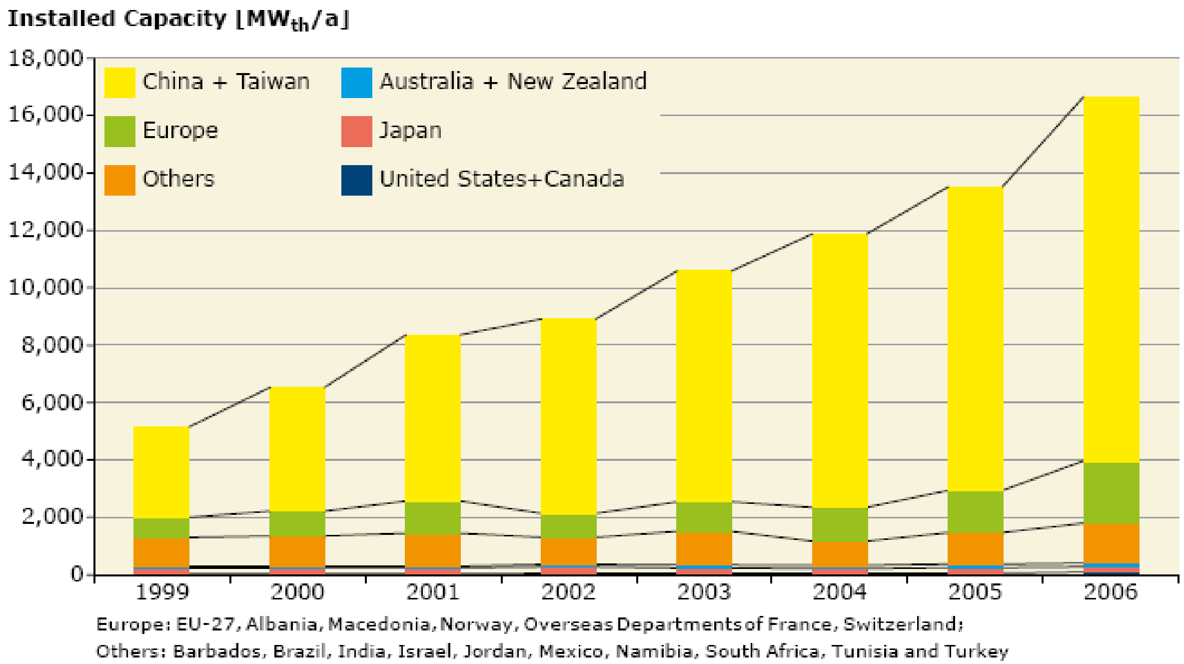

Figure 4: Annual installed capacity of flat-plate and evacuated tube collectors (1999 to 2006) [3]

[4] Haberstock, R. (2008): Detail-Infos zum Solarmarkt Österreich. Austriasolar, Wien.

In 2007 a total of 895 000 m² thermal solar collectors with a maximum heat recovery of 310 million kWh were installed in Upper Austria[5]. That equalled 0.64 m² per resident that was mainly used for warm water in residential buildings and swimming pools, as well as to partially heat buildings.

Since 1980 there has been an exponential increase in total installed area of solar panels. Market penetration (total capacity in operation per 1,000 inhabitants) for flat-plate and evacuated tube collectors in Austria is high, putting Austria with 231 kW_{th} on place number three worldwide. Upper Austria holds the leading position within Austria.

China, Taiwan and Europe are the most dynamic markets for flat-plate and evacuated tube collectors with 22% and 20% respectively, followed by Australia and New Zealand (16%). Market-penetration (installed kWh_{th} per 1,000 inhabitants)

Total capacity (kW_{th}) per 1,000 inhabitants (status 2006) [3]:

Cyprus	680	Germany	68.2	USA	5.5
Israel	506	China	49.5	South Africa	3.5
Austria	231	Spain	15.4	Canada	1.8
Barbados	208	Tunisia	12.3		
Greece	207	Brazil	11.7		

Thermal solar collectors have an annual energy yield of 500 to 700 kWh/m².a (thermal energy). The factor of 0.7 kW_{th}/ m² to derive the normal capacity from the area of installed collectors is internationally agreed on. With 10 m² of panels an average household can cover about three quarters of its annual warm water demand. A limit of the maximum energy yield of thermal collectors due to a maximum capacity of the storage medium (warm water) provides a certain disadvantage. Therefore, a combination with heating systems (bigger puffer capacities) is useful.

[5] Land OÖ (2008): Oö Energiekonzept - Energy 21 – Die Umsetzung des oö. Energiekonzeptes. Berichtsjahr 2007; Linz.

For solar cooling about 3 m² collector area per kW cooling capacity are needed. Systems for cooling air provide a cooling air rate of 10 m² collector area per 1,000 m³ supply air. In Europe, about 200 units of solar cooling of buildings are installed, 250 to 300 units are installed worldwide. Most of the units are situated in Germany and Spain. In Austria, solar air conditioning is used for wine cellars, an eco-park, public offices, most of them situated in Styria.[4] The great convention hall of the trade fare grounds in Wels in Upper Austria is a most recent and prominent example of solar cooling use for commercial buildings.

Along with an even more extensive use of thermal solar units in the low temperature segment (up to 80°C), there is also a potential in the medium temperature range (up to about 250°C) to be targeted for commercial and industrial uses. Improved flat-plate collectors and concentrating as well as high concentrating flat-plate and evacuated tube collectors are options for temperatures of 150°C to 250°C. For the higher temperature ranges, at least one-axis tracking is required.

For heat storage, water based systems with larger storage sizes will need to be complemented by new storage concepts and technologies, such as thermo-physical methods (e.g. using phase-changing materials).[6]

The following industrial sectors have a high potential for thermal solar use (Fig. 5-7) :

food and beverages	30 °C – 150 °C	drying, washing, pasteurizing, boiling, sterilizing, heat treatment
textile industry	40 °C – 160 °C	washing, bleaching, dyeing
chemical industry	95 °C – 300 °C	boiling, distilling, chemical processes
other sectors	30 °C – 100 °C	pre-heating of boiler feed water, space heating of halls

Solar use for industrial processes is one of the least developed applications, however with a high potential and the need for suitable support to foster market penetration. Of the 30-40% of energy consumption in EU countries, two thirds are used as heat. In the EU-15 the energy demand for industrial process heat up to 250°C amounts to 300 TWh. The more than 85 existing solar thermal plants (food industry, chemical industry, transportation) in the EU in the industrial sector have an installed capacity of 27 MW_{th} (collector area: 38.500 m²).[6]

[6] European Solar Thermal Industry Federation (2006): Solar industrial process heat – State of the art.

Figure 5: Transportation company Hammerer, Austria, hot water to clean transportation containers for trucks (capacity: 126 kW_{th}; collector area: 180 m²).[6]

Figure 6: Coffee drying, Coopeldos, Costa Rica; (capacity 595 kW_{th}, collector area: 850 m²) [6]

Figure 7: Pharmaceutical Chemicals, Egypt. (capacity 1.33 MW_{th}, collector area (parabolic): 1,900 m²) [6]

B.2. Photovoltaics

Capacity of photovoltaic units in Upper Austria only reached 6,834 kW (peak) in 2006 with an estimated yield of about 5 million kWh. That corresponds to an area of about 62,000 m². Therefore photovoltaic use in Upper Austria lags behind thermal solar in installed area by at least a factor of 14.

The annual yields of photovoltaic cells amount to 100 kWh/m².a, however in form of electricity[7]. About 40 m² photovoltaic panels are needed to provide the electricity demand of an average household in Central Europe. About 5 GWh were recovered from photovoltaic units in Upper Austria in 2006. The potential for photovoltaic electricity production in 2030 is estimated from 100 up to 300 GWh/a. The technical potential is about 1,000 GWh.[1]
Photovoltaic plants can pass their excess energy to the grid or store it in storage media.

[7] Energy yield between 80 and 100 kWh/m².a with 1000 hours of sun and an efficiency of 10%; For 1 kWh (peak) an panel area of about 10 m² is needed.

B.3. Costs and market stimulation

Costs of thermals solar collectors and photovoltaic panels in Austria are comparable at 500 €/m². Thermal collectors have an higher energy yield (relation 5:1), while photovoltaic panels provide high end electricity. High investment costs of photovoltaic units, along with recent unfavorable tariff for feeding into the grid are key factors that amortization runs up to 25 years (without subsidies). In comparison the amortization time of thermal solar units is at best about 10 years (without subsidies; with subsidies it is only 5 years).

Subsidies for thermal solar units were a key factors of developing a functioning market and certain standards for thermal solar collectors and have fostered economic investment costs.

C. Recommendations

The extensive use of thermal solar energy can provide a growing base to meet heat demands in the private household sector (warm water, space heating) and selected commercial and industrial uses. Photovoltaics can provide supplementing alternatives in electricity production for household and commercial use and for close range transportation.

In Central Europe, space heating and mobility require up to 90% of the private household energy demand (about 70.000 kWh per household and year). Buildings should be viewed as potential power plants.

Despite the considerable area of 895,000 m² of thermal solar collectors installed in Upper Austria since 1980, an expansion from recently 0.64 m² per inhabitant to up to 3 m² per inhabitant would make sense. An equal large area as targeted for private households is possible to be installed in the public, commercial and industrial sector.

Implementing state-of-the-art building standards for energy efficiency and prioritizing subsidies for new construction based on minimum standards of zoning and availability of public transportation will help tackle energy questions in regard to new housing development. Combining zoning, transportation and housing will assist to reduce urban sprawl.

Beside solar-based space heating and warm water production the importance of decentralized electricity production will increase to cover part of the electricity demand for household appliances and mobility. In economic centers and densely populated areas, electric and hybrid cars will gain importance for short and medium distances. Areas with increasing air quality and noise problems along mayor transportation routes will benefit from the crucial contribution of electrical engines for transportation vehicles to alleviate the pollutant and noise load.[8]

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[8] Compared with the efficiency of 30% of combustion motors, the efficiency of electrical motors is around 80%. The energy yield per m² of photovoltaic panels

Starting 2007, the energy intensity[9] needs to be reduced by 3,6% annually, to meet the Austrian Federal Government´s goal of a reduction of energy consumption by 20% until the year 2020 (with reference to the level in 2004). However, between 1980 and 2005 the intensity of the use of electrical power has risen by 0,1% annually, between 2000 and 2005 even by 0,2% annually. Continuing this trend, an increase of the intensity of the use of electrical power by 0,9% annually is predicted until 2020.[10] In the sector of private households home-electronics, alternative heat recovery (e.g. electricity for thermal solar units or heat pumps), ventilation, etc boost the electricity consumption. Increases in efficiency of appliances are over-compensated.[11]

Solar electricity production needs to be part of a mix of different sources of the future electricity production. With current 0.07 PJ photovoltaic production (status in 2006), the potential for photovoltaics for all Austria is estimated with 83 PJ in the future. [12] [13] [14]

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with tracking system surpasses that of bio-fuel production manifold (differences by the factor 50 to 70 in overall efficiency) (see: Christian, R. und R. Bolz (2008): Potenziale erneuerbarer Energien. Eckpfeiler einer zukunftsfähigen Strategie der Energieversorgung. *In:* Forum Wissenschaft & Umwelt (eds) (2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S.134-144.)

[9] Energy intensity (degree of energy efficiency) is the relationship of energy used to archived economic performance.

[10] Lechner, H. (2008); Trendwende mit Energieeffizienz. Wege zur nachhaltigen österreichischen Energieversorgung. . *In:* Forum Wissenschaft & Umwelt (eds)(2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S. 118-127.

[11] The Austrian electricity demand is increasing by 1.5 to 2.5% annually. A detailed "Electricity Efficiency Program" of the Austrian Energy Agency considers the investment of 68 million Euro annually over a period of 7 years necessary, to cut the increase of electricity consumption of private households into half by the year 2020.

Of this investment, 38 million Euro per year would need to done in private households, 20 million Euro per year are necessary in the public and private service sector, and 10 billion Euro per year are required in the production of goods. (see: Lechner, H. (2008); Trendwende mit Energieeffizienz. Wege zur nachhaltigen österreichischen Energieversorgung. *In:* Forum Wissenschaft & Umwelt (eds) (2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S. 118-127.

[12] Christian, R. und R. Bolz (2008): Potenziale erneuerbarer Energien. Eckpfeiler einer zukunftsfähigen Strategie der Energieversorgung. *In:* Forum Wissenschaft & Umwelt (eds)(2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S.134-144.

[13] Estimation run between 30 and 83 PJ potential energy yield, depending on the assumed frame conditions. For a possible goal of 3 m² photovoltaic panels per inhabitant it would mean an installed area of 25 billion m² with a yield of 2,500 GWh (these are close to 10 PJ).

[14] Austrian total electricity demand in 2006: about 65,000 GWh; estimated a Austrian total electricity demand 2050: about 100,000 GWh

This means an increase in photovoltaic panel area by the factor of 1,000. The first interim goal would be, to match the average potential thermal collector area of 3 m² per inhabitant by an equally large photovoltaic panel area per inhabitant. With only 3% of the total surface area of Austria the total energy demand of Austria could be met under current technical framework conditions. (This means the total energy demand, not only the electricity demand). A basic area of development needs to be that of energy storage. For the use of solar energy to produce electricity the suitable instruments are not in place in Austria currently, to trigger a boom comparable to that for thermal solar use. This could be an area of cooperation between the partner regions. [15]

In Austria there are estimated to be 1.8 million buildings of different types (floor area; about 776 million m²). The specific energy consumption of buildings erected before 1960 is between 180 and 230 kWh/m².a. Residential buildings require a third of the sector´s final energy consumption, single family houses two thirds. A decrease of the space heating energy demand for residential buildings by the factor 10 (up to 15 at the maximum) is possible.

Support measures and financial stimulation (e.g. in form of subsidies or tax incentives) should focus on

- an increase of thermal solar use, especially for space-heating, to 3 m² per inhabitant
- promoting thermal solar use for commercial and industrial processes (low (up to 80 °C) and medium (up to 250 °C) temperature range)[16]
- requiring solar use in public buildings
- introducing solar cooling on a broad scale

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with a share of 20% photovoltaic electricity the use of 60% of the available potential surfaces is necessary (total surface area potential in all of Austria: about 140 km² roof area + about 50 km² facade-area) (see:: Fechner, H. (2008): Solarstrom im Supernetz. Die Zukunft der Photovoltaik und der Umbau der Stromversorgungsnetze. *In:* Forum Wissenschaft & Umwelt (eds) (2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S. 146-153.)

[15] The current share of nuclear electricity in the Austrian grid is estimated between about 7-10%. On the basis of the planned expansion of nuclear power plants by other EU-countries, the share of nuclear energy in the European electricity mix could increase even more (status in 2004: 32,6%)(see: Lutter, E. (2008): Eine neue Energiepolitik für Europa. Das EU-Energiepaket und die Auswirkungen auf Österreich. *In:* Forum Wissenschaft & Umwelt (Hrsg)(2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S.38-43.). Due to an increasing importance of electricity for future energy and mobility solutions, it is crucial to countersteer in order to avoid increasing dependence on nuclear and gas power plants. At present, the EU depends 50% on energy imports, with an increasing trend.

[16] Of about 200 PJ/a heat demand for industry (status: 2002), up to 5.4 PJ/a could be produced as solar process heat (including the medium temperature range up to 250° C). The potential for solar process heat is estimated at 3 GW (see Vannoni, C et al : SHIP Potential Studies Report)

- an emphasis on photovoltacis (facades, roof areas)
- the adaptation of the electrical grid ("smart grid") to provide feed-in options
- binding all building standards to minimum requirements of energy efficiency and link housing, zoning and transportation[17]
- prioritizing energy retrofit of existing buildings [18] [19] [20]

[17] Single-family homes with a space-heat-demand of 50 kWh/m² per year are state-of-the-art already since 1991. Passive energy house standards established since 15 years are the prerequisite for zero-energy-houses. Supports for new housing construction therefore should focus on zero-energy-houses (passive house standards e.g. in combination with photovoltaics), to public raise acceptance. Support for state-of-the-art techniques (passive energy house standards) is an economic necessity.

[18] see: Guschlbauer-Hronek K., G. Grabler-Bauer et al (2004): Altbausanierung mit Passivhauspraxis. Berichte aus Energie und Umweltforschung 02/2004

[19] For buildings in Austria erected between 1945 and 1980, the necessary investment for their state-of-the-art energy retrofit is about 80 billion Euro (see: Lechner, H. (2008); Trendwende mit Energieeffizienz. Wege zur nachhaltigen österreichischen Energieversorgung.. *In:* Forum Wissenschaft & Umwelt (Hrsg) (2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S. 118-127.)

[20] With an annual rate of energy retrofit of 3% between 2008 and 2020, about 1 billion household units (single- and multiple family homes, built before 1990) in Austria can be energetically renovated. For all of Austria, the demand of subsidies fort his undertaking is 2 billion Euro, which would require about 80% of the current housing construction subsidies. (see: Christian, R. und R. Bolz (2008): Potenziale erneuerbarer Energien. Eckpfeiler einer zukunftsfähigen Strategie der Energieversorgung. *In:* Forum Wissenschaft & Umwelt (eds)(2008): Energiezukunft. Wissenschaft & Umwelt Interdisziplinär 11/2008. S.134-144.)

The future of energy is solar. The contribution of solar heating and photovoltaics and their potential is still an underestimated fact in energy policy. The cooperation of the partner regions in the frame of an exchange of best practices, developing demonstration projects and planning guidelines can help increase the confidence in emerging solar technologies and broaden their use.