MSc Program
Renewable Energy in Central & Eastern Europe

Micro-grid for providing a small housing area with energy

A Master Thesis submitted for the degree of
“Master of Science”

supervised by
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Vienna, 30.10.2008

Affidavit

I, **Mag. Markus Redl**, hereby declare

1. that I am the sole author of the present Master Thesis, "Micro-grid for providing a small housing area with energy",
   41 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, ________________ ______________________________

Date Signature

I Abstract

The paper deals with the question if a centralized energy supply system based on biomass, solar thermal and photovoltaic can make sense for a row house area with 37 row houses. I decided to look at the technical and economical parameters that determine whether such a system can have success or not. The problem is that the question cannot be answered simply with yes or no, it is a little bit more complicated. The reason for this is that we have to consider the targets of the building company of the living area and the consumers of the houses according to installation costs, running costs, emissions and so on. Depending on their attitude towards these topics such a centralized heating system can make sense or not. In my opinion this system is a very good alternative to conventional heating system based on fossil fuels.

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1. Introduction

The reason for writing this paper is that I'm working in a building services company and there I have to deal with different energy concepts every day. We are dealing with some row house projects and the heating concepts are mainly based on natural gas or heat pumps. I think that there are also other possible heating systems that can be used for heating a row house area, especially I was thinking about biomass.

Therefore this work deals with a project where a micro grid for providing a small housing area with energy should be built up. This micro grid is designed for 37 row houses and based on a biomass heating system combined with solar thermal collectors for producing heat and hot water. Beside this there will be photovoltaic cells on each house for producing electricity.

The overall energy demand increases every year and most of this increase is produced by using fossil fuels. This development will lead to higher prices for fossil fuels and to bad outcomes for our environment. In my opinion such a combined heating system can be a good alternative to fossil fuels. Therefore the paper should provide an overview over the most important points that are relevant when installing such an energy supply system based on alternative forms of energy. It deals with technical questions as well as economical questions whether such a system makes sense or not for this project.

Generally seen it is very important for such an alternative energy concept that the addressed people are not only interested in very low installation costs, they also have to care about the running costs and the environment. The described energy concept has of course higher investment costs than a conventional system based on natural gas. The higher investment costs at the beginning are only one part, what is more important in my opinion are the running costs. Here biomass has big advantages because the price is lower than the price of fossil fuels and biomass usually comes from the neighbourhood which also decreases the costs for exploitation and transportation. It also has to be considered that oil or gas are not renewable therefore the price level will increase when the raw material gets scarce.

Another important fact is that all burning processes cause emissions. Nowadays the discussion about emissions is up to date and nearly everybody is concerned about it. There are a lot of regulations on the national level or on a multi-national level in order to decrease the emissions in the atmosphere. If we look at the Key World Energy Statistics of the International Energy Agency we can see that heating, hot water preparation and electricity consumption of households are quite substantial factors in the energy market.[1] Therefore such small grid systems can be at the one hand a good way in the direction of a more

[1] IEA 2007; p. 28ff

efficient energy use and on the other hand a good way to produce energy from renewable sources. This would also be a possible way to reduce the emissions in our environment.

The paper is divided into two main parts. The first part deals with the technical description of the technologies that are used in our energy concept. This means that the basics of biomass, solar thermal and photovoltaic are explained. The second part deals with the project itself. Here the theoretical background of the first part is used in order to answer the key question of this work whether such a small grid system based on renewables is an interesting alternative to a typical heating system for the described row house project.

2. Technical description

In this part of the work the basics of the different technologies which are important for the project are described. There are three important technologies which are used to fulfil the energy demand in our project. First we have a biomass plant which is producing heat and warm water by firing pellets and/or corn. The second part deals with solar thermal collectors which are also used to produce heating energy and hot water. As a third part solar collectors for producing electricity, so called photovoltaics, are used.

2.1. Biomass

Biomass is the total amount of plant material, vegetation, or agricultural waste which can be used for energy production.[2] When biomass is burned CO_2 is emitted into the air but the amount of CO_2 which is emitted is equal to the amount of CO_2 which has been adsorbed by the plant before.[3] Through the climate discussions in the last years biomass gets more and more important when talking about heating households, small villages, businesses and so on. Everybody is talking about biomass in general but the problem is that there are a lot of different types of biomass products available at the market. Therefore it is very important to look at the technical and economical circumstances during the decision process for a biomass heating system. In order to deal with this problem the next part of this master thesis illustrates the two different types of biomasses that will be used in our project.

2.1.1. Pellets

Pellets are made of plane and saw residues which are compressed under high pressure and cut in length. The raw material for example is a waste product in saw mills. All pellets must be manufactured according to the ÖNORM M 7135 and DINplus which ensures that all pellets have the same specifications.[4] The amount of pellet fired boilers increased a lot in the last years. The reason for this development was that such boilers provide a very high degree of comfort. This means that it is very easy for customers to use it. Another reason was that

[2] Österreichischer Biomasseverband 2008
[3] Quaschning 2007, p. 297
[4] Quaschning 2007, p. 299f

the heating costs are relatively low compared to fossil heating systems as it is shown in the figure below.

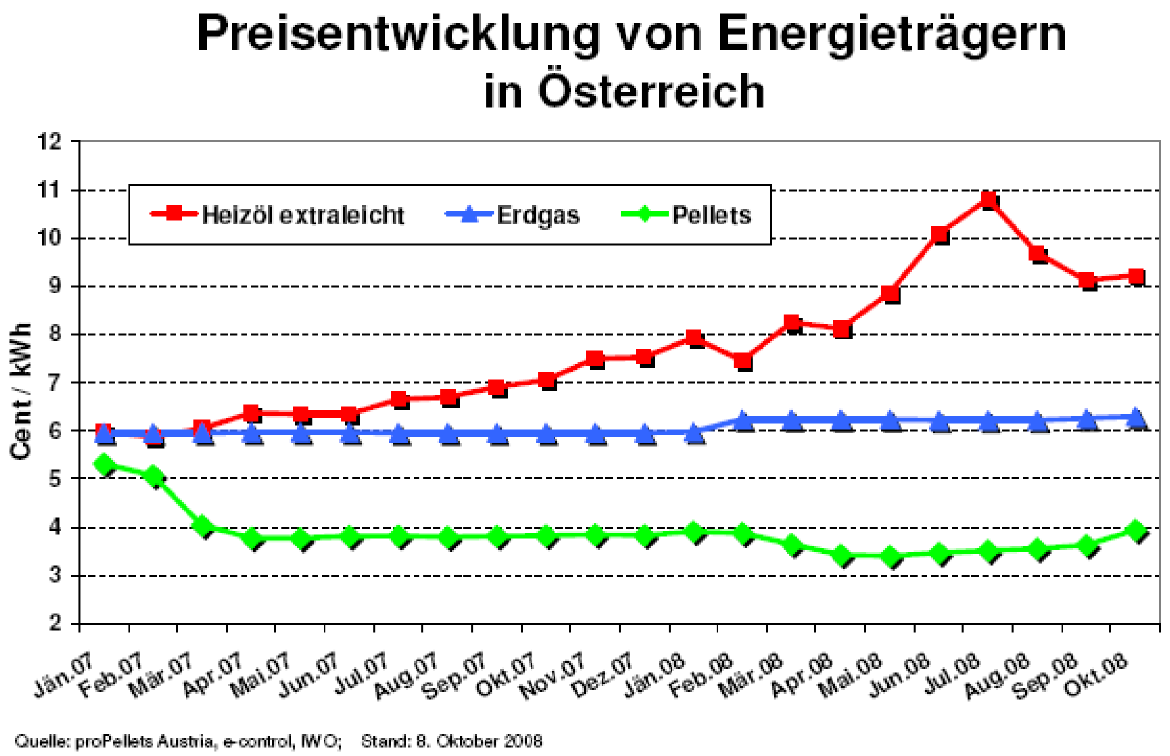

Figure 1: Comparison of different heating substances
Source: http://www.propellets.at/images/content/pdfs/200810_entwicklung_energietraegerkosten.pdf

The Austrian pellet production has a volume of 1 million tons per year and the domestic consumption accounts for 450.000 tons a year, the rest is exported. This business is not only booming in Austria, the worldwide amount of pellets produced should reach 15 million tons in 2010. Up to the year 2015 this could be 150 million tons a year.[5]

As mentioned before heating with pellets is very easy to handle for the customer. The reason for this is that the technological background is very well established and there is a very high degree of automation. According to the heat demand the boiler is fed with pellets by a screw which transports the pellets from the storage into the boiler. In most cases there is another screw which transports the ash which emerges during the burning process out of the boiler. Figure 2 shows a pellet boiler with a screw.

[5] Rakos 2008

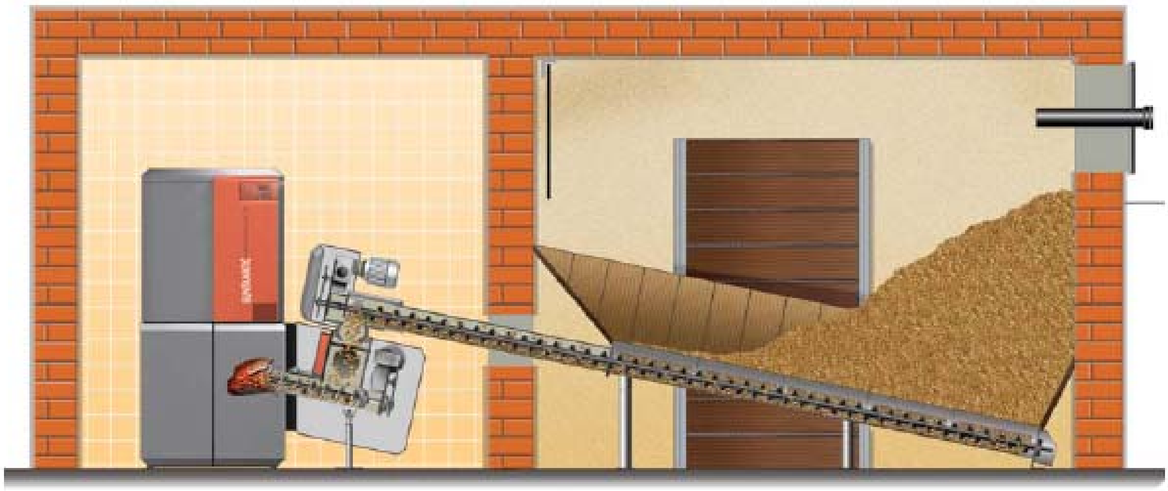

Figure 2: Pellet boiler with a screw

Source: http://www.guntamatic.com/pdf/guntamatic-pellets5-06.pdf

In the last years there has been a new development in the pellet boiler production. Most of the producers wanted to have a boiler which can also be fed with some other materials like maize or corn. Therefore the topic of energy corn which is described in the next section of this work appeared.

2.1.2. Energy Corn

The discussion about using energy corn for heating purposes is a very recent one. The reason was that the farmers got very low prices for their products. Therefore they decided to grow grain for heating purposes. The problem with this development was that there was an ethic discussion about “burning bread” at the beginning. As a result the term “energy corn” has been developed.

Nowadays the farmers are very familiar with the technology of growing, harvesting and storing corn. The water content of the grain should be about 14 wt%. In many cases this water content can be reached without drying the grain. The potential of energy corn is very difficult to discuss, because the available grain can be used as corn for people, as animal food, as feedstock for biogas plants and so on.[6] Therefore it is not possible to define an amount which is available for heating purposes. The availability of grain in Austria is about 600.000 ha and 190.000 ha maize[7].

[6] Dr. R. Brökeland et al. 2006

[7] Statistik Austria, Bodennutzungserhebung, Agrarstrukturerhebung 1995/97/99/2003

The Combustion of grain is not that easy as the combustion of wood. There are some points that have to be considered when talking about firing grain, like a higher content of ash, a lower ash melting behaviour and the content of chlorine and nitrogen. As a result of this the boilers have to be adapted to these requirements. For example the boilers need a larger room for storing of ash. Another problem is that through a higher amount of ash also the fraction of dust emissions increases. Therefore some additional constructions for separating parts of the dust are necessary in order to reach the legal requirements. Considering the ash melting behaviour of grain, boilers need burning chambers which allow lower combustion temperatures. In order to avoid the slugging of the ash special grates have to be used.[8] Some companies use moving grates as it can be seen in the picture below.

Figure 3: Moving Grate

Source:http://www.guntamatic.com/powerchip.htm

The chlorine content of grain is also a problem when burning it. The reason for this is that the chlorine can form acids during the burning process which can cause corrosions in the burning chamber and the heat exchanger.[9] In order to overcome this problem companies use stainless steal or an exchangeable bush where the flue gases can pass. Such an exchangeable bush is shown in figure 4.

[8] Dr. R. Brökeland et al. 2006

[9] Dr. R. Brökeland et al. 2006

Figure 4: Exchangeable bush in the heat exchanger
Source:http://www.guntamatic.com/powerchip.htm

Also the emissions of nitrogen in the burning process have to be considered. The amount of nitrogen is very high and it is very hard to reach legal requirements. Through special populations of corn the amount of nitrogen can be reduced but in most cases this is not enough to reach legal requirements.[10] The producers of energy corn fired boilers work very hard on this in order to reach the legal requirements.

The second part of our combined heating system is an amount of solar thermal collectors which are described in the following chapter.

2.2. Solar Thermal

The sun is the most important energy producer in our solar system. It is the basis of the whole energy supply on our planet. The energy coming from the sun to the earth is 1.08 x 10^{18} kWh every year. This is 10.000 times the primary world energy demand. When talking about using the energy from the sun we have to bear in mind that there are two forms of solar radiation. The first is direct solar radiation. Here the radiation from the sun is directly used for producing energy, for example in solar-thermal power plants, collectors and so on. The second form of solar radiation is indirect. This means that an energy source is produced by solar radiation and this energy source is used for direct energy production. The best example for this indirect form is hydropower. Here the energy of the sun is stored in the water which is afterwards converted by hydropower plants into electrical energy.[11]

[10] Dr. R. Brökeland et al. 2006
[11] Quasching 2007, p. 36f

The development of the solar thermal market in Austria is very interesting. Figure 5 shows this for the years from 1990 to 2005. From 1990 to 1996 the annually installed collector area has increased a lot. Then there was stagnation in the market. In the year 2003 and 2004 the market has increased by about 9%. In 2005 there was a big hype with a growth rate of about 28%. This development is based on different market conditions like subsidies. Whenever there has been a change within this market conditions, the whole market reacted in the way that the annually installed collector area increased or decreased.[12]

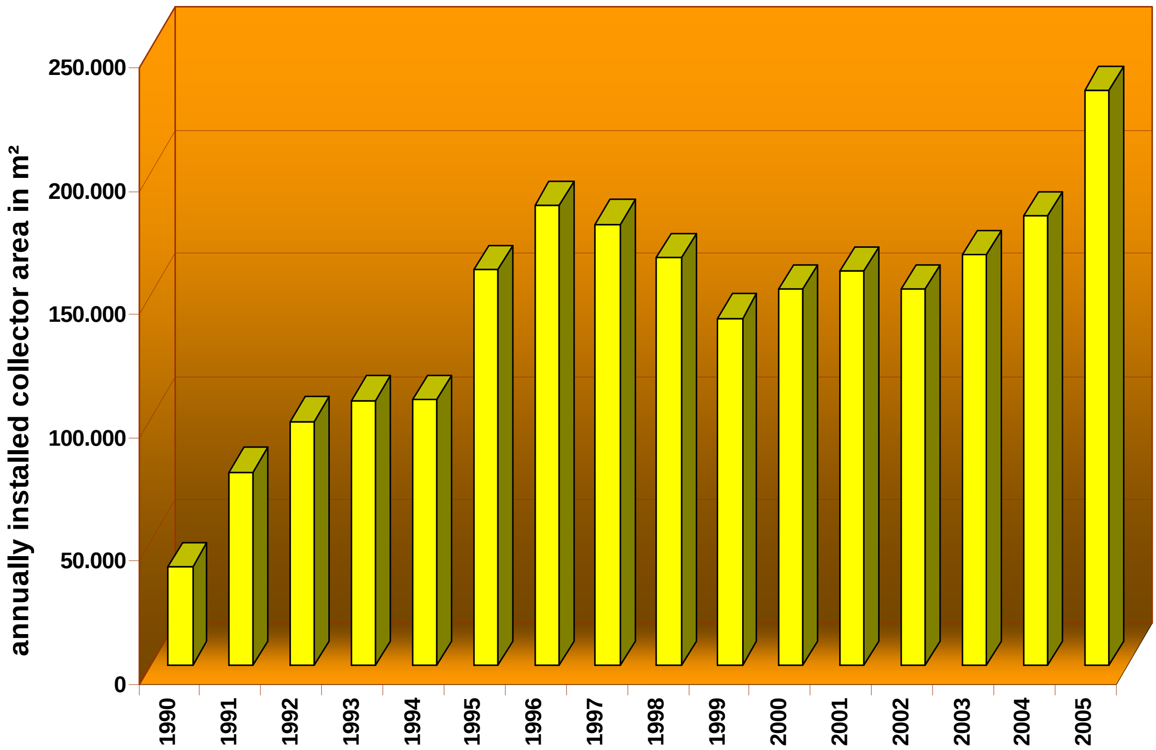

Figure 5: Development of solar thermal market in Austria
Source: http://www.solarwaerme.at/Sonne-und-Energie/Marktstatistik

The next part of this work will provide a short overview over the most important parts of solar thermal systems and how these systems can be used for producing energy.

2.2.1. Main parts of solar thermal systems

The most important part of a solar thermal system is the collector which transforms solar radiant energy into heat that can be used for heating and for hot water preparation. In principle it can be distinguished between three types of collectors:[13]

[12] Klima:aktiv 2007
[13] Weiss 2007, p. 20

- uncovered (unglazed) collectors
- flat plate collectors
- evacuated tubular collectors

The flat plate collector is the most common system for hot water preparation and for space heating in Europe and it is also used in the model in chapter 3.2. Basically this collector type consists of a transparent cover, a collector box and an absorber. The inner part of the collector is the absorber plate. This plate is usually made of copper, aluminium or stainless steel, which is connected to flow tubes and the headers. The absorber is either selected coated or in the case of simple collectors just painted black. The radiation penetrates through the transparent cover and is converted into heat by the absorber. As a result the temperature of the absorber increases and the heat transfer medium is heated up. The backside of the collector consists of insulation in order to keep the losses low.[14]

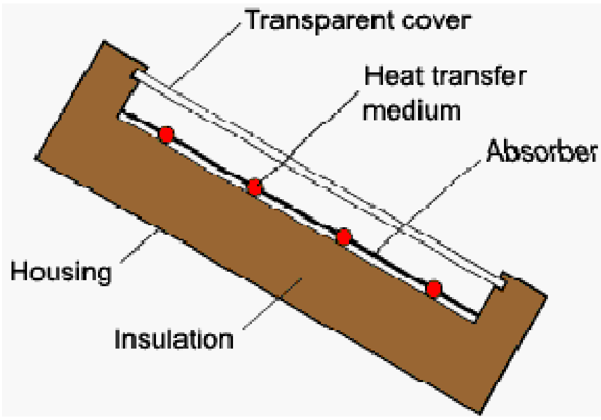

Figure 6: principle of a flat plate collector
Source: http://www.solarserver.de/wissen/sonnenkollektoren-e.html#fla

The collectors are normally used either in a single system in order to produce hot water or in a combi-system which also includes heating purposes. Both systems will be explained in the next section.

2.2.2. Usage of solar thermal systems

In Central and Northern Europe double-circuit systems with forced circulation are used in nearly all cases. Thereby the separation of the collector and the tank is a characteristic element. The collectors are either mounted on the roof of the house or on the roof of the

[14] Quaschning 2007, p. 90ff

garage whereas the tank is installed in the cellar of the house. During the summer months in Europe the sun is efficient enough to cover nearly 100% of the hot water demand. Also during the inter seasons the sun helps to pre-heat the domestic water. This means that the energy which is needed to reach the full hot water temperature can be reduced. This energy comes from the normal heating system in the house. Also during winter time hot water temperatures of 30 to 50°C can be reached on sunny days.[15]

Figure 7 shows a relatively easy scheme of producing hot water with solar collectors and an additional heating system. The solar collector converts the radiation into heat and conveys it to the heat transfer medium. The pump in the control station is relevant for the transfer of the heat to the solar boiler. The pump starts to operate when the temperature of the solar collector is higher than the temperature in the boiler. If the boiler temperature on the top isn't enough the additional heating system is used in order to reach the needed temperature. Only the upper third of the boiler is heated up with the conventional heating system.[16]

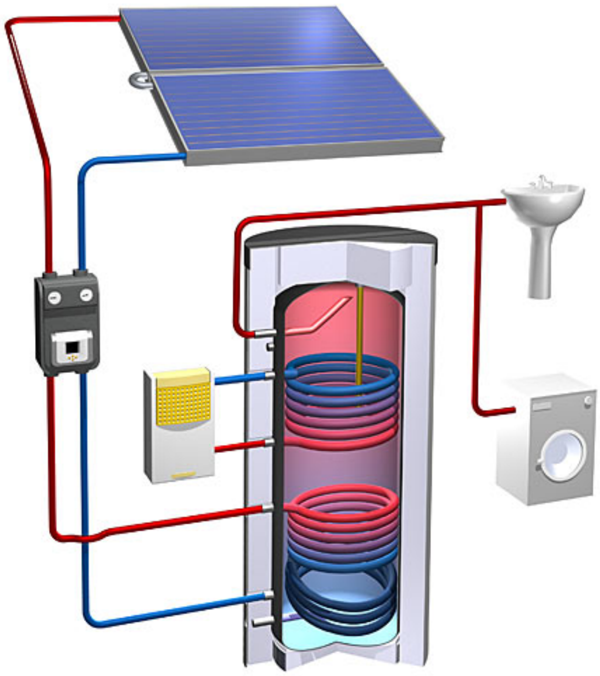

Figure 7: Scheme of producing hot water with solar collectors and an additional heating system
Source: http://www.wagner-solar.com/wagnerDE/SW/01/01.php?navid=4

The dimensioning of the hot water system is a very important task that should be considered before planning and installing a solar system. The hot water demand of a single person or a family is corresponding to their habits. The daily hot water demand can be estimated as shown in figure 8.

[15] Weiss 2007, p. 57
[16] Weiss 2007, p. 58

		Low demand (litres)	Medium demand (litres)	High demand (litres)
Residential buildings	Per person and day	30	50	60
Sport facilities	Per shower	20	30	50
Accommodation	Per bed	20	40	60

Figure 8: Hot water demand for different users at a hot water temperature of 50°C
Source: Weiss W., MODULE 3 “Solar Energy” MSc Program Renewable Energy in Central and Eastern Europe, p. 80

Although the hot water demand can be estimated as shown in figure 8 it is better if there are more precise figures for the system design. As a second step the volume of the storage tank has to be specified. It should be 0.8 to 1.2 times the daily demand for regions with very high solar radiation and 2 to 2.5 times the daily demand for regions with lower radiation. The producers of storage tanks don’t offer tanks in every possible size and therefore the rule of thump is that the capacity of the storage tank should not be less than 90% and not more than 120% of the calculated volume.[17]

When the daily hot water demand has been specified the collector area can be determined. There are several factors which are crucial for the dimensioning of the solar collector area such as[18]:

- collector type
- size of the solar storage tank
- location, tilt, and orientation of the collectors
- local climatic conditions

These factors are not discussed in this paper in detail but there are some simulation programs available at the market which will help in dimensioning the solar system. Figure 9 represents a rough dimensioning overview for hot water solar systems under Central Europe conditions.

[17] Weiss 2007, p. 80f
[18] Weiss 2007, p. 82ff

Daily hot water demand (litres)	Solar storage capacity (litres)	Collector area (depending on the required solar fraction) selective coating (m²)
- 100	200	4
- 200	400	6
- 300	500 – 750	8 – 12
- 500	750 – 1000	12 – 16

Figure 9: Dimensioning of domestic hot water solar systems for Central European Conditions
Source: Weiss W., MODULE 3 “Solar Energy” MSc Program Renewable Energy in Central and Eastern Europe, p. 84

As mentioned above there are also combi-systems available at the market which use the solar energy for heating purposes and for producing hot water. In many parts of Austria the installation of such combi-systems is possible. There is enough solar radiation to warm up the domestic water and also the water for heating the rooms. Especially in single family houses these systems are introduced nowadays.

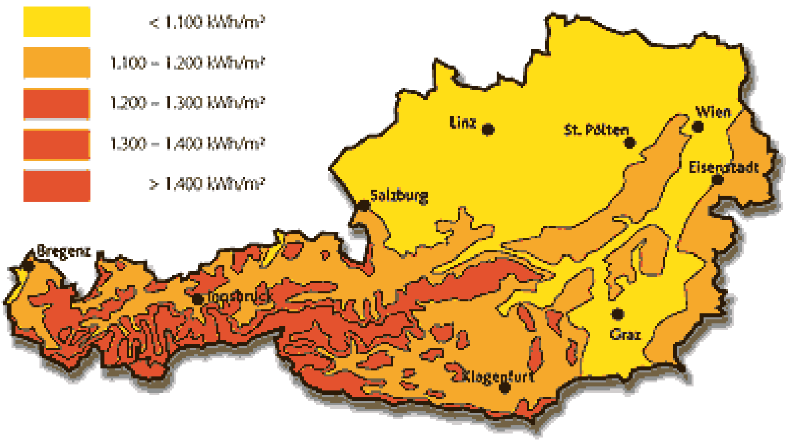

Figure 10: Solar radiation in Austria
Source: www.austriasolar.at

Figure 10 shows different regions in Austria with their solar radiation. The best regions for installing solar thermal combi-systems are regions with a lot of sun and only a little amount of fog. In autumn and spring it can be possible to heat the houses in these regions exclusively with solar energy. During winter time an additional heating system will be necessary.
Through the developments in building houses which consume less energy, solar systems get very important for producing hot water and heating. Modern low-energy houses with an annual space heating demand of less than 60kWh per square meter of living space combined with a low temperature heat supply system like wall or floor heating systems provide ideal circumstances for solar heating. The dimension of the system should contain a

15 – 20 m² solar collector and a storage tank of about 1000 – 1500 litres. Such a system can produce up to 50% of the total annual heat demand. An additional heating system like oil, gas, pellets and so on provides the rest of the needed heat[19].

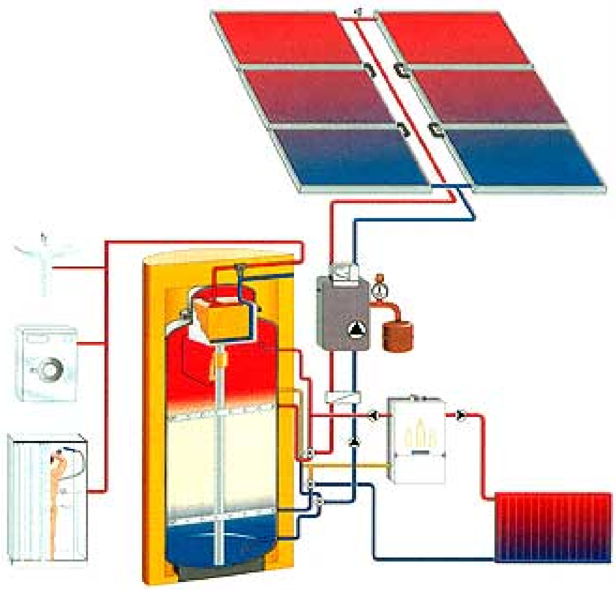

Figure 11: Scheme for solar combi systems
Source: http://www.haustechnik-kuhlmann.info/html/body_thermische_solaranlagen.html

Figure 11 shows the system design of a solar combi-system. It consists of solar collectors, pumps, a combi-boiler, an additional heating system and a heat transfer system. This system can either be a high temperature heat supply system (radiators) or a low temperature supply system like wall or floor heating systems. As mentioned above a low temperature system would be better because it needs much lower system temperatures.
There are no existing clear rules for the dimensioning of solar combi-systems. But there are some important conditions that have to be considered:[20]

- well insulated standard of buildings
- low temperature heat supply systems like wall or floor heating systems
- little amount of fog in autumn and spring
- favourable arrangement of the collectors
- enough space for the storage tank

[19] Klima:aktiv 2007
[20] Klima:aktiv 2007

Through a good system design a solar fraction of 15 -50% can be reached very easy. The real fraction depends mostly on the next four points:[21]

- heating demand of the system
- collector area
- storage tank
- reduction of losses (insulation of the tank and the pipe)

A solar fraction of 100% is technically possible but nowadays it is too complex and too expensive to design such solar systems. Generally seen, the development of well insulated low energy houses, the awareness of people and the expensive fossil energy will lead to a further increase in the demand of solar combi-systems.[22] Another type of energy production based on solar is done by photovoltaic cells which will be discussed in the next section.

2.3. Photovoltaic

Photovoltaic means conversion of sun rays direct into electricity. The potential for this electricity generation is nearly unlimited since the energy source is the sun. By using roofs and facades you don't need additional space for the cells.[23]

Therefore this technology is worldwide seen as one of the most important technologies in electricity production. Germany and Japan are the leading countries in using photovoltaic. Austria has not yet reached a very high distribution of this energy system because of non favourable subsidy conditions. Photovoltaic has the most additional potential within all renewable energy forms in Austria. The technical potential of building integrated photovoltaic accounts for 140km² roof area and 50km² façade area.[24]

Today efficiencies of such photovoltaic systems are between 14 to 16% and there are reliable products on the market with guaranteed performance of 20 years and more. The technological background of this system is based on the "photo-electric-effect" which has been discovered by the French scientist E.A. Becquerel in 1839. He observed that photons from the sun cause specific energy levels in semiconductors which generate electric voltage. After connecting the contacts electrical current flew within the semiconductor.[25]

[21] Weiss 2007, p. 84ff
[22] Weiss 2007, p. 59ff
[23] Fechner 2007, p.132
[24] Fechner et. al. 2007, 7ff
[25] Fechner 2007, p.132

As mentioned above a semiconductor is very important for a photovoltaic system. So PV cells are generally made either from crystalline silicon or thin film. The majority of module production is nowadays based on crystalline silicon but the thin film technology based on silicon and other materials is expected to gain a much larger share of the PV market in the future. There are also some other cell types available at the market but these are not discussed in this paper.[26]

For designing PV systems some important points have to be taken into account:[27]

- **Climate condition at the location:** Things like solar radiation, shadowing, …
- **Electrical grid available:** possibility of connecting the PV system to the grid or build up a stand alone system
- **Autonomous operation wanted:** only for grid connection
- **Maximum power needed:**
  - Electricity demand for electrical devices
  - Load profile
- **Economic factors:**
  - Available budget
  - Feed in tariffs, subsidies, electricity tariff, …

These points are very important for the installation of PV systems. Especially subsidies and feed in tariffs should be designed in the way that they are in favour of photovoltaic.

All the technologies which have been described in the chapters above are used in our project in order to supply a row house area with heat and electricity. Therefore the next part of this work deals with the system design of the project.

3. Micro grid for a living area

The following chapters will provide a short overview over the implementation of the above described technologies into a housing area. The goal of this project is to provide 37 row houses with a central heat supply where biomass and solar thermal energy are used. Furthermore each house will have a small photovoltaic area on the roof in order to produce electricity. This electricity will be fed into the grid.

[26] Fechner 2007, p.137
[27] Fechner 2007, p.142

3.1. Housing area

The housing area consists of 37 lowest energy row houses which are built around a central street. Each of the houses has two parking lots for the cars which are also situated beside the central street. The houses are all built out of special energy saving bricks and with 20 centimetres of upgraded insulation. Figure 12 shows a map of the building area and how the houses are distributed on the land.

Figure 12: Housing area of the project

The location where the houses should be situated is very good for the delivering of the raw material because there is a very big street nearby the land. This means that trucks have a very easy access to the central heating plant. They also have a direct access to the storage in order to refill it when it is needed. Another important thing is that the area where the central heating plant will be situated is big enough to build up the storing tank beside the power plant which reduces the building costs.

The houses have a living space of a little bit more than 100 square meters and a cellar with about 50 square meters. All houses are built under the Upper Austrian regulation for lowest energy houses which means that the "Nutzheiz-Energiekennzahl" is lower than 30 kWh/m², a.[28] Beside this they are all equipped with a low temperature floor heating and a ventilation system. This combination is in favor of a combined heating system based on biomass and solar thermal cells because the houses have a very low energy demand.

3.2. System design

As mentioned in the chapter above all houses should be supplied with heat through a small central heating system based on biomass and solar thermal energy. When talking about such a system some important points have to be considered:

- Energy demand for heating the houses
- Energy demand for providing houses with hot water
- Transportation of the energy to the houses with very little losses
- Space for power plant, solar collectors, puffers and storing of raw material
- Direction of the solar panels to the sun
- Legal regulations
- Building permission
- Subsidies

First I tried to calculate the energy demand for heating the whole housing area. As mentioned above the houses have a living area of about 100 square meters and a maximum energy demand of 30W/m². As there is no detailed Energy Performance Certificate available for the houses we have to estimate the maximum energy demand in order to have sufficient energy available. Figure 13 shows how this energy demand is calculated.

Living area of house	Max. energy demand (W/m²)	Max. energy demand of house (W)	Max. energy demand of house (KW)
102,75	30	3082,50	3,08

Number of houses	Max. energy demand of house (KW)	Max. energy demand for heating of housing area (KW)
37	3,08	113,96

Figure 13: Maximum energy demand of a single and all houses

[28] Land Oberösterreich 2008, Reihenhäuser

But this calculated energy demand is not the whole amount of energy which is needed for the houses. There is also a quite huge energy demand for providing the houses with hot water. As mentioned in the solar chapter a medium to high demand of hot water is between 50 and 60 litres of water at a temperature of 50°C per day and person. Therefore I estimated an additional energy demand for heating up hot water of about 20% of the energy needed for heating. Figure 14 shows the result of this calculation.

Number of houses	Max. energy demand of house (KW)	Max. energy demand of housing area (KW)	Additional energy needed for hot water (KW)
37	3,08	113,96	22,79

Figure 14: Energy needed for hot water preparation

The sum of the energy needed for heating and hot water preparation accounts for 136,75 KW. Therefore I decided to build up a power plant with three 50 KW boilers which are able to work with different biomass products especially pellets and energy corn. I want to use the VERNER A501G which is shown in the figure below.

Figure 15: Verner A501G
Source: http://www.verner-heizung.eu/verner_a501g.html

The main advantage of this boiler is that you are able to use different substances for burning. This means that the boiler can be fed with maize, pellets, pellets with bark, pellets out of rape, pellets out of sun flowers, parts of pressed rape, wheat and oat. Through this you are not so dependent on the quality of the pellets. One thing that has to be considered when burning other materials than pellets is that the legal regulations concerning dust and other emissions have to be fulfilled. Another important circumstance why I decided to use this boiler for the project is that through the big area of the heat exchanger the efficiency is relatively high. The handling is also very easy because the boiler starts automatically with an integrated hot air ignition.[29] Beside this I want to install a modem in order to have to the possibility to get all problems up to date on the mobile telephone of a technician. The next figure shows some important parameters of the boiler.

Verner A501G		**Pellets**	**Mais**	**Getreide**
Nennleistung	kW	48	48	48
Wirkungsgrad	%	92,1	91,3	92,7
Brennstoffverbrauch bei Nennleistung	kg/Std	10,5	12,0	12,7
Inhalt des Behälters	Liter	240	240	240
Gesamtgewicht	kg	650	650	650
Rauchrohrdurchmesser	mm	160	160	160
Vorgeschriebener Kaminzug	Pa	15-30	15-30	15-30
Elektrischer Anschluss	V/Hz	230/50	230/50	230/50

Figure 16: Technical parameters of the Verner A501G
Source: http://www.verner-heizung.eu/verner_a501g.html

The next thing is that you also have to store some raw material in order to be a little bit independent on the market. This means that if you have to buy the raw materials each day you always have to pay the market price which could result in high running costs. In order to overcome this problem I decided to build up a storage room where we the raw material for about two months can be stored. Therefore I estimated the yearly demand of pellets for one single house. The assumption is that in a normal year a house needs 800kg pellets for heating up the house and producing hot water. The next thing I assumed is that 1kg of pellets accounts for 4kWh including all losses from the boilers, buffers, the grid and so on. As shown in figure 17 I calculated the amount of pellets which is needed for a normal two months energy production.

[29] Verner a.s. 2008

Assumption 1:	Yearly demand of pellets/house:	800	Kg
Assumption 2:	1kg Pellets:	4	kWh
Assumption 3:	Heating days	210	Days
Jearly energy demand of house:	3.200	kWh	
Energy demand/Heating days:	15,2	kWh/Heating day	
Energy demand for 60 heating days for 37 houses	33.829	kWh	
Amount of pellets for 2 months	8.457	Kg	

Figure 17: Amount of pellets needed for two months storage

The next assumption which is needed for calculating the storage is that 1m³ accounts for 650kg of pellets.[30] In addition to this I decided that the height of our storage building is fixed at 3 meters because the storage of the raw material takes place in the same building where the boilers are located.

3 Boilers in 2 months (Kg)	Space needed (m³)	Height (m)	Base area (m²)
8.457	13	3	4,34

Figure 18: Calculation of base area for storage

As it can be seen from the figures above the base area of the storage building has to be a little bit more then 4.3 square metres. Therefore I decided to build up a storage building with a length and a width of 2.5 and a height of 3 meters. The raw material is transported via a screw form the calculated storage room to the boilers where it is burned. The produced heat goes directly from the power plant to buffer tanks where it is stored. The size of these buffers will be discussed a little bit later. The ash which is produced by burning biomass is automatically transported from the boilers to an external place where it can be easily collected.

[30] Wiga Energietechnik 2008

For the solar collectors we decided to use the parking lots in front of the houses. Normally these parking lots don't have a roof. Therefore I use the solar collectors as roofs for the parking and I get a double advantage out of this. On the one hand the cars are protected against the weather and on the other hand the roofs of the row houses can be used for the photovoltaic cells. A normal flat plate collector has a length of about 2 and a width of about 1.3 meters.[31] As a result you can use 2 collectors for each house. If I calculate the whole amount of solar collectors we get an area of about 200m² of aperture area. This aperture area is very important because it is the calculation basis for the subsidy we get.

From the solar area I can now calculate the size of the buffer I need for the heating system. Therefore I estimated that for each square meter of solar collector I should have a buffer volume of about 60 litres. As I have calculated a solar area of about 200m² for the whole system I get a buffer volume of 12000 litres. In order to reduce the size of the buffer and the length of the pipelines to the houses I decided to build up 4 buffers each with 3000 litres. The position of buffers is shown in figure 19.

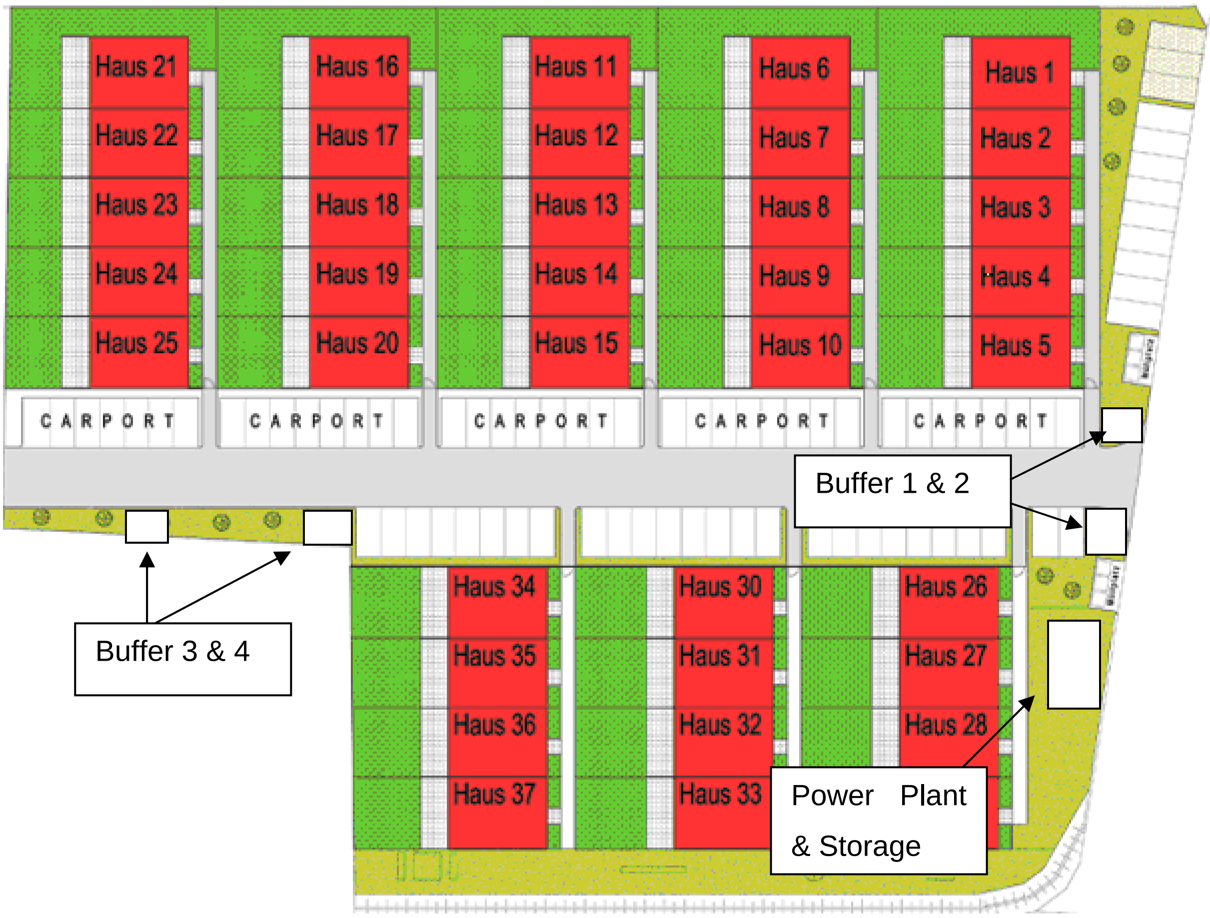

Figure 19: Location of power plant and buffers

[31] MEA Solar 2008

The produced heat from the biomass boilers and the solar collectors has to be transported to the houses and supply the consumers with warm water and heat for their floor heating system. In order to reach this each buffer is linked to nine or ten houses with a district heating pipeline. The advantage of the placing of the buffers is that there is only one long pipeline from the power plant to the buffers and relatively short pipelines to the houses. The buffers and the pipelines are also very well isolated in order to reduce the overall system losses. The costs for placing the pipelines under the earth are also relatively low because the construction company has to dig up the whole area in order to get the telephone, television and electricity connection into the house.

The hot water from the buffers gets via the pipelines to a special designed heat transfer station which is installed in the cellar of the house. Figure 20 shows how this heat transfer station is designed.

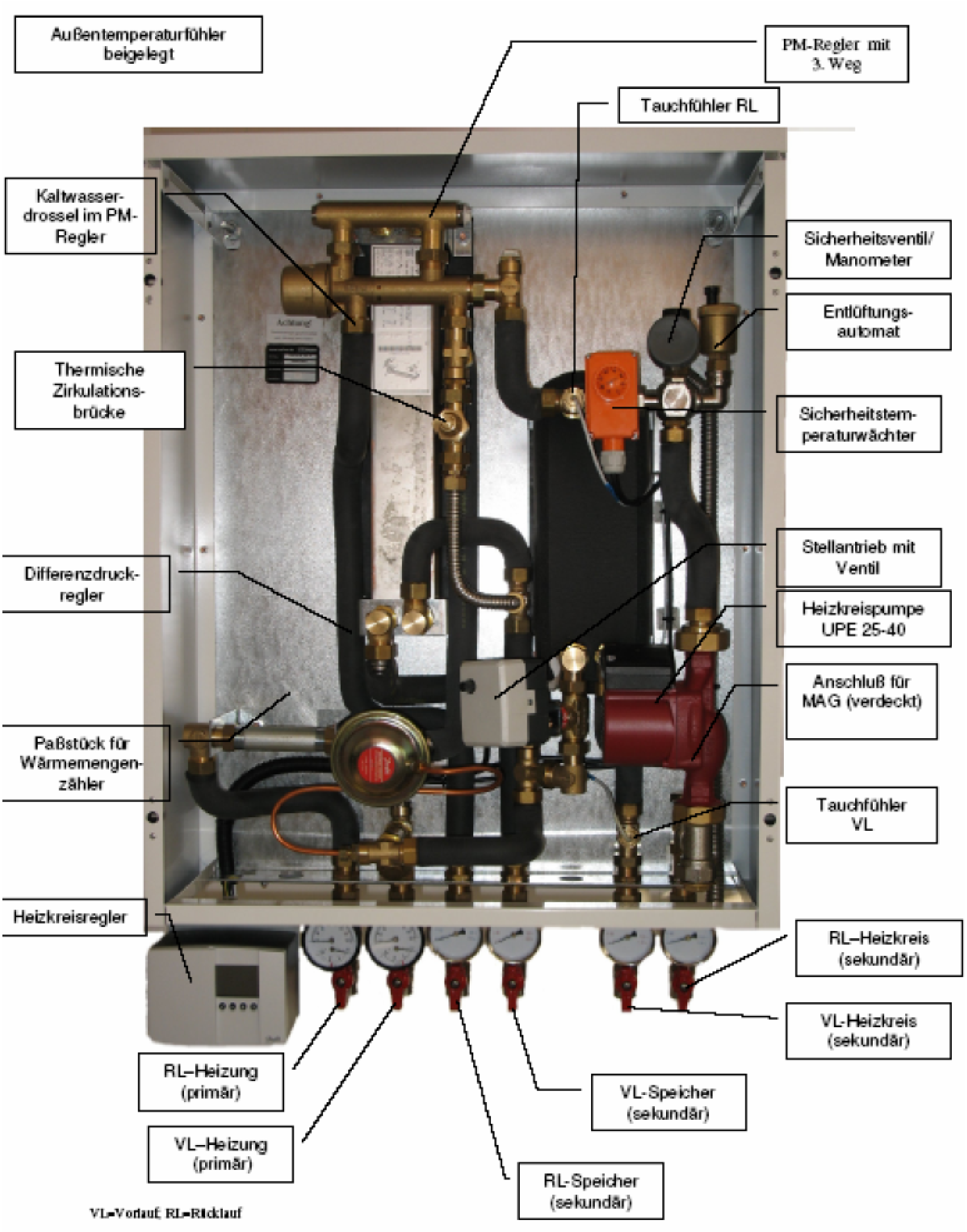

Figure 20: Heat transfer station within the house

Source: Zauner Anlagenbau GmbH

This heat transfer station works like it is shown in the scheme in figure 21. This means that whenever somebody wants to have hot water and opens the tab hot water is produced in the flow-through principle on the primary side. The secondary side is regulated by an outside temperature sensor. This system is relatively easy to install and do not need much space inside the house. Another big advantage of this system is that it is very hygienic from the side of hot water preparation because there is no stored hot water inside the pipes within the house. Therefore the growing of Legionella isn't possible. As addition the Austrian ÖNORM B5019 is also fulfilled through this type of installation.

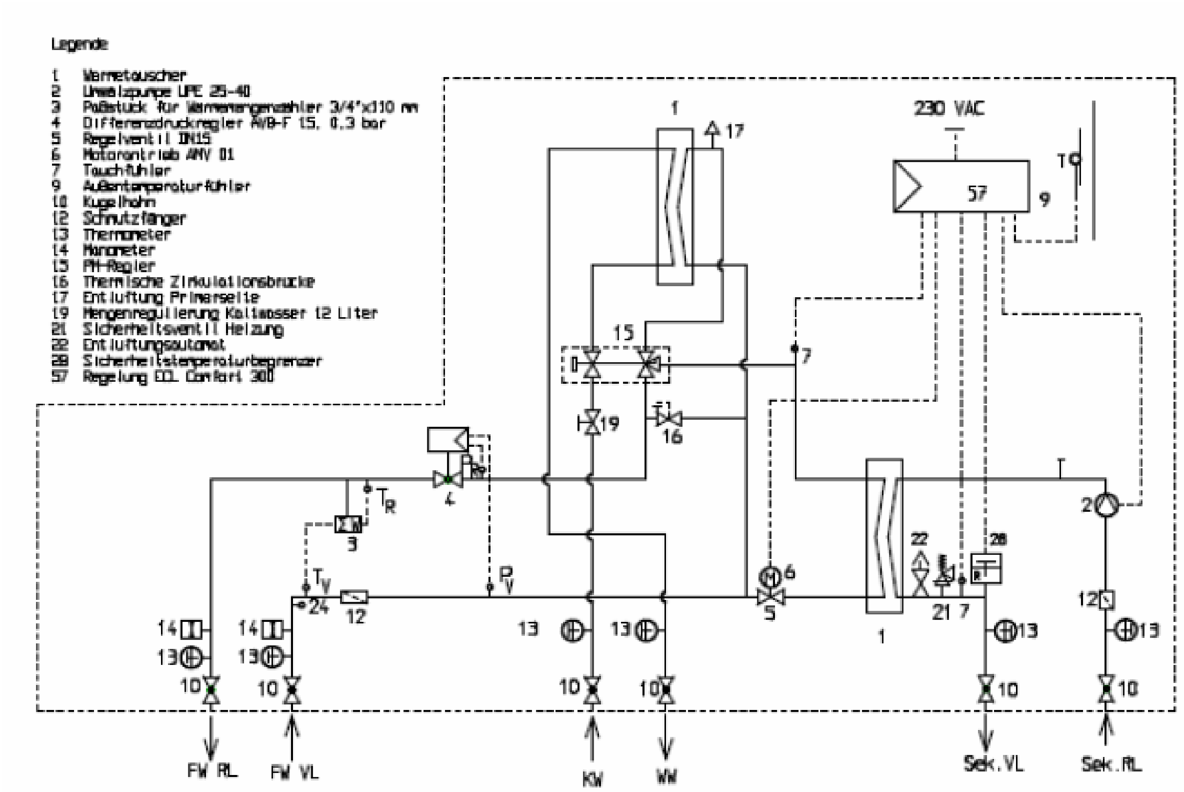

Figure 21: Scheme of heat transfer station
Source: Zauner Anlagenbau GmbH

The next thing that has to be considered is that I want to integrate photovoltaic cells in my energy concept. I decided to install a decentralized photovoltaic system into the roof of each row house. The reason for integrating the cells into the roof is that you don't have build up a roof first and put the collectors on this roof which accounts for higher costs and doesn't look very good. So each house produces electricity from the sun and gives it back into the grid. I will install a 2kWp system which means that the photovoltaic collectors need an area of about 16m². If I assume that a 1kWp unit produces about 900kWh electricity per year in this region, then you can say that more or less half of the yearly demand of electricity of a household is produced through this system. In order to get the "Ökostrom" tariff you have to feed the electricity into the grid. This means that the households produce electricity through the photovoltaic system and this electricity is given to the grid. Therefore the households get a higher price for their sold electricity.

3.3. Costs and benefits of the system

When talking about the costs and benefits of such an energy concept you have to distinguish between internal and external effects. This means that with such a project on the one hand you get direct costs and benefits that can be measured in absolute values and on the other hand you get indirect costs and benefits that can't be measured in absolute values. Therefore it is not very easy to determine the absolute costs and benefits of this system ex ante. The topic of indirect costs and benefits is also very important during the presentation phase where the project is introduced to the building company, the bank and the consumers. You have to show our counterparts from the beginning on that you have taken these indirect influences into account. As a result I decided to point out possible costs and benefits that are linked to this project.

3.3.1. Costs

First you have to look for the direct costs that go along with the energy project. Most of these costs are relatively easy to measure because there are companies available at the market that offer the products. The following points represent the most important direct costs of our project:

- Building costs of power plant and storage
- Costs of the boilers, buffers and the grid
- Costs of solar thermal and photovoltaic collectors
- Losses of the grid

As mentioned above not only the direct costs are relevant when talking about centralized energy concepts. Here are two examples of external costs that can occur during the discussion with other parties.

- Emissions of the power plant
- Sight of power plant

3.3.2. Benefits

There are a lot of benefits for the consumers when there is a central heating system. Of course there are also direct and indirect benefits that have to be considered. Some direct benefits:

- Energy saving through combi-system
- No heating system in the house, less installation in the house
- Guaranteed energy delivering, not dependent on oil and gas shocks
- Better bargaining power, better price for raw material

Indirect benefits:

- Consumers are “green” citizens
- Consumers don’t have to take care about the heating system

As you have seen there are a lot of direct and indirect costs and benefits that have to be taken into account. Now the next step is to value the direct costs and benefits for this heating system.

3.3.3. Valuing costs and benefits

Valuing the direct and indirect costs and benefits should help the addressed persons in the decision process. Therefore it is very important to understand the targets of these persons. This means that for example a company which builds up cheap houses for people with very little income wants to have low building costs in order to have the possibility to sell the houses at a low price. This company wouldn’t take care as much about the running costs of the houses. If we look at a company which wants to build up a special high standard living area with low running costs it is more likely that this company has to invest more at the beginning in order to decrease the running costs. But not only the addressed persons are relevant for the decision process. We also have to take care about legal regulations such as the subsidy directive from the government where the project should be realized. As our project should be realized in Upper Austria we tried to find out the minimal criteria in order to get a building subsidy. The most important criteria based on the energy supply are stated below:[32]

- Houses with a “Nutzheiz-Energiekennzahl” higher than 30kWh/m²a don’t get a subsidy.
- Houses with a maximum of 30kWh/m²a get 72.000 euro.
- Houses with a maximum of 10kWh/m²a get 77.000 euro.
- Heating supply systems based on coal, oil or electricity are forbidden.
- Low temperature heat distribution system within the house (wall of floor heating system).

[32] Land Oberösterreich 2008, Reihenhäuser

- Houses need solar collectors with a minimum aperture area of 4m², except they are linked to a district heating system.

There are more regulations that have to be fulfilled in Upper Austria in order to get a building subsidy for a row house but they are not discussed in detail within this paper. Beside the building subsidy for the new houses we also need a building and operation permission for our power plant. It is very important to visit the officials as soon as possible in order to minimize the time which is needed for the pre-building phase. If the building of the power plant is relatively fixed it is very necessary to bring all papers needed to the official services. During this permission phase the officials decide whether the project can be built like it is handed in or if it has to be adopted. Most of the time an adoption goes along with a change in the costs and the duration of the project. Therefore it is not very easy to figure out the exact costs of the project ex ante. This has to be done when all circumstances are fixed. The next figure shows an estimation of the most important costs which go along with this project. In order to get the real costs there has to be a tender offer after the permission phase where all the exact data are included.

Costs of power plant and grid	
Boilers with screw	47.000
Building costs	18.000
Puffer costs	13.000
Grid	100.000
Heat transfer station in the house	129.500
Photovoltaic	340.400
Solar thermal	62.000
Total costs	**709.900**

Figure 22: Estimated costs of centralized power plant

Valuing the benefits of a centralized power plant is more difficult than valuing the direct costs. The main part is based on lower running costs through a centralized combi-system based on biomass. Another big advantage is a guaranteed energy delivering because the raw material comes from the neighbourhood. Therefore a crisis where two countries are fighting for natural gas or oil does not affect our system that much. The third big advantage of a centralized biomass power plant is that we have a better bargaining power when buying the raw material because normally you get a better price if you buy more. You are also able to fix long term contracts with the suppliers of the raw material in order to get a better price and a guaranteed supply.

Valuing the indirect costs and benefits is even more difficult than valuing the direct ones ex ante because these costs and benefits are mainly based on a personal level. Therefore it is very important that such indirect factors are recognized in a very early phase by the presenters of the project so that they can react in a proper way on these emotional behaviours.

You also have to consider the fact that the consumers get subsidies for having alternative energy concepts. Therefore the next chapter deals with subsidies that are available for our project.

3.4. Subsidies

As mentioned in the chapter above there are special subsidies for building row houses. But there are also other subsidies that the consumers get for a centralized energy supply system combined with a solar and photovoltaic system. Therefore you have to distinguish between different types of subsidies. One of these types is the building subsidy for row houses in Upper Austria which was described shortly in chapter 3.3. Although this subsidy is somehow bound to efficient energy use it will not be described in further detail within this paper. The detailed basics can be found under http://www.land-oberoesterreich.gv.at/cps/rde/xchg/SID-576A6991-92B2E630/ooe/hs.xsl/34822_DEU_HTML.htm. The next chapters deal with other subsidies based on the energy concept of our project.

3.4.1. Solar thermal subsidy

From the beginning of 2009 each new built row house has to have a solar thermal system with at least 4m² aperture area in order to get a building subsidy in Upper Austria. This regulation doesn't have to be fulfilled if there is a district heating system where the house is connected to. So in this case it is not necessary to build up a solar thermal system because there is a district heating system where all houses are connected to. In the energy concept of our project a solar thermal system is integrated because we are able to load our buffers or a least a part of our buffers with solar energy which helps to decrease the amount of biomass needed. The subsidy we get for the installation of 200m² of solar collectors is organised by the Upper Austrian administration. For each square meter of aperture area the subsidy accounts for 200 Euro if there are at least 2,5m² installed for each unit.[33] This means for this project that we get a subsidy of about 40.000 euro.

3.4.2. Photovoltaic

Photovoltaic cells are also a very important part in our energy concept. In Austria the subsidies for photovoltaic systems are not that high as for solar thermal installations. The most important subsidy is the feed in tariff consumers get if the feed the produced electricity into the grid. This feed in tariffs are regulated in the “Ökostrom” law. This law has been adopted the last time in July 2008 and will get into action in the new form at the beginning of the year 2009. Through this adoption there will be 1.36 million euro available for subsidising photovoltaic systems. This means that with a feed in tariff of 0.45 Euro/kWh, 3.3 MWp can be installed and financed. In Upper Austria the feed in tariff for systems up to 5 KWp is 45.99 Cent/kWh.[34] Therefore the consumers of our row houses get 45.99 for each kWh they feed into the grid.

3.4.3. Biomass

The connection to a district heating system is also subsidized by the Upper Austrian administration. The subsidy accounts for 880 euro for the connection to a district heating system. If more than 50% of the heat is produced by forms of renewable energy the subsidy increases to an amount of 1.200 euro.[35]

As the topic of renewable energy concepts gets more and more important throughout the world it is also possible that there are additional or higher subsidies available at the time when the project is realized. Therefore it is necessary to get additional information form the EU, the state and the province about possible subsidies as soon as the project is fixed.

[33] Land Oberösterreich 2008, Förderung von Wärmepumpe - Solaranlage - Fern-/Nahwärme - Kessel-/Tankentsorgung
[34] Photovoltaic Austria 2008, Fördersituation Oberösterreich
[35] Land Oberösterreich 2008, Förderung von Wärmepumpe - Solaranlage - Fern-/Nahwärme - Kessel-/Tankentsorgung

3.5. Comparison of Natural Gas with Biomass

This chapter deals with a short comparison between our project heated with natural gas and heated with biomass, like it is described in the chapters above. The most important criteria for comparing the two different heating systems are the costs and the emissions which are produced. Solar thermal and photovoltaic collectors are not discussed in this section because they are same for both types of heating systems.

3.5.1. Costs

When talking about the cost side of the two different heating systems we have to distinguish between installation costs and running costs. The installation costs for a single house with a natural gas fired heating system are relatively easy to calculate. The only things you need are a natural gas boiler and a hot water storage tank which is also designed for using solar thermal collectors. The costs for a centralized heating system based on biomass are not that easy to calculate as it is also mentioned in chapter 3.3.3 because there are a lot of circumstances that have to be considered and which have a real big influence on the cost side. Figure 23 shows a comparison of the installation costs produced by a natural gas heating system and the estimated costs for our centralized biomass heating system.

Natural gas heating system for one house	
Boiler including all installation costs	4.000
Hot water storage tank 300 litres	900
Total costs	**4.900**
Centralized biomass heating system for one house	
Boilers with screw	1.270
Building costs	486
Puffer costs	351
Grid	2.703
Heat transfer station	3.500
Total costs	**8.311**

Figure 23: Comparison of Installation costs

As it can be seen from the figure above the installation costs for a centralized heating supply system are higher than the costs for a natural gas heating system. If you consider the subsidy consumers get if they are connected to a district heating system the difference gets lower but is still quite high. The next things that have to be considered are the running costs for the different heating systems. These costs also depend on the user of the system and the fees that have to be paid for providing the raw material and supplying the consumers with heat. As these costs are different between different suppliers figure 23 shows only a comparison of the price of different raw materials.

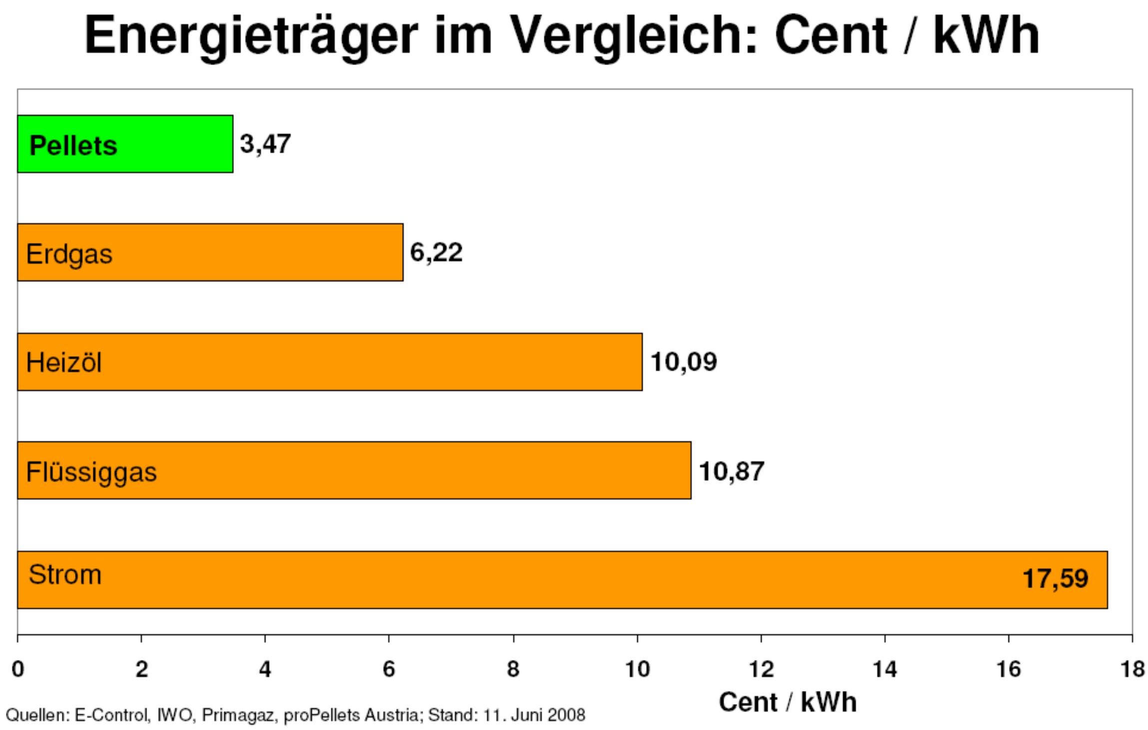

Figure 24: Energy costs of different heating systems

Source: http://www.propellets.at/images/content/pdfs/200806_energietraeger_im_vergleich.pdf

As it can be seen in the figure above the price for 1kWh produced by burning pellets is much lower than by burning natural gas. If we consider the fact that natural gas is a fossil fuel and there is a limited capacity available on the earth the price for this raw material tends to increase above the average over the next years. This can also be seen if we compare the first figure in this paper with the figure above. The price of pellets decreased from May 2007 until June 2008 by about 8% and the price of natural gas increased by more or less 4%. The additional costs for providing the raw material, maintaining the grid and so on also have to be considered. If we consider the fact that through the scarcity of fossil fuels the exploitation gets more and more expensive we can estimate that the difference in the price between natural gas and biomass tends to get bigger in the next years.

The bargaining power for buying the raw material is also better with a centralized power plant because you have to buy a bigger amount and therefore you normally get a better price. In

addition to this the power plant in the project has a storage volume of two months which means that you don't have to buy at a daily market price.
Another important thing when talking about providing heat are the emissions which are produced during the burning process. Therefore the next chapter deals with this topic.

3.5.2. Emissions

When talking about emissions caused through the burning process for producing heat we have to distinguish between different types of emissions that are emitted. The most important and heavily discussed type is CO2 but there are also other ones like PM10 which are relevant for the environment and the people. Figure 25 shows the CO2 emissions caused by burning different raw materials.

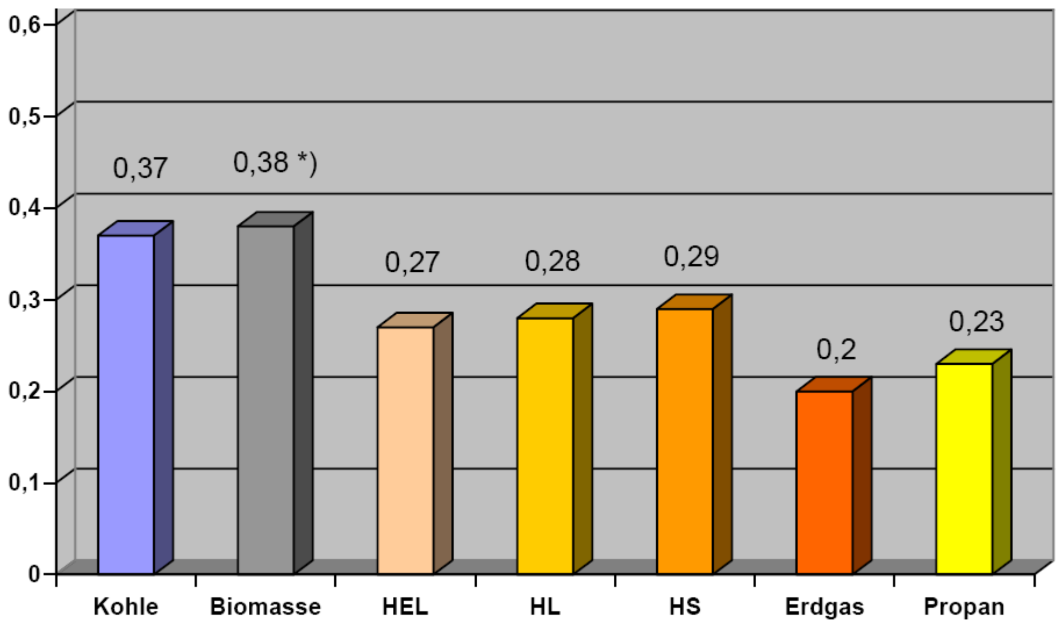

Figure 25:CO2 emissions of different heating substances ($Kg/kWh_{endenergy}$)
Source: Erdgas OÖ

The figure shows that biomass has the highest CO2 emissions but this fact has to be seen in a broader context. As biomass is a renewable form of energy the CO2 emissions are zero. This means that the CO2 which is produced by burning biomass is adsorbed by the living plants and trees ex ante. Therefore burning biomass can be seen as CO2 neutral because no additional CO2 is produced. Figure 26 shows how this process is working in reality. The plants and trees adsorb CO2, water and solar radiation during the photosynthesis. Through the burning process this CO2 is given back to the atmosphere and the produced ash can be used as a fertilizer in the wood. When talking about burning fossil fuels this is not the case because here additional CO2 is given to the atmosphere because the CO2 has been adsorbed by the plants and trees million of years ago.

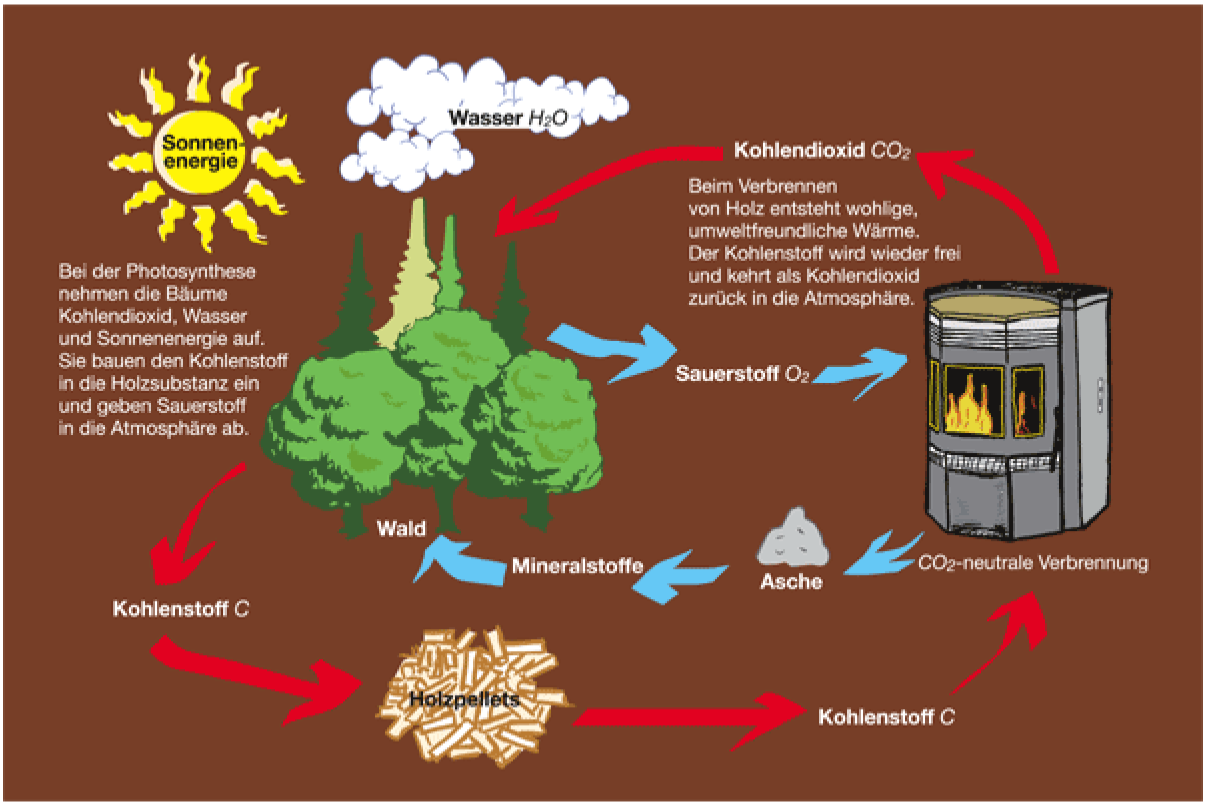

Figure 26: Why biomass is CO2 neutral
Source: http://www.biomasseverband.at/biomasse?cid=1749#id4

Another type of emissions which has been discussed very heavily in the last few years are PM10 (particles which are smaller than 10µm) emissions. But fine dust caused by Pellets consists mainly of different salts which are usually air soluble. The concentration of toxic fine dust, which is usually talked about, is about ten times lower out of pellet stoves then out of diesel engines. A modern Pellet stove produces only about 7 – 20 mg/MJ dust which is comparable to old oil burners. A modern gas burner has nearly no PM10 emissions. In respect to this the producers of pellet boilers tried and try a lot in order to bring these types of emissions down. Of course there are also other emissions which are produced during the burning process but it is very hard to tell something about these emissions in detail because they depend very much on the quality of the burned material.[36] The most important thing for judging different heating system based on there emissions is that the emissions are seen in a big context beginning by the exploitation, transportation and so on. Here biomass has big

[36] Umweltbundesamt 2006, p. 216ff

advantages compared to other burning materials.[37] Figure 27 shows a comparison between different types of heating substances based on CO2 emissions including their life cycle.

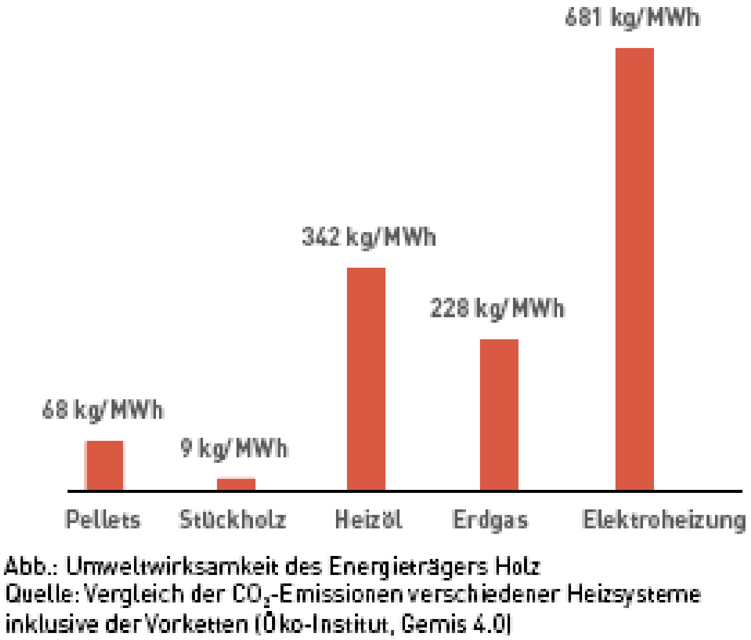

Figure 27: Comparison of different heating types based on CO2 including life cycle

Source: Holzwärme im mehrgeschoßigen Wohnbau

Concerning the figure above we have to consider that biomass has a very regional character compared to fossil fuels. Most of the biomass used for heating purposes in Austria comes from the regional market and this market has a lot of additional potential. Therefore the life cycle emissions are quite low. Also the creation of value stays within the country. This means that heating with biomass is very important industry sector in Austria. It is also an established technology where the consumers can be sure that the heating system is working in a very stable and comfortable form.[38]

[37] Energieinstitut Vorarlberg 2004, p. 4f

[38] Stingl Larome et al. 2008

4. Conclusion

As it can be seen from the chapters above there are a lot of different circumstances that have to be considered when talking about a centralized heating supply system for this housing area. The problem is that there is not a clear result which says that a centralized micro grid is better than a decentralized heating supply. As we have seen in chapter 3.5.1 a decentralized system will result in lower installation costs for the consumers but nobody can predict the overall running costs over the next 50 years. If natural gas gets more and more expensive like it was in recent years the advantage of lower installation costs will be exceeded by lower running costs after some years.

There are also indirect influencing factors that have to be considered and cannot be measured in absolute values. The thing is that a small power plant has to be built in front of the houses and each consumer has to look at this power plant every day. For some people this fact doesn’t matter but for other people this might be a psychological problem and they don’t want to live with such a power plant.

Another thing is the topic of emissions caused by such heating systems. On the one hand natural gas is one of the “cleanest” fossil fuels with very low emissions but on the other hand we have biomass which has CO2 emissions of zero. According to this we have to bear in mind that not only the emissions caused during the burning process are relevant. It is more important to look at the total emissions of the raw material. This means that also emissions for exploitation, conversion and transportation have to be considered. Here biomass has big advantages compared to fossil fuels.

The realisation of this project and other micro-grid projects is very heavily depending on the target group of the system and the whole project. From the beginning on it should be clear that a centralized heating system is installed and that the circumstances are planned in favour of this system. This means for example that the power plant is situated nearby the street in order to make the delivery of the raw materials relatively easy. Another important thing is that all houses are built up at the same time and not in different building phases with some years in between because the adoption of the heating system is relatively difficult and costly.

For the described project in my opinion the centralized heating supply system is a very good possibility because it is relatively easy to integrate a biomass power plant with a solar thermal system that can provide the households with heat. Although the installation costs for this centralized system are higher in my opinion the system will pay off. The exact calculations should be done after the general decision has been taken that a centralized heating supply system based on biomass and solar thermal is installed. For these calculations it is necessary that all building data for the row houses are available. For example the energy certificate gives more detailed information about the energy which is needed to heat the house. After that an exact calculation of the energy demand of the row houses can be done.

From the point of saving the environment which is discussed very heavily in the media all the time the houses could raise the interest of additional groups of consumers which are very interested in having a row house with an innovative heating supply system. Therefore such a centralized heating system will also be a very good marketing concept. It can also be a leading example which other building companies can visit. Maybe some of them will do the same thing and build up row house areas with a centralized heating supply system.

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