3rd Year BEng

Photovoltaic panels for domestic use in Cantabria, Spain

MARÍA DEL MAR DEL BARRIO SÁEZ

2012

I certify that all material in this thesis that is not my own work has been identified and that no material has been included for which a degree has previously been conferred on me.

Signed…………………………………………………………………...

Photovoltaic panels for domestic use in Cantabria, Spain

MARÍA DEL MAR DEL BARRIO SÁEZ

2012

ABSTRACT PAGE

The project studies how Cantabria, an autonomous region in the north of Spain, would be able to change the way the region gets the energy for domestic consume with not renewable resources and the chance of changing it to a renewable energy with photovoltaic panels.

The first idea was just supplying a quantity of megawatts, but my tutor Abel Nyamapfene thought it will be interesting if we think in another way, for example supplying the domestic energy use of my city, and then we thought about the autonomous region.

A Matlab code has been done in order to extend the project to any other place, with just giving some data in the first steps and the amount of material and money will be displayed in the end of the code.

The reason I am attracted by photovoltaic panels came from some years ago, when a project was being studied by my father. It was about building up a petrol station with solar panels. Panels will supply the station and the roof of the station will change its position, so that when you were taking petrol, you will be in the shadow. It was though for a place where the sun is really heavy.

Keywords: Renewable energy, photovoltaic

TABLE OF CONTENTS:

CHAPTER 1: INTRODUCTION

Nowadays, renewable resources are becoming more and more important. The reason of that is that the primary elements used at the moment are finite and there will not be enough if we keep on using them as we have been doing. The good thing about renewable resources is that we can take advantage of natural ways of getting energy and not produce as much pollution as it is done when we transform different elements in energy for the common use. This change of mind is mainly based on new laws, in which at least 12% of primary consumed energy in Spain should come from renewable resources. This way, the quantity of CO_2 spread in the atmosphere will decrease [1].

In Spain, because of different subsidies and changes on laws, photovoltaic installations have become an essential way to obtain electricity and even earn money [2].

Conergy, a well known company for solar installation, has produced and sold more than 1.5GW of solar energy worldwide. We have some example of their work in Germany, Italy, Greece, South Korea, Thailand and also in Spain. The Spanish installations are from very different sizes; we can see a Córdoba installation with 2.27MWp or in Albacete, with an installation of 21.2MWp [3].

Talking about Cantabria, solar installation is not the best option. For that reason, now there are some other renewable energy in the region, such as tidal power, in Santoña with a first stage installation of 40KW and a future enlargement in order to achieve 150KW [4].

Another project being studied at the moment is a wind installation to get 1400MW, but because of the actual economic crisis and different political opinions, is now stopped [5].

On the other hand, solar panels have been a good way to obtain green energy, because of its lack of visual impact (compare with wind energy) and the different subsidies the government have been dealing with in the last years.

Improving the efficiency of photovoltaic panels is a deal that companies from different countries are studying. For example, from the American company 'Semprius Inc.', we can find photovoltaic modules with an efficiency of 33.9%, which is a really good improvement, so that this kind of renewable energy could make a big advance and we can start to think in this renewable resource as something with truly future [6].

We can obtain energy from the sun in three different ways. Thinking about the heat of the sun, we would be talking about solar thermal energy, which takes the heat and high temperature of the sun and uses it to heat water for domestic use, or for cooking. With the same idea, heating water and then using the steam that is produced, we would be talking about solar thermal energy. We would then power a turbine and we would generate the electricity as in a thermal power station. The only different is how the steam is produced. And finally, photovoltaic, that take the light from the sun and because of using semiconductors, we would automatically obtain a continuous voltage [7].

The reason I chose photovoltaic panels is that in the area where the installation would be installed, the sun has not a really high irradiation, and so the two first options would not be the suitable ones. We would see this more in depth in following chapters, talking about irradiation and temperature in the region [8].

This project started with a simple idea: achieve a quantity of energy from photovoltaic panels. The idea changed to, what if we want to supply the city I live in with this kind of renewable resource and compare it with a better place in the country.

We finally think about focusing in my autonomous community and supply the domestic electricity with photovoltaic panels. Having in mind that we will not connect the electricity that the modules generate to the network, we would have to store it somehow in order to be able to have energy whenever we need it.

The project is structured in the following chapters:

Chapter 1: Introduction. We will talk about why the project is important and the justification of the renewable resource chosen.
Chapter 2: Review. The situation with renewable resources in Spain.
Chapter 3: Methods. A detailed step by step of the calculations that have been used.
Chapter 4: Result and discussion. We would see an example of the Matlab code and analyse it in order to see how feasible it would be for the region.
Chapter 5: Conclusion. We will discuss if the project is viable or not and what we can do to make it better.
Chapter 6: References. The list of the references used in the project.
Chapter 7: Appendix 1. The Matlab code that has been done, in order to get figures for any other region, with just changing the input data.
Chapter 8: Appendix 2. Excel table with benefits and years depending on the available money.
Chapter 9: Preliminary report. The first idea about the project.

CHAPTER 2: REVIEW

Spain is really dependent on other countries in which energy concerns. Spain is just a 23.3% self sufficient generating only 32.9MTep of energy, compared with the 104.36MTep consumed in the year 2004 [9].

We can see in the following graphics the distribution of the primary energy consumption in the country, and the electricity generated in the country.

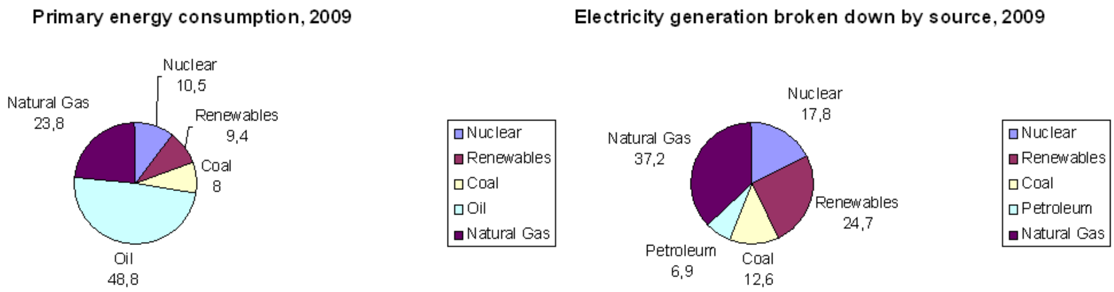

Figure 1: Energy consumption and electricity generation [9: Figure 1]

The final consume in Cantabria, thinking about domestic, transport, industrial and services is like the following graphic

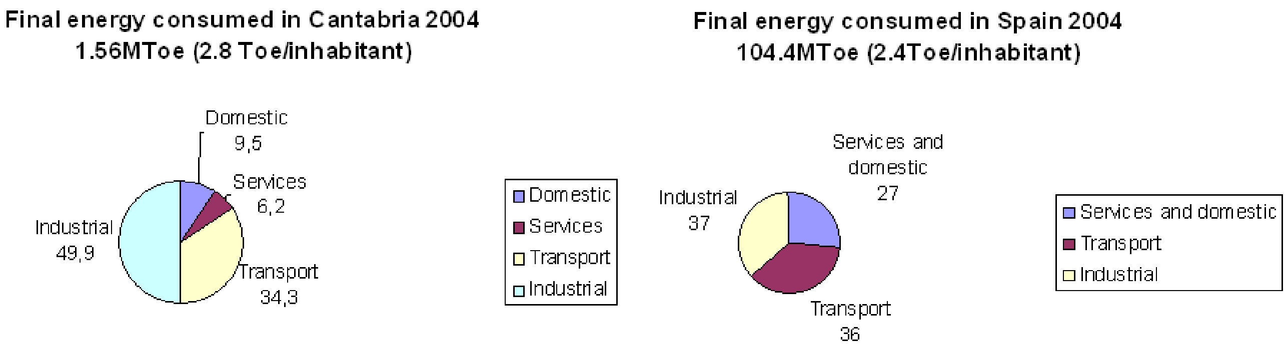

Figure 2: Distribution of dinal energy consumption sectors [10: Figure 2]

Spain aspires to become a better country increasing the percentage of renewable resources. For that reason, in the [11], we can see the on time vision of the renewable progress. For example, in Cantabria, in the year 2010 there was a power installation of 120MW of renewable resources, with 73MW from hydraulic energy, 32MW from wind energy, 3MW from biomass, 2MW from photovoltaic energy and the 10MW left from other renewable resources. If we consider Andalucía, we find in the graphic that from renewable resources, 4330MW were installed, from which 139MW were from hydraulic energy, 2913MW from wind energy, 222MW from biomass, 715MW from photovoltaic,331MW from thermoelectric energy and the 12MW left from other renewable resources. Finally, if we see the figures for Castilla y León, we see that it is the autonomous community with more power installed of renewable resources. 5002MW of renewable energy, from which 214MW were from hydraulic energy, 4382MW from wind energy, 25MW from biomass, 792MW from photovoltaic, and 100MW from thermoelectric energy. We can see that depending on the area of Spain, one renewable resource is better than another. Comparing the photovoltaic and the thermoelectric energy, we can see that in Andalucia, as it is a region with higher temperatures, we can find installed more thermoelectric energy, and in Castilla y León, we find more photovoltaic energy.

Potencia instalada del régimen especial (*) *(MW)*

	Andalucía	Aragón	Asturias	Baleares	C. Valenciana	Canarias	Cantabria	Castilla-La Mancha	Castilla y León	Cataluña
Renovables	4.330	2.134	527	138	1.363	308	120	4.800	5.002	1.429
Hidráulica	139	253	77	0	31	0,5	73	125	214	280
Eólica	2.913	1.699	314	4	1.050	143	32	3.728	4.382	859
Otras renovables	1.279	183	137	134	282	165	15	947	406	290
Biomasa	222	34	86	0	15	1	3	55	25	43
Solar fotovoltaica	715	148	1	59	251	125	2	792	380	192
Solar termoeléctrica	331	0	0	0	0	0	0	100	0	0
Resto renovables	12	0	50	75	16	38	10	0	0	55
No renovables	962	662	95	6	689	33	301	467	651	1.262
Calor residual	12	0	0	0	9	0	0	0	0	0
Carbón	0	0	0	0	0	0	44	0	0	0
Fuel-Gasoil	129	30	24	5	49	33	6	107	57	108
Gas residual	56	10	23	0	57	0	0	0	0	0
Gas natural	765	621	48	2	573	0	251	360	594	1.155
Total 2010	**5.292**	**2.796**	**622**	**144**	**2.052**	**341**	**421**	**5.267**	**5.653**	**2.692**
Total 2009	4.843	2.686	621	94	1.909	316	406	5.174	4.901	2.420
% 10/09	9,3	4,1	0,2	53,4	7,5	7,9	3,7	1,8	15,3	11,2

	Ceuta	Extremadura	Galicia	La Rioja	Madrid	Melilla	Murcia	Navarra	País Vasco	Total
Renovables	0	645	3.892	536	199	2	513	1.296	449	27.686
Hidráulica	0	20	492	26	44	0	14	149	54	1.991
Eólica	0	0	3.290	430	0	0	191	976	194	20.203
Otras renovables	0	626	111	80	155	2	308	172	201	5.491
Biomasa	0	2	49	4	43	0	9	44	77	712
Solar fotovoltaica	0	374	11	76	82	0,1	288	127	18	3.643
Solar termoeléctrica	0	250	0	0	0	0	1	0	0	682
Resto renovables	0	0	51	0	30	2	10	0	106	455
No renovables	0	19	605	49	300	0	306	167	456	7.032
Calor residual	0	4	0	0	0	0	3	0	40	68
Carbón	0	0	0	0	0	0	0	0	0	44
Fuel-Gasoil	0	0	326	3	17	0	30	7	46	980
Gas residual	0	0	0	0	0	0	0	0	9	156
Gas natural	0	16	278	46	283	0	273	160	361	5.784
Total 2010	**0**	**665**	**4.497**	**586**	**499**	**2**	**820**	**1.463**	**905**	**34.718**
Total 2009	0	453	4.448	584	441	2	732	1.399	841	32.272
% 10/09	-	46,6	1,1	0,3	13,1	0,0	11,9	4,6	7,6	7,6

Fuente: Comisión Nacional de Energía (CNE) y empresas eléctricas. (*) Datos provisionales

Figure 3: Installed power of the special regimen [11: Figure 3]

From the [9] we can see the following table:

Table 10a: Estimation of total contribution (installed capacity, gross electricity generation) expected from each renewable energy technology in Spain to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity 2010-2014 (C)

	2005		2010		2011		2012		2013		2014	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydro	18,220	35,503	18,687	34,617	19,869	35 353	19 909	34 960	19 949	36 023	19 999	36 559
<1MW	239	893	242	831	244	739	247	677	249	716	251	718
1MW-10MW	1,534	5,719	1,603	4,973	1,640	4 568	1 665	5 607	1 703	4 592	1 731	4 613
>10MW	16,447	28,891	16,842	28,813	17,985	30 045	17 997	28 676	17 997	30 716	18 017	31 228
of which pumping:	2,727	5,153	2,546	3,640	3,700	5 130	3 700	5 130	3 700	6 577	3 700	6 577
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0
Solar	60	41	4,653	7,561	5,877	9 945	6 949	12 553	7 693	14 570	8 300	16 123
photovoltaic	60	41	4,021	6,417	4 498	7 324	4 921	8 090	5 222	8 709	5 553	9 256
concentrated solar	0	0	632	1,144	1 379	2 621	2 028	4 463	2 471	5 861	2 746	6 867
Tide, wave, ocean	0	0	0	0	0	0	0	0	0	0	0	0
Wind	9,918	20,729	20,155	40,978	21 855	43 668	23 555	47 312	24 986	50 753	26 466	53 981
onshore	9,918	20,729	20,155	40,978	21 855	43 668	23 555	47 312	24 986	50 753	26 416	53 906
offshore	0	0	0	0	0	0	0	0	0	0	50	75
Biomass	601	2,653	752	4,517	771	4 655	803	4 876	844	5 151	897	5 499
solid	449	2,029	596	3,719	604	3 769	624	3 898	653	4 078	692	4 319
biogas	152	623	156	799	167	885	179	978	191	1 073	205	1 180
Bioliquids (29)	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL (w/o pumping)	26,072	53,773	41,701	84,034	44 672	88 490	47 516	94 571	49 722	99 921	51 962	105 586
of which co-generated	177	747	246	1,462	250	1 501	254	1 532	266	1 604	287	1 724

(C) CLARIFICATION: According to Article 5(3) of Directive 2009/28/EC, the electricity generated by hydropower and wind power are to be accounted for in accordance with the normalisation rules set out in Annex II of the Directive.

(29) Taking into account only those that satisfy sustainability criteria. See Article 5(1) last paragraph of Directive 2009/28/EC.

Figure 4: Estimation of total contribution in Spain [9: Figure 4]

We can see that in Spain, talking about photovoltaic energy, by now there should be installed 6949MW.

Photovoltaic panels have been chosen for this project. As we will discuss later on this report, we will put some of them in the roofs of the different buildings, so that the impact is not going to be a really big deal, and it can even be aesthetic, because the design is nice and with soft lines.

The way photovoltaic panels works is really simple:

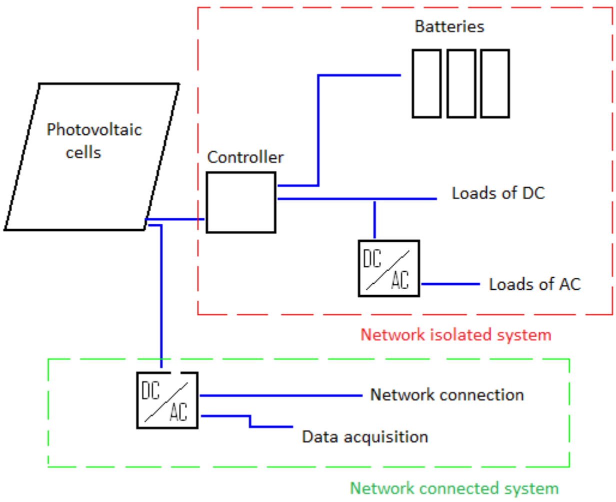

Figure 5: How photovoltaic works [12: Figure 5]

We will briefly describe the parts of the system:

Photovoltaic cells: They are the main part of the system. They are the ones who take the energy from the sun and convert it into electricity. There are some types of cells, and the more used are the ones that uses the monocrystalline and polycrystalline technology.

Batteries: They are the ones that store the voltage from the photovoltaic cells, so that if we do not need at that moment energy, they will keep it until we demand it. They work like the car battery or any other battery we can think about.

Inverters: These, with the photovoltaic cells, are the interesting thing. From the photovoltaic cells, we obtain a continuous voltage, and it is not the one we use at home, that it is the alternating current, so we have to change the energy we are storing in the batteries, to alternating current in order to be able to use it at home as we do it now. They are also the ones which stop giving voltage to the grid if anything abnormal happens while the energy is going from one place to another.

In this project, we are trying to get an isolated system, that is the reason we will need batteries. If we just connect the energy we achieve from the photovoltaic panels to the network, it would be easier but we will not be able to fulfill the demand of electricity in the region.

We have sized the solar installation following the steps shown now:
We first consider a module, referencing with another projects with similar behaviour. Then, we know the watts for each panel we would be getting, taking notice of the efficiency of the module. Consulting figures about the temperature, radiation and hours of sun light, we can then know how many energy we would get from every panel.

Considering the average energy consumed in the region by an average family, we would know the number of modules needed to satisfy the demand of every home. As we have to give electricity to every family in the region, we can easily extend the number for the region with just knowing the number of houses of the region. With it, we would have calculated the number of panels that will be needed for the project. It is always recommendable to oversize the design in order to get the purpose of the project. So with an oversize of 20% in the energy needed, and doing again the same calculations for the new energy, we obtain the final number of modules needed.

The calculate the number of inverters knowing the power of the inverter and module chosen and to calculate the number of batteries, we will have to think about the number of days we want to have the energy stored, in case there are some followed days with not enough amount of radiation and the specifications from the battery itself, such as voltage, capacity…

For a correct design, we have to think how modules are going to be displaced in the area we have chosen for them. For that reason, we will have to calculate the shadows that the modules will produce and so, put them with enough distancing so that no shadow will be produced.

Photovoltaic panels have become really famous because of different subsidies government had been giving. In fact, for network connected system, we can read that different kind of tariffs will be applied depending on the power of the installation.

		RATING	TYPE OF INSTALLATIONS
TYPE I	I.1	P · 20 KW	Roofs or facades with uses: Residential, services, commercial, industrial, crop & livestock
	I.2	20 KW · P · 20 MW	Car Parks with those uses. (Lot with urban cadastre reference)
TYPE II	II	P · 10 MW	OTHERS, not included in type I

The tariff and quota framework for 2009 is shown in the following table:

		2009			
	Type	1C	2C	3C	4C
TARIFF (c€/KWh)	I.1	34.0000	34.0000	34.0000	34.0000
	I.2	32.0000	32.0000	32.0000	32.0000
	II	32.0000	30.7189	29.9113	29.0857

		ALLOCATED	REGISTERED	ALLOCATED	REGISTERED	ALLOCATED	REGISTERED	ALLOCATED	REGISTERED
ALLOCATION (c€/KWh)	I.1	6.675	1.668	6.675	3.631	6.675	2.786	6.675	4.670
	I.2	60.075	20.916	60.075	31.691	60.075	35.601	60.075	60.104
	II	58.250	66.113	94.552	94.718	89.512	90.411	85.620	89.995

		2010		
	TYPE	1C	2C	3C
TARIFF (c€/KWh)	I.1	34.000	33.4652	33.0597
	I.2	31.1665	30.3099	29.5200
	II	28.1045	27.3307	26.5509

		ALLOCATED	REGISTERED	ALLOCATED	REGISTERED	ALLOCATED	REGISTERED
ALLOCATION (c€/KWh)	I.1	6.675	6.016	6.653	5.760	6.675	-
	I.2	61.640	62.522	61.439	61.480	61.640	-
	II	50.033	50.894	51.339	52.380	52.105	-

Figure 6: Groups defined under the R.D. 1578/2008 [13: Figure 6]

We can also see in the Real Decreto 314/2006 [14], that every new building should have any renewable system in order to get hot water.

CHAPTER 3: METHODS

This project will be concentrated in Cantabria, but changing the input data in the Matlab code, we would be able to use the analysis for any region.

Cantabria is an autonomous region situated in the north of Spain, as we can see in the figure:

Figure 7: Map of Spain [15:Figure 7]

The number of inhabitants in Spain is 47,200,000 from which Cantabria correspond to a 1.257 % with a number of 593,121 inhabitants. Spain has an extension of 505,963 km^2 and Cantabria is 5,321 km^2 which is a 1.05% of the total of Spain [16].

We have used the 1.56MTep as the energy that Cantabria uses annually and the 9.5% of domestic use (that we have seen in figure 2).

Knowing that 1tep (1 toe) is equivalent to 418,686 Joules and at the same time to 11.63 MWh we can say that the final energy consumed in Cantabria is:

$$\text{Final Energy Consume in Cantabria} = \left(1.56\,Mtoe \times 11.63\,MWh\right) = 18{,}142{,}800\,MWh$$

Of which the 9.5% is for domestic use, meaning 1,723,566 MWh correspond to the domestic use.

With this data, we can say that the usage per individual is the division between the energy and the number of inhabitants:

$$\text{Usage per individual} = \frac{totaldomesticenergy}{numberofpeople} = \frac{1{,}723{,}566MWh}{593{,}121\,people} = 2905.93KWh$$

For the analysis we will take into account that the number of people in an average house is about 2.90 people in Spain and if we reference it to Cantabria, the number is of 3.04 people. The annual average consume in a house in Spain is about 3,250 KWh [16].

Our photovoltaic panels would give us a power of 230 W with an efficiency of 14.13% [3], so we will get:

$$\text{Watts/panel} = (230W \times 01413) = 32.499W / panel$$

We know that we have an average light time in Cantabria of 1,639 hours in a year, according to the following table, with the numbers taken for the capital of the region, Santander, with the figures from 2001 to 2010. Santander has a latitude of 43° 27' 39'' N and a longitude of 3° 48' 28'' W

Month	T	R	H
January	10.2	1.42	88
February	10.0	2.06	100
March	12.0	3.45	134
April	12.7	4.17	147
May	15.5	5.12	169
June	18.2	5.55	174
July	20.0	5.55	189
August	20.7	4.90	182
September	18.9	3.97	157
October	17.0	2.63	127
November	12.6	1.59	98
December	10.5	1.22	74

Figure 8: Temperature, radiation and light hours in Santander [8: Figure 8]

T = Average month temperature (°C)
R = Average month radiation (KWh/m^2/day)
H = Average sunny hour per month (hours)

With the addition of the sunny hours per month we get the 1,639 hours so with each panel we will get:

$$\text{Wh/panel} = (32.499W / panel \times 1{,}639hours) = 53{,}265.861Wh / panel = 53.266KWh / panel$$

We can now calculate the number of panels that an average house will need in order to fulfill the energy:

$$\text{Number of panels per house} = \frac{3{,}250KWh}{53.266KWh / panel} = 61.01469\,panels$$

Considering the 3.04 people in each house, and the number of inhabitants in Cantabria, we can say that:

$$\text{Number of houses} = \frac{inhabi\tan tsCantabria}{averagepeoplehouse} = \frac{593{,}121}{3.04} = 195{,}105.59 houses$$

$$\text{Number of panels} = (houses \times panels / house) = (195{,}105.59 \times 61.01469) = 11{,}904{,}307\, panels$$

In order to really get the amount of energy from the photovoltaic panels, we have decided to oversize the design in a 20%. With it, we calculate the average energy per family, giving us the result of 3,900KWh

$$20 = \frac{[(x - 3{,}250{,}000) \times 100]}{3{,}250{,}000} \rightarrow x = 3{,}900 KWh$$

So, recalculating the minimum number of panel per house:

$$\text{Minimum number of panels per house} = \frac{3{,}900 KWh}{53.266 KWh / panel} = 73.218728 panels$$

If we want to know the number of panels in total, we do the following as before:

$$\text{Total panels} = (houses \times panels / house) = (195{,}105.59 \times 73.218728) = 14{,}285{,}169\, panels$$

In Cantabria, we can estimate that a 20% of the houses are individual ones and the rest are buildings with flats. It means that we have 39,021.118 individual houses and 156,084.47 building flats.

Thinking about putting the modules in the roof of the buildings and estimating the average size available of $100m^2$ for the individual houses, we can provide

$$\text{Area individual available} = (houses \times area / house) =$$
$$= (39{,}012.118 houses \times 100 m^2 / house) = 3{,}902{,}111.8 m^2 available$$

The dimensions of the photovoltaic module are 1,651 x 986 x 46 mm, so every panel has an area of 1.627886 m^2

With these figures, we can then obtain the number of panels that we would be able to put in the roof of individual houses:

$$\text{Panels individual houses} = \frac{3{,}902{,}111.8 m^2}{1.627886 m^2} = 2{,}397{,}042.4\, panels$$

For the building flats, we would consider that the roof has and average available surface of $200m^2$ and in every building flat, we would have in average 50 families. With those figures we can easily calculate the amount of panels that we would be able to put in the roofs:

$$\text{Area flat available} = \frac{(houses \times area / house)}{families} =$$

$$= \frac{156{,}084.47 houses \times 200 m^2 / house}{50\, families} = 624{,}337.88 m^2 available$$

$$\text{Panels flat houses} = \frac{624{,}337.88 m^2}{1.627886 m^2} = 383{,}526.78\, panels$$

So, if we add both figures, we discover that, putting modules in every roof of the region, we would only be able to provide place to 2,780,569.2 panels, and we have left:

$$\text{Panels left} = (14{,}285{,}169 - 2{,}780{,}569.2) = 11{,}504{,}600\, panels$$

With that huge amount of panels left, we will have to think about places to put them. We though about solar farms, so we will have to think about the price of lands to put the modules, and the shadows of the panels in order to put them in the best way to get the best of the sun and trying to optimise the design.

If we consider, just to get an idea, to put every panel that are left, together, they will need the following area:

$$\text{Area left} = (11{,}504{,}600 panels \times 1.627886 m^2) = 18{,}728{,}177 m^2$$

Which means the 0.3520% of Cantabria. Just to get a spatial idea, Devon area is of 6,707km^2 and Cantabria, we remember is 5,321km^2.

Thinking about soccer stadiums, with dimensions of 105 x 68 m; we will need:

$$\text{Number of stadiums} = \frac{18{,}728{,}177 m^2}{(105 \times 68) m^2} = 2{,}622.944 stadiums$$

And this approximation is just thinking about putting them together, without considering any inclination nor spaces between the modules.

Considering now that we will put the modules in structures, for the land we will use the structures Conergy SolarGigant [3], and we would put in every structure a number of 24 modules. The reason for that is that after doing the first calculations, we saw the number of inverters that we will need, and this design is the best that fits the project.

Putting the modules in a vertical way, with 8 panels in the horizontal way and 3 in vertical, we would get the 24 modules we were talking before. With those dimensions, we see that every structure will have the following dimension:

Vertical→3 x 1.651 m = 4.953 m

Horizontal→8 x 0.986m = 7.888m

We can also say now the number of land structures that we will need, because every 24 photovoltaic panels, we will need one structure, so:

$$\text{Land structures} = \frac{11{,}504{,}600\, panels}{24\, panels / structure} = 479{,}359 structures$$

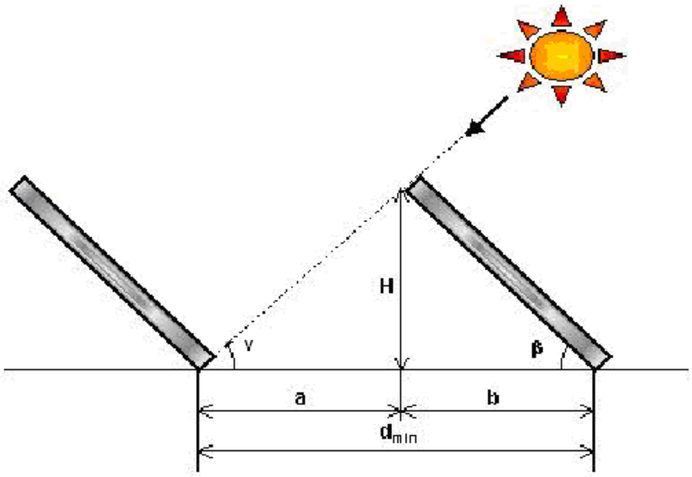

Figure 9: Shadows with structures [12: Figure 9]

Consulting different pages, the proper angle of inclination would be around the latitude number.We can also have a good eficciency around adding or substraing 15 degrees of the latitude.

With the pvsig page [17],we get that, for Santander,the optimum inclination for the panels would be 35°

So, β will be 35º and so, with the Pythagoream theorem and a simple analysis with the angles, we will get the minimum distance between structures.

$$
\begin{aligned}
&\mathrm{b} = 4.952 \times \cos 35^{\circ} = 4.05726m \\
&\mathrm{H} = \sqrt{\left(4.952^2 - 4.05726^2\right)} = 2.841m \qquad [12] \\
&\gamma = \left(90^{\circ} - latitude\right) - 23.5 = 23.23^{\circ} \\
&a = \frac{H}{\tan\gamma} = 6.6188m \\
&\mathrm{dmin} = a + b = 10.676059m
\end{aligned}
$$

In order to get round figures, we will separate the structures every 12 meters. Every 12 meters we put 24 photovoltaic panels.

$$\text{Land area} = 12m \times 7.888m = 94.656m^2 \; for 24 \, panels$$

As we have still 11,504,600 panels left, we will need 45,374,142m^2 for being able to put the panels in the land.

Taking in mind that land prices are going down with the actual economic crisis that is undergoing Spain, we can think that 10€/m^2 is a reasonable price. So, just buying the land for the panels, because we assume that as it is for domestic use, the roofs we were talking previously would be use without any problem, we will need the following amount of money:

$$\text{Money land} = 45{,}374{,}142m^2 \times 10€/m^2 = 453{,}741{,}420€$$

With the actual change to pounds, in order to see a familiar figure, as 1.2€ is around 1£:

$$\text{Money land} = 45{,}374{,}142m^2 \times (10/12)£/m^2 = 378{,}117{,}850£$$

We want to transform the energy from the sun to electricity that we can use in our houses, so we will need inverters to take the continuous signal into alternating current. For every inverter from Conergy IPG 5S, with 5Kw of nominal and maximum power [3] we would be able to connect 24 modules. That is the main reason we put 24 in every structure, to simplify future troubles with connections.

As we are not going to put the energy into the electrical web, we will need batteries in order to be able to get energy at any time, knowing that during the day, the Spanish consume draws the following graphic:

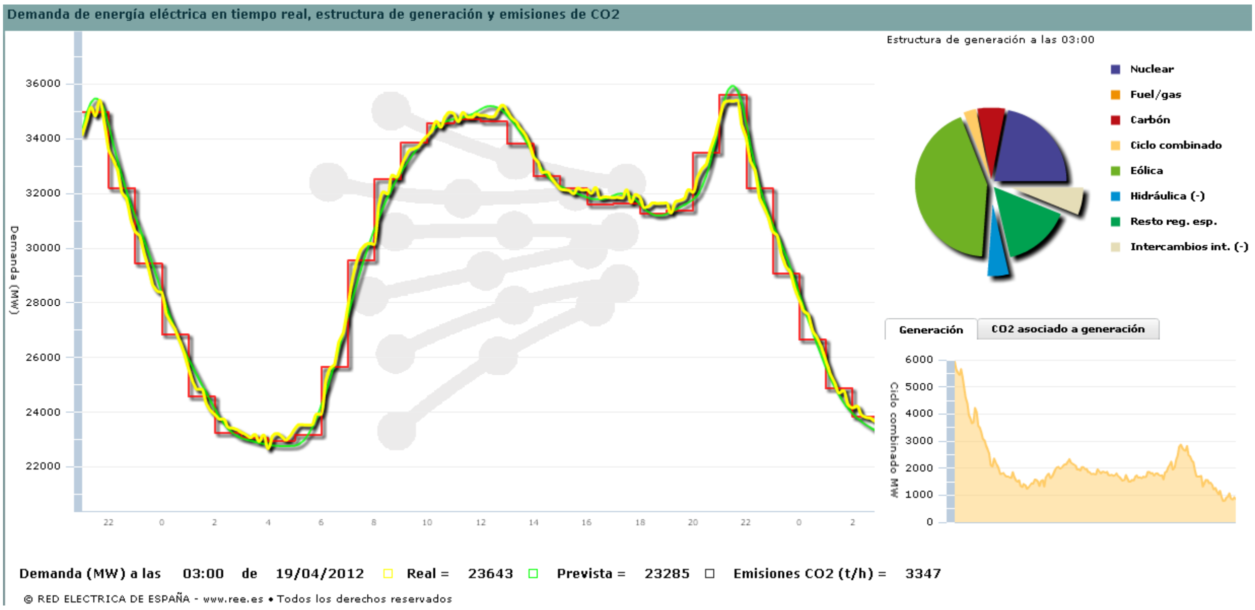

Figure 10: Consume in Spain [18: Figure 10]

To calculate the number of batteries needed, we know that the batteries are measured with their capacity battery, known as C (A·h). We have chosen a battery with 249 Ah and a voltage of 12 V [19].

$$C = \frac{(E \times N)}{(V \times Pd)} \qquad [20]$$

$$E = \text{Energy per day} = \frac{3{,}900KWh}{365days} \times 195{,}105.59houses = 2.0847 \cdot 10^9 Wh/day$$

N = number of days energy will last in the battery = 4 days
V = nominal voltage of the battery = 12 V
Pd = 70% = 0.7 which is a factor that goes from 0.65 to 0.9.

With all these information, we can calculate the number of batteries we will need:

$$C = \frac{((3{,}900 \cdot 10^3 / 365) \times (195{,}105.59 \times 4))}{(12 \times 0.7)} = 992{,}709{,}460Ah$$

$$\text{Number of batteries} = \frac{992{,}709{,}460Ah}{249Ah} = 3{,}986{,}785batteries$$

I have keep in contact with some enterprises in order to get an idea of the prices, and if because of asking for so huge quantities we will get a discount. For the photovoltaic panels, the normal price is 0.93 €/Wp but demanding big quantities, we can reduce the price to 0.5-0.7 €/Wp. About the structures, we will have to pay around 250€ each and about the inverters 1.250 € each one and with a big request, we would be able to subtract 100 €.

About the batteries, we know that, every battery will cost around 800€.

The government of Cantabria will provide for this kind of project approximately 21,512,349€ [21], which, as we can see, will not be enough for paying the land for the installation.

On the other hand, we will be saving money for paying the electricity bill, and having on mind that an average family pay 0.05€/KWh, we can assign the money for the project and we will have:

$$\text{Energy installed} = (3{,}900KWh \times 195{,}105.59houses) = 760{,}911.8MWh$$
$$\text{People money} = (760{,}911.8MWh \times 0.05€/KWh) = 38{,}045{,}590€$$

We will then have 21,512,349€ + 38,045,590€ = 59,557,939€

Nothing to do with the land, but we can think that with the years the land will get cheaper, or because of a project like this, people with properties will increase their prices.

CHAPTER 4: RESULT AND DISCUSSION

If we simulate the Matlab code with the figures for Cantabria, we obtain the following:

We will ask you firstly the main figures for the design,according to the region we will do the analysis
Please,enter the number of inhabitants of the region: 593121
Please,enter the area of the region in km^2: 5321
Please,enter average people per house in the region: 3.04
Please,enter the annual average consume in the region per house in wh: 3250000
Please,enter the total energy consumed in the region in wh: 1.56*10^6*11.63*10^6
Please,enter the percentage of domestic consume in the region: 9.5

We will ask now for the specifications from the materials used for the installation
Please,enter the nominal power of the photovoltaic panels in watts: 230
Please,enter the efficiency of every panel: 14.13
Please,enter the large of the panel,in meters: 1.651
Please,enter the wide of the panel,in meters: 0.986
Please,enter the hours/years of sunlight in the region: 1639

We will estimate different figures in order to get an idea of the type of houses in the region
Please,enter the percentage of individual houses in the region: 20
We assume that what it is left correspond to flat buildings
Please,enter the average size of the roof for individual houses in m^2: 100
Please,enter the average size of the roof for flat buildings in m^2: 200
Please,enter the average number of families in a flat building: 50
Please,enter the price of meter square of land,in euros: 10

To obtain the number of batteries,we will ask you some data in order to be able to calculate the number of them
Please,enter the number of days of self autonomy: 4
Please,enter the nominal voltage of the battery: 12
Please,enter the maximum discharge (by default 0.7): 0.7
Please,enter the capacity of the battery in Ah: 249

Please,enter the price of the photovoltaic panels in €/wp: 0.5
Please,enter the price of structures used: 250
Please,enter the price of the inverter: 1150
Please,enter the price of the batteries used: 800

For domestic supply,we have the following amount of material:

The number of panels that we need to supply the domestic energy in the region are: 14285168.6789
We will be able to put in the roof of the individual houses are: 2397042.4478
We will be able to put in the roof of the flat buildings are: 383526.7916
Then, we will be able to put in the roofs of the buildings of the region: 2780569.2394

The number of panels we will be have to put in a solar farm are: 11504599.4395
We will need the following structures: 595215.3616
We will need the following inverters: 595215.3616
We will need the following batteries: 3986785.0225

For domestic supply,we have the following prices:

Photovoltaic panels will cost: 1642794398.0707
Structures will cost: 148803840.405
Inverters will cost: 684497665.8628
Batteries will cost: 3189428017.9736
Buying the land for the panels will cost: 453741401.8931
For domestic supply,the cost will be: 6119265324.2051

Talking about 20% of consume with photovoltaic panels,we have the following amount of material

The number of panels that we need are: 81746017.3975
We will need the following structures: 3406084.0582
We will need the following inverters: 3406084.0582
We will need the following batteries: 22814137.1749

For 20% renewable supply we have the following prices:

Photovoltaic panels will cost: 9400792000.7151
Structures will cost: 851521014.5575
Inverters will cost: 3916996666.9646
Batteries will cost: 18251309739.9382
Buying the land for the panels will cost: 3224062926.1583
For 20% renewable supply,the total cost will be: 35644682348.3337

Our installation will cost, comparing with another projects with similar procedures, around 43,535,753 €. We will have to add that number to the final cost of the design, that is 6,119,265,324.2051€, giving us a total of 6,162,801,077.2051€ and with the 18% of the Spanish Vat, the project will cost 7,272,105,271.10€

If we compare the figure with the money the government will support and the Spanish people would pay in order to get the renewable photovoltaic energy the sooner, we see that there will be needed at least 122 years to pay the installation.

We should not forget that taking the amount of materials we need is not an easy thing. We can estimate that 300,000 photovoltaic panels are done in a year (talking about Spain, and so transport will not be really expensive), and as we need 14,285,168.6789 panels, we will need at least 48 years (47.6172 years).

We have to think that guarantee for materials are about 25 years, so, we will have to replace the materials without having finished the installation.

Because of that, I have made an Excel table, in which I estimate that every year, the budget of the money that the government of Cantabria would provide will increase in a 1% of what it is stipulate for this year. With that premise, and also thinking that light bill would be increased by the same percentage, we can see that we would be able to pay the project in years 80 years.

If the budget would increase in a 5%, the installation would be paid in 40 years.

If we consider that the budget of Cantabria is the 5% of the total budget, instead of adding the different parts, we can see that, as the total budget is of 2,439,242,271€, the 5% of that is 121,962,113.55€, with the same supposition as before, increasing the budget in a 1%, the installation would be paid in 38 years. Now, increasing the budget in a 5%, it will be paid in 24 years. We see that just increasing a little bit the budget the government provide, we can easily pay the material and human work. We then have to see where to take the materials, because with just Spanish photovoltaic panels, we will be stacked.

Considering now the last developed photovoltaic panels we have talked about in the project, with an efficiency of 33.9% and incrementing the number of sunlight that the region have, for example, with the ones in Almeria [8], we see that the final figures are:

Month	T	R	H
January	12.3	2.48	191
February	13.0	3.21	191
March	15.0	4.47	228
April	16.8	5.28	250
May	19.8	6.42	299
June	23.8	6.94	322
July	26.0	6.89	338
August	26.4	6.04	312
September	23.5	4.90	257
October	20.2	3.76	221
November	15.7	2.53	187
December	13.1	2.17	176

Figure 11: Almeria data [8:Figure 11]

T = Average month temperature (°C)
R = Average month radiation (KWh/m^2/day)
H = Average sunny hour per month (hours)

We will ask you firstly the main figures for the design,according to the region we will do the analysis
Please,enter the number of inhabitants of the region: 593121
Please,enter the area of the region in km^2: 5321
Please,enter average people per house in the region: 3.04
Please,enter the annual average consume in the region per house in wh: 3250000
Please,enter the total energy consumed in the region in wh: 1.56*10^6*11.63*10^6
Please,enter the percentage of domestic consume in the region: 9.5

We will ask now for the specifications from the materials used for the installation
Please,enter the nominal power of the photovoltaic panels in watts: 230
Please,enter the efficiency of every panel: 33.9
Please,enter the large of the panel,in meters: 1.651
Please,enter the wide of the panel,in meters: 0.986

Please,enter the hours/years of sunlight in the region: 2972

We will estimate different figures in order to get an idea of the type of houses in the region
Please,enter the percentage of individual houses in the region: 20
We assume that what it is left correspond to flat buildings
Please,enter the average size of the roof for individual houses in m^2: 100
Please,enter the average size of the roof for flat buildings in m^2: 200
Please,enter the average number of families in a flat building: 50
Please,enter the price of meter square of land,in euros: 10

To obtain the number of batteries,we will ask you some data in order to be able to calculate the number of them
Please,enter the number of days of self autonomy: 4
Please,enter the nominal voltage of the battery: 12
Please,enter the maximum discharge (by default 0.7): 0.7
Please,enter the capacity of the battery in Ah: 249

Please,enter the price of the photovoltaic panels in €/wp: 0.5
Please,enter the price of structures used: 250
Please,enter the price of the inverter: 1150
Please,enter the price of the batteries used: 800

For domestic supply,we have the following amount of material:

The number of panels that we need to supply the domestic energy in the region are: 3283658.5059
We will be able to put in the roof of the individual houses are: 2397042.4478
We will be able to put in the roof of the flat buildings are: 383526.7916
Then, we will be able to put in the roofs of the buildings of the region: 2780569.2394
The number of panels we will be have to put in a solar farm are: 503089.2665
We will need the following structures: 136819.1044
We will need the following inverters: 136819.1044
We will need the following batteries: 3986785.0225

For domestic supply,we have the following prices:

Photovoltaic panels will cost: 377620728.1781
Structures will cost: 34204776.1031
Inverters will cost: 157341970.0742
Batteries will cost: 3189428017.9736
Buying the land for the panels will cost: 19841840.6708
For domestic supply,the cost will be: 3778437332.9998

Talking about 20% of consume with photovoltaic panels,we have the following amount of material

The number of panels that we need are: 18790538.0318
We will need the following structures: 782939.0847
We will need the following inverters: 782939.0847
We will need the following batteries: 22814137.1749

For 20% renewable supply we have the following prices:

Photovoltaic panels will cost: 2160911873.6526
Structures will cost: 195734771.1642
Inverters will cost: 900379947.3553
Batteries will cost: 18251309739.9382
Buying the land for the panels will cost: 741098819.9727
For 20% renewable supply,the total cost will be: 22249435152.083

Doing the same as we have done before, the cost of the installation would be 200,146,770€ that if we add it to the total domestic cost, 3,778,437,332.9998€, it gives us 3,978,584,102.9998€ with the 18% of the Spanish Vat, the final cost would be of 4,694,729,241.5398€

Recalculating with the previous example, we would just need 11 years to have the amount of photovoltaic panels needed.

If we see the number of years that we will have to pay, it solves out that we will need 79 years.

Increasing the budget in a 1%, we will need 58 years.

Increasing the budget in a 5%, we will need 32 years.

With a budget of the 5% from the total Cantabria budget, and increasing it 1%, we will need 25 years

Increasing finally the Cantabria budget in a 5% every year, we will need to pay the installation 18 years.

With these figures, we can see that being able of installing the project is also a question of good materials with an enough efficiency to reduce the number of modules, and so the structures, inverters and batteries.

We can do the same study about getting the 20% from renewable energy and we obtain:

For the first example, the number of panels are 81,746,017.3975. The cost for the installation would raise to 4,982,614,400€, added with the total cost of material, we would have to pay in total 40,627,296,748.3337€. Adding the 18% Vat, we have 47,940,210,163.0338€ in total. Using the same Excel table, increasing the 5% of the budget money, we would paid the project in 76 and 56 years respectably.

For the second example, with a number of panels of 18790538.0318 the cost of the installation would become 1,145,328,000 €. Adding the cost of the material, we would have to pay 23,394,763,152.083€. With the correspondent 18% Vat, the final price of the project would be 27,605,820,519.4579€. With the Excel table, we see that increasing in a percentage of 5% the money available, we would need 65 and 46 years respectably to pay the project.

CHAPTER 5: CONCLUSION

In this project I have analysed the feasibility of replacing domestic electricity supply in Cantabria, entirely with solar energy.

The main problem for the success of the project is the money it will cost and the not enough budget from the government to do it.

Maybe a good and possible solution is an improve in the efficiency of the materials we are dealing with, and an improvement of the economic of the country, in order to have more money for projects like this and start thinking in a more green way, just for the future generations and achieve the numbers from the Kyoto protocol [9] of generating a 20% from the energy consumed by renewable energies.

With that premise, we can conclude that out project would take the following figures:

Using the figures that we can deal now about efficiency and sun light hours:
47,940,210,163.0338€ to have profits in 56-67 years.

With a better efficiency and a little increased of the sun light hours:
27,605,820,519.4579€ to have profits in 46-65 years

My personal impression of how the project has been work out is positive, noticing that I can do a deep study in photovoltaic energy and give figures about the final project. I will try to, at least, with my nearest people, let them think about a world run by renewable energy as long as it is possible.

In conclusion, it must be noted that the project extends considerably the initial proposal. The proposal focussed on the design of a single solar power system. This was done in Chapter 3. I felt that it may be more important to determine feasibility of solar energy in Cantabria rather than just focussing in a single system.

FUTURE WORK:

This work can be extended by trying to come up with an optimal mix of energy supply for Cantabria. This requires an understanding of the cost associated with all the energy system such as nuclear, coal wind and hydro electricity. This was not studied in this project because of time limitations.

.

CHAPTER 6: REFERENCES

[1] *Resumen Plan de Energías Renovables 2005-2010*. Ministerio de Industria Turismo y Comercio. España 21 de Julio 2005.
http://www.minetur.gob.es/energia/desarrollo/EnergiaRenovable/Plan/Documents/ResumenPlanEnergiasRenov.pdf
[2] Energy Spain http://www.energy-spain.com/energia-solar/fv-inyeccion-a-red
[3] Conergy http://conergy.es/
[4] Iberdrola http://www.eve.es/jornadas/ponencias_jornadamarina/Iberdrola.pdf
[5] "Cinco grupos cántabros y dos líderes mundiales se llevan el concurso eólico", *El Diario Montañes*, June 19, 2010.
http://www.eldiariomontanes.es/v/20100619/cantabria/cinco-grupos-cantabros-lideres-20100619.html
[6] Adfer Dazne, "Nuevo récord de eficiencia en panel fotovoltaico", February 9, 2012.
http://blog.is-arquitectura.es/2012/02/09/record-de-eficiencia-en-paneles-fotovoltaicos-concentrados-semprius/
[7] Brittanica Online, http://www.britannica.com/
[8] Agencia Estatal de Meteorología. Ministerio de Agricultura, Alimentación y Medio Ambiente. http://www.aemet.es
[9] *Plan de Acción Nacional de Energías Renovables de España (Paner) 2011-2020*. España 30 Junio 2010.
http://www.minetur.gob.es/energia/desarrollo/EnergiaRenovable/Documents/20100630_PANER_Espanaversion_final.pdf
[10] *Plan Energético de Cantabria 2006-2011 Plenercan*
http://www.genercan.es/plan-energetico-de-cantabria
[11] Informe Red Eléctrica de España, 2010.
http://www.ree.es/sistema_electrico/pdf/infosis/Inf_Sis_Elec_REE_2010_ElSistElectporCCAA.pdf
[12] *Diseño de una cubierta fotovoltaica conectada a la red eléctrica e integrada en un edificio industrial*. España. http://es.scribd.com/doc/37252611/28/Calculo-de-sombras-y-distancia-entre-paneles
[13] *Real Decreto 1578/2008*. Ministerio de Industria, Turismo y Comercio. España 27 Septiembre 2008. http://www.boe.es/boe/dias/2008/09/27/pdfs/A39117-39125.pdf
[14] *Real Decreto 314/2006*. Ministerio de Vivienda. España 28 de Marzo 2006.
http://www.boe.es/boe/dias/2006/03/28/pdfs/A11816-11831.pdf
[15] A.M. 13 Octubre 2011 http://elrincondeantoniomartinez.es/2011/10/13/mapas-y-planos/
[16] Instituto Nacional de Estadística. http://www.ine.es/inebmenu/mnu_cifraspob.htm
[17] Institute for Energy and Transport
http://re.jrc.ec.europa.eu/pvgis/apps/pvreg.php?lang=en&map=europe
[18] Red Eléctrica de España. https://demanda.ree.es/demanda.html
[19] Batteries**,** Trojan J185H-AC 12V 249Ah C100
http://www.sfe-solar.com/suministros-fotovoltaica-aislada-autonoma/trojan-j185h-ac-12v-249ah-c100/
[20] José A. Alonso Lorenzo, "Boletín Solar Fotovoltaica Autonoma. Sunfields Europe". http://www.sfe-solar.com/calculo-sistemas-fotovoltaicos-aislados-autonomos/
[21] *Presupuestos Generales de la Comunidad Autónoma de Cantabria. Estado de ingresos y gastos 2012*. Gobierno de Cantabria.
http://www.cantabria.es/documents/16870/1513231/ESTADO+DE+INGRESOS+Y+GASTOS.pdf

CHAPTER 7: APPENDIX 1

Matlab Code:

```
%Photovoltaic panels for domestic use in Cantabria, Spain

clear all;

%We will ask first the principle data for the analysis of the design
disp('We will ask you firstly the main figures for the
design,according to the region we will do the analysis');
inhabitants_cantabria=input('Please,enter the number of inhabitants of
the region: ');
area_cantabria=input('Please,enter the area of the region in km^2: ');
people_house_cantabria=input('Please,enter average people per house in
the region: ');
average_consume=input('Please,enter the annual average consume in the
region per house in wh: ');
energy_consume_cantabria=input('Please,enter the total energy consumed
in the region in wh: ');

%As we are going to do the calculations for supplying the domestic
consume
%in the region,we ask for the percentage electricity consumed in the
region
domestic_percentage=input('Please,enter the percentage of domestic
consume in the region: ');
domestic_consume_cantabria=(domestic_percentage/100)*energy_consume_ca
ntabria;

%Specifications for the solar panels
disp(' ');
disp('We will ask now for the specifications from the materials used
for the installation');
nominal_power =input('Please,enter the nominal power of the
photovoltaic panels in watts: ');
efficiency_panel =input('Please,enter the efficiency of every panel:
');
large=input('Please,enter the large of the panel,in meters: ');
wide=input('Please,enter the wide of the panel,in meters: ');
dimension_panel =large*wide;
average_sunlight =input('Please,enter the hours/years of sunlight in
the region: ');

%We calculate numbers in order to get answer for our design
energy_panel = nominal_power *
(efficiency_panel/100)*average_sunlight; %wh each panel
number_houses_cantabria=inhabitants_cantabria /
people_house_cantabria;

%We will oversize the design in order to get the energy we need
without any inconvenience
%Oversizing the design in a 20%,we see that we will need 3900Kwh for
each house

oversizing_design_energy = ((20*average_consume) +
(average_consume*100))/100;
minimum_panels_house = oversizing_design_energy / energy_panel;
```

```
total_panels = number_houses_cantabria * minimum_panels_house; %Number
of panels to supply the domestic energy in cantabria

%We will calculate now the amount of panels we would be able to put in
the roofs of the houses and how many we will have to put in solar
farms
%Considering a percentage of individual houses and flat buildings,we
know how many of them we have
disp(' ');
disp('We will estimate different figures in order to get an idea of
the type of houses in the region ');
percentage_individual_houses=input('Please,enter the percentage of
individual houses in the region: ');
individual_houses = (percentage_individual_houses/100) *
number_houses_cantabria;
disp('We assume that what it is left correspond to flat buildings');
flat_houses = ((100-percentage_individual_houses)/100) *
number_houses_cantabria;
%We will estimate the size that we can take from the roofs in order to
put the panels
size_roof_individual_houses = input('Please,enter the average size of
the roof for individual houses in m^2: ');
area_individual_houses_avaliable = individual_houses *
size_roof_individual_houses; %Area avaliable for panels in individual
houses
panels_individual_houses = area_individual_houses_avaliable /
dimension_panel; %Panels we will be able to put in the roof of the
individual houses
%With flat buildings,we also have to think that there are more than
one family in the building
size_roof_flat_houses = input('Please,enter the average size of the
roof for flat buildings in m^2: ');
families=input('Please,enter the average number of families in a flat
building: ');
area_flat_houses_avaliable = flat_houses * size_roof_flat_houses /
families; %Area avaliable for panels in flat houses
panels_flat_houses = area_flat_houses_avaliable / dimension_panel;
%Panels we will be able to put in the roof of the individual houses

roof_panels = panels_individual_houses + panels_flat_houses; %Number
of panels we can put in the roof of the houses
land_panels = total_panels - roof_panels; %The rest of the panels we
will need to put them somewhere else,in a solar farm



%DOMESTIC FIGURES,using the percentage of the domestic energy consumed
in Cantabria
%Having in mind the inclination of the sunshine and the shadows, we
will need 12m between every line of structures, so,the area in the
ground would be the following, noticing that every structure would
have 24 modules,3x8

domestic_real_area_structure = 12*8*wide;
domestic_real_area_total = (domestic_real_area_structure *
land_panels)/24;
number_structures_domestic_land = land_panels / 24;

meter_square=input('Please,enter the price of meter square of land,in
euros: ');
```

```
cost_land_domestic_euro = domestic_real_area_total * meter_square;
%10€/m^2

%We will use an inverter for every 24 modules,so,we will need:
domestic_inverters = total_panels / 24;


%In order to get the number of batteries we will need,following the
steps, we get:
%Capacity_battery = C (A.h)
%C = E.N / V.Pd
%E = energy
disp(' ');
disp('To obtain the number of batteries,we will ask you some data in
order to be able to calculate the number of them');
N=input('Please,enter the number of days of self autonomy: ');
V=input('Please,enter the nominal voltage of the battery: ');
Pd=input('Please,enter the maximum discharge (by default 0.7): ');
capacity_battery = input('Please,enter the capacity of the battery in
Ah: ');

%Calculations for domestic use
E = (oversizing_design_energy / 365) * number_houses_cantabria;
capacity_domestic = (E*N) /( V*Pd);
number_batteries_domestic = capacity_domestic / capacity_battery;


%We will calculate now the price of the design in order to see if it
would be a good idea or if we should change something
disp(' ');
panel_price = input('Please,enter the price of the photovoltaic panels
in €/wp: ');
total_panel_price = total_panels * panel_price * nominal_power;
structure_price = input('Please,enter the price of structures used:');
total_structure_price = total_panels/24 * structure_price;
inverter_price = input('Please,enter the price of the inverter: ');
total_inverter_price = total_panels/24 * inverter_price;
battery_price = input('Please,enter the price of the batteries used:
');
total_battery_price = number_batteries_domestic * battery_price;

total_money_domestic =cost_land_domestic_euro + total_panel_price +
total_structure_price + total_inverter_price + total_battery_price;


%20%RENEWABLE ENERGY
%Thinking about supplying a 20% of the total energy by photovoltaic
panels,we will do the same analysis and we obtain:

%If we want to have the 20% of total energy with solar panels, we will
need the following:
twenty_energy = energy_consume_cantabria * 0.2; %wh in cantabria

%Oversizing in a 20% in order to get the minimum necesary

oversizing_twenty_energy = ((20*twenty_energy) +
(twenty_energy*100))/100;
panels_twenty_energy = oversizing_twenty_energy / energy_panel;
%Number of panels to supply the 20% energy of Cantabria
```

```
%This time,we will put every panel in the land,not in any roof and we
get
twenty_real_area_structure = 12*8*wide;
twenty_real_area_total = (twenty_real_area_structure *
panels_twenty_energy)/24;
number_structures_twenty_land = panels_twenty_energy / 24;
cost_land_twenty_euro = twenty_real_area_total * meter_square;
%10€/m^2 in euros

%The number of inverters this time will be
twenty_inverters = panels_twenty_energy / 24;

%Calculations for obtaining the 20% of renewable energy
E = (oversizing_twenty_energy / 365);
capacity_twenty = (E*N) /( V*Pd);
number_batteries_twenty = capacity_twenty / capacity_battery;

%We calculate the price of the design as we have done previously
twenty_total_panel_price = panels_twenty_energy * panel_price *
nominal_power;
twenty_total_structure_price = panels_twenty_energy/24 *
structure_price;
twenty_total_inverter_price = panels_twenty_energy/24 *
inverter_price;
twenty_total_battery_price = number_batteries_twenty * battery_price;
twenty_total_money =cost_land_twenty_euro + twenty_total_panel_price +
twenty_total_structure_price + twenty_total_inverter_price +
twenty_total_battery_price;

%FINAL FIGURES
%The final result for domestic supply are the following
disp(' ');
disp(' ');
disp('For domestic supply,we have the following amount of material:');
disp(' ');
disp(['The number of panels that we need to supply the domestic energy
in the region are: ',num2str(total_panels)]);
disp(['We will be able to put in the roof of the individual houses
are: ',num2str(panels_individual_houses)]);
disp(['We will be able to put in the roof of the flat buildings are:
',num2str(panels_flat_houses)]);
disp(['Then, we will be able to put in the roofs of the buildings of
the region: ',num2str(roof_panels)]);
disp(['The number of panels we will be have to put in a solar farm
are: ',num2str(land_panels)]);
disp(['We will need the following structures:
',num2str(total_panels/24)]);
disp(['We will need the following inverters:
',num2str(domestic_inverters)]);
disp(['We will need the following batteries:
',num2str(number_batteries_domestic)]);
disp(' ');
disp(' ');
disp('For domestic supply,we have the following prices:');
disp(' ');
disp(['Photovoltaic panels will cost: ',num2str(total_panel_price)]);
disp(['Structures will cost: ',num2str(total_structure_price)]);
disp(['Inverters will cost: ',num2str(total_inverter_price)]);
disp(['Batteries will cost: ',num2str(total_battery_price)]);
```

```
disp(['Buying the land for the panels will cost:
',num2str(cost_land_domestic_euro)]);
disp(['For domestic supply,the cost will be:
',num2str(total_money_domestic)]);

%The final result fot 20% renewable energy is the following
disp(' ');
disp(' ');
disp('Talking about 20% of consume with photovoltaic panels,we have
the following amount of material ');
disp(' ');
disp(['The number of panels that we need are:
',num2str(panels_twenty_energy)]);
disp(['We will need the following structures:
',num2str(panels_twenty_energy/24)]);
disp(['We will need the following inverters:
',num2str(twenty_inverters)]);
disp(['We will need the following batteries:
',num2str(number_batteries_twenty)]);
disp(' ');
disp(' ');
disp('For 20% renewable supply we have the following prices:')
disp(' ');
disp(['Photovoltaic panels will cost:
',num2str(twenty_total_panel_price)]);
disp(['Structures will cost:
',num2str(twenty_total_structure_price)]);
disp(['Inverters will cost: ',num2str(twenty_total_inverter_price)]);
disp(['Batteries will cost: ',num2str(twenty_total_battery_price)]);
disp(['Buying the land for the panels will cost:
',num2str(cost_land_twenty_euro)]);
disp(['For 20% renewable supply,the total cost will be:
',num2str(twenty_total_money)]);
```

cost example 1, domestic 'a'	7272105271
cost example 2, domestic 'b'	4694729242
cost example 1, renewable 'c'	47940210163
cost example 2, renewable 'd'	27605820519

1% incremented to the government money and people

year	1	2	3	4	5
government	21512349	21727472.49	21944747.21	22164194.69	22385836.63
people	38045590	38426045.9	38810306.36	39198409.42	39590393.52
addition	59557939	60153518.39	60755053.57	61362604.11	61976230.15
still to pay 'a'	7,212,547,332	7152393814	7091638760	7030276156	6968299926
still to pay 'b'	4635171303	4575017784	4514262731	4452900126	4390923896
still to pay 'c'	47,880,652,224	47,820,498,706	47,759,743,652	47,698,381,048	47,636,404,818
still to pay 'd'	27546262580	27486109062	27425354008	27363991404	27302015174

5% incremented to the goverment money and people

year	1	2	3	4	5
government	21512349	22587966.45	23717364.77	24903233.01	26148394.66
people	38045590	39947869.5	41945262.98	44042526.12	46244652.43
addition	59557939	62535835.95	65662627.75	68945759.13	72393047.09
still to pay 'a'	7,212,547,332	7150011496	7084348868	7015403109	6943010062
still to pay 'b'	4635171303	4572635467	4506972839	4438027080	4365634033
still to pay 'c'	47880652224	47818116388	47752453760	47683508001	47611114954
still to pay 'd'	27546262580	27483726745	27418064117	27349118358	27276725311

5% of the Cantabria budget

total Cantabria budget	2439242271
5% means:	121962113.6

1% incremented of the previous figure

year	1	2	3	4	5
government	121962113.6	123181734.7	124413552	125657687.6	126914264.4
addition	160007703.6	161607780.6	163223858.4	164856097	166504657.9
still to pay 'a'	7,272,105,271	7110497491	6947273632	6782417535	6615912877
still to pay 'b'	4534721538	4373113757	4209889899	4045033802	3878529144
still to pay 'c'	47780202459	47618594679	47455370820	47290514723	47124010066
still to pay 'd'	27445812816	27284205035	27120981177	26956125080	26789620422

5%incremented of Cantabria budget

year	1	2	3	4	5
government	121962113.6	128060219.2	134463230.2	141186391.7	148245711.3
addition	160007703.6	168008088.7	176408493.2	185228917.8	194490363.7
still to pay 'a'	7,112,097,568	6944089479	6767680986	6582452068	6387961704
still to pay 'b'	4534721538	4366713449	4190304956	4005076038	3810585675
still to pay 'c'	47780202459	47612194371	47435785878	47250556960	47056066596
still to pay 'd'	27445812816	27277804727	27101396234	26916167316	26721676952

6	7	8	9	10	11	12	13	14
22609695	22835791.95	23064149.87	23294791.37	23527739.28	23763016.67	24000646.84	24240653.31	24483059.84
39986297.45	40386160.43	40790022.03	41197922.25	41609901.47	42026000.49	42446260.49	42870723.1	43299430.33
62595992.45	63221952.38	63854171.9	64492713.62	65137640.76	65789017.16	66446907.33	67111376.41	67782490.17
6905703933	6842481981	6778627809	6714135096	6648997455	6583208438	6516761530	6449650154	6381867664
4328327904	4265105951	4201251780	4136759066	4071621425	4005832408	3939385501	3872274124	3804491634
47,573,808,825	47,510,586,873	47,446,732,701	47,382,239,987	47,317,102,347	47,251,313,330	47,184,866,422	47,117,755,046	47,049,972,556
27239419182	27176197229	27112343058	27047850344	26982712703	26916923686	26850476779	26783365402	26715582912

6	7	8	9	10	11	12	13	14
27455814.39	28828605.11	30270035.37	31783537.14	33372714	35041349.7	36793417.18	38633088.04	40564742.44
48556885.05	50984729.3	53533965.77	56210664.06	59021197.26	61972257.12	65070869.98	68324413.48	71740634.15
76012699.45	79813334.42	83804001.14	87994201.2	92393911.26	97013606.82	101864287.2	106957501.5	112305376.6
6866997363	6787184028	6703380027	6615385826	6522991915	6425978308	6324114021	6217156519	6104851143
4289621333	4209807999	4126003998	4038009796	3945615885	3848602278	3746737991	3639780490	3527475113
47535102255	47455288920	47371484919	47283490718	47191096807	47094083200	46992218913	46885261411	46772956035
27200712611	27120899277	27037095276	26949101074	26856707163	26759693556	26657829269	26550871768	26438566391

6	7	8	9	10	11	12	13	14
128183407.1	129465241.1	130759893.6	132067492.5	133388167.4	134722049.1	136069269.6	137429962.3	138804261.9
168169704.5	169851401.6	171549915.6	173265414.7	174998068.9	176748049.6	178515530.1	180300685.4	182103692.2
6447743173	6277891771	6106341856	5933076441	5758078372	5581330322	5402814792	5222514107	5040410415
3710359440	3540508038	3368958122	3195692708	3020694639	2843946589	2665431059	2485130374	2303026682
46955840361	46785988959	46614439044	46441173629	46266175560	46089427511	45910911981	45730611295	45548507603
26621450717	26451599316	26280049400	26106783986	25931785917	25755037867	25576522337	25396221652	25214117959

6	7	8	9	10	11	12	13	14
155657996.8	163440896.7	171612941.5	180193588.6	189203268	198663431.4	208596603	219026433.2	229977754.8
204214881.9	214425626	225146907.3	236404252.7	248224465.3	260635688.6	273667473	287350846.6	301718389
6183746822	5969321196	5744174289	5507770036	5259545571	4998909882	4725242409	4437891563	4136173174
3606370793	3391945167	3166798259	2930394007	2682169541	2421533853	2147866380	1860515533	1558797144
46851851714	46637426088	46412279181	46175874928	45927650463	45667014774	45393347301	45105996455	44804278066
26517462071	26303036445	26077889537	25841485285	25593260819	25332625131	25058957658	24771606811	24469888422

15	16	17	18	19	20	21	22	23
24727890.44	24975169.35	25224921.04	25477170.25	25731941.95	25989261.37	26249153.99	26511645.53	26776761.98
43732424.63	44169748.88	44611446.37	45057560.83	45508136.44	45963217.8	46422849.98	46887078.48	47355949.27
68460315.07	69144918.22	69836367.41	70534731.08	71240078.39	71952479.18	72672003.97	73398724.01	74132711.25
6313407349	6244262430	6174426063	6103891332	6032651254	5960698774	5888026770	5814628046	5740495335
3736031319	3666886401	3597050033	3526515302	3455275224	3383322745	3310650741	3237252017	3163119306
46,981,512,241	46,912,367,322	46,842,530,955	46,771,996,224	46,700,756,145	46,628,803,666	46,556,131,662	46,482,732,938	46,408,600,227
26647122597	26577977679	26508141311	26437606580	26366366502	26294414023	26221742019	26148343295	26074210583

15	16	17	18	19	20	21	22	23
42592979.56	44722628.54	46958759.97	49306697.97	51772032.87	54360634.51	57078666.23	59932599.55	62929229.52
75327665.86	79094049.15	83048751.61	87201189.19	91561248.65	96139311.08	100946276.6	105993590.5	111293270
117920645.4	123816677.7	130007511.6	136507887.2	143333281.5	150499945.6	158024942.9	165926190	174222499.5
5986930497	5863113820	5733106308	5596598421	5453265139	5302765194	5144740251	4978814061	4804591561
3409554468	3285737790	3155730278	3019222391	2875889110	2725389164	2567364221	2401438031	2227215532
46655035389	46531218711	46401211200	46264703313	46121370031	45970870086	45812845143	45646918953	45472696453
26320645746	26196829068	26066821556	25930313669	25786980388	25636480442	25478455499	25312529309	25138306810

15	16	17	18	19	20	21	22	23
140192304.5	141594227.6	143010169.8	144440271.5	145884674.3	147343521	148816956.2	150305125.8	151808177
183924729.2	185763976.4	187621616.2	189497832.4	191392810.7	193306738.8	195239806.2	197192204.2	199164126.3
4856485685	4670721709	4483100093	4293602260	4102209450	3908902711	3713662905	3516470701	3317306574
2119101952	1933337976	1745716360	1556218527	1364825717	1171518978	976279171.7	779086967.4	579922841.1
45364582874	45178818897	44991197281	44801699449	44610306638	44416999899	44221760093	44024567889	43825403763
25030193230	24844429254	24656807638	24467309805	24275916995	24082610256	23887370450	23690178245	23491014119

15	16	17	18	19	20	21	22	23
241476642.6	253550474.7	266227998.4	279539398.3	293516368.3	308192186.7	323601796	339781885.8	356770980.1
316804308.4	332644523.8	349276750	366740587.5	385077616.9	404331497.7	424548072.6	445775476.3	468064250.1
3819368865	3486724342	3137447592	2770707004	2385629387	1981297889	1556749817	1110974341	642910090.4
1241992836	909348312	560071562	193330974.5	-191746642.4	-596078140.2	-1020626213	-1466401689	-1934465939
44487473757	44154829234	43805552483	43438811896	43053734279	42649402781	42224854709	41779079232	41311014982
24153084114	23820439590	23471162840	23104422252	22719344636	22315013138	21890465065	21444689589	20976625339

24	25	26	27	28	29	30	31	32
27044529.6	27314974.9	27588124.65	27864005.89	28142645.95	28424072.41	28708313.13	28995396.27	29285350.23
47829508.76	48307803.85	48790881.89	49278790.7	49771578.61	50269294.4	50771987.34	51279707.21	51792504.29
74874038.36	75622778.74	76379006.53	77142796.6	77914224.56	78693366.81	79480300.48	80275103.48	81077854.52
5665621297	5589998518	5513619511	5436476715	5358562490	5279869124	5200388823	5120113720	5039035865
3088245267	3012622488	2936243482	2859100685	2781186461	2702493094	2623012793	2542737690	2461659835
46,333,726,189	46,258,103,410	46,181,724,403	46,104,581,607	46,026,667,382	45,947,974,015	45,868,493,715	45,788,218,611	45,707,140,757
25999336545	25923713766	25847334760	25770191963	25692277739	25613584372	25534104071	25453828968	25372751113

24	25	26	27	28	29	30	31	32
66075691	69379475.55	72848449.33	76490871.79	80315415.38	84331186.15	88547745.46	92975132.73	97623889.37
116857933.5	122700830.2	128835871.7	135277665.3	142041548.5	149143625.9	156600807.2	164430847.6	172652390
182933624.5	192080305.7	201684321	211768537.1	222356963.9	233474812.1	245148552.7	257405980.3	270276279.4
4621657937	4429577631	4227893310	4016124773	3793767809	3560292997	3315144444	3057738464	2787462185
2044281907	1852201601	1650517280	1438748743	1216391780	982916967.4	737768414.7	480362434.4	210086155
45289762829	45097682523	44895998202	44684229665	44461872701	44228397889	43983249336	43725843356	43455567076
24955373185	24763292879	24561608558	24349840021	24127483057	23894008245	23648859693	23391453712	23121177433

24	25	26	27	28	29	30	31	32
153326258.8	154859521.4	156408116.6	157972197.8	159551919.7	161147438.9	162758913.3	164386502.5	166030367.5
201155767.6	203167325.2	205198998.5	207250988.5	209323498.4	211416733.3	213530900.7	215666209.7	217822871.8
3116150807	2912983481	2707784483	2500533495	2291209996	2079793263	1866262362	1650596152	1432773281
378767073.6	175599748.4	-29599250.12	-236850238.6	-446173736.9	-657590470.3	-871121370.9	-1086787581	-1304610452
43624247995	43421080670	43215881671	43008630683	42799307185	42587890451	42374359551	42158693341	41940870469
23289858352	23086691026	22881492028	22674241039	22464917541	22253500808	22039969907	21824303697	21606480826

24	25	26	27	28	29	30	31	32
374609529.1	393340005.5	413007005.8	433657356.1	455340223.9	478107235.1	502012596.9	527113226.7	553468888.1
491467462.6	516040835.7	541842877.5	568935021.4	597381772.4	627250861.1	658613404.1	691544074.3	726121278
151442627.8	-364598207.9	-906441085.4	-1475376107	-2072757879	-2700008740	-3358622144	-4050166219	-4776287497
-2425933402	-2941974237	-3483817115	-4052752136	-4650133909	-5277384770	-5935998174	-6627542248	-7353663526
40819547520	40303506684	39761663807	39192728785	38595347013	37968096152	37309482748	36617938673	35891817395
20485157876	19969117040	19427274163	18858339142	18260957369	17633706508	16975093104	16283549030	15557427752

33	34	35	36	37	38	39	40	41
29578203.73	29873985.77	30172725.63	30474452.88	30779197.41	31086989.39	31397859.28	31711837.87	32028956.25
52310429.33	52833533.62	53361868.96	53895487.65	54434442.53	54978786.95	55528574.82	56083860.57	56644699.17
81888633.06	82707519.39	83534594.59	84369940.53	85213639.94	86065776.34	86926434.1	87795698.44	88673655.42
4957147232	4874439713	4790905118	4706535177	4621321538	4535255761	4448329327	4360533629	4271859973
2379771202	2297063683	2213529088	2129159148	2043945508	1957879732	1870953298	1783157599	1694483944
45,625,252,124	45,542,544,604	45,459,010,010	45,374,640,069	45,289,426,429	45,203,360,653	45,116,434,219	45,028,638,521	44,939,964,865
25290862480	25208154961	25124620366	25040250426	24955036786	24868971010	24782044575	24694248877	24605575222

33	34	35	36	37	38	39	40	41
102505083.8	107630338	113011854.9	118662447.7	124595570.1	130825348.6	137366616	144234946.8	151446694.1
181285009.5	190349260	199866723	209860059.1	220353062.1	231370715.2	242939250.9	255086213.5	267840524.1
283790093.3	297979598	312878577.9	328522506.8	344948632.1	362196063.7	380305866.9	399321160.3	419287218.3
2503672091	2205692493	1892813915	1564291409	1219342776	857146712.7	476840845.8	77519685.55	-341767532.7
-73703938.3	-371683536.3	-684562114.2	-1013084621	-1358033253	-1720229317	-2100535184	-2499856344	-2919143562
43171776983	42873797385	42560918807	42232396300	41887447668	41525251605	41144945738	40745624577	40326337359
22837387340	22539407742	22226529164	21898006657	21553058025	21190861961	20810556094	20411234934	19991947716

33	34	35	36	37	38	39	40	41
167690671.2	169367577.9	171061253.6	172771866.2	174499584.8	176244580.7	178007026.5	179787096.8	181584967.7
220001100.5	222201111.5	224423122.6	226667353.8	228934027.4	231223367.6	233535601.3	235870957.3	238229666.9
1212772180	990571068.7	766147946.1	539480592.3	310546564.9	79323197.28	-154212404	-390083361.4	-628313028.3
-1524611553	-1746812664	-1971235787	-2197903141	-2426837168	-2658060536	-2891596137	-3127467094	-3365696761
41720869369	41498668257	41274245134	41047577781	40818643753	40587420386	40353884784	40118013827	39879784160
21386479725	21164278614	20939855491	20713188137	20484254110	20253030742	20019495141	19783624183	19545394517

33	34	35	36	37	38	39	40	41
581142332.5	610199449.1	640709421.5	672744892.6	706382137.2	741701244.1	778786306.3	817725621.6	858611902.7
762427341.9	800548709	840576144.5	882604951.7	926735199.3	973071959.3	1021725557	1072811835	1126452427
-5538714839	-6339263548	-7179839692	-8062444644	-8989179843	-9962251802	-10983977360	-12056789195	-13183241622
-8116090868	-8916639577	-9757215722	-10639820673	-11566555873	-12539627832	-13561353389	-14634165224	-15760617651
35129390053	34328841344	33488265200	32605660248	31678925049	30705853089	29684127532	28611315697	27484863270
14795000410	13994451701	13153875556	12271270604	11344535405	10371463446	9349737889	8276926054	7150473627

42	43	44	45	46	47	48	49	50
32349245.81	32672738.27	32999465.65	33329460.31	33662754.91	33999382.46	34339376.29	34682770.05	35029597.75
57211146.17	57783257.63	58361090.2	58944701.11	59534148.12	60129489.6	60730784.49	61338092.34	61951473.26
89560391.98	90455995.9	91360555.86	92274161.42	93196903.03	94128872.06	95070160.78	96020862.39	96981071.01
4182299581	4091843585	4000483030	3908208868	3815011965	3720883093	3625812932	3529792070	3432810999
1604923552	1514467556	1423107000	1330832839	1237635935	1143507063	1048436903	952416040.3	855434969.3
44,850,404,473	44,759,948,477	44,668,587,921	44,576,313,760	44,483,116,857	44,388,987,985	44,293,917,824	44,197,896,962	44,100,915,891
24516014830	24425558834	24334198278	24241924116	24148727213	24054598341	23959528181	23863507318	23766526247

42	43	44	45	46	47	48	49	50
159019028.8	166969980.3	175318479.3	184084403.3	193288623.4	202953054.6	213100707.3	223755742.7	234943529.8
281232550.4	295294177.9	310058886.8	325561831.1	341839922.7	358931918.8	376878514.7	395722440.5	415508562.5
440251579.2	462264158.2	485377366.1	509646234.4	535128546.1	561884973.4	589979222.1	619478183.2	650452092.3
-782019111.9	-1244283270	-1729660636	-2239306870	-2774435417	-3336320390	-3926299612	-4545777795	-5196229887
-3359395141	-3821659300	-4307036666	-4816682900	-5351811446	-5913696420	-6503675642	-7123153825	-7773605917
39886085780	39423821622	38938444256	38428798021	37893669475	37331784502	36741805280	36122327097	35471875004
19551696136	19089431978	18604054612	18094408378	17559279832	16997394858	16407415636	15787937453	15137485361

42	43	44	45	46	47	48	49	50
183400817.4	185234825.6	187087173.8	188958045.6	190847626	192756102.3	194683663.3	196630500	198596805
240611963.6	243018083.2	245448264	247902746.7	250381774.2	252885591.9	255414447.8	257968592.3	260548278.2
-868924991.9	-1111943075	-1357391339	-1605294086	-1855675860	-2108561452	-2363975900	-2621944492	-2882492770
-3606308725	-3849326808	-4094775072	-4342677819	-4593059593	-4845945185	-5101359633	-5359328225	-5619876503
39639172196	39396154113	39150705849	38902803103	38652421328	38399535736	38144121289	37886152696	37625604418
19304782553	19061764470	18816316206	18568413459	18318031685	18065146093	17809731645	17551763053	17291214775

42	43	44	45	46	47	48	49	50
901542497.8	946619622.7	993950603.9	1043648134	1095830541	1150622068	1208153171	1268560830	1331988871
1182775048	1241913801	1304009491	1369209965	1437670463	1509553987	1585031686	1664283270	1747497434
-14366016670	-15607930470	-16911939961	-18281149926	-19718820390	-21228374376	-22813406062	-24477689332	-26225186766
-16943392699	-18185306500	-19489315991	-20858525956	-22296196419	-23805750406	-25390782092	-27055065362	-28802562796
26302088222	25060174421	23756164931	22386954966	20949284502	19439730516	17854698830	16190415560	14442918126
5967698579	4725784778	3421775287	2052565322	614894858.7	-894659127.9	-2479690814	-4143974084	-5891471518

51	52	53	54	55	56	57	58	59
35379893.73	35733692.67	36091029.59	36451939.89	36816459.29	37184623.88	37556470.12	37932034.82	38311355.17
62570987.99	63196697.87	63828664.85	64466951.5	65111621.02	65762737.23	66420364.6	67084568.25	67755413.93
97950881.72	98930390.54	99919694.45	100918891.4	101928080.3	102947361.1	103976834.7	105016603.1	106066769.1
3334860117	3235929727	3136010032	3035091141	2933163060	2830215699	2726238865	2621222262	2515155492
757484087.5	658553697	558634002.5	457715111.2	355787030.9	252839669.7	148862835	43846231.96	-62220537.13
44,002,965,009	43,904,034,618	43,804,114,924	43,703,196,033	43,601,267,952	43,498,320,591	43,394,343,756	43,289,327,153	43,183,260,384
23668575365	23569644975	23469725280	23368806389	23266878309	23163930948	23059954113	22954937510	22848870741

51	52	53	54	55	56	57	58	59
246690706.3	259025241.6	271976503.7	285575328.9	299854095.3	314846800.1	330589140.1	347118597.1	364474527
436283990.6	458098190.1	481003099.7	505053254.6	530305917.4	556821213.2	584662273.9	613895387.6	644590157
682974696.9	717123431.8	752979603.4	790628583.5	830160012.7	871668013.3	915251414	961013984.7	1009064684
-5879204584	-6596328016	-7349307620	-8139936203	-8970096216	-9841764229	-10757015643	-11718029628	-12727094312
-8456580614	-9173704046	-9926683649	-10717312233	-11547472245	-12419140259	-13334391673	-14295405657	-15304470341
34788900308	34071776876	33318797272	32528168689	31698008676	30826340663	29911089249	28950075264	27941010580
14454510664	13737387232	12984407629	12193779045	11363619033	10491951019	9576699605	8615685621	7606620937

51	52	53	54	55	56	57	58	59
200582773	202588600.7	204614486.7	206660631.6	208727237.9	210814510.3	212922655.4	215051882	217202400.8
263153761	265785298.6	268443151.6	271127583.1	273838858.9	276577247.5	279343020	282136450.2	284957814.7
-3145646531	-3411431830	-3679874981	-3951002565	-4224841423	-4501418671	-4780761691	-5062898141	-5347855956
-5883030264	-6148815563	-6417258715	-6688386298	-6962225157	-7238802404	-7518145424	-7800281874	-8085239689
37362450657	37096665359	36828222207	36557094624	36283255765	36006678517	35727335497	35445199047	35160241232
17028061014	16762275715	16493832563	16222704980	15948866121	15672288874	15392945854	15110809404	14825851589

51	52	53	54	55	56	57	58	59
1398588315	1468517731	1541943617	1619040798	1699992838	1784992480	1874242104	1967954209	2066351919
1834872305	1926615921	2022946717	2124094053	2230298755	2341813693	2458904378	2581849596	2710942076
-28060059071	-29986674992	-32009621709	-34133715761	-36364014517	-38705828210	-41164732587	-43746582184	-46457524260
-30637435101	-32564051022	-34586997738	-36711091791	-38941390546	-41283204239	-43742108617	-46323958213	-49034900289
12608045820	10681429900	8658483183	6534389130	4304090375	1962276682	-496627695.2	-3078477292	-5789419368
-7726343823	-9652959744	-11675906461	-13800000513	-16030299268	-18372112961	-20831017339	-23412866935	-26123809011

60	61	62	63	64	65	66	67	68
38694468.72	39081413.41	39472227.54	39866949.82	40265619.31	40668275.51	41074958.26	41485707.85	41900564.92
68432968.07	69117297.75	69808470.73	70506555.43	71211620.99	71923737.2	72642974.57	73369404.31	74103098.36
107127436.8	108198711.2	109280698.3	110373505.2	111477240.3	112592012.7	113717932.8	114855112.2	116003663.3
2408028056	2299829344	2190548646	2080175141	1968697901	1856105888	1742387955	1627532843	1511529180
-169347973.9	-277546685.1	-386827383.3	-497200888.6	-608678128.9	-721270141.6	-834988074.4	-949843186.6	-1065846850
43,076,132,948	42,967,934,236	42,858,653,538	42,748,280,033	42,636,802,793	42,524,210,780	42,410,492,847	42,295,637,735	42,179,634,072
22741743304	22633544593	22524263895	22413890389	22302413149	22189821136	22076103203	21961248091	21845244428

60	61	62	63	64	65	66	67	68
382698253.3	401833166	421924824.3	443021065.5	465172118.8	488430724.7	512852261	538494874	565419617.7
676819664.8	710660648.1	746193680.5	783503364.5	822678532.7	863812459.3	907003082.3	952353236.4	999970898.3
1059517918	1112493814	1168118505	1226524430	1287850651	1352243184	1419855343	1490848110	1565390516
-13786612230	-14899106044	-16067224549	-17293748979	-18581599630	-19933842814	-21353698158	-22844546268	-24409936784
-16363988259	-17476482074	-18644600578	-19871125008	-21158975660	-22511218844	-23931074187	-25421922298	-26987312814
26881492662	25768998848	24600880343	23374355913	22086505262	20734262078	19314406734	17823558624	16258168108
6547103018	5434609204	4266490700	3039966270	1752115618	399872434.1	-1019982909	-2510831020	-4076221536

60	61	62	63	64	65	66	67	68
219374424.8	221568169	223783850.7	226021689.2	228281906.1	230564725.2	232870372.4	235199076.2	237551066.9
287807392.9	290685466.8	293592321.5	296528244.7	299493527.1	302488462.4	305513347	308568480.5	311654165.3
-5635663349	-5926348816	-6219941137	-6516469382	-6815962909	-7118451371	-7423964718	-7732533199	-8044187364
-8373047082	-8663732549	-8957324870	-9253853115	-9553346642	-9855835104	-10161348451	-10469916932	-10781571097
34872433840	34581748373	34288156051	33991627807	33692134280	33389645817	33084132470	32775563990	32463909824
14538044196	14247358729	13953766408	13657238163	13357744636	13055256174	12749742827	12441174346	12129520181

60	61	62	63	64	65	66	67	68
2169669515	2278152991	2392060641	2511663673	2637246856	2769109199	2907564659	3052942892	3205590037
2846489180	2988813639	3138254321	3295167037	3459925389	3632921658	3814567741	4005296128	4205560935
-49304013440	-52292827079	-55431081400	-58726248437	-62186173826	-65819095485	-69633663226	-73638959354	-77844520289
-51881389470	-54870203109	-58008457430	-61303624467	-64763549856	-68396471514	-72211039255	-76216335384	-80421896319
-8635908548	-11624722187	-14762976508	-18058143545	-21518068934	-25150990593	-28965558334	-32970854462	-37176415397
-28970298192	-31959111831	-35097366152	-38392533189	-41852458578	-45485380236	-49299947978	-53305244106	-57510805041

69	70	71	72	73	74	75	76	77
42319570.57	42742766.28	43170193.94	43601895.88	44037914.84	44478293.99	44923076.93	45372307.7	45826030.77
74844129.34	75592570.63	76348496.34	77111981.3	77883101.12	78661932.13	79448551.45	80243036.96	81045467.33
117163699.9	118335336.9	119518690.3	120713877.2	121921016	123140226.1	124371628.4	125615344.7	126871498.1
1394365480	1276030143	1156511453	1035797575	913876559.4	790736333.3	666364704.9	540749360.3	413877862.2
-1183010550	-1301345887	-1420864577	-1541578454	-1663499470	-1786639696	-1911011325	-2036626669	-2163498167
42,062,470,372	41,944,135,035	41,824,616,344	41,703,902,467	41,581,981,451	41,458,841,225	41,334,469,597	41,208,854,252	41,081,982,754
21728080728	21609745391	21490226701	21369512824	21247591808	21124451582	21000079953	20874464609	20747593111

69	70	71	72	73	74	75	76	77
593690598.6	623375128.5	654543884.9	687271079.2	721634633.1	757716364.8	795602183	835382292.2	877151406.8
1049969443	1102467915	1157591311	1215470877	1276244420	1340056642	1407059474	1477412447	1551283070
1643660042	1725843044	1812135196	1902741956	1997879054	2097773006	2202661657	2312794739	2428434476
-26053596826	-27779439870	-29591575066	-31494317021	-33492196075	-35589969081	-37792630738	-40105425477	-42533859954
-28630972855	-30356815899	-32168951095	-34071693051	-36069572105	-38167345111	-40370006768	-42682801507	-45111235983
14614508066	12888665022	11076529826	9173787870	7175908817	5078135811	2875474154	562679414.5	-1865755062
-5719881577	-7445724621	-9257859817	-11160601773	-13158480827	-15256253833	-17458915490	-19771710229	-22200144705

69	70	71	72	73	74	75	76	77
239926577.6	242325843.4	244749101.8	247196592.8	249668558.8	252165244.3	254686896.8	257233765.7	259806103.4
314770706.9	317918414	321097598.1	324308574.1	327551659.9	330827176.5	334135448.2	337476802.7	340851570.7
-8358958071	-8676876485	-8997974083	-9322282657	-9649834317	-9980661493	-10314796942	-10652273744	-10993125315
-11096341804	-11414260218	-11735357816	-12059666390	-12387218050	-12718045227	-13052180675	-13389657478	-13730509048
32149139117	31831220703	31510123105	31185814531	30858262871	30527435695	30193300247	29855823444	29514971873
11814749474	11496831060	11175733462	10851424888	10523873228	10193046051	9858910603	9521433800	9180582230

69	70	71	72	73	74	75	76	77
3365869538	3534163015	3710871166	3896414724	4091235461	4295797234	4510587095	4736116450	4972922273
4415838982	4636630931	4868462477	5111885601	5367479881	5635853875	5917646569	6213528897	6524205342
-82260359271	-86896990201	-91765452679	-96877338280	-1.02245E+11	-1.07881E+11	-1.13798E+11	-1.20012E+11	-1.26536E+11
-84837735300	-89474366231	-94342828708	-99454714309	-1.04822E+11	-1.10458E+11	-1.16376E+11	-1.22589E+11	-1.29113E+11
-41592254379	-46228885309	-51097347787	-56209233388	-61576713269	-67212567144	-73130213713	-79343742610	-85867947952
-61926644022	-66563274953	-71431737430	-76543623031	-81911102912	-87546956787	-93464603356	-99678132254	-1.06202E+11

78	79	80	81	82	83	84	85	86
46284291.08	46747133.99	47214605.33	47686751.39	48163618.9	48645255.09	49131707.64	49623024.72	50119254.96
81855922.01	82674481.23	83501226.04	84336238.3	85179600.68	86031396.69	86891710.66	87760627.76	88638234.04
128140213.1	129421615.2	130715831.4	132022989.7	133343219.6	134676651.8	136023418.3	137383652.5	138757489
285737649.1	156316033.9	25600202.5	-106422787.2	-239766006.8	-374442658.6	-510466076.8	-647849729.3	-786607218.3
-2291638380	-2421059996	-2551775827	-2683798817	-2817142036	-2951818688	-3087842106	-3225225759	-3363983248
40,953,842,541	40,824,420,926	40,693,705,094	40,561,682,105	40,428,338,885	40,293,662,233	40,157,638,815	40,020,255,163	39,881,497,674
20619452897	20490031282	20359315451	20227292461	20093949242	19959272590	19823249172	19685865519	19547108030

78	79	80	81	82	83	84	85	86
921008977.1	967059426	1015412397	1066183017	1119492168	1175466776	1234240115	1295952121	1360749727
1628847223	1710289584	1795804063	1885594267	1979873980	2078867679	2182811063	2291951616	2406549197
2549856200	2677349010	2811216461	2951777284	3099366148	3254334455	3417051178	3587903737	3767298924
-45083716154	-47761065164	-50572281625	-53524058909	-56623425057	-59877759512	-63294810691	-66882714428	-70650013352
-47661092184	-50338441194	-53149657655	-56101434938	-59200801086	-62455135542	-65872186720	-69460090457	-73227389381
-4415611262	-7092960272	-9904176733	-12855954017	-15955320165	-19209654620	-22626705799	-26214609536	-29981908460
-24750000906	-27427349916	-30238566377	-33190343661	-36289709809	-39544044264	-42961095442	-46548999179	-50316298103

78	79	80	81	82	83	84	85	86
262404164.4	265028206.1	267678488.1	270355273	273058825.8	275789414	278547308.2	281332781.2	284146109
344260086.4	347702687.3	351179714.2	354691511.3	358238426.4	361820810.7	365439018.8	369093409	372784343.1
-11337385402	-11685088089	-12036267803	-12390959314	-12749197741	-13111018552	-13476457570	-13845550979	-14218335322
-14074769135	-14422471822	-14773651536	-15128343048	-15486581474	-15848402285	-16213841304	-16582934713	-16955719056
29170711787	28823009099	28471829385	28117137874	27758899447	27397078637	27031639618	26662546209	26289761866
8836322143	8488619456	8137439742	7782748230	7424509804	7062688993	6697249974	6328156565	5955372222

78	79	80	81	82	83	84	85	86
5221568386	5482646806	5756779146	6044618103	6346849008	6664191459	6997401032	7347271083	7714634637
6850415609	7192936390	7552583209	7930212370	8326722988	8743059138	9180212095	9639222699	10121183834
-1.33386E+11	-1.40579E+11	-1.48132E+11	-1.56062E+11	-1.64389E+11	-1.73132E+11	-1.82312E+11	-1.91951E+11	-2.02073E+11
-1.35964E+11	-1.43157E+11	-1.50709E+11	-1.5864E+11	-1.66966E+11	-1.75709E+11	-1.8489E+11	-1.94529E+11	-2.0465E+11
-92718363562	-99911299951	-1.07464E+11	-1.15394E+11	-1.23721E+11	-1.32464E+11	-1.41644E+11	-1.51283E+11	-1.61404E+11
-1.13053E+11	-1.20246E+11	-1.27798E+11	-1.35728E+11	-1.44055E+11	-1.52798E+11	-1.61978E+11	-1.71618E+11	-1.81739E+11

87	88	89	90	91	92	93	94	95
50620447.51	51126651.99	51637918.51	52154297.69	52675840.67	53202599.08	53734625.07	54271971.32	54814691.03
89524616.38	90419862.55	91324061.17	92237301.78	93159674.8	94091271.55	95032184.26	95982506.11	96942331.17
140145063.9	141546514.5	142961979.7	144391599.5	145835515.5	147293870.6	148766809.3	150254477.4	151757022.2
-926752282.2	-1068298797	-1211260776	-1355652376	-1501487891	-1648781762	-1797548571	-1947803049	-2099560071
-3504128312	-3645674826	-3788636806	-3933028405	-4078863921	-4226157792	-4374924601	-4525179078	-4676936101
39,741,352,610	39,599,806,095	39,456,844,115	39,312,452,516	39,166,617,001	39,019,323,130	38,870,556,321	38,720,301,843	38,568,544,821
19406962966	19265416452	19122454472	18978062872	18832227357	18684933486	18536166677	18385912200	18234155177

87	88	89	90	91	92	93	94	95
1428787213	1500226574	1575237903	1653999798	1736699788	1823534777	1914711516	2010447092	2110969446
2526876657	2653220490	2785881514	2925175590	3071434369	3225006088	3386256392	3555569212	3733347672
3955663870	4153447064	4361119417	4579175388	4808134157	5048540865	5300967908	5566016304	5844317119
-74605677222	-78759124285	-83120243702	-87699419090	-92507553247	-97556094112	-1.02857E+11	-1.08423E+11	-1.14267E+11
-77183053251	-81336500315	-85697619732	-90276795119	-95084929276	-1.00133E+11	-1.05434E+11	-1.11E+11	-1.16845E+11
-33937572330	-38091019393	-42452138810	-47031314198	-51839448355	-56887989220	-62188957128	-67754973431	-73599290550
-54271961973	-58425409037	-62786528454	-67365703841	-72173837998	-77222378863	-82523346771	-88089363075	-93933680194

87	88	89	90	91	92	93	94	95
286987570.1	289857445.8	292756020.3	295683580.5	298640416.3	301626820.5	304643088.7	307689519.6	310766414.8
376512186.5	380277308.4	384080081.5	387920882.3	391800091.1	395718092	399675272.9	403672025.7	407708745.9
-14594847509	-14975124817	-15359204899	-15747125781	-16138925872	-16534643964	-16934319237	-17337991263	-17745700009
-17332231242	-17712508551	-18096588632	-18484509514	-18876309605	-19272027697	-19671702970	-20075374996	-20483083742
25913249679	25532972371	25148892289	24760971407	24369171316	23973453224	23573777951	23170105925	22762397180
5578860036	5198582727	4814502646	4426581764	4034781673	3639063581	3239388308	2835716282	2428007536

87	88	89	90	91	92	93	94	95
8100366369	8505384688	8930653922	9377186618	9846045949	10338348247	10855265659	11398028942	11967930389
10627243026	11158605177	11716535436	12302362208	12917480318	13563354334	14241522051	14953598153	15701278061
-2.127E+11	-2.23858E+11	-2.35575E+11	-2.47877E+11	-2.60795E+11	-2.74358E+11	-2.886E+11	-3.03553E+11	-3.19255E+11
-2.15277E+11	-2.26436E+11	-2.38152E+11	-2.50455E+11	-2.63372E+11	-2.76936E+11	-2.91177E+11	-3.06131E+11	-3.21832E+11
-1.72032E+11	-1.8319E+11	-1.94907E+11	-2.07209E+11	-2.20127E+11	-2.3369E+11	-2.47932E+11	-2.62885E+11	-2.78586E+11
-1.92366E+11	-2.03525E+11	-2.15241E+11	-2.27544E+11	-2.40461E+11	-2.54024E+11	-2.68266E+11	-2.8322E+11	-2.98921E+11

96	97	98	99	100
55362837.94	55916466.32	56475630.98	57040387.29	57610791.17
97911754.48	98890872.02	99879780.74	100878578.6	101887364.3
153274592.4	154807338.3	156355411.7	157918965.8	159498155.5
-2252834663	-2407642002	-2563997413	-2721916379	-2881414535
-4830210693	-4985018031	-5141373443	-5299292409	-5458790564
38,415,270,229	38,260,462,890	38,104,107,478	37,946,188,513	37,786,690,357
18080880585	17926073247	17769717835	17611798869	17452300714

96	97	98	99	100
2216517919	2327343815	2443711005	2565896556	2694191384
3920015056	4116015809	4321816599	4537907429	4764802800
6136532975	6443359623	6765527605	7103803985	7458994184
-1.20404E+11	-1.26847E+11	-1.33613E+11	-1.40717E+11	-1.48176E+11
-1.22981E+11	-1.29425E+11	-1.3619E+11	-1.43294E+11	-1.50753E+11
-79735823525	-86179183148	-92944710753	-1.00049E+11	-1.07508E+11
-1.0007E+11	-1.06514E+11	-1.13279E+11	-1.20383E+11	-1.27842E+11

96	97	98	99	100
313874078.9	317012819.7	320182947.9	323384777.4	326618625.1
411785833.4	415903691.7	420062728.6	424263355.9	428505989.5
-18157485842	-18573389534	-18993452263	-19417715618	-19846221608
-20894869575	-21310773267	-21730835996	-22155099352	-22583605341
22350611346	21934707654	21514644926	21090381570	20661875580
2016221703	1600318011	1180255282	755991926.3	327485936.9

96	97	98	99	100
12566326908	13194643254	13854375416	14547094187	15274448897
16486341964	17310659062	18176192015	19085001616	20039251697
-3.35741E+11	-3.53052E+11	-3.71228E+11	-3.90313E+11	-4.10352E+11
-3.38318E+11	-3.55629E+11	-3.73805E+11	-3.9289E+11	-4.12929E+11
-2.95073E+11	-3.12383E+11	-3.3056E+11	-3.49645E+11	-3.69684E+11
-3.15407E+11	-3.32718E+11	-3.50894E+11	-3.69979E+11	-3.90018E+11

CHAPTER 9: PRELIMINARY REPORT

The proposal of the project would be the analysis of production and the study of the profitability of the installation of solar panels connected to the power supply with a power of around 100Kwp

Photovoltaic Systems connected to power supply are in the “Plan de Fomento de las Energías Renovables” elaborated by the Spanish govern, meaning achieve the deals signed in the Kyoto protocol, in which it was said that the 12% of primary energy consumed in Spain has to come from renewable energy, in order to reduce in an important quantity the CO_2 emissions to the atmosphere.

A photovoltaic installation transforms light energy coming from the sun into electric energy that is injected to the power supply immediately, without any kind of storage battery. This process is done with photovoltaic solar modules that produce electric energy into direct current. This current is converted into alternating current with inverter. This is the current that we will inject into the power supply at the correct voltage and frequency. This energy would help to the reduction of the CO_2 emissions because of the decrease of power loss as power is generated near the points where it is consumed.

Our installation would have the following elements:

Photovoltaic modules
Solar inverter
Solar tracker
Monitoring elements

The connection with the power supply would be done where the electric company would agree with us. Near this point, there will be an electricity meter in order to be able to read the production accumulated in our system.