MARMARA UNIVERSITY
FACULTY OF ENGINEERING

Design and Development of 100 % Renewable Energy Cities in the Home Towns Case Study for Erzurum Province

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GRADUATION PROJECT REPORT

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MARMARA UNIVERSITY
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Design and Development of 100 % Renewable Energy Cities in the Home Towns Case Study for Erzurum Province

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Introduction

Nowadays people's energy consumption is increasing distruptively. Most of the countries started to focus on renewables because energy consumption is effecting our environment. The cities need clean energy in order to mitigate climate change and increase quality of life of the next generations. That is the reason we need to have an energy plan with renewables.

Gradual increase in energy consumption due to the global increase in population and urbanisation movements in parallel to the developing industry and advancing technology force people to search for new and environment friendly energy sources. On-time, economic, safe, constant and clean energy procurement has become one of the most important problems of the day when energy requirement has increasingly more significance not only in industry but also in the daily lives of people. As to the aforementioned importance of energy, the gradual increase in the demand towards energy causes fossil energy sources to be rapidly consumed. Diversifying energy sources and presenting renewable energy sources alongside with the traditional ones have become more and more important to establish a sustainable balance in energy procurement. Energy consumption of Turkey gradually increases in parallel to its attempts towards becoming a developed country. It is an energy importer country due to the lack of enough conventional energy sources which can be accepted as the driving motor of development. Electric energy demand of our country annually increases by 8 pct on average. Our country, just as the majority of all world countries, faces some short and long term problems in energy procurement. Turkey should at first attempt to increase the amount of energy acquired from new and renewable energy sources to cover basic requirements of society and realise economic expansion, refrain as much as possible from local and global environmental problems caused by energy consumption and production and especially reduce foreign-dependency in energy. This is valid for not only our country but also other countries of the world as the aforementioned problems shall be solved not only for today but also for the next generations and it can be achieved not by the countries themselves but by the joint effort of all.

Energy is indispensable both for economy and social and cultural life. Accordingly, it is an irrevocable necessity to present consumers constant and safe energy. The ever increasing energy demand, especially electric energy consumption, gaines parallel to development. When we analyse energy consumption data in our country, we see the rate of this increase augment by doublingevery tenyears. When we have a look at energy statistics of our country, we see that a significant amount of the consumed energy is constituted by fossil fuels. The overall share of fossil fuels nowadays to cover the required energy is generally around 80 pct. According to 2008 data, Turkey provides 31,5 pct of the energy it consumes from oil, 31,3 pct of the natural gas, 29,6 pct from coal and 7,6 pct from hydraulic and other renewable energy sources. However, 93 pct of the oil consumed, 85.8 pct of the coal and 97,5 pct of the natural gas is imported. When we make a general evaluation, we see that around 65-70 pct of the overall consumed energy is imported (WEC-TNC, 2009, 88).The energy demand of Turkey is anticipated to augment in the future which would lead to a rise in foreign-dependency. The overall energy demand of the country is envisaged to reach 126 millions tons oil equivalent (Mtoe) in 2010 and 222 Mtoe in 2020 (WEC-TNC, 2009, 89).

Table1 - Distribution of Turkish Energy Consumption According to Sources (In thousand toe)

Year	Hard Coal	Lignite	Asphaltite	Oil	Natural Gas	Hydro-Electric	Geo-thermal	
							Elec	Heat
1970	2 883	1 628	15	7 579	-	261	-	23
1980	2 824	4 299	240	15 309	21	976	-	60
1990	4 997	12 941	119	22 700	3 110	1 991	69	364
2000	9 390	18 156	9	31 072	13 729	2 656	65	648
2008	13 859	21 074	271	30 756	33 604	2 861	68	1 011

Year	Wind	Sun	Wood	Animal, Vegetable waste	Overall
1970	-	-	3 845	2 128	17 862
1980	-	-	4 730	2 953	31 412
1990	-	28	5 361	1 847	51 527
2000	3	262	5 081	1 376	82 447
2008	71	420	3 679	1 123	108 797

Source:Turkish Energy Report 2009, World Energy Council Turkish National Committee, p.88, Ankara.

The overall electric production of Turkey reached 198,2 billion kWh at the end of 2008. 49,7 pct of the produced electric energy was acquired from natural gas, 16,8 pct from hydraulic, 29 pct from coal, 3,8 pct from fuel oil. While 82,7 pct of electric production was from thermal power plants in 2008, 17,2 pct was from renewable energy sources. As it is clear in Table 2, electric production of our country generally relies upon natural gas. Around

2/3 of energy requirement of Turkey is covered by import which may cause unexpected problems to be confronted in achieving its sustainable development targets. It is required to use alternative energy sources to procure the required energy in a way to reduce external dependence. In this respect, the political stability recently attained by Turkey enhanced some enterprises on energy procurement to be realized. For instance, Nuclear Power Station tender, having been on the agenda for long years without being finally realized due to various reasons, is opened and a concrete step is taken to benefit from nuclear energy. Moreover, with the enforcement of renewable energy law, it is aimed to have possible developments not only in wind energy but also in solar, geo-thermal, bio-mass energy and energy production out of various wastes. It is always possible for the decision-makers to be influenced by changing governments when it comes to the realization of long-term plans in developing countries as Turkey. The political stability having attained in our country after so many years seems to have created appropriate environment for both medium and long-term preparation of energy policies and the realization of these plans. Alternative energy sources led by local and renewable sources are required to reduce energy dependency of the country. Activating alternative sources will provide energy supply security and reduce energy dependency on foreign countries. Therefore, hydroelectric production shall be initiated in Turkey not only on big rivers but also on small rivers pouring out the Black Sea coast. Besides, electric requirement of Turkey should be covered through the establishment of solar panels and wind energy facilities and thus foreign-dependency shall as much as possible be reduced.

Besides making hydroelectric power plants more widespread in the Black Sea region having the most amount of rainfall in Turkey, electric energy shall be procured through solar panels established on the southern slopes of Toros mountains having convenient conditions to produce solar energy and through the production centres to be established in the Southeast Anatolian Region. Besides, considering especially western and north western regions of our country are important fields for wind energy procurement, geographical superiority and convenience of various regions of Turkey have high importance in terms of our economic development.

As our energy production: The established electric capacity of Turkey increases in time. For instance, it was 9 122 MW in 1985, while it increased more than double in 1995 when compared to the figures of ten years ago to reach 20 954 MW and by the end of 2008, it augmented to overall 41 817 MW. When we have a look at the distribution of overall established capacity in terms of sources, we see 33 pct is covered by hydroelectric, 36 pct by natural gas and the remaining 11 pct by other sources. The established capacity according to sources is shown in graph 1.

Graph 1 - Distribution of Turkey’s Established Electric Power Production According to Sources (2008)

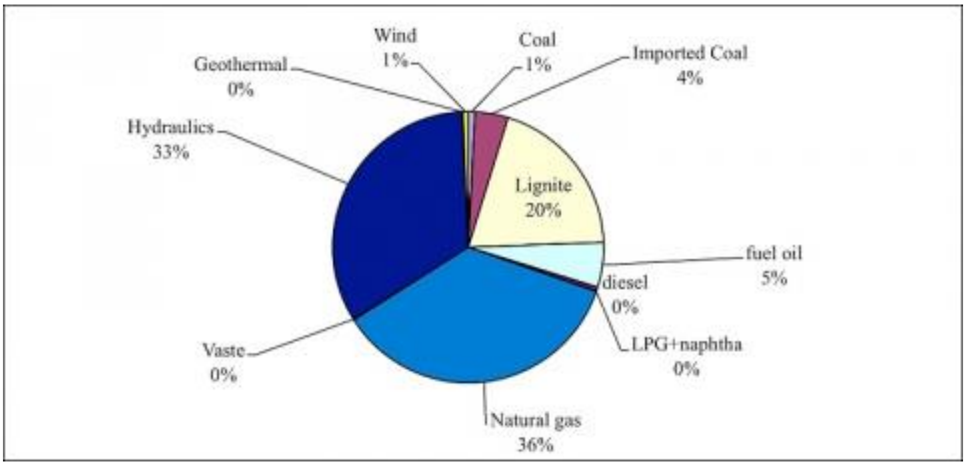
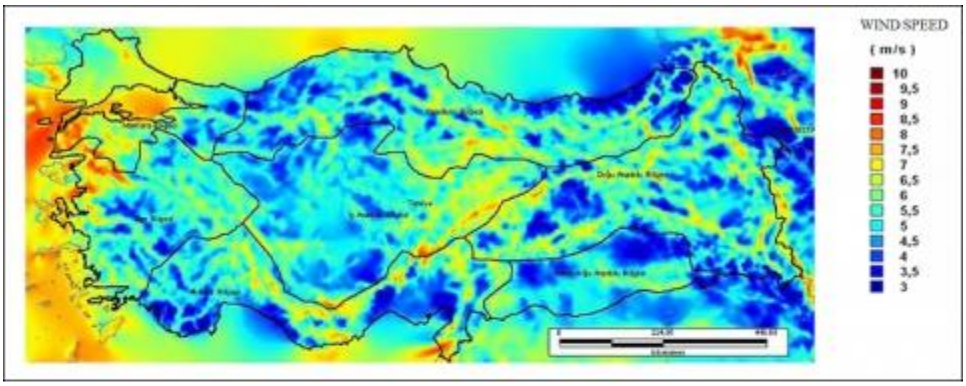


Table 2 - Distribution of Turkey’s Electric Production According to Fuel Types (as GWh)

Year	Coal	Fuel Oil	Natural Gas	Renewable Energy Sources and Waste	Hydraulic	Geo. and wind	Overall
1985	15 28	7 82	58	0	12 045	6	34 219
1990	29 81	3 43	10 92	0	23 148	80	57 543
1995	28 47	5 72	16 79	222	35 541	86	86 247
2000	38 86	9 11	46 17	220	30 879	109	124 922
2005	43 93	5 43	73 45	122	39 561	153	161 956
2008	57 16	7 19	98 85	219	33 270	1 009	198 418

Source : World Energy Council Turkish National Committee Working Group Reports and TEIAS Statistics.

Map 3 - The Distribution of Average Wind Speed in 50 m. of Elevation Above Ground



We can see what potential Erzurum has for wind. In the late 2017, they decided to build 50 MW Wind Turbines to Erzurum for the first time. Soon they will build more.

Turkey has high solar energy potential due to its geographical location. According to the Solar Energy Map (SEM) of Turkey prepared by the Renewable Energy General Directorate, it has been determined that the total annual insolation time is 2.741 hours (a total of 7,5 hours per day), and the total solar energy derived per year is 1.527 kWh/m^2 per year (total 4,18 kWh/m^2 per day). While solar energy technologies are extremely varied in terms of their methods, materials and technological levels, they can be split into two principle groups.

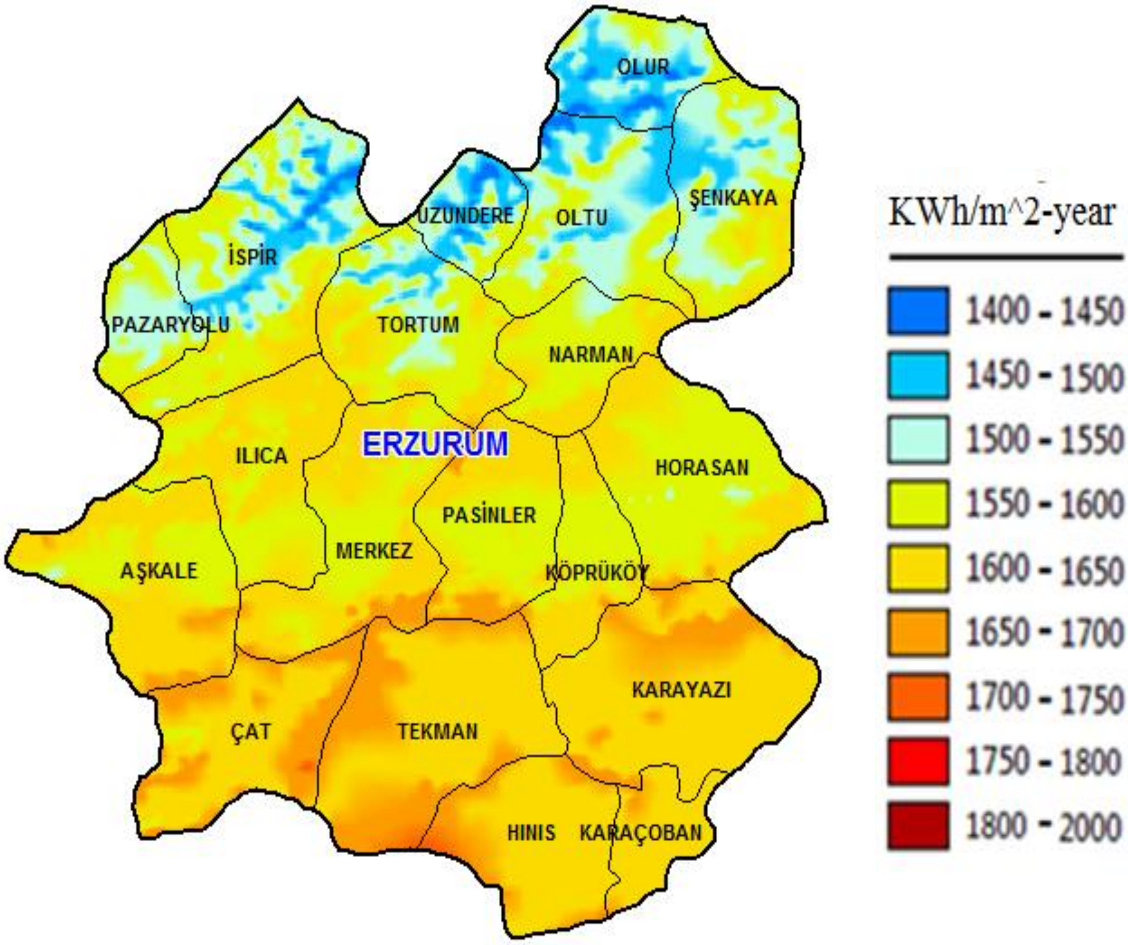
Photo-emissive Solar Technologies and Concentrated Solar Power (CSP):In this system heat is obtained from solar energy, and can be used either directly or in the generation of electricity.

Solar Cells:Semi-conducting materials, which are also known as photovoltaic solar energy systems, convert the sunlight directly into electricity.

The total established solar collector area within our country as of 2017 was calculated as being close to 20.000.000 m^2. Also, in 2017, close to 823.000 TEP Tonnes Equivalent to Petrol) heat energy was produced using solar collectors.

As of the end of 2017, there were 3.616 solar power plants with a total installed capacity of 3.421 MW. This is the equivalent of 4% of the total potential. In 2017, electricity production based on solar energy have realized 2.684 GWh and 0,91% of our electricity production was obtained from solar energy.

Solar Map



Turkey is Europe’s leading markets for future hydropower development due to a combination of abundant resources, a supportive government, and favourable policy framework.

Sitting at the crossroads of Asia and Europe, Turkey is a high-altitude country with over 25 river basins, including the trans-boundary Tigris and Euphrates rivers. As part of its potential accession to the EU, Turkey has integrated its electricity infrastructure with that of Europe, while at the same time pursuing a strategy of overall energy diversification, including the development of all types of renewable energy.

Furthermore, electricity demand in Turkey is forecast to grow by more than 90 per cent over the next ten years, adding to the suite of drivers for hydropower development.

Turkey has ambitious plans for hydropower over the coming decade. The country is aiming to mark its 100 years as a republic in 2023 with a total installed electric power capacity of 100 GW – up from 32 GW in 2002 and 64 GW in 2014 – with 30 per cent of electricity generation coming from renewables.

This rate was around 20 per cent in 2014 due to low rainfall. The country is pushing ahead with its formidable goal to exploit all of its estimated 166,000 GWh/year of economical hydropower potential, which would include an expected total of about 24,000 hydropower plants.

To date, roughly 50 per cent of this potential has been tapped, with a further 15 per cent under construction, leaving the country with some way to go in achieving its target. At the end of 2014, Turkey's installed hydropower capacity was 23.6 GW, producing 40,400 GWh/year of electricity.

Turkey has a suite of policies that will support hydropower development, including a 30 per cent target for renewables by 2023, a feed-in-tariff for projects completed by the end of 2015, VAT and customs exemptions, and licence fee exemptions for renewable projects.

In early 2015, the Turkish Government announced it would allocate USD 16 billion to hydro development until 2018 as part of its Tenth Development Plan. In addition, deregulation of the power sector has encouraged private investment, with independent power producers taking on the bulk of new developments.

Hydropower development will be further supported by Turkey's interconnections into the European grid and potential for further linkages east into Asia.

In 2003, Turkey liberalised its energy market and embarked on a process of privatising existing assets as well as attracting private sector investment into new projects, although several strategic hydropower facilities will be exempted from the privatisation programme. In recent years, E.ON and Statkraft have made major investments in the country, while China has engaged through a plan to develop hydropower with local companies.

In 2014, Turkey commissioned seven projects (not including micro hydro schemes), including the Arkun Barajı (245 MW), Kavşak Bendi (190 MW), and Yamanly (88 MW) stations. The 102 MW Kargı project was commissioned in August 2015.

It is estimated that there is now up to 15 GW of new capacity currently under construction in Turkey, including the Yusufeli (540 MW), Çetin (517 MW) and Kığı (180 MW) projects.

Our objective: The main purpose of the project was to see if we can reach 100% renewables. Colleting all consumption and production datas in order to see when if we can run for %100 renewable energy for different scenario.

Erzurum

We started to search about Erzurum Province, power plants, energy consumption, electricity production, population and all the datas needed:

TOTAL POWER: 790 MW
NUMBER OF POWER PLANTS: 33 (4 UNLICENSED)
ELECTRICITY PRODUCED BY POWER PLANTS: 1.607 GW
Population: 779321 (2015)
Area: 25355 km^2
Altitude: 1853 m

Power Plant Types

Solar	7,18 MW	0,9 %
Wind	0,00 MW	0,0 %
Geothermal	0,00 MW	0,0 %
Biogass	0,00 MW	0,0 %
Hydro	758,7 MW	97,7 %
Natural Gas	0,00 MW	0,0 %
Coal	0,00 MW	0,0 %
Other	10,90 MW	1,4 %

Erzurum's energy consuption is 952.360,26 MWh in 2016. Erzurum's electricity demand is 0.63% of Turkey.
First, we researched what kind of energy carriers, process/conversion technologies, demands and demand technologies to draw Reference Energy System of Erzurum Province.

CALCULATIONS

After finalizing our reference energy system, we collected all the datas needed for Answer-Times: Energy production of power plants, energy consumption of demand technologies, efficiency and availability of all power plants and demand technologies and their life time.
So first we started with collecting all datas for process/conversion technologies.

Power Plants	bound on capacity(gw)	bound on activity(pj)	bound on activitiy(pj)	annual availibility(%)	fixom($)	invest cost($)	life(year)	start
Erzurum Sugar Factory Thermal Reactor	0,0054	0,2274	0,0946	0,416	10,89	2645	75	1956
Aşkale Güneş Enerji Santrali	0,005	0,1575	0,0293	0,186	21,6	2950	20	2018
Halk Enerji Erzurum GES	0,0049	0,1548	0,0288	0,186	21,6	2950	20	2016
Erkal Elektrik GES	0,00099	0,0312	0,0058	0,186	21,6	2950	20	2015
Her-İş İnşaat GES	0,00099	0,0312	0,0058	0,186	21,6	2950	20	2015
Pado Dondurma GES	0,0003	0,0091	0,0017	0,186	21,6	2950	20	2015
Arkun Barajı ve HES	0,245	7,7421	1,3007	0,168	14,93	600	50	2007
Ayvalı Barajı ve HES	0,122	0,0000	0,0000	0	14,93	600	50	2015
Güllübağ Barajı ve HES	0,096	3,0367	0,5436	0,179	14,93	600	50	2010
Erzurum Özlüce HES	0,036	1,1486	0,2538	0,221	14,93	600	50	2010
Erzurum Aksu HES	0,027	0,8618	0,2413	0,28	14,93	600	50	2010
Tortum Gölü HES	0,026	0,8345	0,3672	0,44	14,93	600	50	1962
Yedigöl Barajı ve HES	0,022	0,6912	0,1970	0,285	14,93	600	50	2010
Kuzgun Barajı ve HES	0,021	0,6592	0,0798	0,121	14,93	600	50	2000
Sırakonaklar HES	0,018	0,5692	0,1417	0,249	14,93	600	50	2010
Tuzlaköy ve Serge HES	0,017	0,5262	0,0958	0,182	14,93	600	50	2010
Alabalık Regülatörü ve HES	0,016	0,5154	0,0953	0,185	14,93	600	50	2010
Yazyurdu Regülatörü ve HES	0,015	0,4700	0,0968	0,206	14,93	600	50	2010
Bağbaşı HES	0,014	0,4297	0,1332	0,31	14,93	600	50	2010
Büyükbahçe HES	0,012	0,3713	0,1188	0,32	14,93	600	50	2010
Kaletepe Regülatörü ve HES	0,011	0,3701	0,1188	0,321	14,93	600	50	2010
Esendurak HES	0,0093	0,2948	0,0970	0,329	14,93	600	50	2010
Yanıkköprü HES	0,0092	0,2905	0,1008	0,347	14,93	600	50	2010
Tuana HES	0,00739	0,2340	0,0466	0,199	14,93	600	50	2014
Havva HES	0,00719	0,2268	0,0828	0,365	14,93	600	50	2010
İncebel HES	0,00693	0,2248	0,0047	0,021	14,93	600	50	2015
Gelinkaya HES	0,00687	0,2176	0,0422	0,194	14,93	600	50	2013
Çayhan HES	0,00619	0,1959	0,0380	0,194	14,93	600	50	2010
Otlu HES	0,00611	1,9330	0,3750	0,194	14,93	600	50	2010
Dumlu HES	0,00398	0,1255	0,0090	0,072	14,93	600	50	2010
Karasu 1 HES	0,00384	0,1214	0,0391	0,322	14,93	600	50	2010
Karasu 2 HES	0,00308	0,0972	0,03	0,322	14,93	600	50	2010
AŞKALE CEMENT FACTORY	0,0055	0,2317	0,0964	0,416	10,89	2695	65	1971

These our power plants and as we can see their total power in gw, energy fx and up(maximum) in petajoule, their availability which means that how much they work in a day, their fix cost and investment cost(dollars per GWh), their lifetime and start year. So depends on our Answer-Time Software, we decided to work on these units because of the program itself. When we calculated bound on activity, we considered year 2016 and how much they produced electricity, then converted to pj. When we calculated annual availability, we considered Cement and Sugar are working 9.00 am to 6.00 pm. For the rest we divided the electricity produced in 2016 to their total power in order to calculate annual availability.

After finishing power plants, we started to search and calculate the datas for demands and their technologies.

So during these research there some small codes that we used:

· Bound on capacity(GW): The electric production rate for power plant for 1 hour
· Upper bound(PJ): 8760h *bound on capacity
· Fix bound on capacity(PJ): 8760h*max annual availibility*bound on capacity
· Annual Availibility(PJ): This is the total time a facility is operating in a year over all year
· Fixom:General fixing cost x dolar per 1 GW capacity
· Investment cost: General investment cost for power plant x dolar per 1 GW
· Life: Life time of a power plant
· Start: Year that power plant starts producing electricty

First we found the datas for residential demands:

	Availability of Capacity (Decimal Fraction) (NCAP_AF)	Efficiency (ACT_EFF) (Decimal Fraction)	Technical Lifetime of Process (Year) (NCAP_TLIFE)	Fix bound with activity (Petajoule) (ACT_BND)				Demand (Petajoule) (COM_PROJ)				
	2016-2031	2016-2031	2016-2031	2016	2021	2026	2031	2016	2021	2026	2031	
Refrigerator	1	0,95	10	0,8165	1,0175	1,2680	1,5802	0,7757	0,9667	1,2046	1,5012	Electricity
Air Conditioner	1	0,8	10	0,3938	0,4908	0,6116	0,7622	0,3151	0,3926	0,4893	0,6097	
Washing Machine	1	0,75	10	0,2232	0,2781	0,3466	0,4319	0,1674	0,2086	0,2599	0,3239	
Dish Washer	1	0,75	10	0,0919	0,1145	0,1427	0,1778	0,0689	0,0859	0,1070	0,1334	
Dryer	1	0,8	10	0,0840	0,1047	0,1305	0,1626	0,0672	0,0838	0,1044	0,1301	
elc. Space Heater	1	0,95	5	0,2442	0,3043	0,3792	0,4725	0,2320	0,2891	0,3602	0,4489	
Television	1	0,75	10	0,1759	0,2192	0,2732	0,3404	0,1319	0,1644	0,2049	0,2553	
Incandescent	1	0,1	5	0,1838	0,2290	0,2854	0,3557	0,0184	0,0229	0,0285	0,0356	
Florasan	1	0,3	5	0,0788	0,0982	0,1223	0,1524	0,0236	0,0294	0,0367	0,0457	
Led	1	0,9	5	0,0446	0,0556	0,0693	0,0864	0,0402	0,0501	0,0624	0,0777	
Other	1	0,6	5	0,2862	0,3566	0,4444	0,5538	0,1717	0,2140	0,2667	0,3323	
Coal Heating Stove	0,4	0,5	10	0,6848	0,8533	1,0634	1,3252	0,1370	0,1707	0,2127	0,2650	COAL
Central Heating Boil.	0,5	0,5	20	0,5478	0,6827	0,8507	1,0601	0,1370	0,1707	0,2127	0,2650	
Coal Cooker	0,2	0,5	10	1,3695	1,7066	2,1268	2,6504	0,1370	0,1707	0,2127	0,2650	
Natural Gas Heater	0,3	0,85	10	20,5000	25,5467	31,8359	39,6733	5,2275	6,5144	8,1181	10,1167	NG
Central Heating Boil.	0,4	0,85	20	9,2250	11,4960	14,3261	17,8530	3,1365	3,9086	4,8709	6,0700	
Natural Gas Cooker	0,1	0,7	10	24,6000	30,6561	38,2030	47,6079	1,7220	2,1459	2,6742	3,3326	

First thing we have done for the calculations is to find number of residence in Erzurum which was:729299. So depends on '2015 Energy Balance Table', we divide the percentage of demand technologies inside of electricity, coal and natural gas tabs. For electricity part, we entered 1 as availability because we calculated these values before we enter fix bound. Their efficieny is up to the technology and we got these rates from our references, lifetimes as well. For coal and natural gas part, availability is equal to how many hours they work in a day/24.
Demand=Fix bound with activity*Efficiency*Avaibility

After 2016, we assumed that every year the needs is increasing %4,5 so we calculated 2021-2026-2031 up to this value. The reason is that is the thing for the previous year so we foresee it in the same level.

Then we started to work on industrial demand:

	Availability of Capacity (Decimal Fraction) (NCAP_AF)	Efficiency (ACT_EFF) (Decimal Fraction)	Technical Lifetime of Process (Year) (NCAP_TLIFE)	Fix bound with activity (Petajoule) (ACT_BND)				Demand (Petajoule) (COM_PROJ)			
	2016-2031	2016-2031	2016-2031	2016	2021	2026	2031	2016	2021	2026	2031
crusher	0,95	0,95	35	0,0135	0,0169	0,0210	0,0262	0,0122	0,0152	0,0190	0,0236
cement baker	0,95	0,4	35	0,0068	0,0084	0,0105	0,0131	0,0026	0,0032	0,0040	0,0050
cooler	0,95	0,95	35	0,0365	0,0455	0,0567	0,0707	0,0330	0,0411	0,0512	0,0638
storage	0,95	0,95	35	0,0095	0,0118	0,0147	0,0183	0,0085	0,0107	0,0133	0,0165
packaging	0,95	0,95	35	0,0135	0,0169	0,0210	0,0262	0,0122	0,0152	0,0190	0,0236
compressor	0,95	0,95	35	0,0487	0,0607	0,0756	0,0943	0,0440	0,0548	0,0683	0,0851
heavy mac.	0,95	0,4	35	0,0068	0,0084	0,0105	0,0131	0,0026	0,0032	0,0040	0,0050
milling machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
turning machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
power machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
drilling machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
grinding machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
presses	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
bending machine	0,416	0,9	35	0,0618	0,0770	0,0960	0,1196	0,0231	0,0288	0,0359	0,0448
other equipments	0,416	0,9	35	0,0309	0,0385	0,0480	0,0598	0,0116	0,0144	0,0180	0,0224
washer	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
baker	0,416	0,4	35	0,0850	0,1059	0,1320	0,1644	0,0141	0,0176	0,0220	0,0274
boiler	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
grinding machine	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
sterilization machine	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
filling machine	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
shaping machine	0,416	0,9	35	0,0850	0,1059	0,1320	0,1644	0,0318	0,0396	0,0494	0,0616
other equipments	0,416	0,9	35	0,0232	0,0289	0,0360	0,0448	0,0087	0,0108	0,0135	0,0168
electric motor	0,33	0,75	15	0,0779	0,0971	0,1210	0,1508	0,0193	0,0240	0,0299	0,0373
electric resistance	0,33	0,75	15	0,0779	0,0971	0,1210	0,1508	0,0193	0,0240	0,0299	0,0373
other industrial equ.	0,33	0,75	15	0,0389	0,0485	0,0605	0,0754	0,0096	0,0120	0,0150	0,0187

I took only 4 main demands which has the biggest energy on Erzurum which were: Cement Demand, Metal Demand, Food Production Demand, Industrial Various Demand.
To find fix bound on activity, I got the data from ‘energy market report 2016’ and divide it to different demands: %40 food production, %30 metal, %20 cement and %10 industrial various demand. Then we assumed that cements are working all day, food production and metal industry is 9.00 am to 6.00 pm for most of the places, so we calculated as 0,416. Industrial various is only 8 hours in a day. Their efficiency is up to how their working principle is. If they have resistance is 0,9-0,95 efficiency they have. For baker and cement baker it consumes natural gas, coal and electricity so we assumed that their efficiency can not be high and must be a bit low. To calculate demand and the other years, we did the same thing as we had in residential demands.

Then we started to work on city service, transport and agricultural demand:

	Availability of Capacity (Decimal Fraction) (NCAP_AF)	Efficiency (ACT_EFF) (Decimal Fraction)	Technical Lifetime of Process (Year) (NCAP_TLIFE)	Fix bound with activity (Petajoule) (ACT_BND)				Demand (Petajoule) (COM_PROJ)			
	2016-2031	2016-2031	2016-2031	2016	2021	2026	2031	2016	2021	2026	2031
Street Lighting	0,38	0,2	6	0,3897	0,4856	0,6052	0,7542	0,0296	0,0369	0,0460	0,0573
Bus	0,58	0,4	12	3,7602	4,6859	5,8395	7,2770	0,8724	1,0871	1,3548	1,6883
Diesel car	0,4	0,4	12	1,2564	1,5657	1,9512	2,4316	0,2010	0,2505	0,3122	0,3890
Gasoline car	0,4	0,25	12	1,0022	1,2489	1,5563	1,9395	0,1002	0,1249	0,1556	0,1939
Lpg car	0,4	0,35	12	1,4658	1,8267	2,2764	2,8368	0,2052	0,2557	0,3187	0,3972
Truck(diesel)	0,25	0,4	12	12,1762	15,1737	18,9092	23,5643	1,2176	1,5174	1,8909	2,3564
Light commercial vehicle(diesel)	0,25	0,4	12	54,1604	67,4937	84,1094	104,8156	5,4160	6,7494	8,4109	10,4816
Tractor	0,05	0,3	10	1,0211	1,2724	1,5857	1,9761	0,0153	0,0191	0,0238	0,0296
Irrigation	0,03	0,8	10	0,0123	0,0153	0,0191	0,0238	0,0003	0,0004	0,0005	0,0006

For the city service, we got it from ‘energy market report’(epdk 2016). So it was 4113379 MWh which is equal to 0,148 pj. So the calculation for fic bound activity for all of these datas here:
0,148 pj*utilization(availability)=fix bound on activity. It was the same idea for all demands (previous ones).

For transport we started to find car, bus, truck numbers of this city from ‘land vehicles up to the cities’(illere gore motorlu kara taşıtları sayısı).
Bus=minibus+autobus=3044+1163=4207
Diesel car=19123
Gasoline car=15253
LPG=22311
Diesel truck=5872
Light Commercial Vehicle=26119
For busses, act bound activity is:
number* 0,0005184*utilization=fix bound activity
For cars, act bound activity is:
number* 0,00002628*utilization=fix bound activity
The rest datas are coming from the same system, availability and efficiency included.

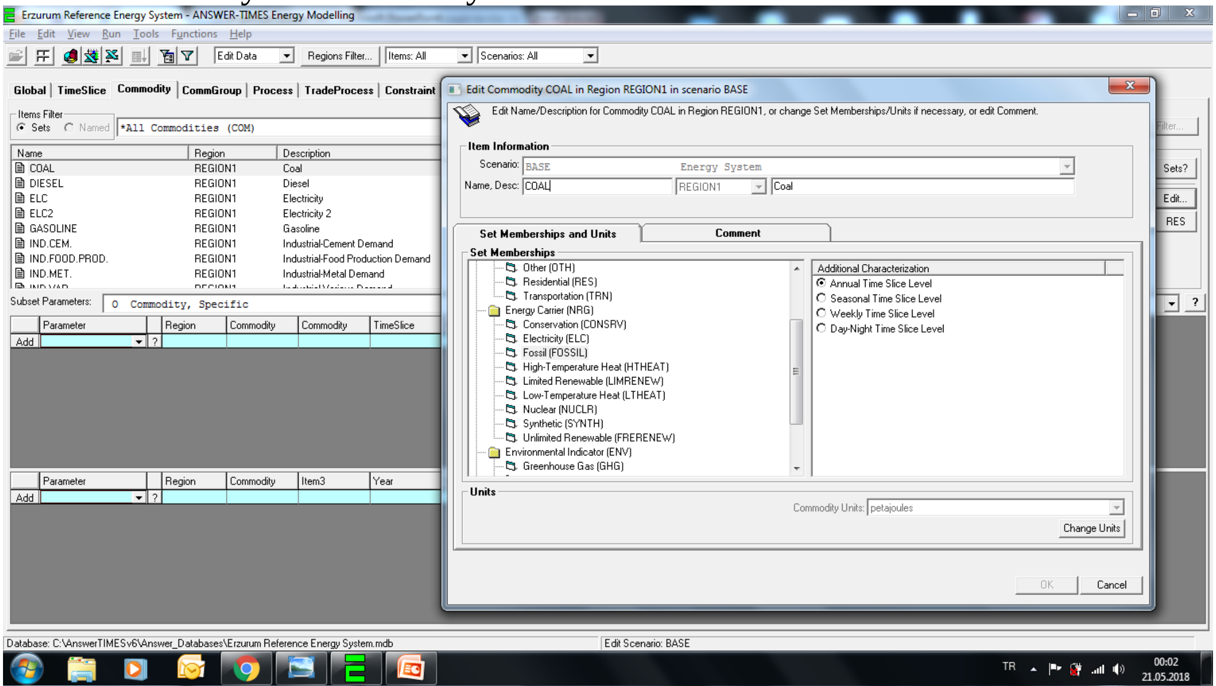
For city service, it was just a little bit different:
Our reference was 1.12pj for 21000 tractors so we have 1,021 pj for Erzurum
Erzurum agricultural irrigation: 0,0122 from epdk report.

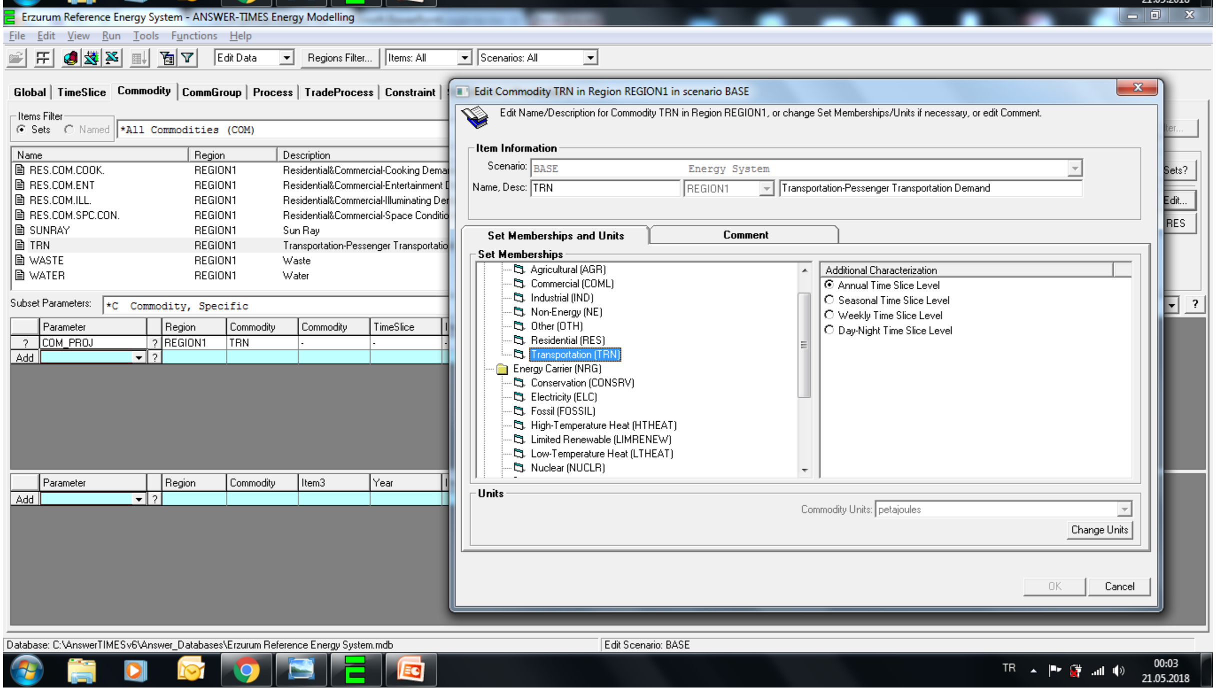
ANSWER-TIMES

I have been using Answer-Times to present my reference energy system and during this process i put all the Energy carriers, Process/convertion Technologies, Final Energy Carriers, Demand Technologies and Demads as it seems in my referance energy system.

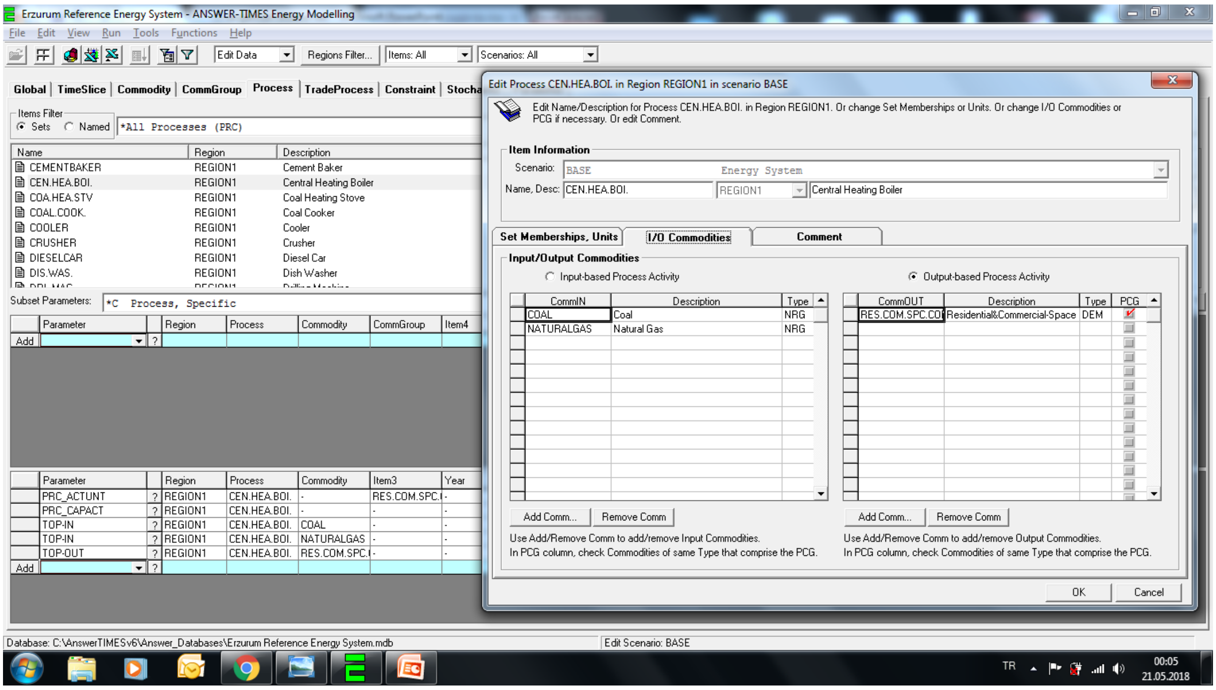
Just some example from Answer-Times:

Energy Tab; i have added all the energy carriers, final carriers and demands from Commodity section one by one.





Right after adding all of these, i have added precess/convertion Technologies and demand Technologies. There were over 50 demand Technologies so here is just an example how it was showed:



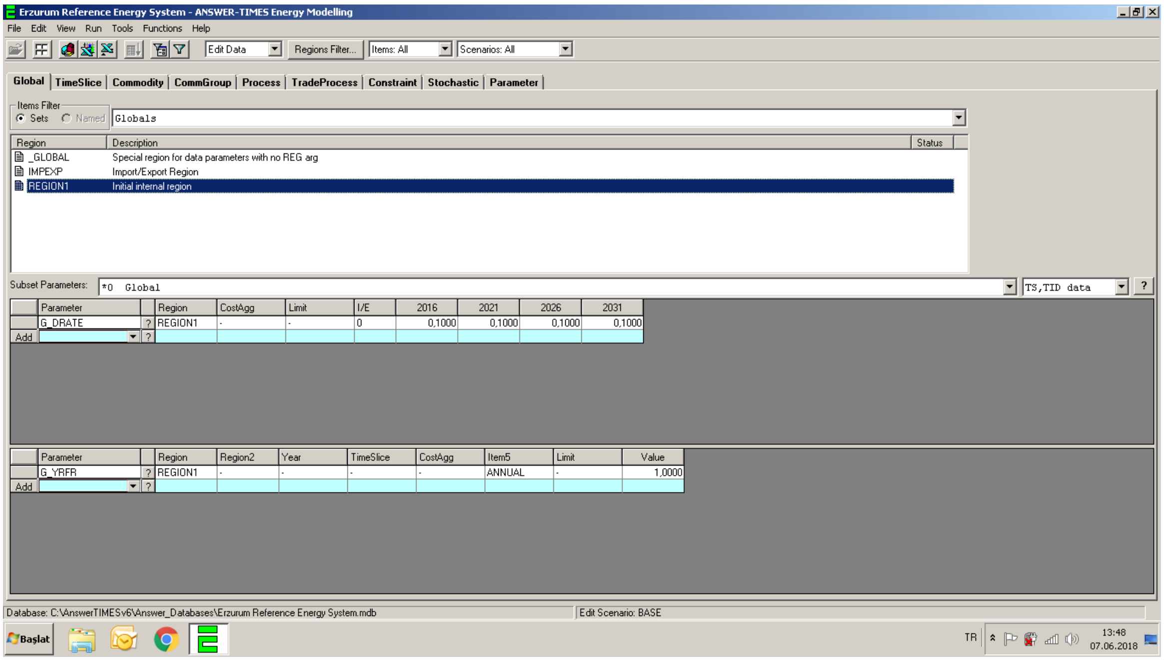
As in the example: Coal and natural gas are the final energy carriers and they are used by 'Central heating boiler'(demand technology) and our output(demand) is 'residental&commerical-conditioning demand'.

So after writing all these datas we had a reference energy system in our program, Answer-Times which was showed like:

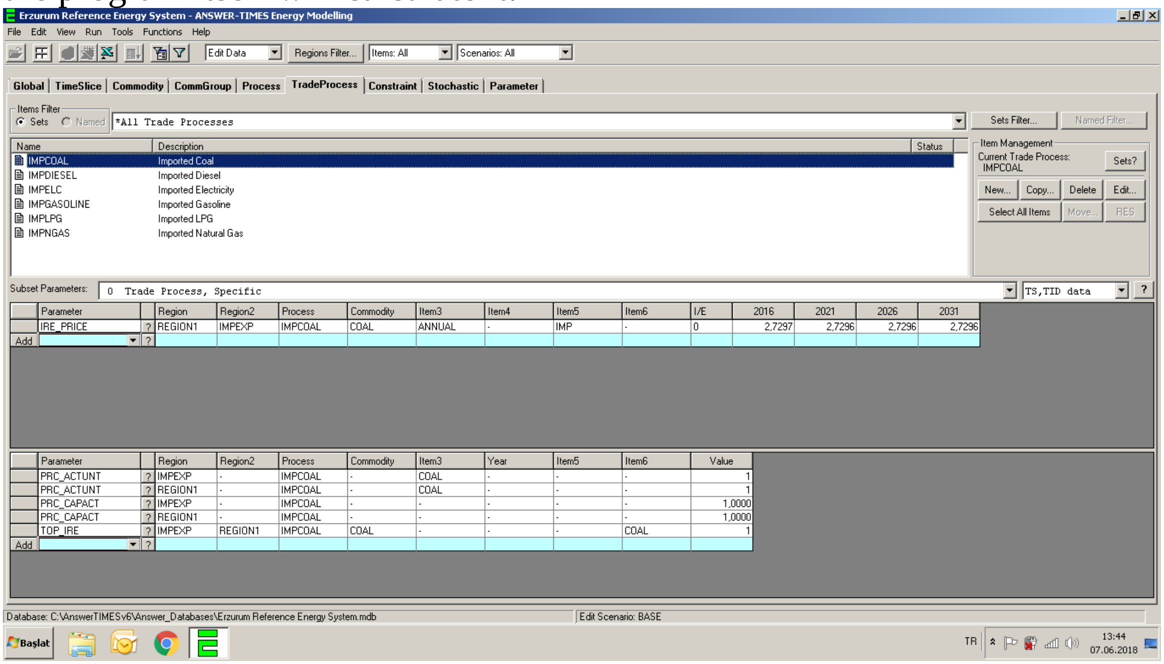
So this is an example from the application. It shows the supply&us for electricity.

After we put our reference energy system to our software. We starter to enter our collected datas.

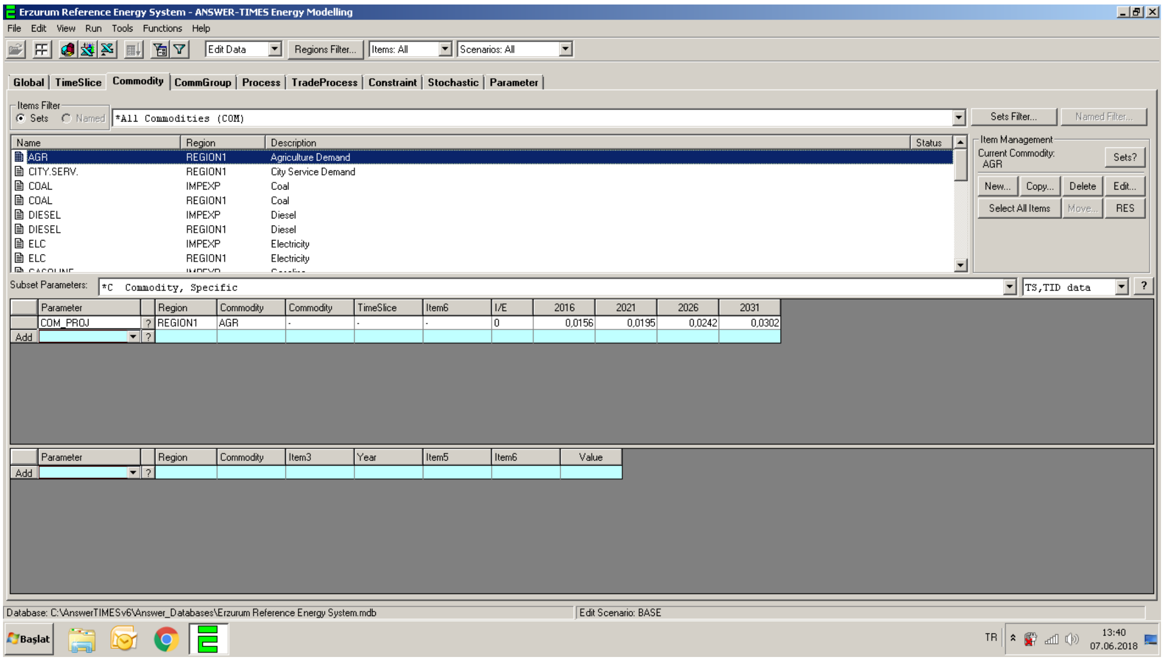
But first, we entered inflation value and add another region which was IMP/EXP for imported and experted values from Global tab:



Then we put our values to TradeProcess tab, their price for the year so that the program itself will calculate it:

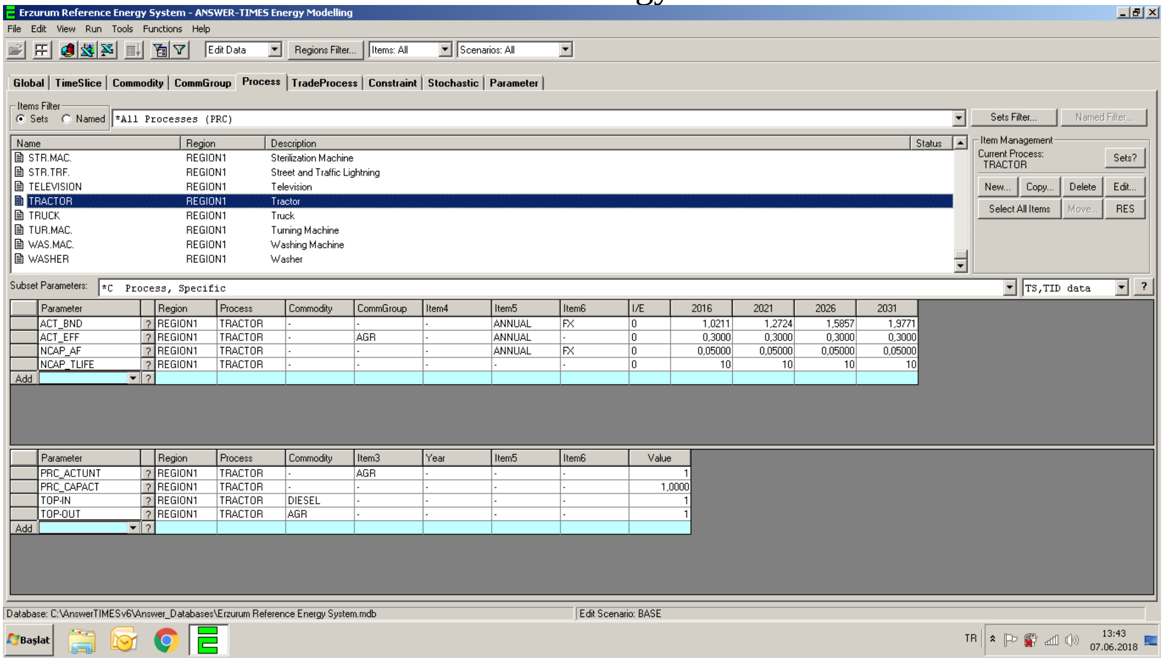


The next thing was to enter all demands with 'COM_PROJ' value: We sum all demand technology 'demand' value and entered as it is shown down below:



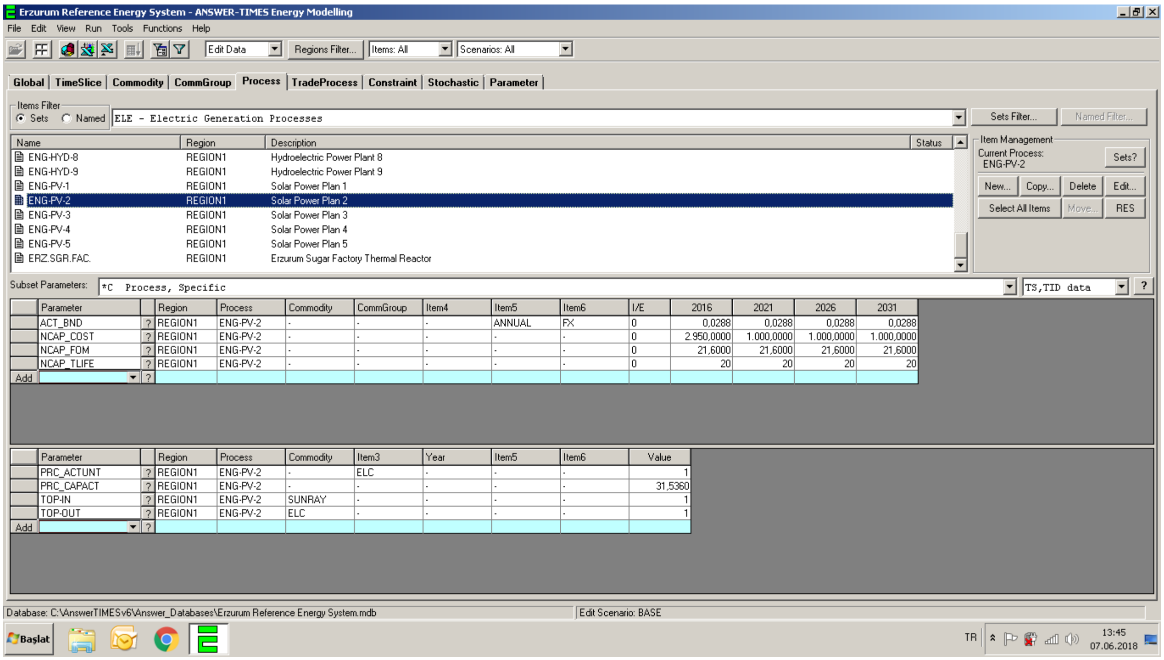
We can also see that we have 2 different regions: REGION1 and IMPEXP in order to calculate and enter values in a proper way.

Then we needed to enter demand technology datas:



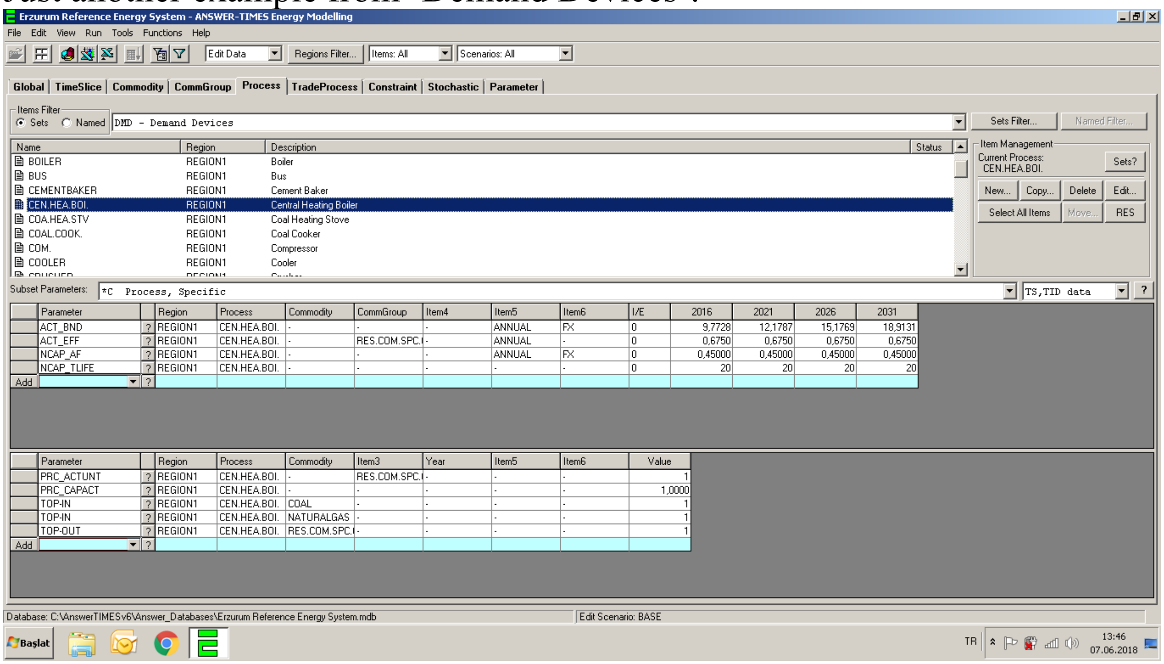
As we can see above, it shows the bound on activities, efficiency, availability and lifetime for tractor for the years 2016-2031. We can also see diesel is the input for tractor and agricultural demand is the output.

So for power plants we made it more specific by choosing ‘Electric Generation Processes’. We can see some of hydropower, solar power plants and one sugar factory.



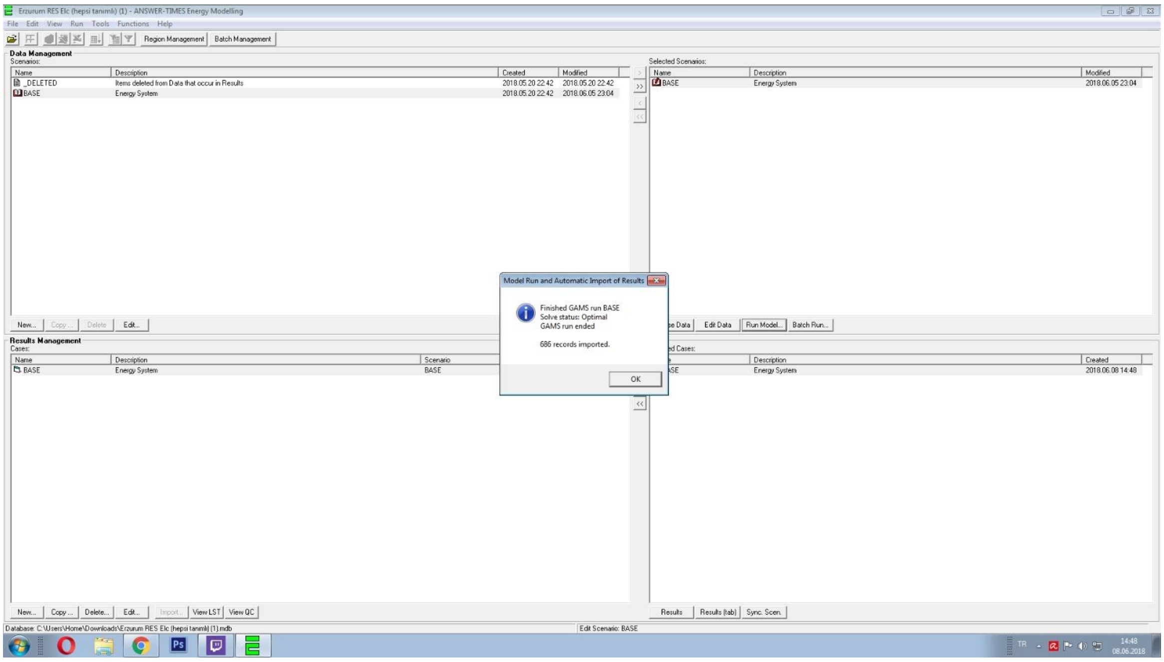
So for solar power plants there were something specific which was that the price is decreasing and even now its 1000, and for the following years it will be less for sure. But since we are trying to define a scenario for the future, we can not assume it should be more. So we said it will stay in the same level which is a possibility.

Just another example from ‘Demand Devices’:



Central Heating Boiler has 2 different inputs which is coal and natural gas.

After putting all these datas together we click the ‘run’ button in order to see if our database is working in optimal level or not. So we checked and it was working in an optimal level:



Conclusion

One of the things we wanted to see in our software program was that when we enter all these datas found, if the program is working in an optimal level or not. Our study showed that it is working in an optimal level.

On the other hand, one of the important findings for me and my friends that renewables has a big potential, not only for energy but at the same time for employment. So we will be working in this field. We will keep improving this model and watching new scenarios after our graduation, make it real in our cities and country in the way to %100 renewable energy.

It is just possible to show that it makes sense to focus on renewables with using Answer-Times. Calculations can show us which year we can achieve 100% renewable energy.

As Erzurum’s potential, hydroelectric power plants are producing most of the energy and there is a huge potential if we focus on solar power plants. They started to build more power plants. Soon they will start building wind turbine.

References

- https://www.mmo.org.tr/sites/default/files/14c4511b3c98f14_ek.pdf
- https://qz.com/61423/coal-fired-power-plants-near-retirement/
- https://www.mmo.org.tr/sites/default/files/14c4511b3c98f14_ek.pdf
- http://www.askalecimento.com.tr/enerji_santralleri.aspx
- https://shiftdelete.net/gunes-enerjisi-fiyatlari-yuzde-26-dustu
- http://eskiweb.epdk.org.tr/TR/Dokumanlar/Petrol/YayinlarRaporlar/Yi

llik

- http://www.eigm.gov.tr/tr-TR/Denge-Tablolari/Denge-Tablolari
- http://www.tuik.gov.tr/PreHaberBultenleri.do?id=24603
- http://www.enerjiatlasi.com/sehir/erzurum/
- https://www.kudaka.org.tr/ekler/b192d-erzurum_icin_oncu_sektorlerin_belirlenmesi_raporu.pdf
- https://journals.openedition.org/echogeo/12457
- http://www.enerji.gov.tr/en-US/Pages/Solar