**U. S. Country Studies Program
Hungarian Country Study Team**

**Hungarian
Climate Change
Action Plan**

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HUNGARIAN CLIMATE CHANGE ACTION PLAN

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Published by Systemexpert Consulting Ltd.

Budapest, 1998

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INTRODUCTION

In 1994-1996, with in the framework of the U.S. Country Studies Program, the Hungarian Country Study Team developed the national greenhouse gas emission inventory, and elaborated the mitigation options for the different sectors of the economy. In 1997, the development of a National Action Plan was begun as the continuation of this work. This report contains the results.

In Hungary, the Ministry for Environment and Regional Policy is responsible for the development of the National Communications. In this work, the Ministry relies on the Systemexpert Consulting Ltd, which is the main background institute in this field. Systemexpert is the focal point institute of the U.S. Country Studies Program on behalf of Hungary. A great number of experts have been and are drawn into the these activities from different institutions, like from the

- Ministry of Industry, Trade and Tourism
- Hungarian Energy Office
- Forest Research Institute
- Budapest University of Economics
- Budapest University of Technology
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Results of the inventory study showed that greenhouse gas emissions decreased from the selected base level (i.e. from the yearly average emissions of 1985-1987) till 1994 by cca. 25%. However, this decrease was primarily caused by the deep economic recession. Therefore our policy makers have to face the problem

of economic recovery without a relevant increase of greenhouse gas emissions in the near future. This is the main focus of our mitigation analysis and national action plan.

Analyses showed that Hungary has the best opportunities for stabilizing/reducing the greenhouse gas emissions in the energy and in the forestry sector. In these sectors there are already ongoing governmental programs, which may contribute to the greenhouse emission reduction, although these programs were primarily devoted for other purposes (energy saving, job creation, etc.).

The economic development predicted for the near future must not lead to a drastic increase of greenhouse gas emissions. Therefore, the National Action Plan should concentrate on economic restructuring, first of all in the energy sector. It also has to take into account the special problems emerged by privatization of all sectors. The resources for financing environmental protection measures are still very limited. Therefore, the Action Plan should be based on ongoing programs, which may also serve such environmental goals like the reduction of greenhouse gas emissions.

The Action Plan is devoted also to promote the development of the National Communications.

U.S. Country Studies Program

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1. ENERGY

1.1. Technological Changes in Power Generation in Hungary

In the world, there are lot of new generation technologies, but only a few of them can be applied in Hungary. There are some limitations in the Hungarian electrical system as follows.

- The maximum size of a new unit should not be larger than $\approx 650 \text{ MW}_e$. Larger unit sizes would cause system regulation problems, and in this case, some extra system reserve capacity is needed, which might be uneconomical for the system.
- There are some limitations on the use of the primary fuels. About half of the primary energy consumption is imported in Hungary. The electrical sector would like to use coal, hydrocarbons and the nuclear energy nearly in the same share. The reason of this strategy is based on the fuel supply risk diversification. Because of the nuclear energy production is about 50% of the total production, it is not probable that a new nuclear power plant will be constructed in the near future. The short term construction strategy is based on coal and hydrocarbon units.
- Because of technical problems of the generation system (low flexibility, there is not enough secondary and primary reserve, high environmental pollution) the new units and the retrofitting of some old units is a difficult task.
- Beside the technical problems the investment strategy has to be realized in a partly privatized system, where the investors have there own aims, and the government wants to assure the least cost solution for the whole system.

New technologies

Based on previous examinations, the following generation technologies can be applied in Hungary in the near future:

a.) Combined cycle units (CCGT)

aa.) CCGT running in cogeneration way

In Hungary, in the large and in the medium size cities, there is an important district heating system. Block of flats and industrial companies are supplied with steam and hot water. These systems are 20-30 years old, it is necessary to renew these systems because of technical and economic reasons. The isolation of the pipelines are bad. The boilers are in a good condition, because most of them had already a retrofit, but in most cases, the electrical energy production is very low compared to the present technical opportunities. The installation of a new cogeneration unit is economical in district heating systems in most cases. These old small power plants can be found in cities. There is not so much place for new units at these sites, and the environmental protection rules are very strict. Therefore, the CCGT technology would be the most economical and feasible solution at these power plants. These units are small (80-100 MW_e), and the operation of these units follows the heat demand of the district heating system. (There are gas motor solutions also in the range of 0.5-1 MW_e , but they are not significant in the generation system.)

ab.) CCGT running in condensation way

The CCGT technology has a lot of advantages, e.g. the construction time is short, the investment cost is low. In Hungary, it has two important disadvantages.

- The long term safeguarding gas supply has not been solved till now. The idea of long term gas supply agreements are very new in Hungary. The PowerGen is the only firm, which has such kind of agreements. The other companies have only yearly agreements.
- Because of the high gas price, these units have to operate in a load following manner, but there is not enough gas storage opportunities in Hungary.

These problems have to be solved before the installation of large CCGT units in Hungary.

ac.) CCGT using inert gas (60-80MW_e)

In Hungary, there are some small inert gas sources. Inert gas can economically be used only for electricity production.

b.) Coal fired units

The unit size is limited by the system (650 MW_e).

The quality of the domestic coal is not good (calorific value is low and the sulphur content is high), and the mining activity is uneconomical in several mines. The government wants to reduce the mining activity step by step, therefore the quantity of the domestic coal will be reduced year by year. The available domestic coal quantity will not be enough for the new generation units, therefore coal import will be necessary in the future.

ba.) Fluid units (150-200 MW_e)

The fluid generation units are planned to be fuelled by coal mixture (of domestic and imported coal) or by purely imported coal. At the beginning of the

operation of these units, the domestic coal will be available, but the quantity of the domestic coal will not be enough. During the lifetime of these units, quantity of the domestic coal will reduce, and later on, only imported coal will be used. The fluid technology is very flexible from the viewpoint of the coal quality. Fluid units might be installed in every existing coal power plant.

bb.) Conventional lignite power plant ($2 \times 500 \text{ MW}_e$)

In Hungary, near Bükkkábrány, there is an open lignite mine. The economically extractable quantity equals the fuel demand of a 1000 MW_e power plant during 30-35 years. The idea of this power plant is about 30 years old, therefore the mine has been searched very well. The risk of this power plant is small. Since the quality of the lignite is low and the sulphur content is high (3%), the production cost of the power plant will be high.

bc.) Conventional power plant on imported coal ($3 \times 650 \text{ MW}_e$)

If the government does not want to reduce the share of the coal power plants in the generation system, power plants based on imported coal has to be constructed.

These power plants need new sites, because the infrastructure of the existing power plants are not enough. Near the river Danube, there are several possible sites. In these sites, fresh water cooling can be applied and ship coal transport would be available as well.

c.) Gas turbines for system regulation

Hungarian Power Companies (MVM Rt.) is responsible for system reliability. For this reason MVM Rt. will install $2 \times 110 \text{ MWe}$ simple gas turbines for secondary reserve and a 160 MWe simple gas turbine for peak reserve.

d.) Other examined technologies

Pumped storage power plant has been examined several times. It would be very useful for system regulation, but in Hungary the configuration of the terrain is not good for such a plant. The Hungarian pump storage power plant may be built in one of our neighbouring country connected with their electrical system.

The domestic oil refinery system will be modified and less residual oil will be available. Therefore, the earlier planned oil fired conventional power plant project (of 600 MW) has been cancelled.

Capacity enlargement

The Hungarian Power Companies issued a tender in 1997 to bring on-line new power generating capacity in Hungary. The new capacities should be put into operation in the period of 2002-2006. The proposals are expected to be submitted and evaluated by the end of 1998.

1.2. Energy efficiency measures in the residential and communal sectors

Basic data

In order to quantify the saving of energy, we have to start from the primary energy consumption of these sectors. This means that we have to estimate also the amount of fuel needed for production of the utilized electric energy and heat. Because of losses in production and transformation, the heat value of fuels is far higher than that of the energy use. In case of district heating, 1.31 GJ fuel is used for

producing 1 GJ heat. As far as electric energy is concerned, this rate is 4.01. Tables 1.1-1.2 present the structure of energy use in the examined two sectors.

Table 1.1. Primary energy consumption of the residential and communal sectors in 1995

Energy Source	Consumption of the Communal Sector (TJ/year)	Consumption of the Residential Sector (TJ/year)
Solid	87347	34185
Natural Gas	74771	181602
Gasoline	3985	14440
Fuel oil	22402	30176
Other	1373	221
Total	135564	314937

Table 1.2. Primary energy consumption according to end uses in 1995

End-Use	Communal Sector (TJ/year)	Residential Sector (TJ/year)
Individual and Central Heating	59417	142389
District Heating	6587	30606
Water Heating for Direct Use	4580	24448
Water Heating by District Heating	537	13730
Electric Energy	61235	86206
Cooking by Individual Fuels	3208	17558
Total	135564	314937

Energy Saving Measures

In what follows, we list the energy saving measures by specific areas. We list only such measures here which are feasible in Hungary in short term.

1. Heat

1.1. Buildings

1.1.1. Subsequent insulation of roofs, walls and foundations

1.1.2. Sealing of gaps between panels

1.1.3. Heat mirrors behind radiators

1.1.4. Renovation of windows

1.1.5. Changing of windows

1.2. Heating

District heating, heat sources

1.2.1. Utilization of industrial waste heat for district heating

1.2.2. Renovation of boilers (change of burners or tuning, energy saving pumps,
heat utilization of flue gases, control, reparation, heat insulation, etc.)

1.2.3. New boilers

1.2.4. Use of biomass in existing heat sources

District heating, distribution system

1.2.5. Alternating mass current

1.2.6. Improvement of heat protection

District heating, heat centers

1.2.7. Improvement of regulation and renovation

1.2.8. System modernization by efficient technologies
(DDC control, central gathering of data, etc.)

Central heating-boilers

1.2.9. Raising of energy efficiency by renovation of boilers

1.2.10. Use of gas instead of coal or oil

Secondary side of central heating systems-distribution

1.2.11. Regulation according to cardinal points

1.2.12. Separate hydraulic regulation of heat cycles

Secondary side of central heating systems - flats

1.2.13. Thermostatic valve + cost distributor + bypass (if needed)

- 1.2.14. Individual measuring, mini heat centers in flats individual heating
- 1.2.15. New boilers of higher efficiency
- 1.2.16. Condensation boilers, including change of radiators
- 1.2.17. Programmable control of heating
- 1.2.18. Thermostatic valves (regulation by rooms)
- 1.2.19. Renovation of gas firing units (tuning, maintenance)

Solar energy

- 1.2.20. Solar energy traps, solariums
- 1.3. Water heating
 - 1.3.1. Individual measuring
 - 1.3.2. Water saving traps
 - 1.3.3. Active heating systems using solar energy
- 1.4. Ventilation
 - 1.4.1. Heat use at artificial ventilation
- 1.5. Raising of awareness
 - 1.5.1. Promotion activity, campaigns, etc.

2. Electric energy

- 2.1. Lighting
 - 2.1.1. Changing of armature
 - 2.1.2. Compact bulbs
- 2.2. Water heating
 - 2.2.1. Use of electricity instead of gas
 - 2.2.2. Electric boilers of higher efficiency
 - 2.2.3. Reducing of outflows
- 2.3. Household appliances
 - 2.3.1. Appliances of higher efficiency (washing machines, refrigerators)
- 2.4. Raising of awareness
 - 2.4.1. Promotion activity campaigns, etc.

In the first step we determined the possible extension of the above measures, i.e. we estimated how much percent of the building and equipment stock can be involved. We estimated then the possible energy saving according to the listed measures.

Tables 1.3 and 1.4 presents the results.

Table 1.3. Energy saving of measures in the residential sector

Measure Code	Area Code	Base (TJ)	Energy Saving		Investment billion HUF	Return year
			TJ/year	%		
1.1.1.	TH	179158	54482	30.41	928.84	17.6
1.1.2.	TH	179158	548	0.31	14.87	24.9
1.1.3.	TH	179158	1689	0.94	6.91	4.3
1.1.4.	TH	179158	30687	17.13	479.17	16.7
1.1.5.	TH	179158	31782	17.74	669.44	21.1
1.2.1.	DH	30606	304	0.99	0.52	2.7
1.2.2.	DH	30606	128	0.42	0.41	4.9
1.2.3.	DH	30606	270	0.88	1.32	8.1
1.2.4.	DH	30606	4953	16.18	25.17	8.2
1.2.5.	DH	30606	675	2.21	2.16	4.7
1.2.6.	DH	30606	982	3.21	56.82	92.8
1.2.7.	DH	30606	491	1.60	1.59	5.2
1.2.8.	DH	30606	1370	4.48	24.52	28.7
1.2.9.	ICH	148552	223	0.15	2.25	10.1
1.2.10.	ICH	148552	65	0.04	0.45	0.4
1.2.12.	DH	30606	550	1.80	1.37	3.2
1.2.13.	DH	30606	8362	27.32	32.28	6.6
1.2.14.	DH	30606	15052	49.18	316.10	30.9
1.2.15.	IGH	91775	4211	4.59	216.55	67.1
1.2.16.	IGH	91775	10228	11.14	471.00	60.1
1.2.17.	IGH	91775	4027	4.39	12.99	4.2
1.2.18.	ICH	148552	4810	3.24	16.15	3.8
1.2.19.	IGH	91775	1790	1.95	4.33	3.2
1.2.20.	ICH	148552	3304	2.22	214.88	65.3
1.3.1.	WHDH	13730	3433	25.00	2.08	0.5
1.3.2.	THW	66653	6339	9.51	13.98	2.4
1.3.3.	WHE	28475	5363	18.83	136.60	29.7
1.5.1.	THW	245811	1283	0.52	2.59	2.0
2.1.1.	E	86206	5481	6.36	49.23	5.5
2.2.1.	E	86206	3778	4.38	37.10	13.0
2.2.2.	WHE	28475	1817	6.38	63.59	46.0
2.2.3.	WHE	28475	4728	16.60	4.66	1.3
2.3.1.	E	86206	11457	13.29	324.03	17.2
2.5.1.	E	86206	4402	5.11	2.59	0.4

Table 1.4. Energy saving of measures in the communal sector

Measure Code	Area Code	Base (TJ)	Energy Saving		Investmen t billion HUF	Return year
			TJ/year	%		
1.1.1.	TH	66003	18816.27	28.51	262.66	16.6
1.1.2.	TH	66003	167.21	0.25	4.54	23.0
1.1.3.	TH	66003	741.45	1.12	4.25	6.9
1.1.4.	TH	66003	14339.00	21.72	230.36	19.7
1.1.5.	TH	66003	20559.15	31.15	333.73	19.3
1.2.1.	DH	6587	48.86	0.74	0.08	2.7
1.2.2.	DH	6587	20.56	0.31	0.07	4.9
1.2.3.	DH	6587	43.24	0.66	0.26	8.1
1.2.4.	DH	6587	795.82	12.08	4.04	8.2
1.2.5.	DH	6587	108.48	1.65	0.35	4.7
1.2.6.	DH	6587	157.86	2.40	6.09	92.8
1.2.7.	DH	6587	78.93	1.20	0.25	5.2
1.2.8.	DH	6587	220.10	3.34	3.94	28.7
1.2.9.	ICH	59417	1083.37	1.82	9.03	10.1
1.2.10.	ICH	59417	156.75	0.26	1.08	0.4
1.2.11	ICH	59417	431.54	0.73	1.44	4.1
1.3.2.	THW	6587	1535.28	23.31	4.63	3.0
1.3.3.	THW	6587	142.27	2.16	43.21	142.3
1.4.1.	TH	66003	1108.89	1.68	11.56	6.97
2.1.1.	E	61235	1095.78	1.79	5.19	3.2
2.1.2.	E	61235	7446.61	12.16	138.29	12.7
2.2.2.	WHE	1470	93.75	6.38	3.28	40.8
2.2.3.	WHE	1470	440.89	30.00	0.56	1.5

Area codes used in Tables 1.3 - 1.4 are as follows.

- ICH - Individual central heating
- DH - district heating
- IGH - individual gas heating
- E - electricity

TH	-	total heating
THWH	-	total heating and water heating
WHE	-	water heating by electricity
WHD	-	water heating by district heating
THW	-	total heated water
WHG	-	water heated by gas

Of course, there are measures which are alternatives of each other, i.e. the realization of them exclude each other (e.g., windows are either renovated or changed). Therefore, we developed two scenarios: a renovation type and a reconstruction type scenario. There are such measures whose saving effect are different, if they are realized together with other measures. For example, if insulation of buildings reduces the heat demand, also this saving should be taken into consideration when calculating with heat sources of higher efficiency.

Scenarios

Tables 1.5 - 1.6 presents the two scenarios mentioned above. We marked the measures belonging to the corresponding scenarios.

Table 1.5. Scenarios for heat use

	Scenario 1 (renovation)		Scenario 2 (reconstruction)	
	Residential Sector	Communal Sector	Residential Sector	Communal Sector
1.1.1.			X	X
1.1.2.	X	X		
1.1.3.	X	X		
1.1.4.	X	X		
1.1.5.			X	X
1.2.1.	X	X	X	X
1.2.2.	X	X		
1.2.3.			X	X
1.2.4.			X	X
1.2.5.	X	X	X	X
1.2.6.	X	X	X	X
1.2.7.	X	X		
1.2.8.			X	X
1.2.9.	X	X	X	X
1.2.10.	X	X	X	X
1.2.11.				X
1.2.12.	X			
1.2.13.	X			
1.2.14.			X	
1.2.15.	X			
1.2.16.	X		X	
1.2.17.	X		X	
1.2.18.	X		X	
1.2.19.	X		X	
1.3.1.	X		X	
1.3.2.	X	X	X	X
1.3.3.	X	X	X	X
1.4.1.		X		X
1.5.1.	X		X	

Table 1.6. Scenarios for electricity use

	Scenario 1 (renovation)		Scenario 2 (reconstruction)	
	Residential Sector	Communal Sector	Residential Sector	Communal Sector
2.1.1.	X	X	X	X
2.1.2.		X		X
2.2.1.			X	
2.2.2.	X	X		
2.2.3.	X	X	X	X
2.3.1.	X		X	
2.5.1.	X		X	

Table 1.7. presents the connections among the effects of the different measures.

Table 1.7. Connections of effects

	ICH	DH	TH	IGH	E	WHE	WHG	WHD	THW	TH
ICH	X		X							X
DH		X	X							X
TH	X	X	X	X						X
IGH			X	X						X
E					X	X				
WHE					X	X			X	
WHG							X		X	X
WHD								X	X	X
THW						X	X	X	X	X
TH	X	X	X	X			X	X	X	X

Considering the mutual effects we calculated the possible energy saving of measures and the corresponding investment costs. Tables 1.8 through 1.11 show the results.

Table 1.8. Scenario 1: Savings and investments in the residential sector

	Measure Code	Investment billion HUF	Return year	Energy Saving TJ	Cumulated Investment, billion HUF
2.5.1.	E	2.59	0.36	4402	2.59
1.2.10.	ICH	0.45	0.40	65	3.04
1.3.1.	WHD	2.08	0.53	3433	5.12
2.2.3.	WHE	4.15	1.15	4486	9.28
1.5.1.	THWH	2.59	2.02	1265	11.87
1.3.2.	THW	14.49	2.24	6904	26.36
1.2.1.	DH	0.52	2.72	303	26.87
1.2.19.	IGH	4.33	3.15	1785	31.21
1.2.12.	DH	1.37	3.16	542	32.58
1.2.18.	ICH	16.15	3.79	4736	48.73
1.2.17.	IGH	12.99	4.20	3807	61.72
1.1.3.	TH	6.91	4.29	1555	68.64
1.2.5.	DH	2.16	4.68	647	70.80
1.2.2.	DH	0.41	4.91	120	71.21
1.2.7.	DH	1.59	5.18	458	72.80
2.1.1.	E	49.23	5.45	5201	122.02
1.2.13.	DH	32.28	6.61	7677	154.30
1.2.9.	ICH	2.25	10.08	205	156.55
1.1.4.	TH	479.17	16.65	26698	635.73
2.3.1.	E	324.03	17.17	10871	959.76
1.1.2.	TH	14.87	24.94	394	974.63
1.3.3.	WHE	136.60	29.70	4244	1111.23
2.2.2.	WHE	63.59	46.00	1167	1174.82
1.2.15.	IGH	216.55	59.99	3084	1391.37
1.2.20.	ICH	214.88	65.35	2398	1606.24
1.2.6.	DH	56.82	92.80	499	1663.06
Total		1663.06		96946	

Table 1.9. Scenario 1: Saving and investments in the communal sector

	Measure Code	Investment billion HUF	Return year	Energy Saving TJ	Cumulated Investment, billion HUF
1.2.10.	ICH	1.08	0.4	157	1.1
2.2.3.	WHE	0.56	1.5	433	1.6
1.2.1.	DH	0.08	2.7	49	1.7
1.3.2.	THW	4.73	3.1	1535	6.5
2.1.1.	E	5.29	3.2	1118	11.7
1.2.5.	DH	0.35	4.7	108	12.1
1.2.2.	DH	0.07	4.9	20	12.2
1.2.7.	DH	0.25	5.2	77	12.4
1.1.3.	TH	4.33	6.9	753	16.7
1.4.1.	TH	11.80	7.1	1111	28.5
1.2.9.	ICH	9.03	10.1	1053	37.6
2.1.2.	E	141.08	13.0	7307	178.7
1.1.4.	TH	235.02	19.8	13929	413.7
1.1.2.	TH	4.63	23.0	127	418.3
2.2.2.	WHE	3.23	40.8	65	421.5
1.2.6.	DH	6.09	92.8	115	427.6
1.3.3.	THW	44.09	145.8	112	471.7
Total		471.70		28068	

Table 1.10. Scenario 2: Savings and investments in the residential sector

	Measure Code	Investment billion HUF	Return year	Energy Saving TJ	Cumulated Investment, billion HUF
2.5.1.	E	2.59	0.4	4402	2.59
1.2.10.	ICH	0.45	0.4	65	3.04
1.3.1.	WHD	2.08	0.5	3433	5.12
2.2.3.	WHE	4.15	1.2	4487	9.28
1.5.1.	THWH	2.59	2.0	1265	11.87
1.3.2.	THW	14.49	2.2	6904	26.36
1.2.1.	DH	0.52	2.7	303	26.87
1.2.19.	IGH	4.33	3.2	1785	31.21
1.2.18.	ICH	16.15	3.8	4736	47.36
1.2.17.	IGH	12.99	4.2	3807	60.35
1.2.5.	DH	2.16	4.7	665	62.51
2.1.1.	E	49.23	5.5	5201	111.74
1.2.3.	DH	1.32	8.1	260	113.06
1.2.4.	DH	25.17	8.2	4771	138.23
1.2.9.	ICH	2.25	10.1	206	140.48
2.2.1.	E	37.10	13.0	3585	177.58
2.3.1.	E	324.03	17.2	10871	501.61
1.1.1.	TH	928.84	17.5	49262	1430.45
1.1.5.	TH	669.44	21.0	19988	2099.90
1.2.8.	TH	24.52	28.7	542	2124.42
1.3.3.	WHE	136.60	29.7	4244	2261.02
1.2.14.	DH	316.10	30.9	5687	2577.12
1.2.16.	IGH	471.00	60.0	5112	3048.12
1.2.20.	ICH	214.88	65.3	1632	3262.99
1.2.6.	DH	56.82	92.8	189	3319.81
Total		3319.81		143401	

Table 1.11. Scenario 2: Saving and investments in the communal sector

	Measure Code	Investment billion HUF	Return year	Energy Saving	Cumulated Investment, billion HUF
1.2.10.	ICH	1.08	0.4	157	1.08
2.2.3.	WHE	0.56	1.5	433	1.64
1.2.1.	DH	0.08	2.7	49	1.72
1.3.2.	THW	4.73	3.1	1535	6.45
2.1.1.	E	5.29	3.2	1118	11.74
1.2.5.	DH	0.35	4.7	108	12.09
1.4.1.	TH	11.80	7.1	1125	23.89
1.2.3.	DH	0.26	8.1	41	24.15
1.2.4.	DH	4.04	8.2	759	28.20
1.2.9.	ICH	9.03	10.1	1062	37.23
2.1.2.	E	141.08	13.0	7307	178.30
1.1.1.	TH	267.96	16.7	15056	446.27
1.1.5.	TH	340.47	19.4	11760	786.73
1.2.8.	DH	3.94	28.7	78	790.67
1.2.6.	DH	6.09	92.8	54	796.76
1.3.3.	THW	44.09	145.8	112	840.85
Total		840.05		40755	

This means that the overall savings are cca 125 PJ and 184 PJ for Scenarios 1 and 2, respectively. Considering the current energy use, this means that even in the worse case the overall anthropogenic CO₂ emission can be reduced by minimum 10% by means of demand side management.

1.3. Utilization of the Renewable Energy Resources in Hungary

Hungary is poor in cheap, clean, high- quality domestic energy resources. The country, has to utilize the low quality domestic fossil fuels e.g., lignite, brown coal (according the international classification peat and lignite), and more than 50% of the energy consumption is satisfied by import. Natural gas, crude oil, petroleum products and nuclear fuel are imported, too.

Nowadays, nearly all of the energy consumption of the country is satisfied by commercial energy, while the share of the non-commercial energy is just a few percents of TPED (total primary energy demand).

Earlier, even in the first part of this century, the share of non-commercial energy, which were practically renewable energy resources, satisfying the energy need of rural consumers was much higher. The different agricultural wastes, residues and by-products (first of all cereal straw, corn-stalk, corn-cob, stem of sunflower, fuel wood, orchard, vineyard trimmings, barks, wood chips, etc.) were utilized for heating and cooking purposes. Hydro potential and wind was used for milling grain, and wind energy even for pumping water for livestock and irrigation purposes, etc. Geothermal energy, thermal water was primarily used for warm water supply of swimming-pools, greenhouses and spas.

In the period of the forced industrialization, i.e. in the 50's, when cheap imported energy was available, the importance of the non-commercial energy decreased. It was not used, even if it was economical. By now, the prices of the commercial energy have drastically increased, and they reached or they are very near to the world market prices. The extensive use of the non-commercial energy, above all the utilization of the neglected renewable energy sources (RES) came into limelight again first of all for the energy supply of consumers far away from supply networks, and/or for additional and/or seasonal energy supply of the existing consumers.

Comparing the share of the penetration of the RES in Hungary to that of Austria, one may see significant differences primarily because of the different natural

conditions. In 1993, the share of the RES in Austria was about 28.3% of the TPED (1149 PJ) as follows:

- Hydro power 169 PJ
- Biomass 144 PJ
- Solar-thermal 1 PJ
- Wind and geothermal 6 PJ
- Heat pumps 5 PJ

Total 325 PJ (28,3%).

As one can see, the share of the hydro power in the RES is more than 50% in Austria. About 65% of their hydro potential and more than 50% of the biomass potential has been used, and there are plans to increase the power generation by wind energy to 85 GWh. Hungary utilizes the biomass potential in a very poor way compared to the Austrian practice.

In the developed countries, the utilization of the RES and their share in the TPED is generally less than 10%. It is generally in the range of 3-7%, except in those countries which have significant hydro potential e.g., Norway, Sweden, Switzerland, Austria.

Of course, the direct comparisons may be sometimes misleading, since the penetration and utilization of the renewable energy sources in the energy market is influenced by many factors like:

- Available resource base
- Technical status of the technology used
- Type, quality and the price of the energy supplied

Taking into consideration all of these, the more intensive utilization of the RES in the future is expected in Hungary, too.

The environmental advantages of the renewable energy sources promote also their market penetration and their competitiveness. Nowadays, the utilization of the RES may be estimated about 30-35 PJ/yr (about 3% of TPED). In Hungary the direct goal is to increase its share in 2000 at least to 5-6% of the TPED and to 175 PJ in 2010. First of all the utilization of agricultural residues, the by-products of logging, forestry, agro-industrial production, and food industry should be promoted and be increased, which is not an unrealistic and uneconomical goal.

The utilization of the RES is and is expected to be realized in the future mainly by direct combustion, but their indirect utilization may come into limelight again. Beside the traditional utilization of the biomass, their modern technologies will play a significant role in the future (e.g., incinerators, biogas reactors, biobriquettes, methane from sewage and landfills, etc.) and the more intensive utilization of the direct solar energy is forecasted. The penetration of the other renewable energy sources is not forecasted, because their prices are not competitive with those of the traditional fossil fuels at present and this will probably not change in the future.

Taking into consideration the potential of the RES, the prices and the characteristics of the renewable energy sources in Hungary, the following energy sources and technologies may be expected to penetrate into the Hungarian energy market in the next decades or may increase their existing domestic significance:

- Direct solar energy
 - Solar-thermal
 - Solar-electricity (photo-voltaic)
 - Biomass, especially agricultural wastes, fuelwood (traditional and modern way of utilization of both)
- Indirect solar energy
 - Hydro power
 - Wind power
- Geothermal energy, thermal waters, heat pumps
- Residential and municipal wastes, incinerators

It was proved by detailed calculations and investigations that the use of renewable energy resources for electrical energy generation in bulk is not economical even for long-run compared to the traditional production generally. But in special cases it may be economically utilized for supply of consumers not connected to the public supply networks, or additional and/or seasonal energy supply beside the traditional way of supply.

The penetration of the RES into the energy market is primarily determined by their costs, by the price level of the traditional energy sources and by the

modification of their price and price structure in the future mainly. The forecast of price changes of energy sources is one of the crucial points in estimating the penetration of the RES into the Hungarian energy market in the future. The Hungarian economy is in transition now from controlled economy to a market one, and our goal is to join the European Union (EU) as soon as possible. Therefore, our prices have to be similar to those of the EU. Taking into consideration all of these, and the fact that a great part of the technologies and appliances for the RES have to be imported, the international prices of these technologies and energy are taken into consideration as a base using the present US Dollar - Hungarian Forint exchange rate.

When estimating the mitigation in the carbon-dioxide and methane emissions connected with the penetration of the renewable energy sources, it was supposed that the RES will primarily be utilized by rural consumers and by the agricultural sector.

Direct solar energy

In Hungary, the insulation is in the range of 1150-1400 kWh/m²/year or 4.14-5.04 GJ/m²/yr. On average, it is about 1265 kWh/m²/yr or 4.55 GJ/m²/yr. The insolation is significantly higher by about 20-22 MJ/m²/day and much less in winter: 1.5-2 MJ/m²/day. The yearly sunshiny hours are in the range of 1900-2000 hours, its monthly distribution varies from 50 hours/month to 280 hours/month depending on the seasons. Therefore, the utilization of the direct solar energy may be realized in the summer period in bulk.

Taking into consideration that the area of Hungary is 93000 km², the total direct solar energy received in a year may be estimated about 430 EJ, which is about 370 times higher than the TPED of the country (1065 PJ) at present. Only a very small share of it is utilized at present mainly by photosynthesis, by the flora and indirectly by the fauna.

The utilizable peak power is in the range 130-210 W/m², which is still very low. In Figure 1.1. the distribution of the insolation, in Figure 1.2. the distribution of the yearly sunshiny hours are shown.

Figure 1.1. The insolation in MJ/m²/yr (continuous lines).

Figure 1.2. Sunny duration in hours in a year (continuous lines)

Solar - thermal energy conversion

The low and medium temperature (till 320-370 K) water producing flat collectors exist on commercial scale for hot water preparation for households, for agricultural purposes (heating of greenhouses, drying of crops, etc.) and for animal husbandry.

In addition, in some cities, there are so-called sun houses, where in the summer period the hot water supply is based on flat collectors. They are relatively mature technology and they are of domestic production. About 20000 m² different types of flat collectors, for residential hot water supply have already been installed, while others are installed in the agriculture. For residential hotwater supply a collector of 1.5-2 m² is needed generally to ensure 40-60 l hot water/ head/day, and 2-5 days storage of the hot water is needed because in certain periods insulation is not adequate.

The installation costs of the low thermal flat collectors are in the range of 60000-200000 Ft/m², and their energy cost may be estimated as 0.7-2.5 Ft/MJ. In case of low concentration thermal collectors supplying water of 100-170 °C temperature, the installation costs are in the range of 200000-400000 Ft/m², and their energy costs are 5.6-22.2 Ft/MJ. Concentrating collectors are not commercially realized in Hungary at present.

The costs of the advanced collectors will decrease. After 2000, low temperature thermal collectors may cost 40000-80000 Ft/m², and 0.3-1.1 Ft/MJ. Linear low concentrating parabolic thermal collectors may cost 150000-300000 Ft/m² and 0.6-1.7 Ft/MJ, respectively.

The cost of the STEC (solar thermal electricity conversion) is estimated as 540000-750000 Ft/kW_{el}, and the price of electricity produced is 26-54 Ft/kWh. This is not competitive with the price of the electricity produced by traditional technologies. If high temperature heat is produced by this technology only, its price may be estimated in the range of 0.8-2.5 Ft/MJ.

Nowadays, the utilized direct solar heat energy is estimated about 2.7 PJ in a year, which may increase to 11-20 PJ after 2000. Taking into consideration the price

level of the different energy sources, and the seasonality of the solar thermal energy, the increased penetration of the low temperature flat collectors can be expected, especially if its penetration are promoted by providing special loans to the consumers. There are special projects supported by the Phare program.

In some cases, the low concentrating linear collectors will be utilized too, but the dispersion of the STEC technology is unlikely, even for hot water preparation because of its extremely high prices even in the future.

Solar electricity, photovoltaic (PV) conversion

Photovoltaic cells are produced in Hungary, but the import cells are cheaper and more reliable at present. Because of financial reasons, it is not competitive or marketable with the traditional commercial energy, thus their utilization is limited at present. It is used by consumers far away from public utility networks, and it is used mainly for the power supply of the telecommunication networks being far from traditional utility power supply network. About 10 kW_{el} capacity PV cells are installed in communication networks at present in Hungary.

The installation costs of non concentrating PV cells are in the range of 1-1.8 million Ft/kW_{el} and price of the electricity produced may be estimated in the range of 50-64 Ft/kWh. In case of concentrating collectors, the costs may be estimated as 1.6- 2 million Ft/kW_{el} and 64-86 Ft/kWh, respectively. The share of costs of storage in the price of the electricity are included generally for the night hours, which may be estimated as 50% of the total costs.

These prices of the PV electricity are not competitive with the prices of electricity produced by traditional technologies, but in case of a consumer at least two-three kms from the distribution networks, the utilization of the PV cells may be economical. Its competitiveness will be enhanced, if the price of the storage decreases together with the price of the PV module.

After 2000, the costs of the advanced PV cells are expected to be significant less, e.g. in case of non-concentrating PV cells they will be 200000-400000 Ft/kW_{el} , 8-18 Ft/kWh, and in case of concentrating PV cells they will be 340000-400000 Ft/kW_{el}, and 16-20 Ft/kWh, respectively. If these prices will be realized in the future,

the penetration of the complex PV solar systems will be promoted, but to a less extent than that of solar thermal systems, which can be estimated as about 1 PJ within the time horizon of this study.

Biomass

For centuries, the biomass was one of the most important energy sources and ensured the normal daily life cycle of the mankind for many thousands of years. It was utilized by direct combustion, and in the late period by pyrolysis, producing charcoal. Nowadays, beside the traditional utilization, modern technologies (e.g., anaerobic digestion, gasification, liquefaction, etc.) are developed and introduced. Till now, the direct combustion has been the most important technology of the biomass utilization.

Because of the low density, a great amount of energy is needed to collect the different residues in the agriculture and to transport it to the boilers or boiler houses, where they are fired. Thus, the price of the biomass on site of the firing may be estimated as 320-780 Ft/GJ in general, which may reduce to 220-540 Ft/GJ in the future. The energy cost will increase significantly, if the biomass should be treated before firing to decrease its volume (e.g. by milling), especially when biobriquette is produced from the waste.

The solar energy stored in the leaves, stems and branches of plants may be estimated as about half of the annual energy consumption of the country at present. The quantity of the yearly biomass production in Hungary may be estimated in the range of 450 PJ, from which 120 PJ may be utilized potentially and about 30-34 PJ may be consumed economically (see figure 1.3.).

Figure 1.3. Biomass production in Hungary in the 90's (estimation)

The quantity of the primary biomass is about 54 million tonnes in a year: 46 Mt comes from the agriculture and 8 Mt comes from the forestry, from which about 20 Mt (65 PJ) may be utilized economically.

The biomass from the agriculture can be estimated as it is shown by Table 1.12.

Table 1.12. Biomass production in agriculture

	1980	1985	1990	1995	2000	2010	2020
Straw Mt	5.1	5.4	4.9	4.4	4.1	3.8	3.6
Straw PJ	45.9	48.9	44.0	39.9	37.1	34.6	32.8
Corn-stalk Mt	8.8	7.6	7.8	7.4	7.2	6.8	6.5
Corn-stalk PJ	132.7	113.7	116.9	111.6	108.0	102.6	97.2
Corn-cob Mt	1.0	0.8	0.9	0.8	0.8	0.8	0.7
corn-cob PJ	15.7	13.5	13.8	13.2	12.8	12.2	11.5
Sunflower Mt	0.8	1.0	1.0	1.4	1.4	1.4	1.4
Sunflower PJ	8.8	11.0	11.2	15.8	15.8	16.1	16.1
Vine-shoot Mt	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vine-shoot PJ	3.4	3.1	2.8	2.8	2.7	2.7	2.7
Trimming Mt	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Trimming PJ	6.2	4.7	4.3	4.2	4.3	4.2	4.2

When calculating the biomass potential in the agriculture, it was supposed that only about 60% of the straw may be utilized, the other part is used for littering and are plowed in. In case of corn-stalk, it should be taken into consideration that only a part of it may be used for energy production, because the other part is utilized for feeding of cattles. At present, a significant part of the agricultural residues is not collected, it is fired on the field.

Nowadays, the crop waste utilisation in the agriculture can be estimated about 5 PJ in a year.

The residues from the forestry and from the wood industry may be estimated as follows:

- Trimming of forestry 4.6 - 7.5 PJ/yr
- Wastes of the timber industry 9.2 - 12.6 PJ/yr

A part of the chips from timber industry is utilized to produce crush-panels. The area of forests will increase in the future, because a part of the plow-land of low-quality will be converted to forests, therefore the fuel-wood production together with

the trimming will increase in the future. It should be taken into consideration that the firing of fuelwood results in a great amount of NMVOC emission, especially dioxin emission, therefore advanced firing appliances and stoves are needed when increasing the fuelwood supply.

The utilization of biomass is realized mainly by direct combustion at present. About 600 burners and/or boilers are fired by agricultural residues in residential, commercial and communal use. The rated capacities of most of the burners exceed $1\text{MW}_{\text{therm}}$, where co-fuelling is realized with alternative fossil fuels normally because of the seasonality of biomass fuels. The total capacity of the burners is about 300 MW. Biomass is fired for district heat supply in Tata (7 MW), Sáropatak (2 MW), Putnok (5 MW), and about 5 MW capacity is to be added to the existing one in Tata.

There are some investigations aiming at the introduction of further biomass energy conversion technologies e.g., gasification, biochemical conversion processes (advanced combustion, gasification, liquefaction, pyrolysis) and at the extension of the existing biobriquette production.

In Szécsény, there is a pilot biogas plant. It has been operating from 1982. It was designed for a farm with 300 dairy cows. The biogas is produced by the manure. The rated capacity of the reactor is about 110 kW peak. Few other biogas plant is being developed for research purposes.

In the agriculture, about 20 Mt manure is produced in a year by the livestock. If there are biogas reactors on commercial scale, not as pilot projects only, a significant part of the manure and agricultural residues and of residential refuses may be utilised for biogas production, especially on farms in rural areas.

The extensive utilization of the biomass is realized at present by the fuelwood consumption of different sectors shown in the Table 1.13. A part of the fuelwood produced is for producing charcoal. Most of it is exported. In the future, the fuelwood production may be multiplied, if there is demand on it especially in the residential sector.

Table 1.13. Fuelwood and charcoal production

	1980	1985	1990	1995	2000	2010	2020
Commercial fuelwood PJ	14.10	14.40	11.70	15.90	18.00	25.00	35.00
Other fuelwood PJ	8.50	9.41	7.26	3.98	5.00	8.00	10.00
Charcoal production PJ	0.42	0.29	0.20	0.00	0.00	0.00	0.00

The residential waste may be utilized for biogas production. The price of the gas produced on site by reactor operated with straw can be estimated in the range of 720-1220 Ft/GJ. If it is operated with wood residue, the prices may increase to 1750 Ft/GJ in extreme cases.

The decay of the residential, municipal wastes in landfills produce gas, which depends on the composition of the waste. It can be estimated as 120-400 (on average 250) m³ gas/t waste. About half of the gas is carbon-dioxide, while the other half is methane. If the waste is stored in open dumps, the methane produced pollutes the environment. If the landfill is covered, the gas may be collected, separated and cleaned, which has a heating value equivalent to the natural gas. Thus it can be either supplied to the consumers, or utilized for other purposes. In big cities, it can be used for electrical energy production. In this case, the price of the electricity is about 20 Ft/kWh.

When calculating the yearly gas production, it should be taken into consideration that decay of the waste is a long process. In the first year after the deposition of the waste, about 10 m³ gas/t waste is produced, which continuously decreases to 1-2 m³ gas/t waste after 20 years.

In the future, the possible utilization of the renewable energy resources in the agriculture may be estimated as follows:

	PJ
• Biomass (primary+secondary+tertiary total)	110-146.5
• Geothermal	6-8.4
• Solar (direct)	1.5-2.1
• Wind	0.4
• Hydro-power	2.1
Total	120-159.5

Indirect solar energy

Hydro-power

There are very different estimations for the hydro potential of Hungary depending on the flow of rivers and taking into consideration the different seasonal effects. The general estimation for the potential is in the range of 4-12 TWh (fuel equivalent 42-126 PJ) in a year from which about 7-7.5 TWh may be exploited technically. The utilization of the economically exploited capacities are limited by different constraints. Nowadays, the environmental and political constraints are the most important ones. About 72% of the hydro potential belong to the Danube, 10% to the Tisza, 9% to the Dráva, 5% to the rivers Rába and Hernád, while about 4% is for other rivers.

According to internationally accepted classification, there are two small hydro power plants on the river Tisza, first of all for irrigation purposes (installed capacity 28 and 11.4 MW, yearly production is about 84.2 and 46.3 GWh), and about 26 mini and micro hydro power plants in Western Hungary on the rivers Rába, Rábca, Lajta (total installed capacity is 2.7 MW, and their yearly production is about 10.76 GWh), and in north-eastern Hungary on the rivers Hernád and Sajó (the total installed capacity is 5.7MW, yearly production is 17.17 GWh). Thus, the total installed capacity of the hydropower plants is 48.4 MW. Depending on the flows of the rivers, there is a slight variability in the yearly generation of the hydro power plants. In Table 1.14, the yearly electrical energy production is shown, where the energy for generation is calculated by fuel equivalent. The fuel equivalent is calculated using

the average heat rate of the domestic fossil fuelled power plants, i.e. if hydro electricity is produced by an average domestic fossil fuelled power plant.

Table 1.14. Power generation by hydro power plants.

	1980	1985	1990	1991	1992	1993	1994	1995
Production TWh	0.114	0.155	0.178	0.194	0.158	0.166	0.161	0.164
Fuel equivalent PJ	1.320	1.550	1.780	1.940	1.580	1.660	1.610	1.640

Table 1.15. presents the detailed data of the small and micro hydro power plants.

Table 1.15. Hydro power plants in Hungary in 1995.

Power plant	River	Rated cap. MW	Peak MW	Production GWh
Kisköre	Tisza	28.00	28.00	84.57
Tiszalök	Tisza	11.40	11.80	43.34
Ikervár	Rába	2.00	2.20	9.88
Western micros		1.30	0.40	3.38
Kesznyéten	Hernád	4.40	4.40	16.91
Gibárt	Hernád	0.50	0.50	2.88
Eastern micros		0.80	0.40	2.59
Total		48.40		163.55

Earlier, the micro hydro power plants used to be water mills. In 1885, there have been more than 22000 water mills in Hungary, some of which have been

transformed to electrical energy production by connecting asynchronous generators to their water wheels or turbines. They supply electrical energy direct to the local low-voltage distribution networks. They produce very cheap electrical energy, but they are not able to cover the cost of the reconstruction of the waterways and other hydro-installations.

There was designed a hydro cascade on the Danube at Bős and at Nagymaros for irrigation, navigation, water regulation and electrical energy production purposes. The Bős hydro power plant have been installed by the Slovak Republic, but the 800 MW Nagymaros hydro power plant was cancelled by the Hungarian Parliament because of environmental, financial, political and other reasons. The specific cost of the investment of the Nagymaros hydro power plant would be twice higher than the specific installation cost of the 1840 MW Paks Nuclear Power Plant.

The investment cost of the hydro power plant depends on the head exploited, on the geographical conditions and on the characteristical hydro potential. Hungary is a plain country, therefore mostly run-of river hydro power plants of low head may be realized, thus the investment cost is high because of the build-up constructions needed. The investment cost of a mini or micro hydro power plant is in the range of 250000-600000 Ft/kW_{el}, which may reach 850000 Ft/kW_{el}, when low head run of river micro power plant is established. In this case, the cost of the electricity produced may be in the range of 3-13.5 Ft/kWh. Because of the high investment costs, the electricity generation alone generally does not justify the economy of the hydro power plant in Hungary, but a combination of flood control, drainage, shipping, fisheries and environmental issues may promote its economy.

Because of problems connected with the Bős-Nagymaros hydro cascade, it is time to deal with new hydro power plants on the main rivers. There are opportunities to install micros on different places, if there is capital to invest.

Not only the build-up constructions for the hydro power plants are too costly in Hungary, but the machinery is expensive, too. Recently, the pipe turbine solutions have come into limelight. Because of the high specific installation cost, the time of the recovery of the investment is too long.

Wind power

The dominant wind directions and the average wind speed are shown in Figure 1.4. in the summer period, and in Figure 1.5. in the winter period.

Figure 1.4. Dominant wind directions and average wind speed in Hungary in summer.

The average wind speed is generally in the range of 2,5-3,5 m/sec in Hungary. The mean energy output of a wind turbine per m^2 of swept rotor area is expressed by equation

$$E = b \cdot v^3 \text{ kWh/m}^2/\text{yr},$$

where b is the performance factor (for wind turbines at present $b \approx 0,32$ at present) and y is the annual average of the wind speed. The capacity factor of wind turbines is about 6-15%, thus their production is low, and their installed capacity is poorly utilized.

Figure 1.5. Dominant wind directions and average wind speed in Hungary in winter.

Since the average wind speed is very low in Hungary, special multibladed wind converters are needed, which start and produce electricity at low wind speed already. Similarly, their energy output is very low, relatively big rotors are needed to produce even these small output. Therefore, the wind energy is not economical for extended utilization in Hungary.

In special cases, where the consumers are more than a couple of kms from the public distribution network, the installation of wind turbine to generate off-grid electricity (0.5-1 kW) may be economical.

Classical multi-bladed, low speed wind turbines are used for water pumping even from 70-90 m deep wells with a capacity of 40-110 litres/min (3.5 kW) and for irrigation or for ventilation of crops (7.8 kW). The low speed wind turbines may be used for pumping water for the animal husbandry, but for irrigation they cannot be used on large scale because of the overall decrease of the underground water level.

It is worth mentioning the environmental problems connected with the operation of wind turbines. For example, TV and radio disturbances may occur, therefore special rotors made of plastics are needed to reduce the serious interference problem. The rotors are dangerous to birds, which has to be taken into consideration when selecting the sites and the features of the wind turbines, etc. The

most serious environmental problem connected with the operation of a wind turbine is the noise, which may be calculated for traditional wind turbines by equation

$$\text{noise} = 22 \cdot \lg D + 72 \text{ dBa},$$

where D is the diameter of the rotor in m.

The installation cost of a wind turbine for electricity generation is in the range of 180000-540000 Ft/kW, and the price of the electrical energy produced may be estimated in the range of 6-23 Ft/kWh, which may slightly decrease in the future to 5-7 Ft/kWh. The prices for smaller wind turbines may increase till 400000 Ft/kW and 25 Ft/kWh, respectively.

Large scale wind energy systems, which is the combination of different energy sources, thus supplying more reliable electrical energy, are three to six times more expensive generally, but their availability and reliability is significant higher than in case of a single wind turbine driven generator.

Utilization of geothermal energy

Hungary has one of the biggest geothermal energy potential of low and medium enthalpy in Europe. The overwhelming part of the thermal water resources occur in the Upper Pannonian as a high temperature water-dominated systems which consists of sand and sandstone and to a minor extent clays and silts. Owing to the lacustrine, littoral facies, as well as to the oscillating rate of subsidence of the Pannonian Basin, the porosity and permeability of the layers vary in an irregular pattern, both horizontally and vertically, thus forming a multi-aquifer reservoir system. The maximum depth of the boundary Lower/Upper Pannonian is more than 2.500 m in the Great Hungarian Plain and in the North of the Little Hungarian Plain. The thermal water is of alkali bicarbonate type and the total dissolved solids normally amount to 500 to 5.00 ppm, at some places exceptionally values of 15.000 ppm do occur.

In basement of Great Hungarian Plain, the geopressed reservoirs have been found. These systems are characterized by high reservoir pressure and at temperature and presence of dissolved natural gas (3 to 12 grams per liter in the liquid phase).

Thus, in well Nagyszénás-3 (South-East part of Hungary) before and during the flow test the following characteristics were measured:

- Well-head temperature (in static conditions): 115°C
 - Well-head pressure (in static conditions): 400 bars
 - Reservoir temperature at depth 3011 m: 198°C
- Well-head temperature (in dynamic conditions): 171°C
- Well-head pressure (in dynamic conditions): 45 bars
- Flow-rate of geothermal brine: 2000 cu.m/d

The quantitative parameters of utilization are on world level but the efficiency is very poor, because of the production of thermal water is extensive (about 200 Million m³/year in 1990), and direct reserve consumer because of water reinjection is nowhere used, water disposal being into surface basins.

The thermal water reserves of Upper Pannonian formations as main geothermal reservoirs are directly consumed.

The possibility of electricity generation by binary Organic Rankine Cycle System (ORC) was analysed on the base of thermal water producing wells and abandoned CH-wells.

The basement areas in Hungary with high enthalpy reservoirs (geopressurized systems) suitable for electric power generation have been allocated.

A preliminary analysis has established that the electric power generation by ORC method and other methods from geothermal energy would result in:

- Potential installation capacity 25 MW
- Generated electric power 215 GWh/a
- The quantity of saved imported

crude oil	500 thousand t/a
its price	50 Million USD/a
- The reduction of annual emission

810 thousand CO ₂ ;
1100 t NO _x ;
3500 t CO.

The investment and operational costs of geothermal current generation have been compared with domestic power plant types and with imported electric power. This comparison has given favorable results.

The utilization of geothermal energy in Hungary has the following special characteristics.

Disadvantages

- The geothermal energy as additive type of energy sources with low energy level has local characteristics and its utilization is possible only in a special type of heat utilization systems
- Scaling in some places has special problems with increasing cost

Advantages

- Hungary has a big geothermal energy potential
- Geothermal energy is an environmentally sound type of energy without air pollution
- The dependency on imported energy sources would be decreased
- Amount of jobs can be increased
- Competitiveness of geothermal energy can be increased because of increasing domestic prices of fossil energy sources

Geothermal pilot projects

The Hungarian Oil Inc. (MOL) has a comprehensive program 'Geothermy' for utilization of geothermal resources.

Because none of the project areas have been associated with a specific use of the known occurrence of geothermal energy so far, project objectives are initially to define pilot projects for each location, examining opportunities for utilization that could range from direct heat exchange systems to integrated energy cascade systems.

The goal is to conduct pre-feasibility studies, involving pilot experimentation, in order to obtain information on appropriate technology and design suitable for the reserves at a given geothermal reservoir location. A corollary objective of the project is to evaluate the economics of each application, including rate of return and cash flow projections, together with investment scenarios, financing and co-financing and related topics.

At present there is no electricity generation using hot water or wet steam in Hungary, yet.

Andráshida-Nagylengyel geothermal pilot project

The area of this project situated in South-Western part of Hungary close to City of Zalaegerszeg. The main objective of the compiled pre-feasibility study is an investigation of possibility of cascaded use of the geothermal energy in a combined production of electricity and hot water. Project focuses on the use of hot water for heating and domestic hot water supply in the city combined with comprehensive use in a proposed new 5 ha greenhouse complex in the vicinity of Andráshida. According to a pre-feasibility study the following premises are used in the economic viability calculations.

Table 1.15. The main economic data of the Andráshida project

Time-life of project (depreciation period)	4% per annum (25 years write off)
Total investment cost, MUSD	1.374 - 4.343
Real interest rate, %	9
Net present value, MUSD	0.905 - 12.700
Internal rate of return, %	13.4 - 25.5
Payback period, years	3.91 - 7.13

Nagyszénás - Fábiánsebestyén geothermal pilot project

According to the preliminary assessment a very large geothermal/geopressured reserves exist in Békés Basin in South Eastern part of Hungary.

Numerical reservoir simulation based on Fábiánsebestyén-4 well flow data shows that the geothermal reserves may be able to sustain 50 MW_e of production for more than 25 years and simulation based on Nagyszénás-3 well show that the well produce up to 6.7 MW_e from combined geothermal fluid and gas production for at last 25 years.

The economic analysis for a 50 MW_e project at Fáb-4 well shows that the project requires an electricity price that begins in 1999 at 6.5 cents USD/kWh and escalates at a fraction of the inflation rate for the 20 year project's life.

The 6.9 MW_e project at Nsz-3 well is economically viable at an electricity price of 9.5 cents USD/kWh.

This cycle is included the following steps.

1. Hydraulic turbogenerator (rotary separator) is installed at the well head to capture that kinetic energy from the geothermal fluid stream
2. An Organic Rankine binary power plant to extract heat energy from the geothermal fluid
3. Methane from the geothermal fluid would be burned in a gas engine to generate additional electricity with the exhaust being used to preheat the working fluid in the binary power plant
4. Direct use included municipal and greenhouse heating

Waste incinerators

One of the modern biomass utilization technologies is the incinerator, where the energy content of municipal waste is utilized for heat or/and electricity production.

The quantity of the residential waste in Hungary in the past and forecasted for the future are shown in Table 1.16.

Table 1.16. Waste generation in Hungary

	1980	1985	1990	1995	2000	2010	2020
Refuse transported 10⁶.m³	9.85	12.56	16.69	17.32	19.40	20.94	22.75
10⁶.tonnes 10⁶.m³	2.35	2.31	2.27	2.25	2.52	2.72	2.95
From flats 10⁶.m³	6.50	7.59	9.87	11.56	12.95	13.98	15.18
Share of flats with ref. transportation %	50.90	57.50	64.90	73.20	78.00	82.00	85.00
In Budapest %	99.70	99.80	99.80	99.90	99.90	99.90	99.90

A slight increase is expected in the future. The energy content of the residential waste can be estimated as 16-12 PJ. It may be utilized either by combustion or by producing methane collecting the gas from landfills or from biogas reactors. (The residential waste production in Hungary per capita is 200-250 kg/yr, which is about 60-65% of the EU average, and the density of the waste is supposed in the range of 0.15-0.3 t/m³). In Budapest and in the cities, about 95% of the total municipal waste is collected, while in rural areas, the residential waste is generally open dump stored, therefore its energy content is not utilized. In Budapest, there is a municipal solid waste incinerator, where about 300 kt/year waste is fired. Its installed capacity is 24 MW. It was planned for CHP production, but it generates only electrical energy at present. The yearly average calorific value of the municipal waste fired is in the range of 6-8 MJ/kg. The main characteristic data of the incinerator in Budapest are shown in Table 1.17.

Table 1.17. Characteristical data of the incinerator in Budapest

	1990	1991	1992	1993	1994	1995
Peak load MW	16.00	20.00	14.30	11.50	14.30	18.60
Production GWh	34.29	48.25	90.99	76.57	90.69	95.10
Heat rate MJ/kWh	17.83	17.83	19.10	19.02	20.99	19.89
Efficiency %	20.19	20.19	18.85	18.93	17.15	18.10
Waste fired PJ	0.61	0.86	1.74	1.46	1.90	1.89
Capacity factor %	16.30	22.95	43.28	36.42	43.14	45.23

The heat generated or the methane produced depends on the amount and on the composition of the waste collected. The yearly average composition of the municipal waste in Budapest is presented in Table 1.18., where the average composition of the waste in the European union are shown, too.

Table 1.18. Composition of the municipal waste in Hungary in % (by weight)

	1980	1990	1993	1995	1996	in the EU
Paper	16.5	19.6	17.1	17.0	19.0	26.0
Plastic	4.5	4.6	5.6	3.5	4.5	7.0
Textile	5.5	6.8	6.6	4.3	3.4	
Glass	4.0	6.3	5.0	3.1	3.0	10.0
Metals	4.5	6.0	4.8	4.2	3.8	5.0
Fermentable organic	28.5	32.0	34.5	35.1	33.5	36.0
Other non organic	36.5	25.7	26.4	32.8	32.8	31.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

In the EU about 63.2% of the municipal waste is stored in landfills, 21.2% fired by incinerators and 8.3% is stored in open dumps. A significant part of the methane

produced in landfills is collected and utilized. As one can see, there is no significant difference in the composition of the municipal wastes in the EU and in Hungary. Therefore, the practice of the EU may be forecasted also for Hungary. At present about 12% of the domestic waste is fired by incinerators in Hungary, therefore more incinerators of smaller rated capacity may be installed in Budapest and in larger cities (about 1.2 million inhabitants produce 300 kt residential waste in a year on average). The installation of a second incinerator is begin planned in Budapest at the moment.

The installation of the incinerators may solve the serious landfill site problems, and it will reduce the methane emission connected with the landfill disposal of the domestic wastes.

To decrease the methane emissions connected with open dump waste disposal in rural areas, a solution can be the installation of biogas reactors. If it is connected with the input of agricultural residues and of manure from the livestock, it is not only suitable for the reduction of the methane emission, but a significant amount of biogas may be generated to cover the energy demand of farms. The market penetration of the biogas reactor will speed up, if its price will be competitive with that of the commercial fossil, especially of gaseous fuels.

The investment of the municipal incinerator is in the range of 300000-500000 Ft/kW, and cost of the electricity produced is in the range of 3.6-36 Ft/kWh, generally. In Dorog, an incinerator fires the industrial, especially the pharmaceutical hazardous wastes.

The reduction of the carbon-dioxide and the methane emissions connected with the more intensive utilization of the renewable energy sources

When calculating the reduction in the emissions of the most important GHGs' i.e. of carbon-dioxide and methane, one has to take into consideration that the penetration of the renewable energy sources in the energy market will depend on the future price structure of the traditional fossil fuels and on the technical status of the devices and appliances utilizing the renewable energy sources. If a significant advance will occur in the technologies in the future, the penetration may certainly be

accelerated. In this estimation normal technical development has been supposed. The results of the forecast based on the traditional way of thinking are in a wide range, therefore the most probable ones are presented only. It is worth mentioning that the market penetration of the RES depends on the infrastructure, and on the service systems, too, which are still not available now. It is, however, supposed that in the transition period of the Hungarian economy the development of the service sector will accelerate. In this case, the penetration of the renewable energy sources may be estimated as it is shown by Table 1.19.

Table 1.19. Forecast of utilization of renewable resources

	1995	2000	2010	2020
Solar-thermal PJ	2.70	8.00	15.00	25.00
Solar-electric(PV) PJ	0.01	0.05	0.10	0.30
Biomass (agr. waste+manure+fuel-wood)	25.00	35.00	65.00	85.00
Hydropower PJ	1.65	1.65	1.65	1.65
Wind energy PJ	0.10	0.20	0.30	0.50
Geothermal PJ	6.50	9.00	12.00	15.00
Incinerators	1.90	1.90	3.80	7.60

When estimating the reduction in carbon-dioxide and methane emissions, it was supposed that use of solid fuels, and electrical energy will be reduced. Figure 1.6. presents the estimation of GHG emission reduction.

Figure 1.6. Forecasts of GHG emission reduction by using renewable resources.

The reduction in methane emission is connected primarily with the waste incineration, because the methane emission from landfills will be reduced.

2. FORESTRY

Forestry may belong to the few branches of the economy, where carbon can actively be removed from the air. Since the carbon-dioxide concentration of the air is still growing, measures that enhance carbon sequestration, first of all afforestations, must be given priority in the Hungarian forestry. In addition, measures can also be taken that aim at preserving carbon that is already fixed in soil, vegetation and wood products. Hungary has large potentials in combatting dangerous levels of carbon-dioxide.

These potentials can be demonstrated by a simple example. The net increase of carbon fixed in the biomass of the forests in Hungary over 1980-1990 amounted to 12.4 million t. This increase, which is a benefit not only for the country, can mainly be attributed to two factors. On the one hand, forest cover was constantly increased in the eighties and the previous decades, and slower growing species and varieties were replaced with fast growing ones, on the other hand. Since the rotation age of fast growing species is 30 years on the average, this is the time span, over which carbon is constantly removed from the air by a plantation with these species. However, the average time of removal in Hungary is longer than 30 years, since the indigenous tree species of the country live much longer. Therefore, in addition to the high speed of sequestration, this long time of removal is another advantage of afforestations.

Sequestering carbon is one of the multiple benefits of forests. These benefits include the protection of the environment, i.e., protection against erosion and deflation, filtering of the air and precipitation, ensuring biodiversity, improving local climate, controlling floods, etc. Therefore, it is desirable to establish new forests on

large areas for a variety of reasons. Although the momentum of the former afforestation programs has temporarily decreased by the ailment and the transition of the economy, the conversion of land from cropland to forest could and must be speeded up to exploit the carbon sequestration potentials mentioned above. This section analyses these potentials.

Setting priorities in the forestry sector

With respect to forestry, Hungary belongs to the most developed countries in the world. The rules of sustainable forestry developed long ago, and all professional, institutional and legal conditions of sustainable management of forests are ensured. A new Forestry Act was enacted in 18 June 1996.

Nevertheless, some recent processes, namely the privatization of land and forests, as well as profound economic and political changes in the country have perturbed the development of forestry, whereas these processes created new challenges and possibilities for further development, too. Privatization will end up in a few years, and every piece of forested land will be owned by one of the many types of forest owners: a single person, a group of people, any type of cooperatives, companies or other institutions, or by the state. The economy has entered into the phase of growth, which will mean growing demand for wood products.

The tasks of forestry in the near future can be deduced from these and other processes and classified as administrative or professional. Administrative tasks include having forestry act and other forestry related regulations got known and accepted by new forest owners, as well as fostering the establishment of forestry

associations and cooperatives of forest owners that would allow for keeping the high level of management of forests. The reinforcement and partial reorganization of forestry inspection is also required. These measures must be realized independently from carbon issues, but these measures will have a beneficial effect on carbon sequestration, too, and fostering carbon sequestration will speed up the general development of forestry.

With respect to carbon mitigation, professional tasks in forestry are rather clear. These tasks can be resolved by a number of methods that can be grouped as management for preservation and management for storage. Table 2.1 summarizes these methods as well as their relative significance.

Table 2.1. Carbon mitigation methods in forestry in Hungary (The number of asterisks shows the relative importance of the various methods, but is not in direct proportion to this importance.)

Methodical group	Method	Significance
Preservation of carbon pools	Preservation of forest land	*
	Preservation of carbon density of stands	*
	Preservation of carbon in soil	***
	Preservation of carbon in wood products	*
Expanding carbon storage (including substitution)	Expanding the area of wood production forests	*****
	Establishing wood fuel plantations	***
	Increasing of efficiency in forestry	*
	Increasing of carbon content of existing stands	**
	Increasing of carbon in wood products	*

With respect to expanding the area of wood production forests and establishing wood fuel plantations, it must be mentioned that, although there are similar measures for the mean planting trees on abandoned land, the technology, financing and other aspects may be quite different. Therefore, they may require different carbon flow and cost-benefit analysis, as well as different implementation measures. Consequently, they are treated separately below if necessary.

Except for expanding forested area, carbon mitigation measures are in line with traditional tasks and objectives of forestry. However, establishing new forests and plantations require a lot of investment, which is beyond the capacity of the country at the moment.

Identifying and selecting measures for evaluation

It follows from the above facts that there are a number of measures that must be considered as possibilities for mitigation. Since forestry is fairly developed in Hungary, little could be achieved by, e.g., enhanced regeneration, agroforestry or urban and community forestry. This does not mean at all, of course, that these measures are not worth consideration. However, it is also clear that the significance of the various measures is quite different. From among all measures, expanding the area of wood production forests and establishing wood fuel plantations are those ones that both are by way the most promising and are worth evaluating and require detailed analysis for implementation. These are the measures that may result in the most benefits in Hungary as far as carbon sequestration goes. In some regions (where specific species and technologies are used), preservation of soil carbon may also be important.

The measures selected above for investigation were partially analyzed by Somogyi (1996, and 1997). According to these analyses, all professional conditions are given for a large-scale afforestation program. Following the presentation of the analysis with respect to flows of carbon, costs and benefits, the administrative and political implications of the measures will be covered.

Evaluating selected measures

General comments and potentials

As compared to the size of the country and to the forest area, large agricultural lands are awaiting conversion. According to recent surveys, more than one million ha of former agricultural land will become available for afforestation. One reason for the size of the land to be converted is that, after a large-scale privatization program, a considerable part of the land is owned by private land owners. Generally, it is, or will be, in the interest of these owners to utilize their land profitably, which may mean that the timber grown in their forests is used in the farm itself. Many people are planning to develop a farm where agriculture and forestry are combined.

Afforestation could not be limited to smallholders' lands. There are also large areas, that are owned by regional and local governments. In afforesting these lands, professional forestry companies would help. These companies would also help private landowners to assess site conditions, select appropriate tree species, provide the landowners with improved propagation material, and to prescribe and assist in technology. The long traditions of afforestation, many nurseries, the expertise of tending and other silvicultural work, as well as other elements of professional background of these forestry companies would ensure high efficiency in afforestation.

In addition, because of low wages and relatively high unemployment in the regions concerned, enough workers will be available for doing necessary field work.

For mechanizable operations, good quality machines are at hand, too. As it was mentioned above, the Hungarian Parliament has recently passed the new Forest Act. This will ensure the sustainable management of the new - and also of all other - forests in Hungary.

Most of the land to be converted used to be covered by forests before the intensive extension of arable land centuries ago. Roughly one half of this area is found in the lowland of the Eastern part of the country, the other half is scattered in the hilly parts of the Northern and Western parts. As far as site and species are concerned, it can be stated that, on the average, fast growing species can be planted on sites of medium quality. The majority of the afforestations would serve for timber production, and the function of most of the rest would be protection, mainly environment protection. Land for conversion could include several thousands ha of tree belt for arable land protection and channel and canal protection, roadside belt and also snowbelt. In addition to breeding, the latest achievements of research on silviculture and yield can also be used to optimize tree growth and, hence, maximal CO₂-sequestration.

Large-scale reforestations can be carried out in the long run only. Therefore, it is assumed that land conversion will be done by 2050. It is also assumed that the afforestation project could already be started in the near future.

All this means that Hungary possesses large potentials for afforestations. The use of timber from traditional forestry is more developed than the utilization of wood fuel from energy plantations. In any case, several scenarios can be set up for analysis.

Scenario assumptions

Scenarios are developed from current trends, as well as from natural and technical potentials. The scenarios are developed for wood production forests; data for energy plantations are deduced from these estimates.

For the baseline scenario, which is unlikely but represents a basis for comparison, it is assumed that no afforestation will take place until 2050. It may, however, happen that the current rate of afforestation will continue, i.e., 3,000 ha of forests will be established per year during the next 50 years. This will require effort of the country, but it can easily be done if politicians decide so, in which case no extra propaganda should be pursued. This is taken as the first mitigation scenario, namely, the *likely-trend scenario* (marked as I). The three other mitigation scenarios were developed by analyzing the potentials.

The second mitigation scenario, the *programmatic scenario (II)* could be carried out in a way similar to the current afforestation program of the government, which is to make afforestations on 150 thousand ha in the next decade or so. That would require finding additional sources in the country, and some foreign aid, too. However, the program is already prepared by making fairly good assessment of the available land, its allocation and site conditions, as well as of the species to be planted. In this scenario it was assumed that the program is restarted and that 210,000 ha forest will be planted by 2010 (this is equal to a yearly afforestation of 15,000 ha).

The third mitigation scenario, the *achievable scenario (III)* requires a yearly reforestation of 11,000 ha land by 2050. This would result in reforesting almost 600

thousand ha of land. According to the latest analyses, this is the land where the site can be regarded as suitable for forest management with acceptable benefits. However, this rate of afforestation is not comparable any more with the production capability of the country, so foreign aid is needed to help decision makers to engage in this program.

The fourth, and last, mitigation scenario, the *technical potential scenario (IV)*, represents an afforestation of nearly 1 million ha land by the year 2050 at a rate of 18,000 ha per year. This program requires substantial aid for the country. This is, however, the mostly preferred scenario because of its beneficial effects: it ensures the highest rate of C-sequestration, green cover on unused or marginal agricultural land, it creates the most job opportunities, it increases biodiversity to the greatest extent, etc.

Modelling of flow of carbon, costs and benefits

In order to analyse the effects of the selected measures, two studies were conducted (Somogyi, 1997 and Hungarian Climate Change Country Study, Chapter II/3). Both studies were based on simple functions of carbon content of pools and flows in the carbon cycle of forests and forestry. The main model in the analysis was CASMOR, which is a modified version of COMAP (LBL, 1995). Details concerning the structure of CASMOR can be found in Somogyi, 1997. Most data used in the model are taken from earlier measurements, and correctly describe both natural processes and technological aspects.

The change in land area, as well as the flow of carbon, costs and benefits are best demonstrated by the outputs of running the model. Because of the large amount of data, only those for the achievable scenario (III, afforesting some 600 thousand ha by 2050) are shown (Figure 2.1).

Figure 2.1. The amount of carbon sequestered in the various afforestation scenarios (I-IV).

As for carbon sequestration, it can be stated that there are considerable differences between the scenarios. However, the amount of carbon sequestered is relatively small compared to the amount of carbon released in Hungary every year: the total amount of carbon fixed in the technical potential scenario (some 39 Mt C

over 54 years) is barely double the amount of carbon that was released in 1990, i.e., in a single year (about 22 Mt C).

Concerning carbon flows, it is worth citing two additional lessons from the model runs. One is that there is substantial difference between the soil carbon pool, and both other carbon pools and the amount of carbon that can be sequestered by either mitigation scenario. This directs the attention to the importance of protecting soil carbon pools. The other lesson is that most of the carbon sequestered is fixed in the second part of the more than half-a-century-long period. This means that in spite of the heavy investments, benefits of carbon sequestration only appear after a rather long period of time. Consequently, afforestation programs should be launched as quickly as possible.

With respect to costs and benefits of the various scenarios, Table 2.2 contains the cost-effectiveness indicators that speak for themselves. (For the definition of the indicators see Countries Studies Management Team, 1995, or Somogyi, 1997.) What should be mentioned here is that the cost of carbon sequestration in forestry in Hungary are well below those in other branches of the economy.

Table 2.2. Cost effectiveness indicators for the four mitigation scenarios

Indicator	Mitigation Option			
	I	II	III	IV
Net Present Value of Benefits				
\$/tC	-7.018	-6.491	-6.481	-6.480
\$/ha	-420.630	-262.842	-262.451	-262.394
Benefit of Reducing Atmospheric Carbon (BRAC)				
\$/tC-yr	-0.526	-0.487	-0.486	-0.486
Initial Cost				
\$/tC	0.007	0.014	0.004	0.002
\$/ha	0.425	0.550	0.150	0.092
Endowment (Present Value of Costs)				
\$/tC	25.447	39.921	21.522	18.839
\$/ha	1525.093	1616.604	871.549	762.895

With regard to costs and benefits, both have been assessed from the practice of the government-owned forestry enterprises. The cost of afforestation in Hungary,

1000-1050 \$/ha, is higher at present than the cost of \$230-1000 \$/ha reported by the Countries Studies Management Team (1995). Timber prices, on the other hand, are lower than in other countries. However, with the Hungarian economy getting more integrated in the European one, and with the ongoing privatization, the price system may substantially change. Costs of forestry operation will thus decrease and benefits will increase because of the higher efficiency of the private forest management.

It must be noted here that the most sensitive part of CASMOR to input data is the one for the economic analysis. In reality, the land to be afforested has not got a uniform site, but rather a very mosaic one. Whereas costs are little dependent on site, growth rate, and hence, benefits do depend a lot. In this analysis, it was impossible to investigate the effect of site on profitability in the lack of proper data on site and on site-dependent economic data. (Such an analysis could be conducted on any specified area in case a reforestation program is seriously planned to undertake.) Therefore, the results of the model runs for costs and benefits should be evaluated with due care.

It must also be mentioned here that establishing energy plantations may or may not take place on the land that was considered in this analysis. Since the yield of energy plantations may be much more than that of forest stands, the amount of carbon sequestered rises with increasing amounts of such plantations. As an achievable scenario, it may be assumed that some 200 thousand ha of land will be used for energy plantations, half of which will be established instead of wood production forests. In this case, the amount of carbon that either can be sequestered

or preserved (due to substitution for fossil fuel) may well be over 30 million t by the middle of the next century.

Choosing measures to be included in the forestry section of the plan

Based on expert opinions and the results of the analyses presented above, three mitigation measures deserve substantial effort for implementation. These are:

- Afforesting large areas
- Establishing energy plantations and organizing the utilization of wood fuel
- Fostering further analysis of applicable technologies to avoid releasing carbon from soil

Since the first measure may have by way the largest impact on the carbon content of the air, it will be analyzed further in the most detail. One must also bare in mind that establishing wood production forests and energy plantations have much in common.

The implementation of either mitigation scenario III or IV would be a major achievement for the Hungarian forestry. According to some analysis, the forest cover in Hungary would be optimal at around a rate of 25-30%. If either of these two scenarios were implemented, the forest cover would be raised to 25 and 28,5%, respectively. This would create a green surface with a lot of benefits for people, as well as for the local and regional environment.

Either of these scenarios would increase the production of wood products, which would be beneficial for the import-export budget of the country. Currently, the country is struggling with a foreign deficit, i.e., more products are imported than

exported. Our reliance of timber products on the willingness or capacity of other countries to export would largely decrease with our growing capacity to produce these timber products.

Another beneficial effect of a large-scale afforestation program would be the job creation. The average unemployment rate is around 10% in the country, and there are some regions where it exceeds 20%. These are usually agricultural regions, where it creates considerable tensions that agriculture becomes unprofitable. These are the regions, where afforestations should be made, which would increase employment possibilities. According to a recent decision of the Hungarian government, a certain sum of money is allocated for public and communal works to cope with unemployment. A reasonable and efficient way of using this money could be the implementation of large-scale afforestations.

However, such a program requires an ample source of financial support. The establishment and first thinning costs amount to ten or several tens of millions of dollars. This is several times more than the amount the Hungarian economy could afford in the last few years, and which seems to be able to afford in at least the next decade. The program could be implemented with joint effort, i.e., joint investment for both economic and environmental benefits.

Policies needed for implementation

Hungary has a long tradition in agriculture and forestry. People in the countryside are used to this type of work also because the industry is not evenly distributed in the country. Since 1990, a sharp change of political and economic

ystem, the acceptance is growing that agriculture will be no more profitable on lands of relatively poor quality. It is, however, not straightforward at all for most people on which lands agricultural production will become marginal or unprofitable, and what these lands should be used for. Careful economic analyses, conducted jointly with land-owners, must be carried out to find solutions that are suitable both for the landowners and for the national economy and environment. This would also imply a general re-analysis of the use, structure and allocation of agricultural lands of the country. This would be necessary even if no afforestation programs will be implemented.

In case only either of the first two scenarios (i.e., the baseline and the likely-trend scenario) will take place, no special measures must be taken. If either of the other scenarios are to be fulfilled, first a survey of suitable and available land is necessary. This would also mean a survey of farmers' willingness to afforesting their land and to join forest associations. Although reliable surveys already been made in most of the country years ago (to provide land for a government-funded afforestation program), these surveys must be redone and completed.

An economic analysis and consulting may also be necessary for the farmers to accept afforestation as a viable form of land use. Agriculture has a long tradition in most of the country, and farmers may reluctant to convert their land to cultures of long rotation. An intensive PR program could promote acceptance in other segments of the society, as well includint communities, local governments, environmental groups etc.

In addition to land use issues, afforestations involve several types of benefits outside the forestry sector. These indirect economic, environmental, social, welfare,

health-care, etc. benefits are always local ones, so they were not accounted for in this analysis, but they are also worth analyzing in any given region where reforestation is an option to take. Based on such an analysis, decision makers may easier embark on launching a program.

Before large-scale planting, planning and production of propagation material are also necessary. In planting and tending, it must be organized that advise, by professional local forest enterprises, on technology, training courses, technical assistance and other help is provided. Finding forms and ways of financial help for farmers and other landowners is also necessary. The developing of the system of long-term loans, low interest rates, premiums on good quality work and other financial techniques is under way.

Afforestation requires careful work, and its cost largely depend on technology and organizing field work. The various companies undertake afforestation work at different costs and effectivity. The companies that guarantee the lowest costs and highest effectivity would and should be selected by competitive bidding.

Important elements of a reliable afforestation programs for carbon sequestration are, among others, up-to-date forestry law and an affective forest inspection. In this respect and concerning other conditions, the country is prepared for large-scale and long-term programs.

Forestry plan

Currently, the country has large areas that could be converted to forest. As recent studies confirm, this conversion would result in intensive carbon

sequestration. The conversion is done by afforesting former agricultural fields and involves several types of activities that are to be financed.

First, a resurvey of suitable and available land is necessary, and former surveys must be completed. The survey is followed by site assessment and the selection of appropriate tree species and production technologies. A survey of farmers' willingness to afforesting their land and to join forest associations is also necessary. An economic analysis and consulting may also be necessary for the farmers to accept afforestation as a viable form of land use.

It must be noted that government has already got an afforestation program that is well founded from a professional point of view, but lacking financing. On state owned land, or on land of cooperatives and associations the above surveys could be done at reduced costs. Therefore, a considerable portion of joint implementation could be conducted by accelerating this state afforestation program and most of financing could be allocated for actual afforestation work.

Before large-scale planting, planning and production of propagation material are also necessary. In planting and later in tending, advice by professionals on technology, training courses, technical assistance and other help are required. Professionals are available; financing is only needed for running the consulting.

Forms and ways of financial help for farmers and other landowners by government are developed. As the new economic system develops, more and more efficient financial methods are worked out. However, a pilot project may be necessary. (No pilot project is necessary for the professional part of afforestation, thinning and other forestry work, since these techniques have long been practiced in the country.)

The various consulting firms and companies that undertake afforestation work at different costs and effectivity. The companies that guarantee the lowest costs and highest effectivity must be selected by competitive bidding. For large investments this method is required by law and a lot of experience has been obtained in this respect in the last decades.

Finally, it must be noted that large areas would be suitable for biomass plantations, i.e. where wood is intensively grown for energy production. The major obstacle of undertaking this option for land use is that the furnace and other infrastructure utilizing the produced biomass is lacking. Surveys and analyses must be done to find out how and where such furnaces must be installed. (Several reference projects, where biomass fuel is used for heating, are under way.)

3. AGRICULTURE

Characteristics of the present situation

The Hungarian agriculture was developed and stable in international comparison until the late 80's. It was based on farming on a large scale. The economic restructuring changed the Hungarian agricultural sector. The farm structure has changed. Small farms of 3-5 ha prevailed, which makes the competitive production impossible. The use of fertilizer and plant protecting agents went back to the level of the 50's. The average yield of wheat and maize is two to three times less than that of the early 80's. Livestock has considerably reduced.

In this situation, it is very difficult to make a strategy for this sector. The government is now working on an agricultural development program, by which the sector should be stabilized and conditions for joining the EU could be established. This program aims at the development of farm structures and regulations needed for a competitive production. This National Agricultural Program also contains requirements for environmentally sound development for this sector.

There is already a consensus concerning the basic principles, but we have not a specific strategy yet, i.e. a possible future for the Hungarian agriculture cannot be forecasted based on it.

In the mid 80's, a study was conducted on the opportunities for use of biogenic materials. This study can be the base of our forecasts. Environmental aspects played an important role in this analysis. The main results are still valid.

The Hungarian agriculture in the 80's

Carbon cycle

The characteristics of the carbon cycle in the biomass circulation is presented by Tables 3.1 and 3.2.

Table 3.1. Carbon content of the primary biomass in 1000 t

	Main Product	Byproduct	Total
Cereals	5696.4	9717.9	15414.3
Leguminous Plants	58.4	141.6	200.0
Industrial Plants	721.6	527.3	1248.9
Rough and Juicy Nutritive Matters	2959.0	64.7	3023.7
Fruits	181.1	-	181.1
Grape and Others	113.7	106.7	220.4
Total	10053.3	10791.3	20844.6
Forest Biomass	2800.0	700.0	3500.0
Hydro Biomass	-	625.5	625.5
Total	12853.3	12116.8	24970.1

Table 3.2. Carbon content of the secondary biomass in 1000 t

	Total
Cattle	1718.0
Swine	913.5
Sheep	207.8
Poultry	414.2
Others	145.2
Total	3410.7

In 1980, the carbon content of fodder consumed by animals was 7800 t. If this is compared with the data of Table 3.2, one can see that there is a considerable difference between the input and output side of the animal husbandry. The difference of the carbon content of fodder and secondary biomass is 4400 t. There is an even greater difference in the balance of dry matters. The difference is the energy used by the animals for subsistence.

According to our estimations the carbon content of exhalation was 3300 thousand t (see Table 3.3), i.e. the difference reduces to 1100 thousand t.

Table 3.3. Exhalation in 1000t

Cattle	1200
Swine	1200
Sheep	110
Poultry	260
Others	530
Total	3300

This means that the difference between carbon input and output of animal husbandry is only 14%. The carbon contained in humus is an important factor from the viewpoint of carbon cycle.

According to some estimations, there is more than $2 \cdot 10^9$ t humus in the upper layer of 1 m of the Hungarian soils. Its carbon content exceeds 1 billion t, which is 40 times higher than the brown coal extraction of Hungary.

Nitrogen

The main source of nitrogen contained in soil is the humus. Of course, the whole nitrogen content of humus is not available for plants, it can only be considered a certain reserve. If there is 3% humus in the upper plowed layer, the nitrogen content is 0,15%. For 1 ha it is 4500 kg nitrogen in the plowed layer. Roughly 5% is accessible in a year, which is 225 kg nitrogen for 1 ha. Certainly, plants cannot take

up all this amount. A part of it gets into the nitrogen circulation of the biomass through the crop. Another part is washed out or fixed in the soil.

The nitrogen of soils would be enough only for 25-30 years, even if we assume only 1% humus content and 10 kg/ha/year nitrogen use without replacement.

The amount of fixed nitrogen in Hungary is $54 \cdot 10^6$ t, which is 300 times higher than the effective substance of nitrogen fertilizer used in 1980. More and more nitrogen should be taken out from soil, if biomass production increases. This can be reached by

- Fertilizer use
- Recycling of organic materials

The recycling increases also the carbon content of soils, which determines the mobility of nitrogen.

Table 3.4 shows the amount of nitrogen used by cultivation of plants.

Table 3.4. Nitrogen use of plants

		N
Main product	/thousand t/	504.0
	%	52.4
By-product	/thousand t/	165.0
	%	29.5
Total	/thousand t/	669.0
	%	44.0

Table 3.5 presents the nitrogen balance of plant cultivation.

Table 3.5. Nitrogen balance

1. Demand on nutritive matter	668960
2. Supply of nutritive matter	
/input/	
- fertilizer	537000
- manure	60000
- by products	19500
- papilionaceae	50000
- from the air	90000
- liquid manure	21000
- wastewater mud	2500
Total	780000
Losses in case of manure	
N: 25 %	
P: 10 %	
K ₂ O: 15 %	135000
Actual use of nutritive matter	645000
Balance of nutritive matter	-23960

Energy circulation

The amount of biomass produced in 1980 in Hungary was 53.4 million t. Its energy content was $941 \cdot 10^{15}$ Joule:

plant cultivation - main product	$412,7 \cdot 10^{15}$ J
plant cultivation - byproduct	$369,3 \cdot 10^{15}$ J
silviculture	$60,0 \cdot 10^{15}$ J

Total	$941,0 \cdot 10^{15}$ J
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Of course, biomass production cannot be considered as an energy producing industry. 0.8 million t dry matter from by-products of plant cultivation was used for energy purposes. Its energy content was cca. $3,2 \cdot 10^{15}$ J. 2.5 million m³ fuelwood was used, which is 20-21% of the overall amount of logging. 0.5 million m³ industrial waste and 0.3 million m³ sawdust was fired as well. The overall energy content was about $25 - 30 \cdot 10^{15}$ J.

Data show that only 4-5% of energy content of the primary biomass is used for energy purposes. In the case of plant cultivation this value is less than 2%. The energy circulation of biomass of agricultural origin is presented by Figure 3.1.

Figure 3.1. Energy circulation of biomass

Only 117 PJ of 782 PJ primary biomass was used for foodstuff production in 1980. 78 PJ of this was used for residential consumption. The consumption per

capita was 20 MJ/head/day or 4750/kcal/head/day. The export was 39 PJ (34%). The output/input ratio (0.15) was relatively low, which is the result of the losses of transformation processes. On the one hand, only 23% of by products of plow lands containing 369.9 PJ energy is directly utilized. On the other hand, the products after transformation of foodstuffs, which can be used for human consumption (meat, milk, egg) contain only 30 PJ (10%) energy.

Animal husbandry is the biggest transformation of biomass. This means that energy balance can be improved primarily in this field. Figure 3.2 presents the energy circulation of animal husbandry.

Figure 3.2. Energy circulation of animal husbandry

The output/input ratio of energy balance of animal husbandry is 10% calculated for main products. This ratio is 40% for the whole biomass production.

The loss of subsistence is 60%.

Opportunities for development of plant cultivation

The expected yields of plow land plants were forecasted by mathematical-statistical methods. Results show that 20-21 million t of cereals could be produced by optimal sowing structure. The key factors of plant cultivation are as follows.

- Use of genetic potential of the different species
- Accommodation to the agroecological characteristics
- Supply with nutritive matters
- Applied equipment

We did not forecasted the change of genetic potential. It was assumed that the same species will be produced. This is certainly not a real assumption. The sowing structure optimally accommodating to the agroecological characteristics may result in the increase of the overall yield of plow land plants by 10-15%.

Generally speaking, production cannot be increased without the increase of supply with nutritive matters, but it can be rationalized. In the future, the use of different organic materials (manure, plant residues) for nutrition will increase. However, fertilizer will continue as the main means of nutrition in the future as well. The byproducts of plant cultivation and manure are also important sources of nutrition. Their share is cca 25 %. This share is expected to increase in the future. This is very important, because in such a way there will be no need for extra fertilizers containing micro elements. By plowing under corn stalks and straw, fresh organic material gets into the soil. They contribute to fixing the nutritive value of the soil and improve the chemical reaction as well.

Opportunities for development of animal husbandry

Analyses show that the biggest part of primary biomass is consumed by livestock. Two thirds of main products and more than one third of the overall amount is used for nutrition of animals. The structure of livestock in Hungary is different from that of other countries having similar agricultural conditions. We consider this difference very important, since share of ruminant livestock is less in Hungary than in other countries. This is shown by Figure 3.3.

Figure 3.3. Swines per every 100 head of cattle in the 80's

This means that in Hungary there are two to three times more swine than cattle compared to any other country of Europe. It is well-known that apart from the genetic capacity, the amount of meat, milk and egg production depends primarily on the protein concentration of nutritive matters.

We have developed scenarios for the development of animal husbandry according to different shares of ruminant livestock. In the baseline scenario, the structure of livestock does not change, but production increases by 27%. In the other scenarios production increases by the same rate, but products of ruminant livestock is higher by 10-20-30-40-50% than those of the baseline.

The primary motives for increasing ruminant livestock are more intensive field and forest management and the rational use of nutritive matters from by-products. In theory, the products of ruminant livestock may be even higher than 50%, but taking into consideration the 27% production increase this would mean that number of cattle should be doubled. This may take decades. The structure of livestock in the different scenarios is presented by Table 3.6.

Table 3.6. Livestock in the different development scenarios

	Average of the 80's	Structure of livestock do not change	Change in case of the increase of share of ruminant livestock %				
Scenario		I	II	III	IV	V	VI
Cattle							
Total	1918	2511	2764	3017	3262	3515	3768
Cow	754	993	1093	1193	1290	1391	1491
Dairy							
Cattle	681	582	582	582	582	582	582
Beef	73	411	511	611	708	809	909
Sheep							
Total	3090	3826	4194	4634	5003	5371	5811
Ewe	1861	2304	2526	2791	3013	3235	3500
Swine							
Total	8330	9036	8878	8720	8562	8404	8258
Sow	612	743	730	717	704	691	679
Poultry	42764	45500	43835	42090	40506	38840	37098

Consequences of the change of livestock structure

The most considerable change can be observed in case of cattle. The specific yield of milk increases from 3569 l to 5500 l, while number of dairy cattle decrease from 681 thousand (this was the level of the 80's) to 582 thousand. This level has already been reached as a consequence of economic changes.

Changes of the structure of livestock influence the use of nutritive matters. Byproducts can be used in a more efficient way if share of ruminants increase. The increase of beef cattle is 3 million t even in the lowest scenario. In case of the highest scenario, 7 million t corn stalk could be used as nutritive matter. This means that in this case less area would be needed for plowed land plants used for nutrition. The increase of sheep stock would have a similar effect according to our calculations, the increase of livestock and of the share of ruminants could improve the utilization of byproducts by 11-26%.

Increase of effectiveness in case of animal products

Effectiveness of the production of animal products can be measured by the amount of nutritive matter per one unit of a usable animal product. A gradual improvement is foreseen in long term, which may reach 15-20%. The condition of the improvement of effectiveness is the increase of protein concentration of nutritive matters as follows. In case of

cattles	cca. 7%
sheep	cca. 9%

swines	cca.	8%
broilers	cca.	14%
others	cca.	4-6%

As a result of genetic development, we calculated 2 t product output per sow per year. In case of cattle, we calculated 420 kg beef per one dairy cow (which is very high in international comparison). The milk yield will probably reach 5000-5500 l/year.

Nutrition

Cost of nutrition present 60-70 % of cost of animal products, therefore they determine basically the rentability of animal husbandry. The utilization of nutritive matters is influenced basically by the genetic characteristics of animals. It is also a very important factor, in what extent the nutritive content approximates the demand of the animals. There are, of course, important exogenous factors as well, such as technology of nutrition, methods of animal husbandry, and the eventual losses from conservation of nutritive matters.

Base of nutritive matters in Hungary

A certain output of animal products requires a certain quantity of nutritive matters in a given structure (energy, protein, fats, fiber, vitamin, etc.). An important index of nutrition is the protein concentration. At the moment, 14.3-20% protein concentration is needed for one unit live weight depending on the species.

According to our calculations, 18.1% protein concentration should have been assured on average in the 80's corresponding to the biological demands. Contrary to this, the protein concentration of nutritive matters was just around 15%. This means that utilization of nutritive matters is either too low, or the protein concentrations should be raised by import of nutritive matters. Improvement of cereals aiming at the increase of protein concentration and increase of production of plants having high protein content will be the way of development in this field. This means that in the future we should concentrate only on energy yields but also on consumable protein yield.

The structure of agricultural byproducts and waste is determined by compounds of lignocellulose type. Certain animal byproducts and wastes contain a considerable amount of protein. Ways of their utilization are as follows.

- Nutritive matter (especially, if it contains also protein and starch, it may substitute import nutritive matters of high protein content)
- Manure (it improves the biologic conditions and the physical and chemical characteristics, its nitrogen, phosphorus and potassium content makes it possible to reduce the fertilizer use)
- Energy source (with firing or biogasification)

According to the examined scenarios the theoretically usable byproducts and wastes in dry matters will be

	million t
Plant cultivation	26.7
Animal husbandry	<u>6.8</u>
Total	33.5

According to estimations, the expected utilization of by-products and wastes will be as

	million t
Nutrition in different forms	7.6
Improvement of soil	
(litter+plowing into the soil)	19.4
Energy by firing	3.5
Biogas production	1.5

Around two third of by products and wastes gets back into the soil.

As far as rice production is concerned, no relevant increase is expected, since the conditions of production are unfavorable in Hungary.

It is not expected that the amount of greenhouse gas emissions from agriculture will change in the future, because

- The basic structure of plant cultivation will not change
- Although there will be some increase from animal husbandry, a more efficient nutrition will compensate it

The possible effect of the climate change

According to some models, the agroecological conditions of Hungary may worsen. The average temperature may increase by 2-4°C, and our climate will be similar to that of the Mediterranean areas. The average precipitation may not change, but its distribution will be different. There will be more precipitation in the

winter and summer will be dryer, which may influence on the production of wheat and maize.

At the moment, Hungary is between the zones of wheat and maize, i.e. both species can effectively be produced. These species are produced on more than half of the arable land.

The heat sum of the summer period will be greater than the maximum registered so far (in 1983) at less amount of precipitation. Such droughts may increase uncertainty of maize production, and this problem cannot be solved by irrigation taking into consideration our natural conditions. In 1983, losses of products reached 30-50%, in certain places it reached 100%.

Simulation models show that production of wheat may go back by 10-20%. In case of potato, decrease may be even greater.

If these losses cannot be avoided by genetic and agrotechnical methods, output of plant cultivation may decrease considerably. It may be necessary to produce other species and potential of nutritive matter production may go back, too. This would involve the change of quantity and structure of livestock.

4. CONCLUSIONS

In Chapters 1 through 3 specific steps were outlined for different sectors, which are necessary and feasible for Hungary in the next couple of years. The mitigation strategy of the country can be based only on ongoing governmental programs, which have originally been launched for other purposes, but they may contribute to a relevant reduction of greenhouse gas emissions (energy saving and

afforestation program). Therefore, the main fields of emission mitigation will be the energy and the forestry sectors. The main reasons of it are as follows.

- The overall energy efficiency is far lower than that of the industrialized market economies. The efficiency on both the demand and the supply side has to be increased even in short run. As far as supply side is concerned, restructuring of the power plant system is unavoidable, since a lot of plants are old.
- There is a certain potential in the country for the utilization of renewable resources.
- Traditionally, the forestry sector is highly developed and there are enough land even for a larger afforestation program.

In the future, further opportunities will be examined and scheduled. It will be necessary that the Hungarian Government should provide additional sources to finance mitigation projects in the different sectors.

In Hungary, there is a lack of capital to support big mitigation projects in the near future. Therefore, opportunities for international cooperation - first of all opportunities of Joint Implementation - is considered. Foreign sources may support the ongoing programs, which slowed down because of financial problems, or new projects can be based on them.

Now Hungary is seeking for partners to finance the following projects:

- Efficiency improvement of lighting systems in some selected public buildings
- Afforestation of selected areas
- Utilization of geothermal sources in selected sites

References

A biomassza komplex hasznosításának lehetőségei (Opportunities for the complex utilization of biomass. In Hungaian), ed. Láng, I., 1985. Mezőgazdasági Kiadó, Budapest, Hungary.

Commission of the European Communities, 1994: *The European renewable energy study. Prospects for renewable energy in the European Community and Eastern Europe up to 2010. Main Report.*

Annex 1. Technology profiles

Annex 2. Country profiles

Directorate General for Energy (DG XVII).

Bacskó, M., Harnos, Z., Mészáros, G., Molnár, S., Somogyi, Z., Tajthy, T., Takács, T., 1997: *Hungary-Climate Change Action Plan*. In: National Climate Change Action Plans: Interim Report Change Action Plans: Interim Report For Developing and Transition Countries, Enviro-Management & Research, Inc., Arlington, Virginia, USA, pp. 84-92.

Bacskó, M., Faragó, T., Harnos, Z., Molnár, S., Pálvölgyi, T., Somogyi, Z., Staub, K., Tajthy, T., Takács, T., 1997: *Hungarian Climate Change Country Study*. U.S. Country Studies Program, Systemexpert Consulting Ltd.

Barótfi, I., 1991: *Energia felhasználói kézikönyv* (Energy utilization textbook, in Hungarian).

Commission of the European Communities, 1994: *Municipal solid waste treatment guide*. Directorate General for Energy (DG XVII).

Comparative cost effect analysis of emission taxation strategies, 1998: Report for International Atomic Energy Agency. No. 302-I1-HUN-9628 B5-HUN-25584. Project leader: Molnár, S.

Countries Studies Management Team 1995. *Guidance for Mitigation Analysis. Version 2.0.* Washington, D.C., Energy Analysis Program, Lawrence Berkeley Laboratories, Berkeley, California, USA.

Dobosi, Z., Felméri, L., 1983: *Klímatológia* (Climatology, in Hungarian). Eötvös Lóránd University, Budapest, Hungary.

Emissions of Greenhouse Gases in Central and Eastern Europe and the Newly Independent States (in Greenhouse Gas Emission Inventories - Interim Results from the U.S. Country Studies Program) Kluwer Academic Publishers, 1996 pp. 223-235.

Energy Policies of Hungary, 1995: Survey. International Energy Agency.

Energy Statistical Year Books 1985-1996. State Authority for Energy Management and Safety, Budapest, Hungary.

Faragó, T., Molnár, S., Pálvölgyi, T., Tajthy, T., Takács, T., 1996: *Greenhouse Gas Emissions and Removals in Hungary (in Greenhouse Gas Emission Inventories - Interim Results from the U.S. Country Studies Program)* Kluwer Academic Publishers pp. 275-287.

Global Climate Change Mitigation Assessment: Results for 14 Transitioning and Developing Countries . U.S. Country Studies Program, August 1997.

Harnos, Z., 1997: *Modelling crop response in Hungary.* Third CLIVARA workshop. Avignon, France. 16-18 March.

Hungarian Climate Change Country Study. 1997. U. S. Country Studies Program, published by Systemexpert Consulting Ltd, Hungary.

International Atomic Energy Agency 1993: *Electricity and the environment*. IAEA-TECDOC-624

Laughton, M.A., 1994: *Renewable energy sources*. The Watt Committee on energy. Elsevier Applied Sciences. Rep. 22.

Molnár, S., Harnos, Z., Mészáros, G., Somogyi, Z., Tajthy, T., Takács, T., 1997: *National inventories of greenhouse gas emissions and removals for 1991-1995*. Systemexpert Consulting Ltd.

Molnár, S., Tajthy, T., Takács, T., 1997: *Projections and action plan for Hungary to mitigate the greenhouse gas emissions*. Proceedings of Clean Energy Symposium, Project Development and Finance for Economies in Transition, Szentendre, Hungary September 23-26.

Molnár, S., 1997: *Assessment of Mitigation Measures and Programs In Hungary* Applied Energy, Vol 56. pp. 325-332.

Pécze, Gy., 1979: *Éghajlat* (Climatology, in Hungarian). Tankönyvkiadó. Budapest, Hungary.

Sembery, P., 1988: *Mezőgazdasági energiagazdálkodás* (Energy Management in agriculture, in Hungarian). Gödöllő University of Agriculture, Gödöllő, Hungary.

Somogyi, Z., 1996: *Mitigation analysis for the sector of forestry in Hungary*. Information report for Systemexpert Consulting Ltd. Manuscript, Forest Research Institute, Budapest.

Somogyi, Z., 1997: *Potentials of carbon sequestration in forestry*. In: Proceedings of the 2nd conference on Forests and Climate (in Hungarian, in press).

Statistical Year Books 1985-1996. Central Statistical Office, Budapest, Hungary.

Statistical Year Books of the Hungarian Power Companies 1985-1996, Budapest, Hungary.

Tar, M., 1991: *Magyarország szélklímájának komplex statisztikai elemzése* (A Complex statistical analysis of the wind climate of Hungary, in Hungarian). Országos Meteorológiai Szolgálat. Kisebb Közleményei 67.sz. Budapest, Hungary.