SIXTH FRAMEWORK PROGRAMME
[6.1]
[Sustainable Energy Systems]

Assessment of externalities related to global and local air pollutants with the NEEDS-TIMES Italy model

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Semi-annual ETSAP Workshop
ANNEX XI: Joint Studies for New and Mitigated Energy Systems

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NEEDS Project

New Energy Externalities Development for Sustainability

SIXTH FRAMEWORK PROGRAMME
[6.1]
[Sustainable Energy Systems]

Overall objective

To **define an integrated methodology for the evaluation of the full costs and benefits (i.e. direct + external) of energy policies and of future energy systems**, both at the level of individual countries and for the enlarged EU as a whole

66 partners - 8 Research Streams (RS) concerning the following main areas:
- **Life Cycle Assesment** (LCA) of new energy technologies
- **Monetary valuation of externalities** associated to energy production, transport, conversion and use
- **Modelling Pan European Energy Scenarios** (RS2a, coordinated by CNR-IMAA)
- Acceptability and stakeholders perspective
- **Integration of data and models** (with reference to LCA, ExternE and Comprehensive analysis)
- **Transferability and generalisation** of results

A common integrated methodology

LCA of the most relevant power supply options

Externalities of technologies for the production, transport, transformation and consumption of energy

The NEEDS TIMES models

- ✓ Time horizon 2000-2050
- ✓ Pollutants included: GHG (CO_2, CH_4, N_2O, SF_6) and LAP (SO_2, NOx, CO, NMVOC, PM2.5, PM10)
- ✓ Multi-region structure and trading of electricity

Sectors and demand categories

- ✓ *Supply:* reserves, resources, exploration and conversion; Country specific renewable potential and availability
- ✓ *Electricity and Heat production:* public electricity plants, CHP plants and heating plants
- ✓ *Residential and Commercial:* All end use technologies (space heating, water heating, space cooling and others)
- ✓ *Industry:* Energy intensive industry (Iron and steel, aluminium copper ammonia and chlorine, cement, glass, lime, pulp and paper); other industries; autoproducers and boilers
- ✓ *Transport:* Different transport modes (cars, buses, motorcycles, trucks, passenger trains, freight trains); aviation and navigation

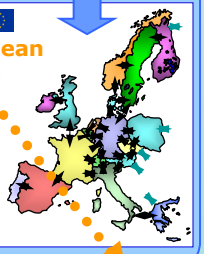
NEEDS Project

New Energy Externalities Development for Sustainability

Energy system models of 30 EU countries

(EU25 + BG, CH, IS, NO, RO)

Pan European Model



RES 2020

Intelligent Energy Europe

REALISEESS

SEVENTH FRAMEWORK PROGRAMME

The externalities evaluation

National level:

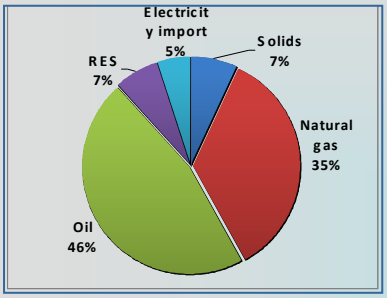
- **Italy**
- Belgium

EU wide scale:

The NEEDS-TIMES Pan EU model

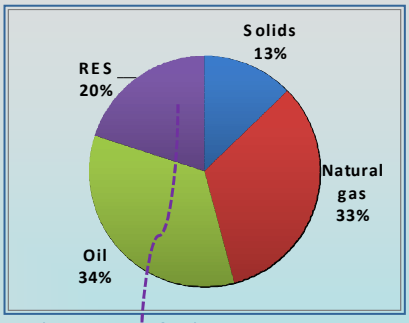
The NEEDS-TIMES Italy model

The 98% of primary energy consumed by Italian energy system is imported (EUROSTAT, 2000).



Primary energy consumption (2000).

Gas, solids and oil are almost all imported



Fuels consumption for electricity generation (2000).

Among the RES contribution:

- hydroelectric has the highest share (87%), followed by
- geothermal plants (9%),
- biomass and waste (3.7%),
- wind and photovoltaic (0.5%).

Consiglio Nazionale delle Ricerche (CNR)
Istituto di Metodologie per l'Analisi Ambientale (IMAA)

Integration of externalities in the NEEDS_TIMES models

Evaluation of environmental damage

EX-POST: damage functions provide an economic evaluation of environmental damage without feedback into optimisation process

EX-ANTE: damage functions are added to the objective function and taken into account in the optimisation process (ecotaxes).

In a given time period, and for a given pollutant, the damage cost is modelled as follows:

$$DAM(EM) = \alpha \cdot EM^{\beta+1}$$

where:

- EM is the emission in the current period;
- DAM is the damage cost in the current period;
- $\beta >= 0$ is the elasticity of marginal damage cost to amount of emissions; and
- $\alpha > 0$ is the external cost of each considered pollutant.

For the Italy case study:

$\beta = 0$

External costs of Local Air Pollutants

Data transferred by the **Research Stream: "New and improved methods to estimate the external costs of energy conversion"**

Pollutants considered:
- NMVOC
- NO_x
- PPM10
- PPM2.5
- SO_2

Geographical coverage:
- **39 European and non-European countries**
- 5 sea regions
- 5 North African countries
- EU27 as an average

Impacts to:
- human health
- crops
- damage to materials
- loss of biodiversity caused by acidification and eutrophication

these costs are available **discounted to the year of emission**

and they are related to three different heights of release

High — *For EPG techs*

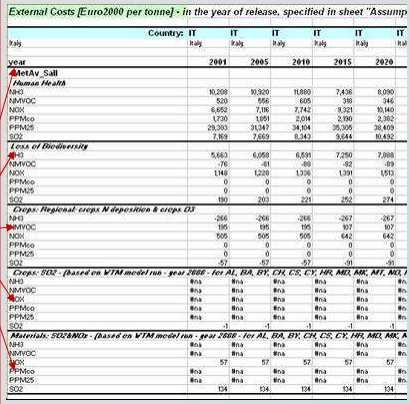
Low

Average — *For all other techs*

External costs of LAP For Italy [Euro 2000/ton]

Country:	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy	IT Italy
	2001	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
MetAv_Sall - year 20xx											
Human Health											
NH3	10,208	10,920	11,880	7,436	8,090	8,802	9,576	9,990	10,422	10,872	11,342
NMVOC	520	556	605	318	346	376	409	427	446	465	485
NOX	5,095	5,450	5,930	7,254	7,892	8,586	9,341	9,745	10,168	10,605	11,064
PPMco	650	696	757	827	900	979	1,065	1,111	1,159	1,209	1,261
PPM25	13,404	14,339	15,600	16,977	18,470	20,094	21,861	22,806	23,792	24,821	25,894
SO2	6,337	6,779	7,375	8,520	9,269	10,084	10,971	11,445	11,940	12,456	12,995
Loss of Biodiversity											
NH3	5,663	6,058	6,591	7,250	7,888	8,582	9,336	9,740	10,161	10,600	11,058
NMVOC	-76	-81	-88	-82	-89	-97	-105	-110	-115	-120	-125
NOX	1,100	1,176	1,280	1,360	1,479	1,609	1,751	1,827	1,906	1,988	2,074
PPMco	0	0	0	0	0	0	0	0	0	0	0
PPM25	0	0	0	0	0	0	0	0	0	0	0
SO2	154	164	179	208	226	246	268	279	291	304	317
Crops: Regional: crops N deposition & crops O3											
NH3	-266	-266	-266	-267	-267	-267	-267	-267	-267	-267	-267
NMVOC	195	195	195	107	107	107	107	107	107	107	107
NOX	352	352	352	506	506	506	506	506	506	506	506
PPMco	0	0	0	0	0	0	0	0	0	0	0
PPM25	0	0	0	0	0	0	0	0	0	0	0
SO2	-44	-44	-44	-74	-74	-74	-74	-74	-74	-74	-74
Crops: SO2 - (based on WTM model run - year 2000 - for AL, BA, BY, CH, CS, CY, HR, MD, MK, MT, NO, RU, TR, UA the value for EU27 (EU25) is used)											
NH3	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
NMVOC	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
NOX	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
PPMco	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
PPM25	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
SO2	7	7	7	7	7	7	7	7	7	7	7
Materials: SO2&NOx - (based on WTM model run - year 2000 - for AL, BA, BY, CH, CS, CY, HR, MD, MK, MT, NO, RU, TR, UA the value for EU27 (EU25) is used)											
NH3	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
NMVOC	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
NOX	55	55	55	55	55	55	55	55	55	55	55
PPMco	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
PPM25	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na	#na
SO2	112	112	112	112	112	112	112	112	112	112	112

Internalisation of LAP's external costs



External Costs [Euro2000 per tonne] - in the year of release, specified in sheet "Assump

Country:	IT	IT	IT	IT	IT	IT
Italy	Italy	Italy	Italy	Italy	Italy	Ital
year	2001	2005	2010	2015	2020	
MetAv_Sall						
Human Health						
NH3	10,208	10,320	11,880	7,436	8,090	
NMVOC	520	556	605	316	346	
NOX	6,852	7,116	7,742	9,321	10,140	
PPMco	1,730	1,951	2,014	2,190	2,382	
PPM25	29,393	31,947	34,104	35,395	38,409	
SO2	7,169	7,669	8,343	9,644	10,492	
Loss of Biodiversity						
NH3	5,663	6,058	6,591	7,250	7,888	
NMVOC	-76	-81	-89	-92	-89	
NOX	1,148	1,220	1,336	1,391	1,513	
PPMco	0	0	0	0	0	
PPM25	0	0	0	0	0	
SO2	190	203	221	252	274	
Crops: Regional: crops N deposition & crops O3						
NH3	-266	-266	-266	-267	-267	
NMVOC	195	195	195	107	107	
NOX	505	505	505	642	642	
PPMco	0	0	0	0	0	
PPM25	0	0	0	0	0	
SO2	-57	-57	-57	-91	-91	
Crops: SO2 - (based on WTM model run - year 2000 - for AL, BA, BY, CH, CS, CY, HR, MD, MK, MT, MD,						
NH3	#na	#na	#na	#na	#na	#n
NMVOC	#na	#na	#na	#na	#na	#n
NOX	#na	#na	#na	#na	#na	#n
PPMco	#na	#na	#na	#na	#na	#n
PPM25	#na	#na	#na	#na	#na	#n
SO2	-1	-1	-1	-1	-1	
Materials: SO2&NOx - (based on WTM model run - year 2000 - for AL, BA, BY, CH, CS, CY, HR, MD, MK,						
NH3	#na	#na	#na	#na	#na	#n
NMVOC	#na	#na	#na	#na	#na	#n
NOX	57	57	57	57	57	
PPMco	#na	#na	#na	#na	#na	#n
PPM25	#na	#na	#na	#na	#na	#n
SO2	134	134	134	134	134	

E_j

In the NEEDS framework the external cost of each pollutant (P_i) was calculated by a linear combination of the considered effects (E_j).

$$DAM\_COST(P_i) = \sum_{j=1}^{5} k_j \cdot E_j$$

$$k_j = 1$$

	2001	2005	.....	2050
NH_3	15605	16712	...	22133
NMVOC	639	670	...	467
NO_X	6602	7034	...	13699
PPM10	650	696	...	1261
PPM2.5	13404	14339	...	25894
SO_2	6566	7019	...	13357

Final values for EPG techs

Euro 2000/ton

External costs of GHG

Two sets of values are identified for GHG external costs

Euro 2000/ton

Scenario 1 (ambitious, reflecting policy targets):

Year	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO_2	23.5	23.5	31	46	51	74	87	110	146
CH_4	493.5	493.5	651	966	1071	1554	1827	2310	3066
N_2O	7285	7285	9610	14260	15810	22940	26970	34100	45260

Scenario 2 (more realistic):

Year	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO_2	23.5	23.5	27	29	32	34	37	50	66
CH_4	493.5	493.5	567	609	672	714	777	1050	1386
N_2O	7285	7285	8370	8990	9920	10540	11470	15500	20460

NEEDS Deliverable n° 1.1 - RS 3a. *"Report on the procedure and data to generate averaged/aggregated data."* P. Preiss, R. Friedrich and V. Klotz.

The scenarios

Scenario	Case variants	Main assumptions
BAU		**Exogenous assumptions around drivers, energy prices and policies follow a rather business as usual trend, without a specific climate policy**
	BAU_GHG	Internalisation of externalities on CO_2, CH_4 and N_2O, according to the values of Scenario 1 (Ambitious)
	BAU_LAP	Internalisation of externalities on local air pollutants (SO_2, NO_x, NMVOC, PM10and PM2.5).
	BAU_LAP-GHG	internalisation of externalities on both local and global air pollutants.
KYOTO_FOREVER		**Stabilization of GHG emissions below the Kyoto cap without the activation of any other tradable permits or flexible mechanisms.**
	Kyoto_LAP	Internalisation of externalities on local air pollutants (SO_2, NO_x, NMVOC, PM10 and PM2.5) in addition to the KP target.

Main exogenous socio-economic assumptions

- The macroeconomic and energy price background assumptions are in line with DG TREN 2005 projections
- Discounted rate: 4%
- Coal and oil consumptions for electricity production were determined according to Unione Petrolifera (UP, 2006) forecasts till to 2020 and extrapolating these values up to 2050
- The percentages of biofuel use for the period 2005-2010 were instead estimated according to the Legislative Decree D.Lgs. 128/2005 as follows:

  1.0 % up to December 2005, 31th

  2.5 % till to December 2010, 31th.

The **Reference scenario** was constructed on these assumptions.

For the **KYOTO_FOREVER scenario** we limited ourselves to a partial equilibrium framework, in the sense that the ***population and macroeconomic assumptions remain those of the Reference scenario.***

Impacts of internalisation

On total discounted system's cost

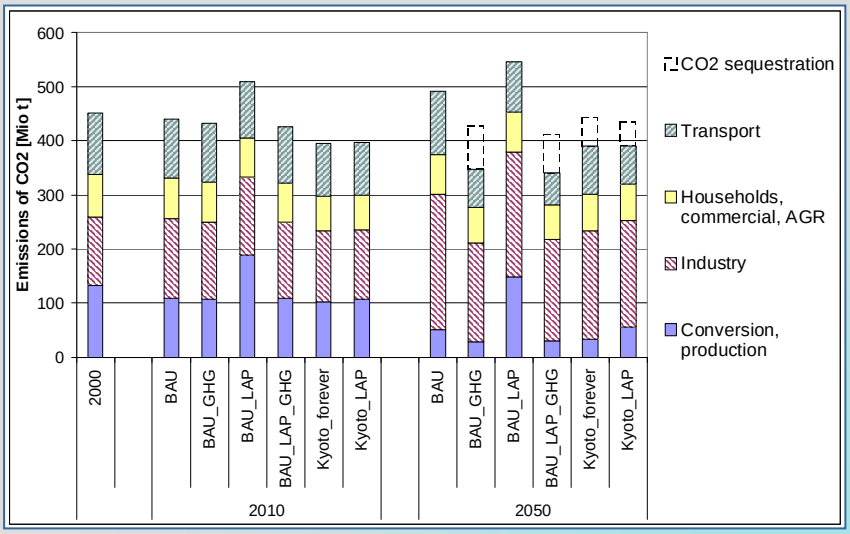
Scenario	Case variants	Total discounted system's cost wo damage (MEuro) *(Reference value)*	Total discounted system's cost (MEuro)		Damage costs
			Ex-post	*Ex-ante**	
BAU		**5158.83**			
	BAU_GHG		5766.64	5727.72	607.81
	BAU_LAP		5743.15	5678.67	584.32
	BAU_LAP-GHG		**6350.96**	6244.86	**1192.13**
KYOTO_FOREVER		**5243.57**			
	Kyoto_LAP		5774.47	5748.27	615.64

1192,13

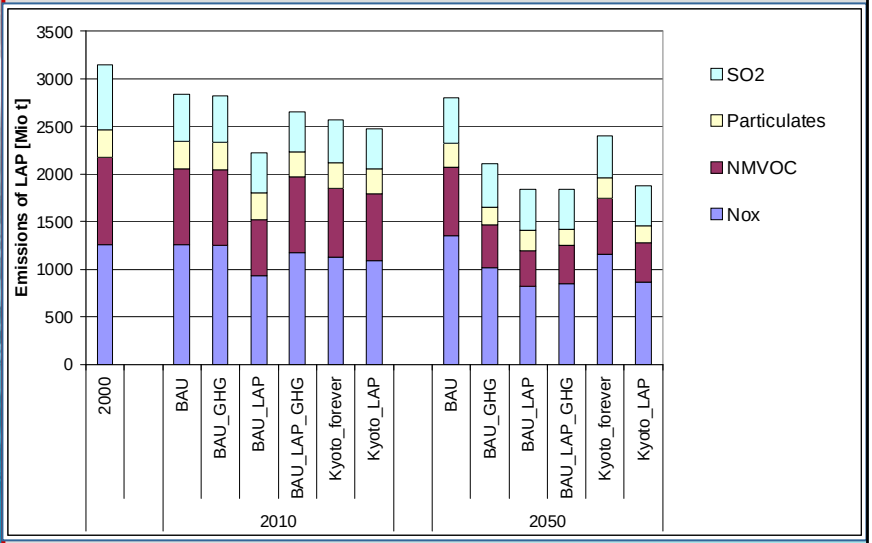
- 106.10

**with internalisation of external costs*

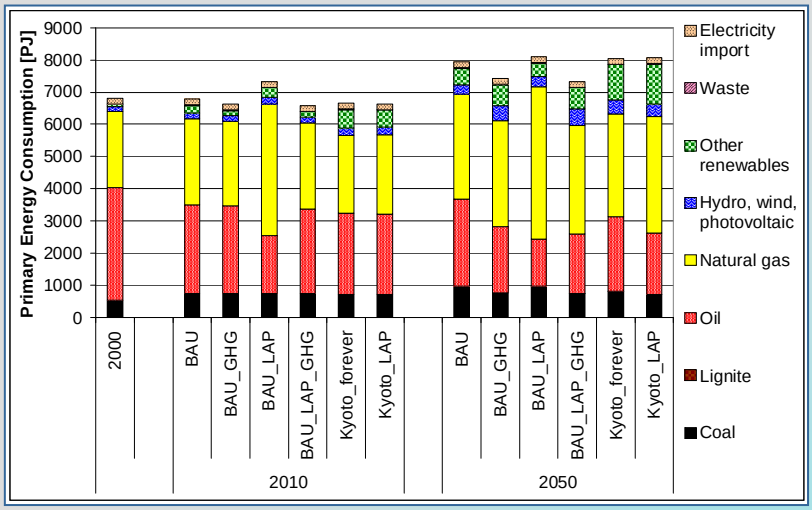
Carbon Emissions in Mt CO_2/yr



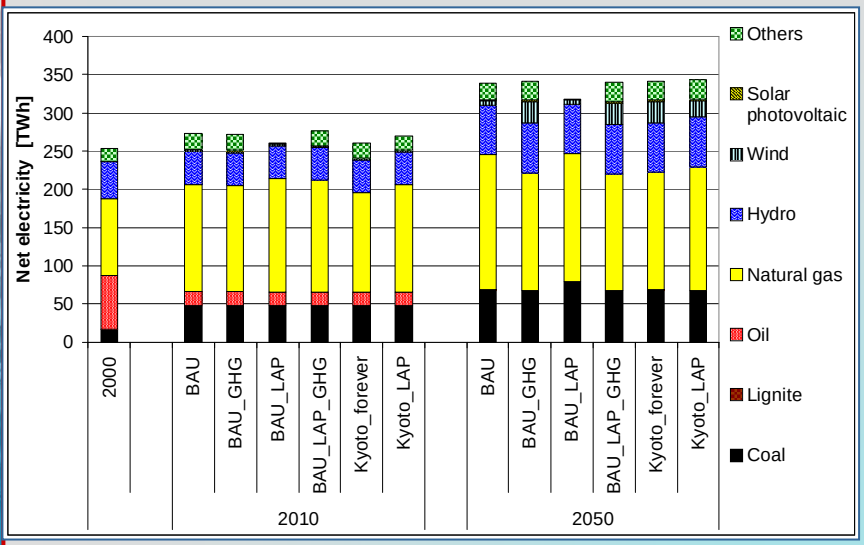
LAP Emissions



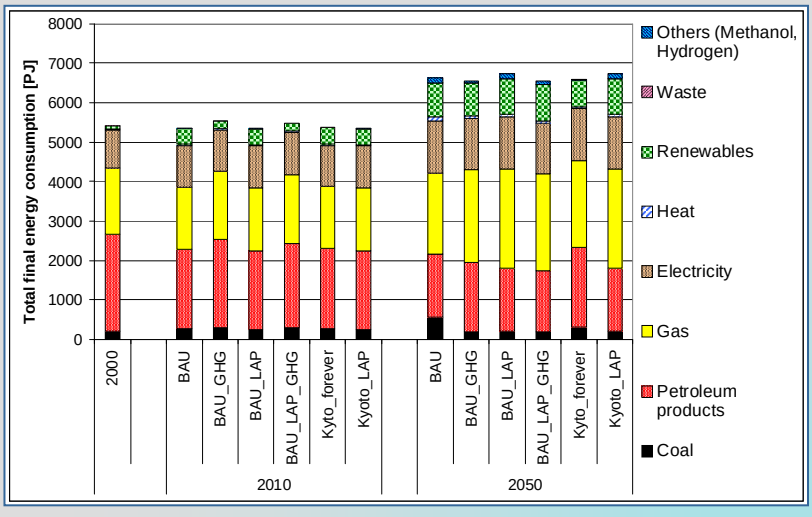
Primary energy consumption



Net electricity generation



Total Final energy consumption



Impacts of internalisation

On emissions

Scenario	Case variants	Emissions on the whole time horizon (Mt)				
		CO_2	SO_2	NO_x	VOC	Particulates
BAU		**24523**	**24.70**	**68.40**	**40.93**	**14.60**
	BAU_GHG	21934 (-10.6%)	24.17 (-3.3%)	63.15 (-8.8%)	35.52 (-14.2%)	13.42 (-7.1%)
	BAU_LAP	27041 (+10.3%)	22.97 (-8.1%)	**47.97 (-30.7%)**	**25.98 (-37.2%)**	13.27 (-8.1%)
	BAU_LAP_GHG	21039 (-14.2%)	**22.32 (-10.7%)**	53.09 (-23.3%)	30.93 (-25.3%)	*11.66 (-19.2)*
KYOTO_FOREVER		**21101 (-14.0%)**	23.41 (-6.3%)	60.75 (-12.2%)	33.40 (-19.3%)	13.14 (-9.0%)
	Kyoto_LAP	**21101 (-14.0%)**	***22.33 (-10.6%)***	*51.43 (-25.7%)*	*28.85 (-30.3%)*	**11.50 (-20.4%)**

Impacts of internalisation

On renewables

Scenario	Case variants	% of renewable in primary energy consumption			
		2000	2010	2020	2050
BAU		**3.8%**	**6.7%**	**8.1%**	**10.7%**
	BAU_GHG		5.7%	7.3%	15.6 %
	BAU_LAP		5.1%	6.1%	8.8%
	BAU_LAP_GHG		5.8%	8.7 %	16.5%
KYOTO_FOREVER		**3.8%**	**12.6%**	**16.2%**	**19.8%**
	Kyoto_LAP		12.0%	16.2 %	**20.7 %**

Contribution of scenarios results to climate and energy targets

Scenario	with damage ex post		Internalising externalities (ex ante)		
	BAU (on GHG and LAP)	Kyoto_Forever (on LAP)	BAU_GHG	BAU_LAP _GHG	Kyoto_LAP
Total discounted cost (M Euro)	6350.96	5774.47	5727.72	6244.86	**5678.67**
CO_2 emissions reduction		-14.0%	-10.6%	**-14.2%**	-14.0%
Share renewables (2020)	8.1%	16.2 %	7.3%	8.7%	**16.2%**
Share renewables (2050)	10.7%	16.2 %	15.6%	16.5%	**20.7%**

Conclusions

An **integrated modelling framework** covering all environmental dimensions linked to energy allows **to exploit synergies and trade-offs between climate and air quality policies.**

The **internalisation of externalities on both GHGs and LAP** allows to achieve an overall **14% reduction of CO_2 emissions on long term**, but the Kyoto target at 2010 is achieved only by imposing an exogenous constraint on GHGs.

The **synergy between climate and air quality** policies **is more effective** in terms of both costs and emissions respect to separate policies: applying the ecotaxes in the optimisation the society has a reduction of damage equal to 106.10 MEuro (about 2% of the total discounted system cost WO externalities).

As concerns the **interactions between climate and energy**, the **combination between a cap on GHGs emissions and the internalisation of externalities on LAP** is the most effective in terms of renewable share.

Renewable and carbon capture have an important role in the mix of options for CO_2 abatement.

A **further development of the technology database** and modelling framework is important to improve the model's performance.

Ongoing work

Further improvements on the Italy NEEDS model will deal with:

-Integrating LCI data on EPG technologies

-Improving the technology database (particularly Residential and Transport technologies)

- Extending LCI to sectors not covered and aggregating LCI coefficients into impact indicators.

Thanks for your kind attention

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THE PAN-EU EXOGENOUS SOCIO-ECONOMIC ASSUMPTIONS

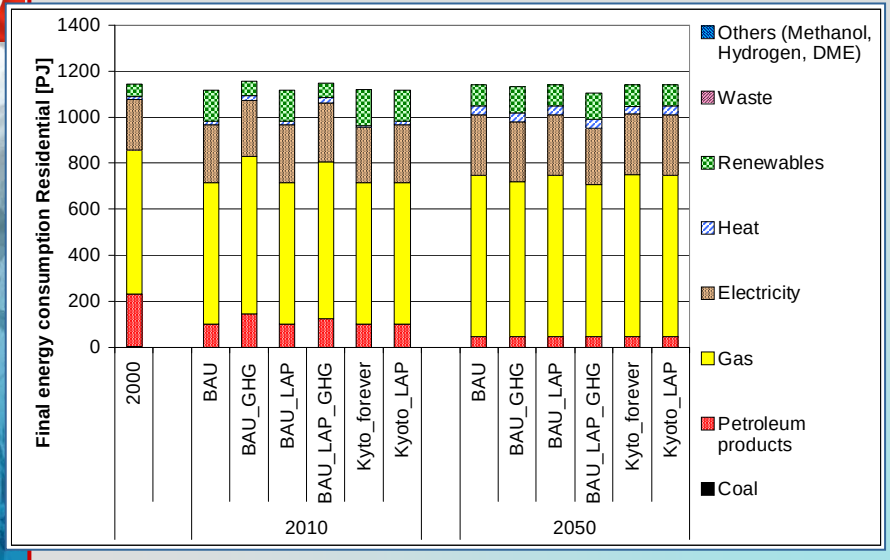
Demographic/economic development (annual growth rate)

	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population	0.3%	0.2%	0.1%	0.0%	0.0%	-0.1%	-0.1%	-0.2%	-0.3%
GDP	2.2%	2.1%	2.1%	1.8%	1.7%	1.6%	1.5%	1.4%	1.2%
Private Consumption	1.9%	1.8%	1.8%	1.7%	1.6%	1.6%	1.6%	1.5%	1.4%
Industrial activity (energy intensive)	2.3%	2.2%	2.0%	1.6%	1.4%	1.2%	1.0%	0.7%	0.4%
Other industrial activity	2.2%	2.1%	2.0%	1.6%	1.5%	1.3%	1.2%	1.0%	0.8%
Transport activity	2.2%	2.1%	1.9%	1.5%	1.4%	1.2%	1.0%	0.8%	0.6%
Service sector activity	2.0%	2.0%	2.0%	1.9%	1.8%	1.8%	1.7%	1.7%	1.6%

Energy prices Euro 2000/GJ

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Import price crude oil	6.51	5.38	5.41	5.79	6.56	6.94	7.01	7.08	7.15	7.23
Import price natural gas	3.65	4.09	4.13	4.46	5.17	5.39	5.45	5.50	5.56	5.61
Import price coal	1.60	1.51	1.61	1.70	1.76	1.80	1.81	1.82	1.83	1.84

Final energy consumption-Residential



Final energy consumption-Industry