Modelos para elaborar proyecciones de GEIs
Revisión y Caso Práctico

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Experiencias y herramientas de la región iberoamericana para el diseño de objetivos de mitigación/contribuciones al Acuerdo de París

Madrid, 24 de Marzo de 2015

Métodos para elaborar proyecciones de GEI

- Valoración de expertos
  - Más sencilla e intuitiva, más transparente
  - Permite simular comportamientos anómalos
  - Permite recoger más detalles técnicos de las alternativas
- Modelos
  - Permiten recoger interacciones entre medidas
  - Estiman penetraciones de forma endógena
  - Bottom-up vs Top-down
  - Optimización vs. Simulación
- En todos casos requieren una baseline correcta (que incluya el avance tecnológico)

Modelos: Una advertencia previa

"There are lies, damned lies, and ~~statistics~~ models"

Modelos energético-ambientales

	MARKAL/TIMES	POLES	WEM	PRIMES	NEMS	EPPA	WITCH
Economic representation	Partial Equilibrium	Partial Equilibrium	Partial Equilibrium	Partial Equilibrium	General Equilibrium	General Equilibrium	General Equilibrium
Env. Feedbacks	No	No	No	No	No	Mainstream EPPA no. Yes, if coupled with IGSM or EPPA-HE.	Yes, IAM
Modelling technique	Optimization	Simulation	Simulation	Optimization	Simulation	Optimization	Optimization
Technological detail	Bottom-up	Bottom-up	Bottom-up	Bottom-up	Bottom-up	Top-Down	Top-Down
Geographic perspective	Customizable	World (46 regions)	World (25 regions)	Extended Europe	USA (sub divisions)	World (16 regions)	World (12 regions)
Time representation	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Future foresight	Perfect	Myopic (recursive dynamic)	Myopic (recursive dynamic)	Myopic or perfect	Myopic or perfect	Myopic or perfect	Perfect
Technological change	Exogenous	Endogenous (both learning by doing and learning by research)	Endogenous (only learning by doing)	Endogenous (only learning by doing)	Endogenous (only learning by doing)	Endogenous	Endogenous (both learning by doing and learning by research)
Internat. energy mkts.	Exogenous	Endogenous	Exogenous	Exogenous	Endogenous	Endogenous	Endogenous

(Marcuse, 1974)
(Fishbone & Abilock, 1981)
(Loulou et al., 2005)

(Criqui, 1996)
(IPTS JRC EC, 2010)
(LEPII-EPE, 2006)

(IEA, 2009)
(IEA, 2012)

(Capros et al., 1998)
(NTUA, 2005)
(NTUA, 2011)

(EIA US DOE, 2009)
(EIA US DOE ,2012)

(Babiker et al., 2001)
(Paltsev et al., 2005)

(Bosetti et al., 2006)
(Bosetti et al., 2009)

Ventajas e inconvenientes

	MARKAL/TIMES	POLES	WEM	PRIMES	NEMS	EPPA	WITCH
Modelling flexibility	5	2	2	3	3	2	2
Technological detail	5	3	4	5	5	2	3
Economic representation	2	3	3	2	4	5	4
Real energy markets	1	3	2	5	5	3	2
Transparency/ ease of utilization	2	2	2	1	1	2	3
Direct policy effect modelling	3	2	2	3	2	3	3
Synergies/ tradeoff analysis	3	1	1	1	1	2	2

- Otros:
  - MESSAGE
  - OSeMOSYS
  - LEAP

MESSAGE

- Desarrollado por IIASA
- Similar a MARKAL-TIMES
- Buenas condiciones de acceso via IAEA
  - Incluye análisis online
- Muchas versiones

OSeMOSYS

- Open Source Energy Modeling System
- http://osemosysmain.yolasite.com/
- Similar a TIMES, más compacto
- Gratuito

LEAP

- Desarrollado por SEI
- http://www.energycommunity.org/
- Basado en simulación y escenarios
- Puede combinarse con OSeMOSYS
- Gratuito para estudiantes y países en desarrollo
- Muy utilizado

El modelo MASTER-SO de Comillas

- Representación detallada, bottom-up, de los sectores energéticos
  - Demanda de servicios energéticos
  - Base de datos de tecnologías de usos finales y de ahorro energético
  - El modelo escoge las tecnologías como parte de la optimización global
  - Tamaño realista
- Representación detallada, bottom-up, de los procesos y vectores energéticos
  - 96 bloques de carga de electricidad
- Base de datos pública
- Unidades uniformes
- Admite distintas funciones objetivo

El modelo MASTER-SO

	MARKAL/TIMES	POLES	WEM	PRIMES	NEMS	EPPA	WITCH	MASTER
Economic representation	Partial Equilibrium	Partial Equilibrium	Partial Equilibrium	Partial Equilibrium	General Equilibrium	General Equilibrium	General Equilibrium	**Partial Equilibrium**
Env. Feedbacks	No	No	No	No	No	Mainstream EPPA no. Yes, if coupled with IGSM or EPPA-HE.	Yes, IAM	**No**
Modelling technique	Optimization	Simulation	Simulation	Optimization	Simulation	Optimization	Optimization	**Optim (MASTER_SO) and Simul (MASTER_DS)**
Technological detail	Bottom-up	Bottom-up	Bottom-up	Bottom-up	Bottom-up	Top-Down	Top-Down	**Bottom-up**
Geographic perspective	Customizable	World (46 regions)	World (25 regions)	Extended Europe	USA (sub divisions)	World (16 regions)	World (12 regions)	**National**
Time representation	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	**Static (MASTER_SO) and Dynamic (MASTER_DS)**
Future foresight	Perfect	Myopic (recursive dynamic)	Myopic (recursive dynamic)	Myopic or perfect	Myopic or perfect	Myopic or perfect	Perfect	**Perfect (MASTER_SO) and Perfect/Myopic (MASTER_DS)**
Technological change	Exogenous	Endogenous (both learning by doing and learning by research)	Endogenous (only learning by doing)	Endogenous (only learning by doing)	Endogenous (only learning by doing)	Endogenous	Endogenous (both learning by doing and learning by research)	**Exogenous**
Internat. energy mkts.	Exogenous	Endogenous	Exogenous	Exogenous	Endogenous	Endogenous	Endogenous	**Exogenous**
	MARKAL/TIMES	**POLES**	**WEM**	**PRIMES**	**NEMS**	**EPPA**	**WITCH**	**(ONLY MASTER_SO)**
Modelling flexibility	5	2	2	3	3	2	2	**4**
Technological detail	5	3	4	5	5	2	3	**4**
Economic representation	2	3	3	2	4	5	4	**1**
Real energy markets	1	3	2	5	5	3	2	**1**
Transparency/ ease of utilization	2	2	2	1	1	2	3	**4**
Direct policy effect modelling	3	2	2	3	2	3	3	**5**
Synergies/ tradeoff analysis	3	1	1	1	1	2	2	**5**

Modelo de optimización

Minimización de costes totales del sistema

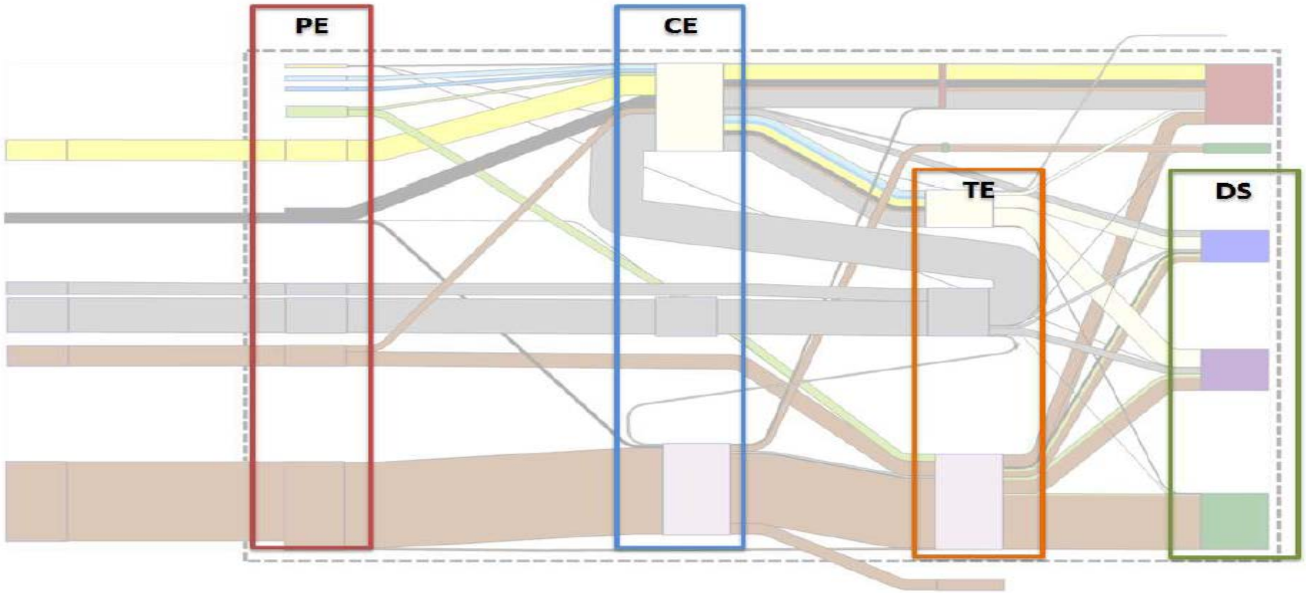
Variables de decisión:

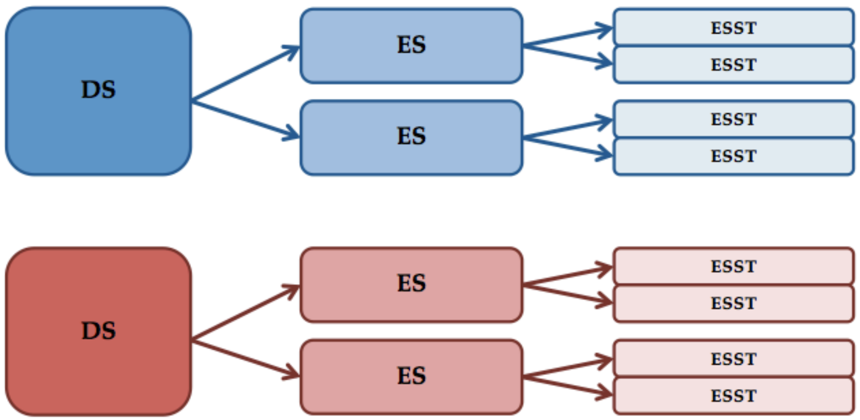
- Flujos de energía
- Inversión y operación de activos energéticos (oferta y demanda)
- Medidas de eficiencia energética
- Reservas

Restricciones:

- Demanda
- Ahorro de energía
- Emisiones de CO2
- Limitaciones de capacidad
- Restricciones técnicas del sistema eléctrico (reservas, fiabilidad)
- Eficiencias de conversión (à la TIMES)

Flujos de energía





Datos de modelado

- Electricidad: generación (más de 20 tec), transporte y distribución, interconexiones, CHP
- Gas natural: transporte (GNL o gasoducto), regasificación
- Productos petrolíferos: importaciones y exportaciones, refino (3 tec)
- Biocombustibles: etanol, biodiesel; producción y distribución
- Carbón
- Nuclear
- Renovables: costes y potenciales, cuotas
- Usos finales

Aplicaciones

- Obtención de curvas MAC y costes de reducción de emisiones en diferentes sectores
- Políticas de promoción de renovables en distintos sectores, obteniendo costes, subsidios necesarios, necesidades de inversión en red, entre otros
- Políticas de eficiencia energética en todos los sectores: tanto de reducción de demanda de servicios energéticos como de uso de tecnologías más eficientes
- Políticas para reducir la dependencia energética y diversificar suministros
- Efectos de impuestos medioambientales: tanto al CO2, como al uso de energía, como a la "ineficiencia energética"
- Resultados de aplicación del "céntimo verde" o una "tasa" a determinadas centrales eléctricas
- Costes y consecuencias de la promoción de uso de energías domésticas, tanto carbón como biomasas

Un caso ejemplo

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Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Renewables vs. energy efficiency: The cost of carbon emissions reduction in Spain

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H I G H L I G H T S

- Energy efficiency is cheaper than renewables for reducing carbon emissions.
- Energy efficiency measures could have saved more than €5 billion per year in Spain.
- Savings could have been bigger without overcapacity in gas combined cycles.

A R T I C L E I N F O

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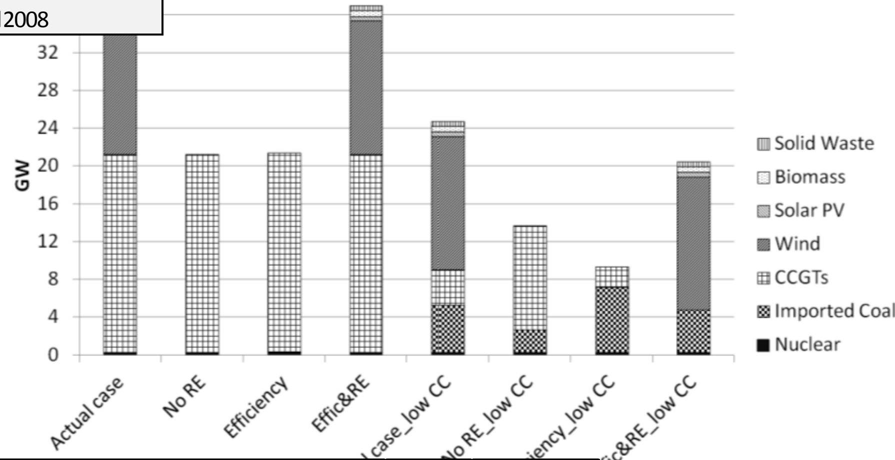
Keywords:
CO_2 emissions
Renewable energy support
Energy conservation

A B S T R A C T

While support instruments have succeeded to largely deploy renewables during the 1996–2008 period, little attention has been paid to energy efficiency measures, resulting in a high energy intensity and large growth of energy demand. Energy-related CO_2 emissions have increased significantly. At the same time, important investments in combined cycle gas turbines have taken place. This paper analyses whether, from a cost minimization viewpoint, renewable support has been the best policy for reducing emissions, when compared to the promotion of energy efficiency in sectors such as transportation or buildings. We use a model of the Spanish energy sector to examine its evolution in the time period considered under different policies. It is a bottom-up, static, partial equilibrium, linear programming model of the complete Spanish energy system. We conclude that demand side management (DSM) clearly dominates renewable energy (RE) support if the reduction of emissions at minimum cost is the only concern. We also quantify the savings that could have been achieved: a total of €5 billion per year, mainly in RE subsidies and in smaller costs of meeting the reduced demand (net of DSM implementation cost).

Resultados (I)

Scenario	RE forced	DSM allowed	CCGTs forced	Emissions constraint
Actual case	Yes	No	Yes	No, "Actual2008" value obtained
No RE	No	No	Yes	Actual2008
Efficiency	No	Yes	Yes	Actual2008
Effic&RE	Yes	Yes	Yes	Actual2008
Actual case_low CC	Yes	No	No	Actual2008
No RE_low CC	No	No	No	Actual2008
Efficiency_low CC	No	Yes	No	Actual2008
Effic&RE_low CC	Yes	Yes	No	Actual2008



Cost (+) and revenues (-). Million €/year	Actual case	No RE	Efficiency	Effic&RE	Actual case_low CC	No RE _low CC	Efficiency _low CC	Effic&RE _low CC
Domestic primary energy production (+)	4,129	2,997	4,073	3,376	2,449	2,189	2,338	2,583
Primary energy imports (+)	7,460	9,735	7,519	6,874	8,371	10,168	8,308	7,376
New conversion capacity investment (+)	4,934	1,888	1,844	4,917	4,410	1,497	1,503	4,029
Conversion capacity fixed O&M (+)	2,154	1,496	1,521	2,103	2,230	1,564	1,674	2,286
Conversion capacity variable O&M (+)	778	790	731	673	783	792	750	696
Final energy transportation (+)	8,068	8,578	7,357	7,217	8,032	8,561	7,202	7,049
Final energy imports (+)	19,495	19,495	18,238	18,238	19,487	19,495	18,202	17,965
Final energy exports (-)	-1,011	-1,011	-1,011	-1,011	-1,010	-1,012	-1,012	-1,012
DSM implementation (+)	0	0	840	840	0	0	840	840
Electricity generation reserve cost (+)	84	65	65	84	103	93	65	84
TOTAL ENERGY SUPPLY COST	**46,092**	**44,032**	**41,177**	**43,311**	**44,855**	**43,348**	**39,870**	**41,896**
Total cost increment (billion €/year)		-2.1	-2.9	2.1		-1.5	-3.5	2.0
Savings vs. "Actual case" (bln. €/year)	0.0	2.1	5.0	2.9	1.2	2.7	6.2	4.2

economics for energy

Resultados (II)

Precios sombra

Emisiones por sector y costes de mitigación

Emissions ($Mt\ CO_2$)	In primary energy	In energy conversion	In final energy consumption	Total emissions	Emiss. constr. shadow price (€/tCO_2)
Actual case	3.16	103.42	209.30	**315.88**	No constraint
No RE	2.19	104.39	209.30	**315.88**	-3.78
Efficiency	3.20	104.77	200.74	**308.71**	0.00
Effic&RE	2.45	80.68	200.74	**283.87**	0.00
Actual case_low CC	1.57	105.01	209.30	**315.88**	-17.78
No RE_low CC	1.42	105.15	209.30	**315.88**	-20.06
Efficiency_low CC	1.56	113.58	200.74	**315.88**	-16.52
Effic&RE_low CC	1.70	91.16	200.74	**293.60**	0.00

Coste de tecnologías

Shadow prices (€/kW)	Actual case	No RE	Efficiency	Effic&RE	Actual case_low CC	No RE_low CC	Efficiency _low CC	Effic&RE_ low CC
CCGT Capacity	91.09	78.37	87.29	82.18	N. App.	N. App.	N. App.	N. App.
Wind Capacity	113.19	N. App.	N. App.	115.28	82.25	N. App.	N. App.	116.87
Solar PV Capacity	469.40	N. App.	N. App.	466.71	436.98	N. App.	N. App.	457.99
Biomass Capacity	188.33	N. App.	N. App.	192.47	45.33	N. App.	N. App.	188.33
Solid Waste Cap.	391.05	N. App.	N. App.	391.27	373.11	N. App.	N. App.	370.95

Otro caso ejemplo

UNIVERSIDAD PONTIFICIA
ICAI ICADE
COMILLAS
MADRID

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)
INGENIERO INDUSTRIAL

ANALYSIS OF ENERGY EFFICIENCY POLICIES FOR SPAIN

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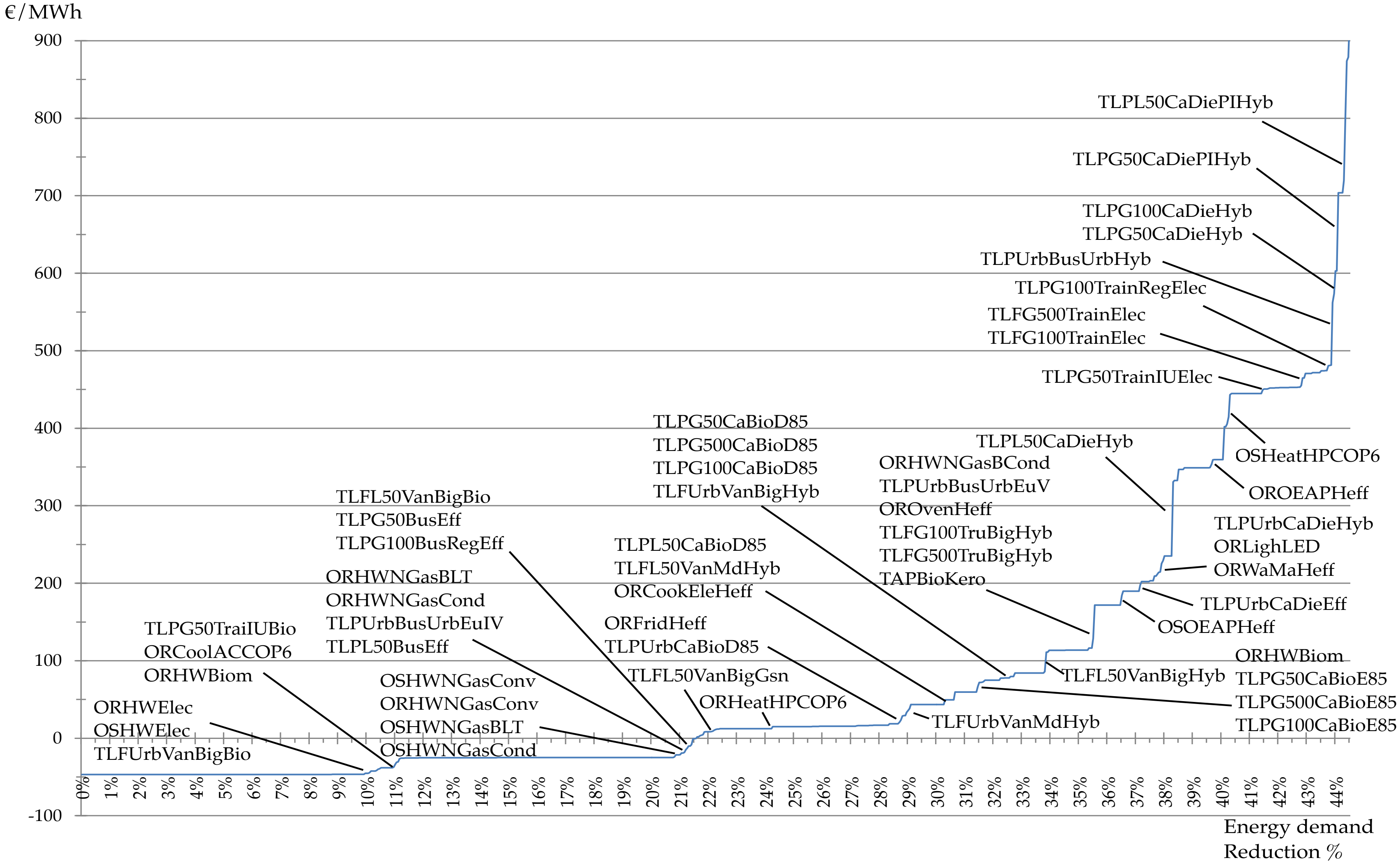
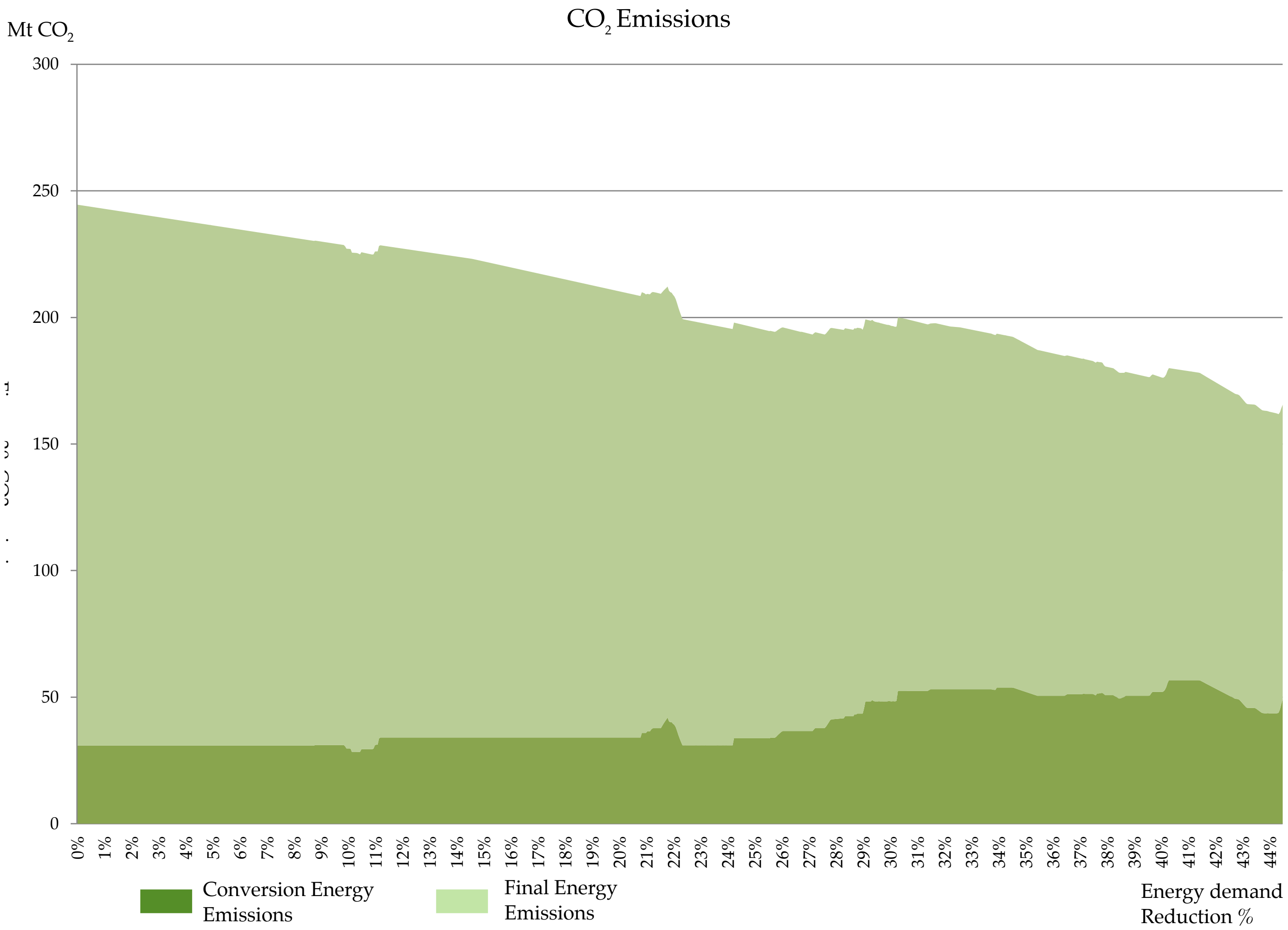
Madrid
Mayo 2014

Ahorro energético

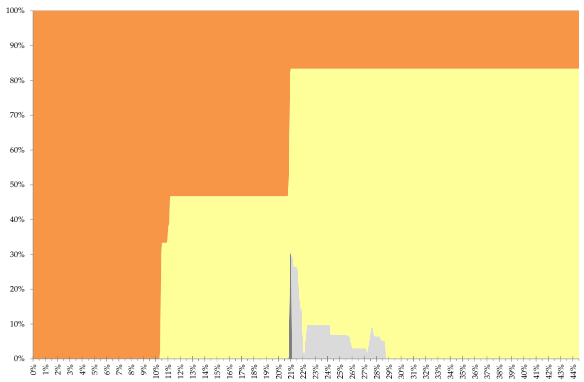


Reducción de emisiones



Análisis de sensibilidad

BAU Scenario



Increased Scenario

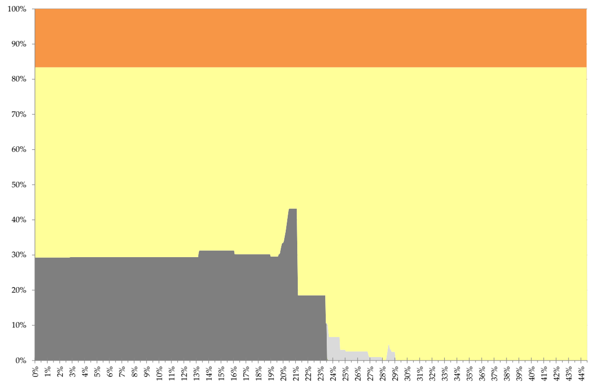
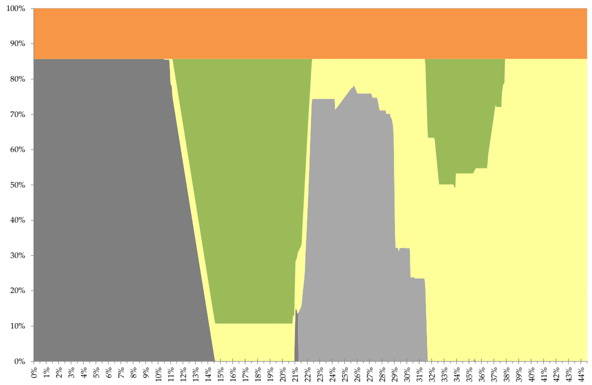


Figure 24. *Hot water in Service sector*
Source: own elaboration

BAU Scenario



Increased Scenario

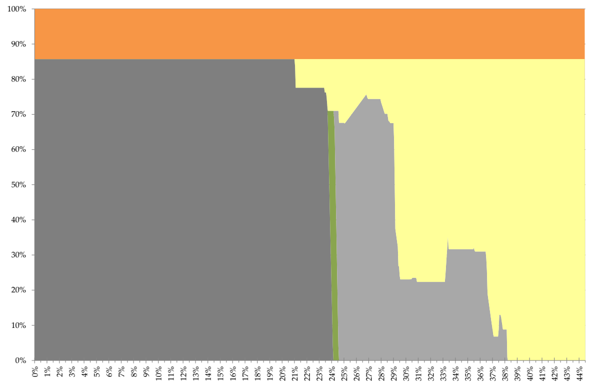


Figure 25. *Hot water in Residential sector*
Source: own elaboration

Gracias por su atención

www.upcomillas.es/personal/pedrol