Energy Demand for Medium to Long Term Decisions

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Content

1. Energy Chain
2. Scenarios and Energy Demand
3. How to measure and prospect energy services demand, focus on households.
4. Energy Poverty.
5. The role of smart meters.
6. The “Project Drawdown” Example.

Energy Chain I

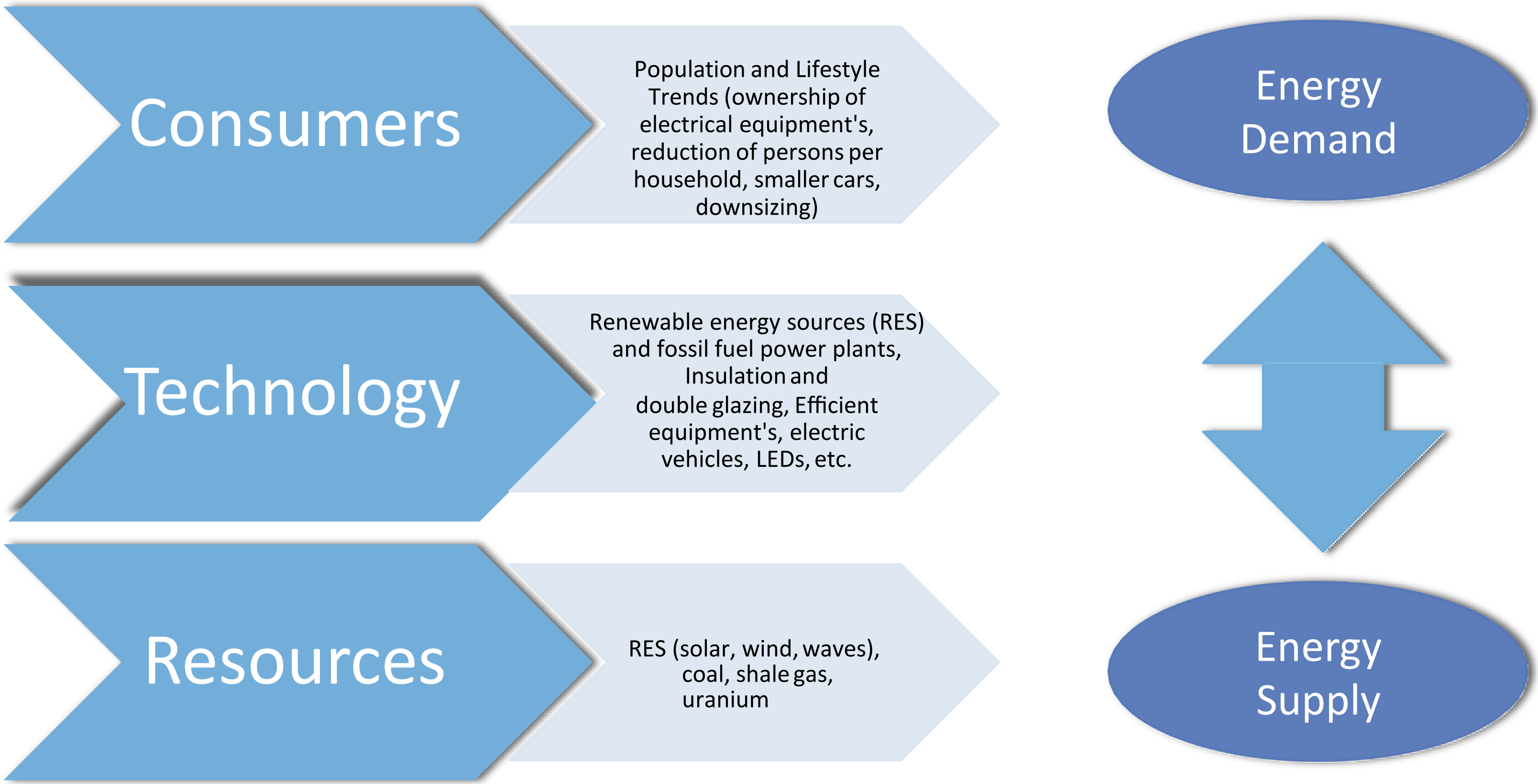

Fig. 1 – Simplified Energy Chain

Energy Chain II

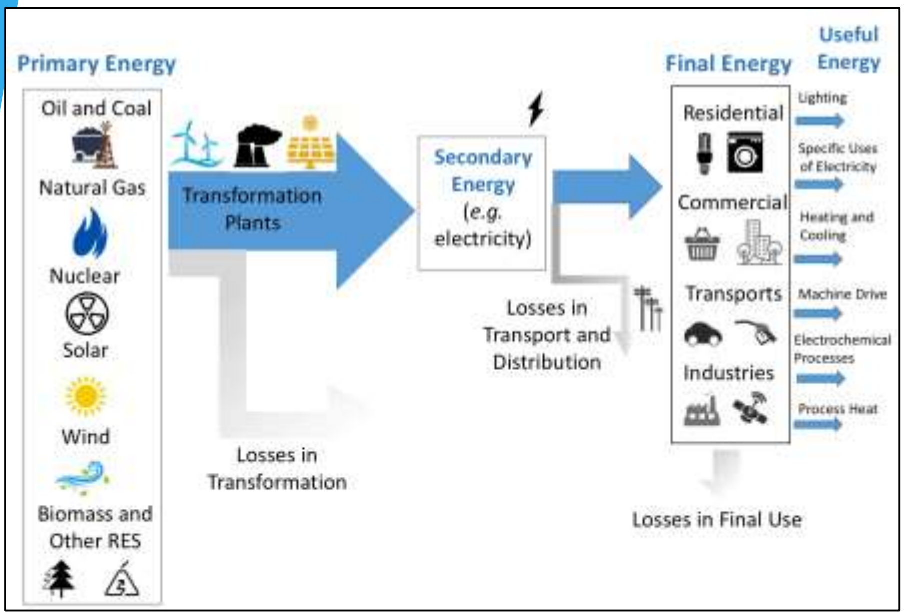

Fig. 2 – From Primary Energy to Energy Services

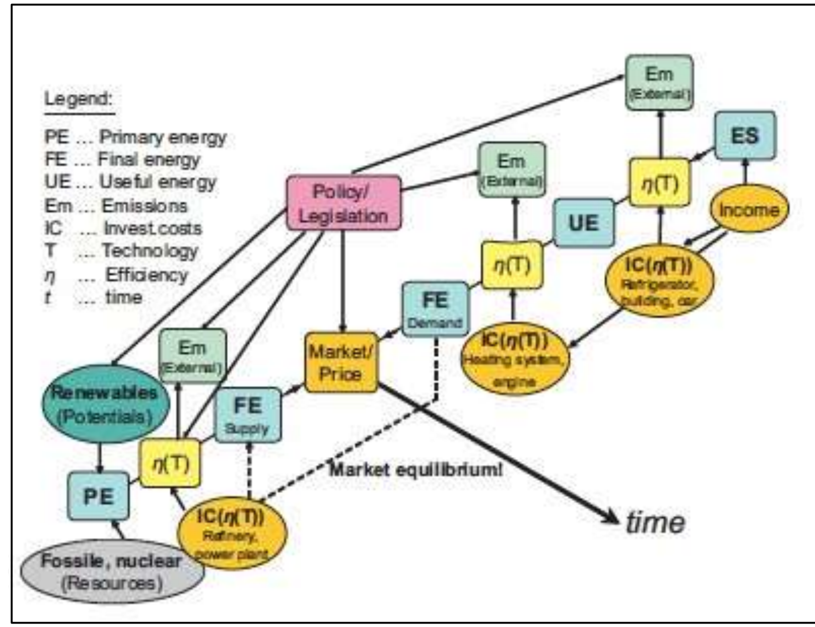

Fig. 3 Impact Factors in the energy chain to finally provide energy services (Haas et al., 2008 in Energy Policy)

Energy Planning

- **<u>Long Term Energy Planning</u>** – concerns the process of developing an overall strategy or a strategic objective, so there is a major need to make energy consumption and associated GHG emissions projections.

- ***Why?***
  - Energy supply security and affordability,
  - Reduction of resources depletion,
  - Support of energy and climate change mitigation strategies.

- ***How?***
  - Quantitative models (e.g. econometric and technological models)

- ***What are the drivers of this relationship?***
  - Energy demand (population, economic growth)
  - Technology (Availability, technical parameters)
  - Resources (techno economic potential)

Concepts

- **Storylines** – A narrative description of a scenario, highlighting the main scenario characteristics and dynamics, and the relationships between key driving forces.

- **Scenarios -** is a coherent, internally consistent and plausible description of a possible future state. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold.

- **Projections** – any description of the future and the pathway leading to it. Considers uncertainties.

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- **Predictions** – intention to "guess" the future, addressing the likelihood of a projection.

Note – Concepts definitions by IPCC (2013)

From storylines to quantitative models

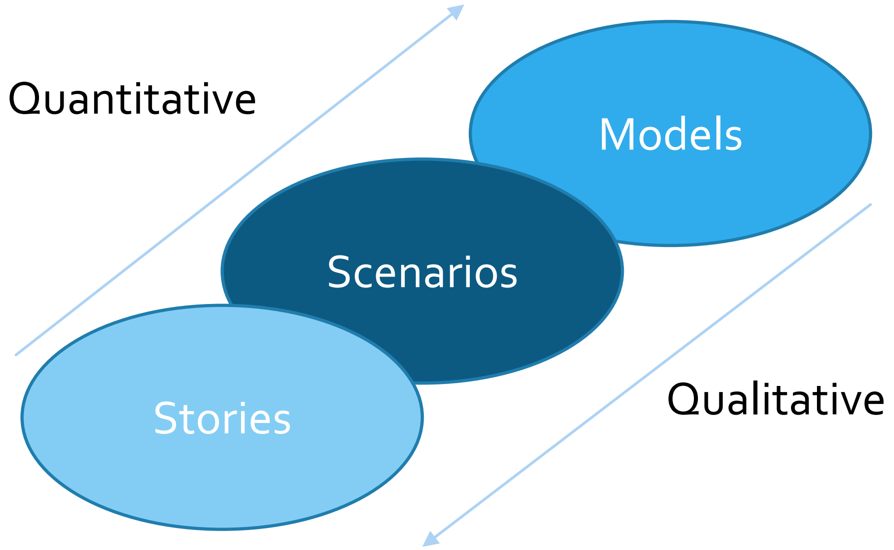


Fig. 4 –Schematic illustration of alternative scenario formulations, from narrative storylines to quantitative formal models (IPCC)

Storylines and Scenarios I

Welcome

- Lack of capacity to attract investment capable of leveraging a change in the productive profile;
- Advocacy for quick - return investments in activities and sectors where Portugal has comparative advantages with a low - skilled and specialized workforce;
- Encouragement of the cluster / health center, driven by the tourism of the elderly population from developed countries, more demanding in health care.

We Cannot Fail

- Economic policy capable of stimulating innovation and technological improvement;
- Capacity to use "endogenous" resources and skills and to attract strategic investment
- Capacity to develop projects that attract activities of high value added, intensive in knowledge and technology: Nano, Bios and TICs.

Source: HYBCO$_2$ project, FCT- NOVA

Storylines and Scenarios II

Communities

- "All politics are local" scenario: the center of the individual's activity is their local / regional community. The aspects, products of the local economy are valued. Valued communities' autonomy and resilience
- The process of globalization slows down: in tourism, in international trade, even in social networks
- Economic growth is low, but in a context where the population regresses, per capita income increases during the period - a scenario of "Japanese"
- There is a relative attraction for smaller communities and a slowdown in the urbanization process
- Displacement is greater on a daily basis - there is a greater dispersion of population

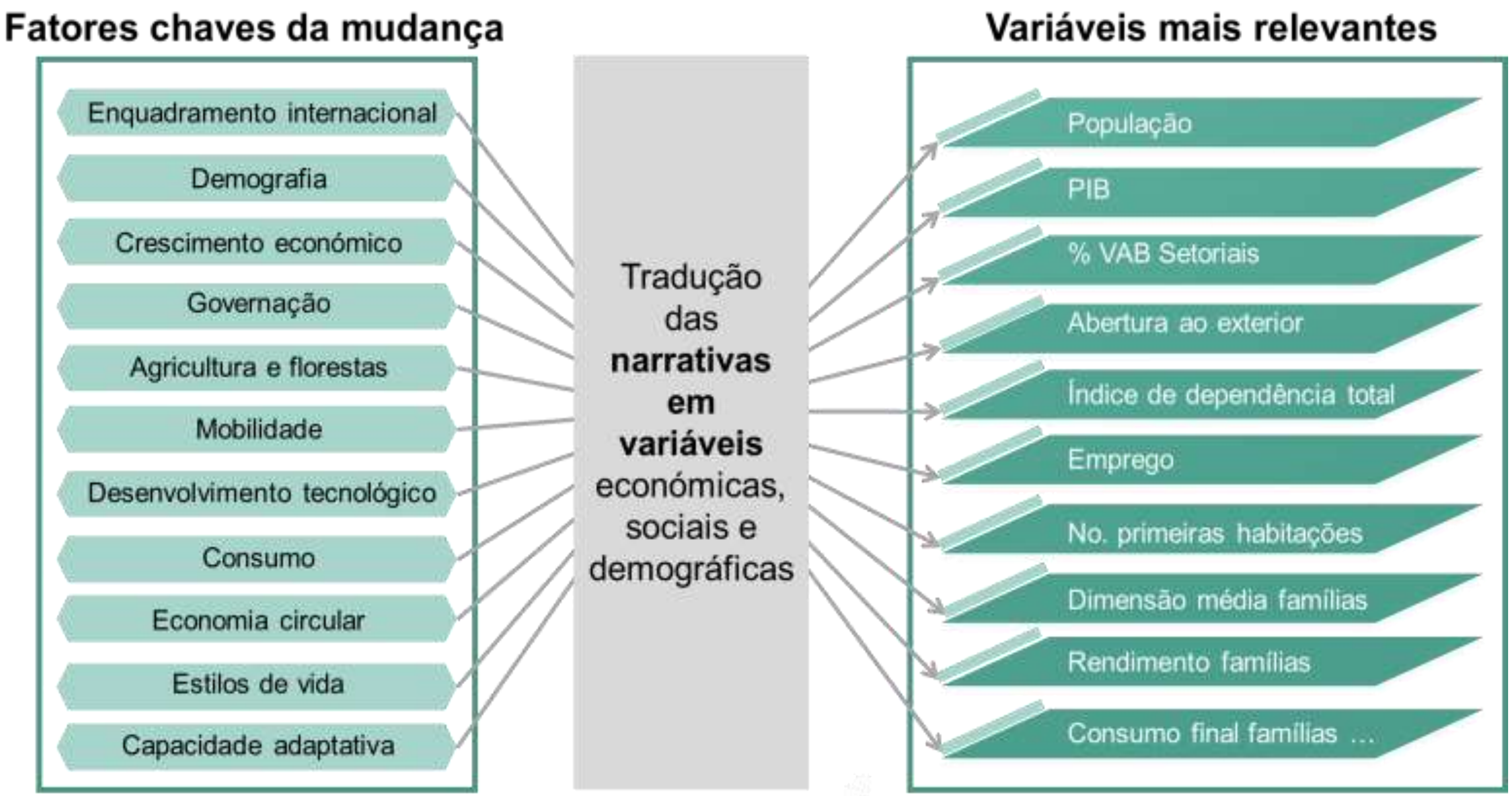
Markets

- Strengthening the primacy of economic relations on social issues and broadening the liberalization paradigm
- The globalization process accelerates: greater international integration; accelerated growth in different regions; "A rising tide rises all boats": growth in Europe and Portugal.
- The population recovers in part, mainly through immigration, but also through recovery of the physiological balance.
- Technology accelerates: industrial revolution 4.0 accelerates: 3d printing, industrial customization, new financial technologies.
- Less political integration: possibly greater social inequality.

Source: RNC2050 Project (2018) , Get2C, FCT--NOVA

RNC2050

Storylines and Scenarios III



Source: RNC2050 Project (2018) , Get2C, FCT--NOVA

Energy and GHG projectionsI

- **<u>Different Scales:</u>** Spatial (i.e. regions, countries, cities) and time (short, medium and long term)

- **<u>Different Objectives</u>** (fuel consumption, GHG emissions, sectoral analysis, technological development)

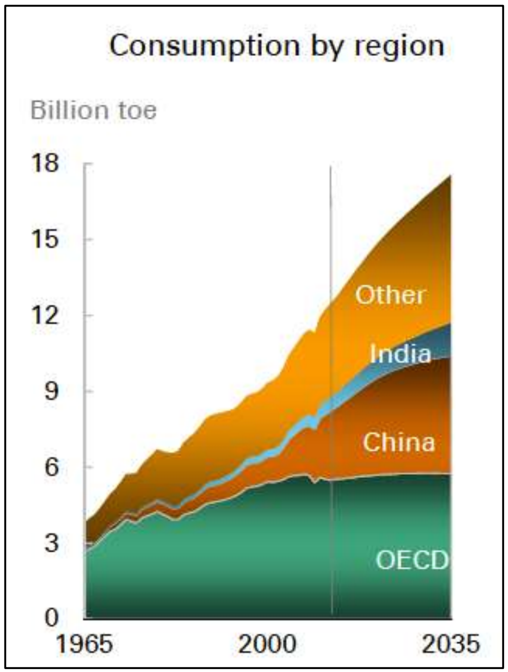


Fig. 5 – Primary energy Consumption by World region (BP 2014, Energy outlook 2035)

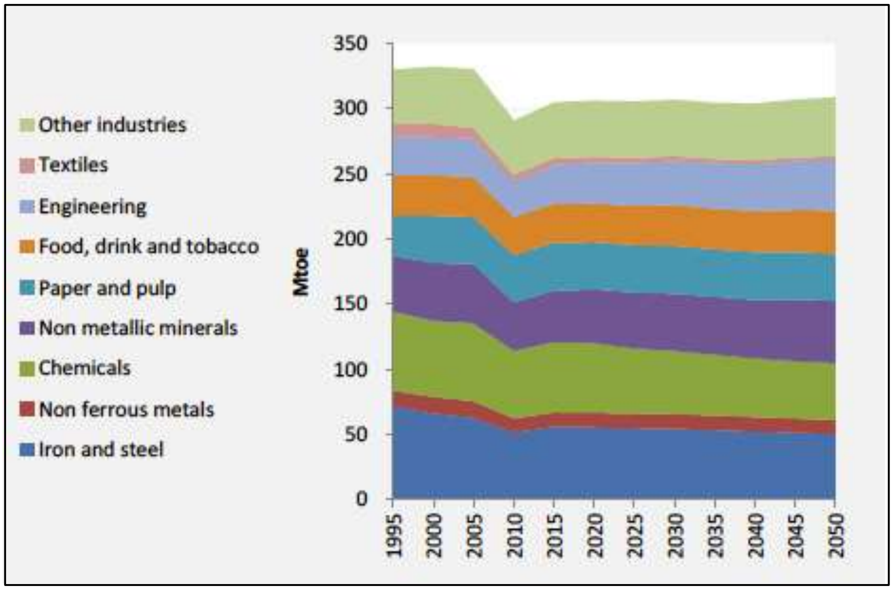


Fig. 6 – Final energy Consumption in EU industrial sectors for 2050 (EC 2013, Trends to 2050)

Energy and GHG projectionsII

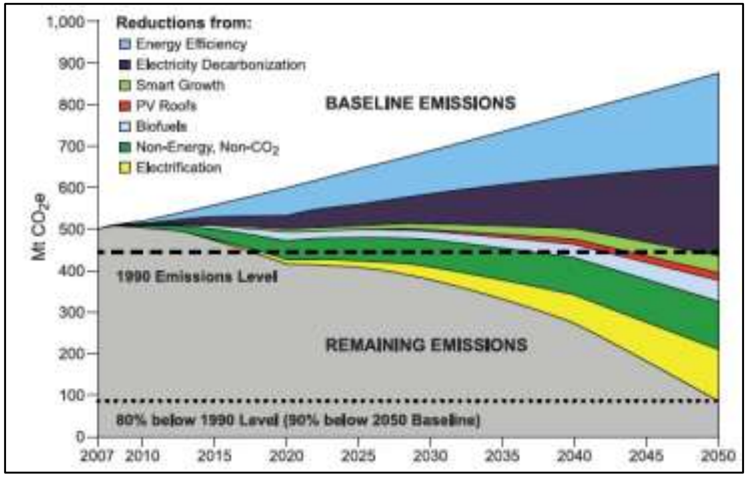


Fig. 7 – Emission Reduction wedges for California in 2050 (Williams *et al.*, 2012 in Science vol. 335)

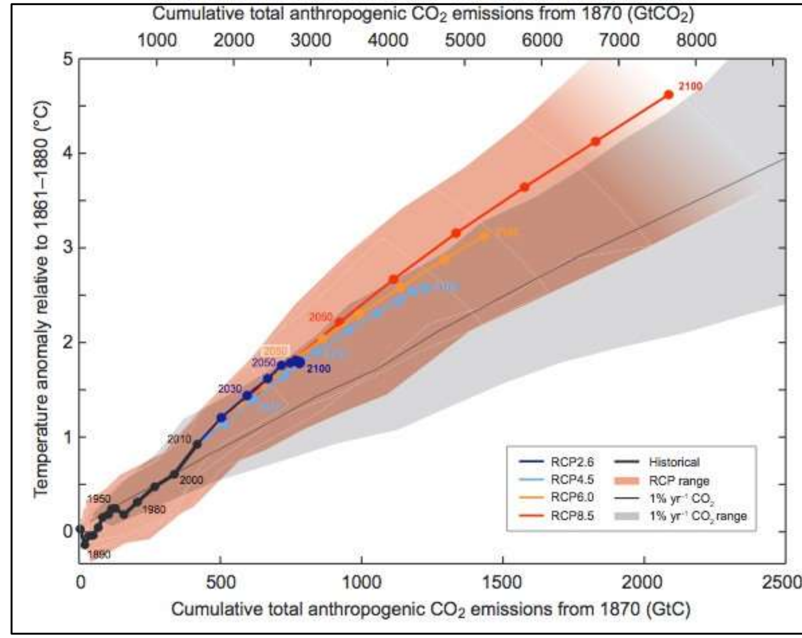


Fig. 8 – Global mean surface temperature increase as a function of cumulative total global CO_2 emissions from various lines of evidence (IPCC 2013, Summary for Policy makers)

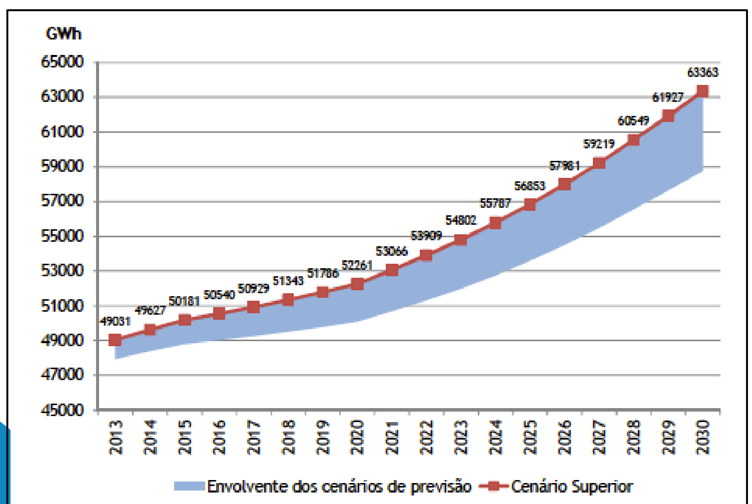


Fig.9 – Electricity demand evolution until 2030 for Portugal (REN and DGEG 2013, Monitorização de segurança do SEN)

Energy and GHG projections III

Mitigation Assessment:

1) Define the Time Frame
2) Define scope (sectors, demand or supply, emissions, technologies)
3) Define participants and key stakeholders (policy makers, NGOs, energy companies, etc.)
4) Select methodologies
5) Standardize key parameters (base year, end year, discount rate, etc.)
6) Define boundaries
7) Define and build Scenarios

Modeling Tools energy analysisI

Purpose:

To estimate:

- Electricity demand profile (hourly, daily)
- Power and electrical energy demand
- Level of energy demand by type of end use and sector
- Energy demand projections (at system level)

Models are of following types:

–Times series models

–Econometric models

–Techno Economic models

Modeling Tools energy analysis II

Typically divided in TOP DOWN or BOTTOM UP

- Top-down– most useful for studying broad macroeconomic and fiscal policies for mitigation, such as carbon or other environmental taxes.

- Bottom--up– most useful for studying options that have specific sectoral and technological implications

Modeling Tools energy analysis III

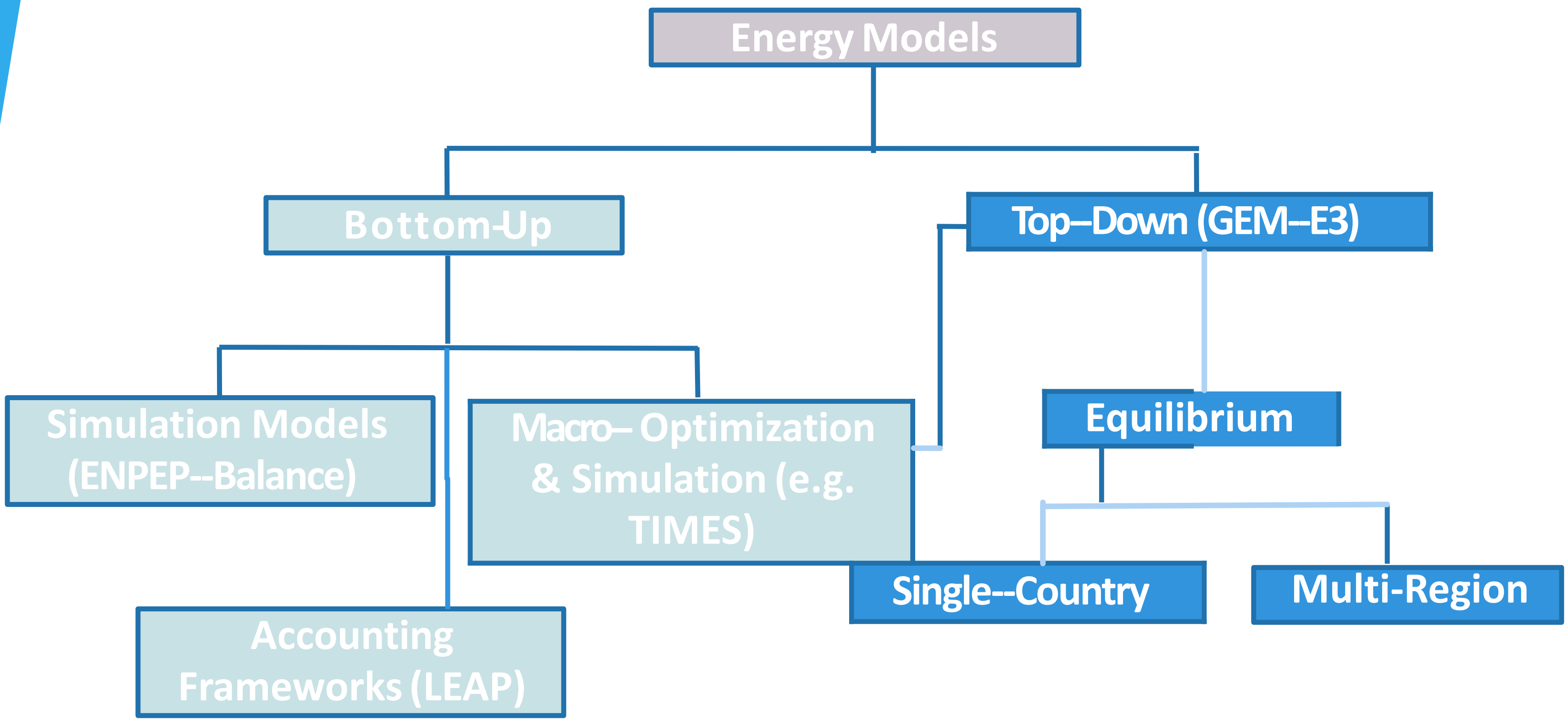


Fig. 10 – Energy Models (Adapted from P. R. Shukla (e2 Analytics), Model comparison)

Integrated Modeling Framework

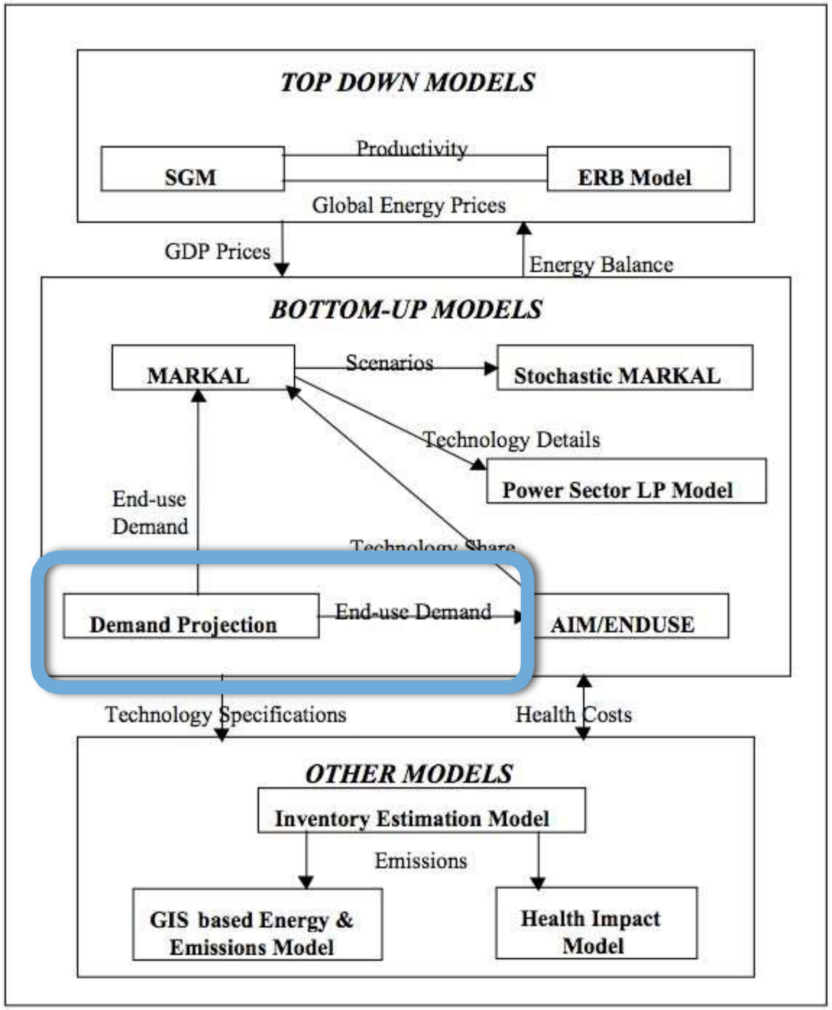


Fig. 11 – Soft Linked Integrated Modeling Framework (Indian Institute of Management)

Energy systems modelling Frameworks

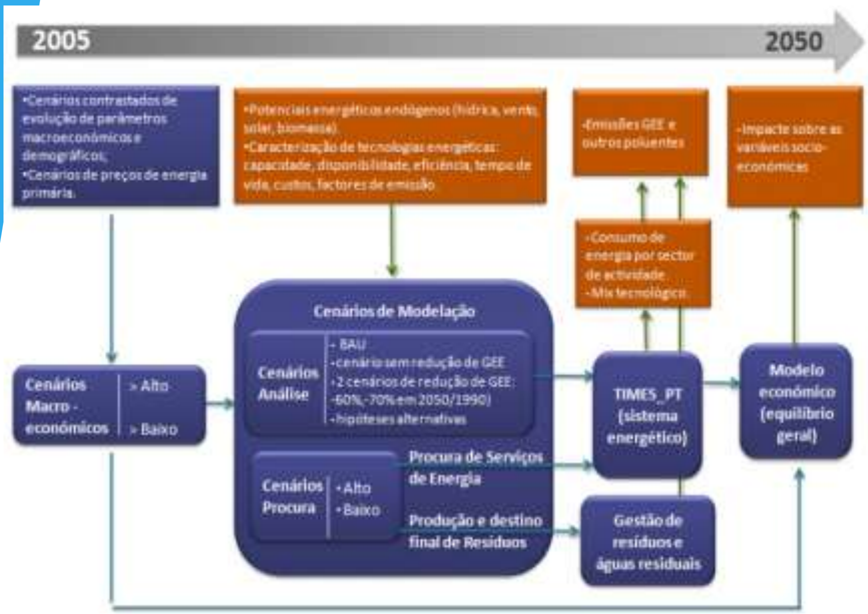


Fig. 12 – Methodological Workflow for the Portuguese Roadmap 2050 (Seixas et al., 2010)

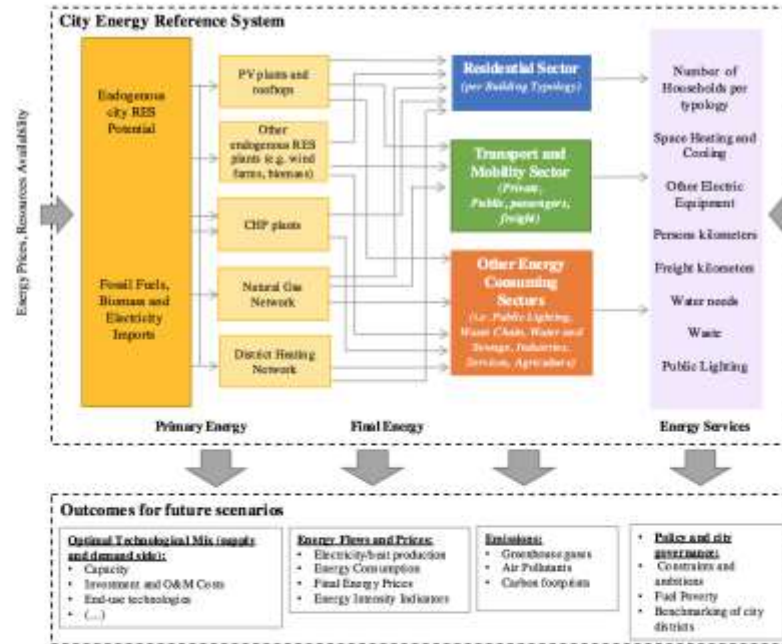


Fig. 13 – City energy Planning structure and major outcomes (EU INSMART project, 2016)

Energy Demand I

Supported on **<u>Final Energy</u>** using top down methods

Main Disadvantage

- Aggregated view of the energy sectors and the economy
- There is the perception that fuels and technologies are the only important elements of energy systems.

Main Advantage

- Easier to apply since is driven by aggregated indicators like economic growth (GDP), price trends, demographic development.

Energy Demand II

Supported on **Energy services** using bottom up methods –

Main Disadvantage

- More Information needed increasing uncertainty with associated assumptions

Main Advantages

- Allows future options of energy resources and technologies available to satisfy energy needs,
- Encompasses the expected changes on drivers of energy consumption (*e.g.* changes on climate, on private consumption and on lifestyle)
- Can be used as input for techno economic models
- Better predictions than trend analysis of historical values

Table 1 – Example of Fuels and technologies to provide five energy services (Girardet and Mendonça, 2009)

Energy service	Sector/scale	Conventional fuel(s)	Renewable fuel(s)
Cooking	Homes, restaurants, commercial stoves and ovens	Liquefied petroleum gas, kerosene	Direct biomass combustion, biogas from digesters, solar cookers
Lighting	Homes, schools, street lighting	Candles, kerosene, batteries, diesel generators	Hydroelectric power, biogas and biomass gasification, wind and solar minigrids
Refrigeration	Homes, hospitals	Diesel generators	Hydroelectric power, biogas and biomass gasification, wind and solar minigrids
Water pumping	Agriculture, drinking water	Diesel pumps	Mechanical wind pumps, solar photovoltaic pumps
Heating and cooling	Crop drying, agricultural processing, hot water	Liquefied petroleum gas, kerosene, diesel generators	Biomass combustion and biogas, solar crop dryers, solar water heaters

Energy Demand III

- A bottom-up approach extrapolates the estimated energy consumption of a representative set of individual houses/consumers to regional and national levels explaining much better the changes in energy use.

- Energy demand is a crucial point factor in model uncertainties. Despite its relevance, medium to long-term studies on energy and climate policy devote small effort and attention on energy services demand.

Energy Demand Projections I

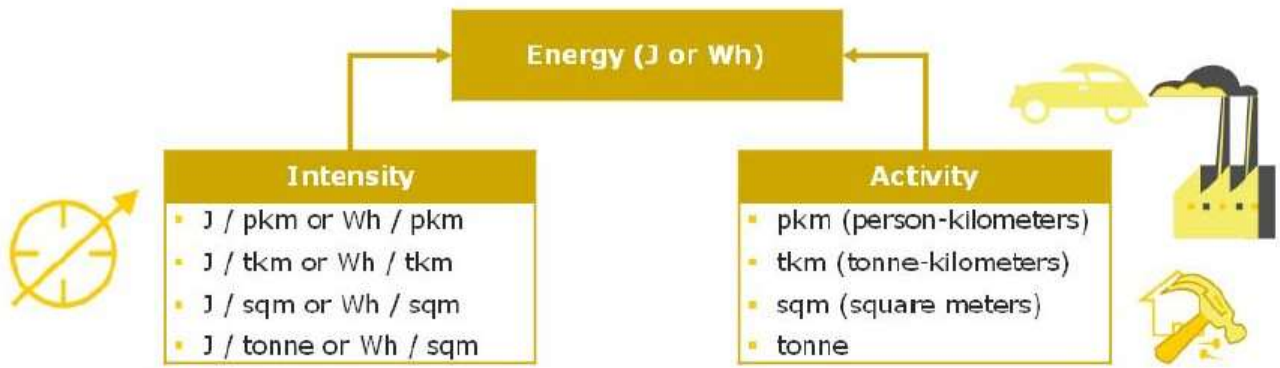
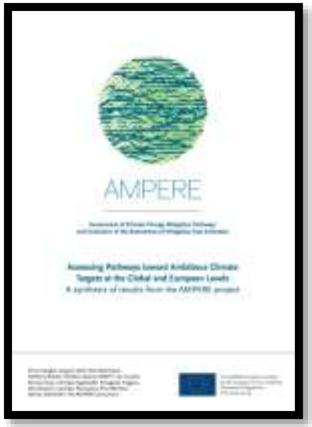


Fig. 14– Conceptual approach for energy demand projections (WWF 2013, The Energy Report)

- Future demand side **activity** can be used from literature or estimated based on population, GDP growth or other drivers.
- Future demand side **energy intensity** can result from technological models, assumptions of roll out of efficient technologies, others.

Examples



2014

MODELS
- AMPERE MESSAGE/MACRO
- AMPERE GEM E3
- AMPERE IMAGE/TIMER

SCENARIOS
- CLIMATE POLICY BENCHMARK (450)
- CLIMATE POLICY BENCHMARK (550)
- REFERENCE POLICY
- (...)

2015

MODELS
- Mesap/PlaNet simulation model

SCENARIOS
- ENERGY [R]EVOLUTION
- ADVANCED ENERGY [R]EVOLUTION
- REFERENCE

2016

MODELS
- IEA ETP - Four interlinked models (energy supply, buildings, transports and industry)

SCENARIOS
- 2 DEGREE SCENARIO (2DS)
- 4 DEGREE SCENARIO (4DS)
- 6 DEGREE SCENARIO (6DS)

Energy Demand Projections II

Economic activity and **population** are the two fundamental drivers of demand for energy services.

POPULATION

- AMPERE Project: UNEP 2010 (medium fertility variant)
- Greenpeace Energy Revolution: UNEP 2014 (medium fertility variant)
- IEA ETP 2016: UNEP 2014 (medium fertility variant)

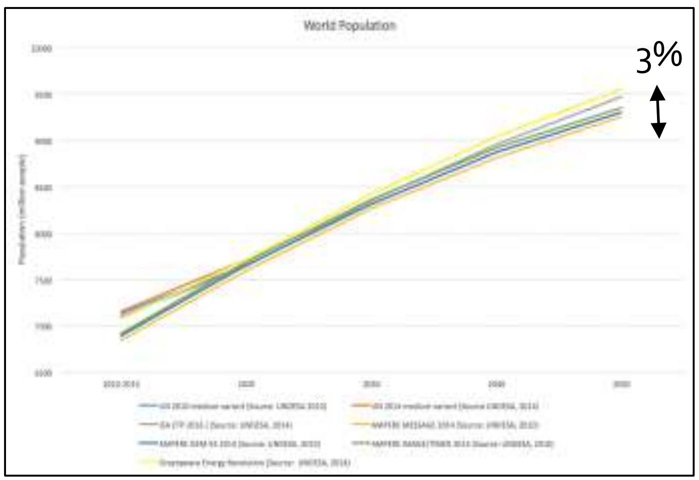


Figure 15 – Population projections between assessed models

ECONOMIC ACTIVITY – GDP (purchasing power parity)

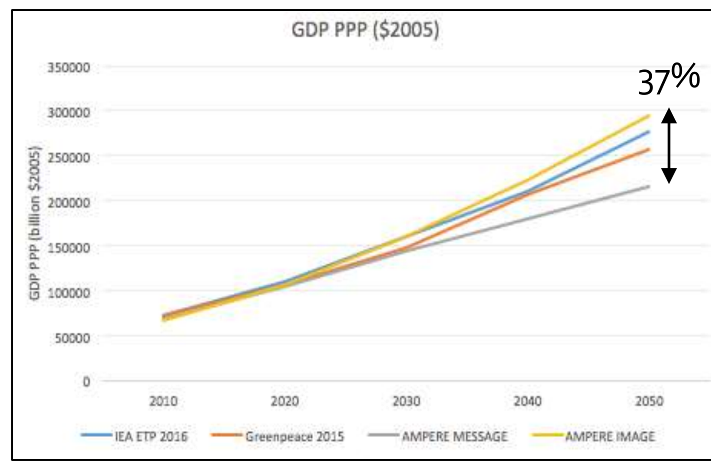
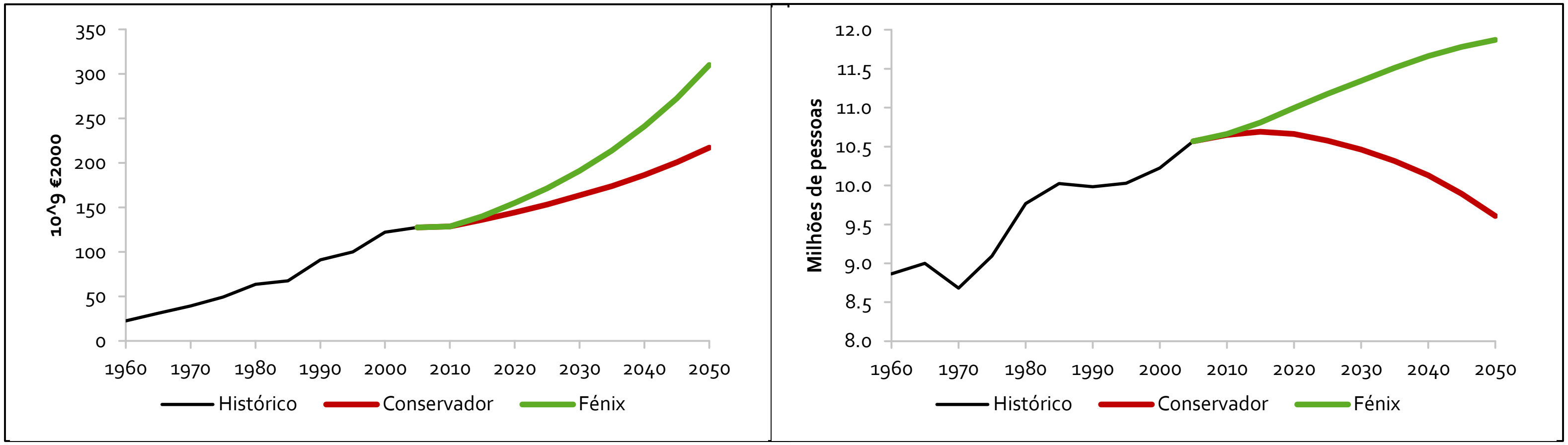


Figure 16 – Examples of GDP PPP projections between assessed models

Energy Demand Projections III

- Socio Economic Scenarios for 2050



Indicator	Unit	2005	2010	2020	2030	2040	2050
GDP/capita	$1000€_{2000}$/hab	12.80	12.1	13.4	15.1	17.2	20.1
			12.1	14.1	16.9	20.7	26.1

Fig. 17 – Socio Economic scenarios for Portugal in 2050 (RNBC, 2010)

Note: GDP growth rates up to 2015 follow the IMF forecasts. From this date, a linear increase up to the 1.56% ('46 / 50) growth value was considered equivalent to the lowest since 1960 (95% confidence interval of the random walk performed with GDP / per capita data)

Residential Sector I

- Energy consumption in buildings deserves special attention since it represents a significant share of energy consumption (20–30%) in EU.

- Wide range of variation in EU is observed within the residential sector from 7.6 to 37.4 GJ *per capita*/annum, with the lowest consumption indicator observed in Southern EU countries.

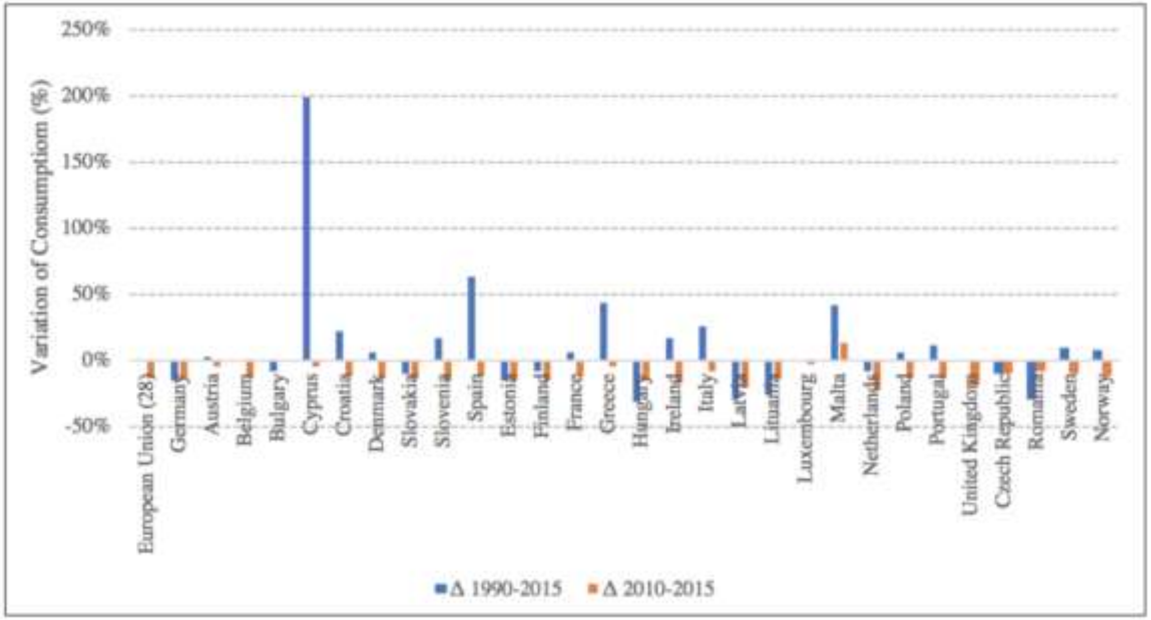


Fig. 19 – Variation of final energy consumption per capita from 1990 to 2015 and 2010-2015 at residential buildings of EU countries (PORDATA, 2016) (In Gouveia, 2017)

Residential Sector II

- Residential sector energy consumption is a complex issue that can be explained by a combination of:
  - Physical (e.g. household type),
  - Technological (e.g. equipment efficiency),
  - Socio Economic (e.g. family dimension),
  - Climate,
  - Behavioral characteristics
  - Energy prices.

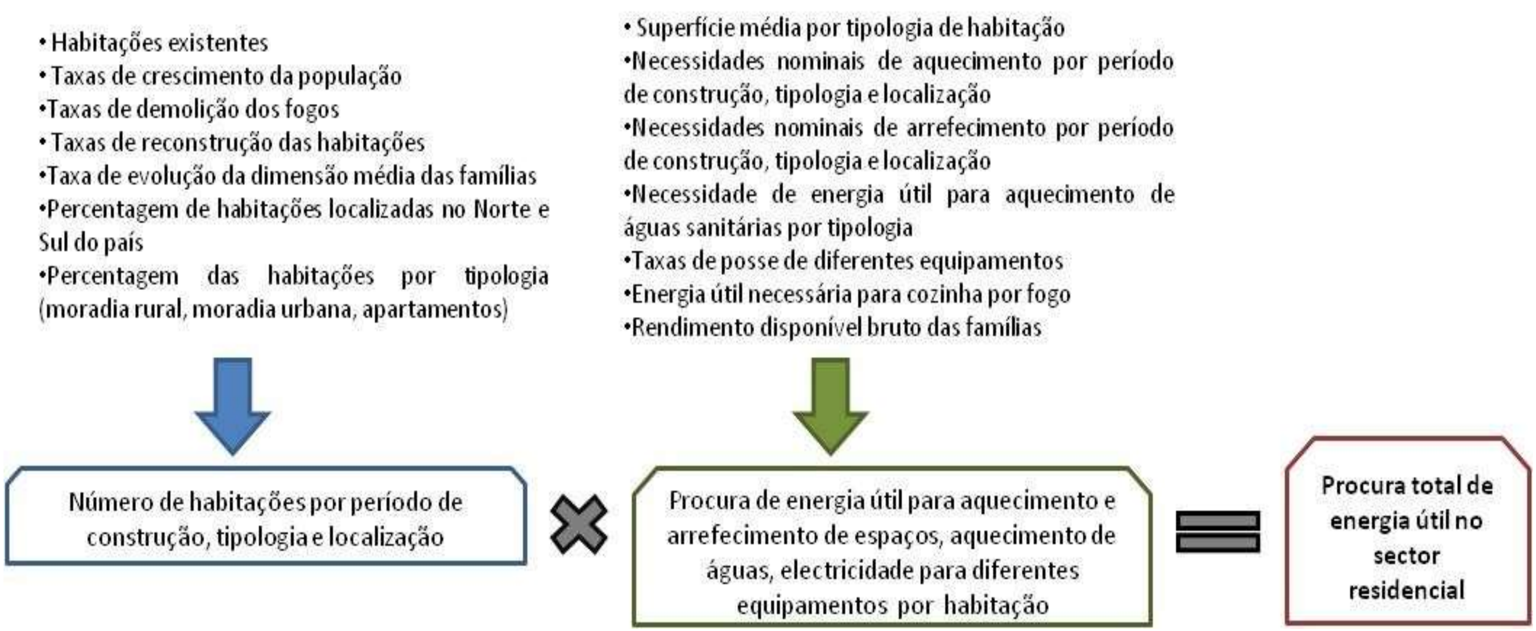
To **reduce energy consumption effectively** while delivering energy services, we need to look not just at technology, but also to the factors that drive how and in what extent people consume energy, including the way they interact with technology.

Energy Consumption Determinants

Table 2 -Factors behind residential energy consumption (Adapted from Paço and Varejão, 2010 and Kowsari and Zerriffi, 2011)

Categories	Factors
Endogenous Factors (household characteristics)	
Economic Characteristics	Income, expenditure
Non-Economic Characteristics	Household size, type and age; occupants gender, age, education, household composition, information, job or occupation, family dimension
Behavioral and Cultural Characteristics	Preferences, personality, practices, attitude, lifestyle, social status, religion, ethnicity, environmental awareness and concern, values
Exogenous Factors (external conditions)	
Physical Environment	Geographic location and urbanization level, climatic condition
Policies	Energy policy, environmental policy, subsidies, market and trade policies
Energy Supply Factors	Prices and affordability, availability, accessibility, reliability of energy supplies
Technology Characteristics	Conversion efficiency, cost and payment method, complexity of operation

General Methodology I

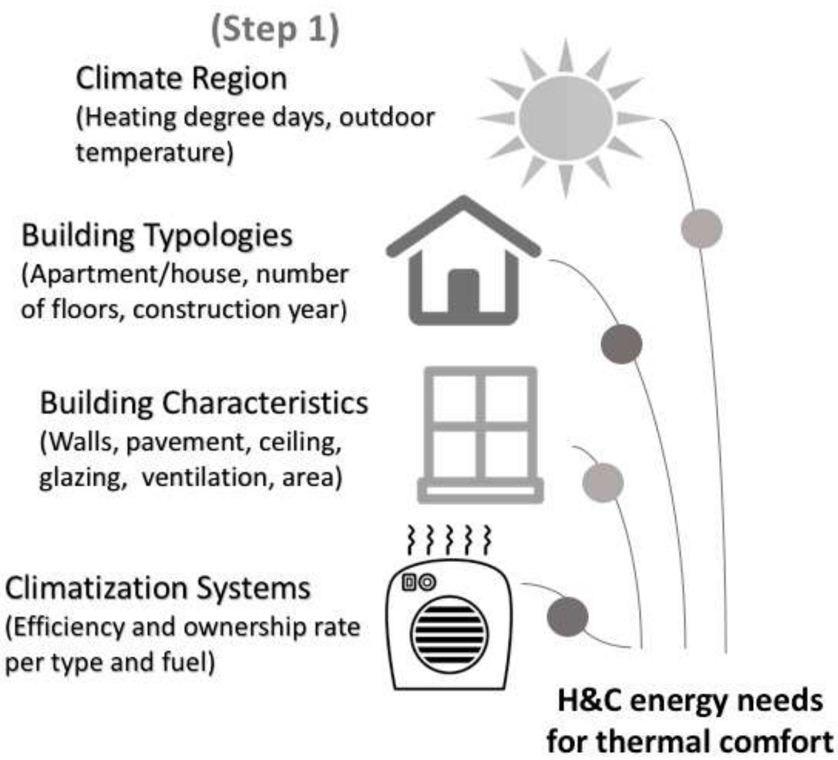


END USES CONSIDERED

Space Heating and Space Cooling	Domestic Hot Water	Cooking	Refrigeration and big electric appliances	Lighting	Other Electric Equipments

Source: Seixas, J., Gouveia, J.P., Fortes, P., Procura de Energia para o ano de 2030, CENSE, FCT--UNL, 2009. Partly funded by REN, S.A.

Space Heating and Cooling



Total heating needs in year n (kWh/year)

=

heating needs per m^2 according to location (N – north, S – south) , type (SH – single house, MA – multi apartment) and age

X

<u>households average surface</u> (m^2)

according to location and type X

<u>number of households</u> in the year *n* for each location, type and age

Source: Gouveia, J.P., Palma, P., Simoes, S., Seixas, J. (2017).

Note: Heating and cooling needs per m2 could be calculated on engineering software's like Energy Plus, Design Builder eQUEst, Trace 700, etc. or supported on more simple Excel[tm] spreadsheets like the ones from RCCTE and REH.

Space Heating and Cooling II

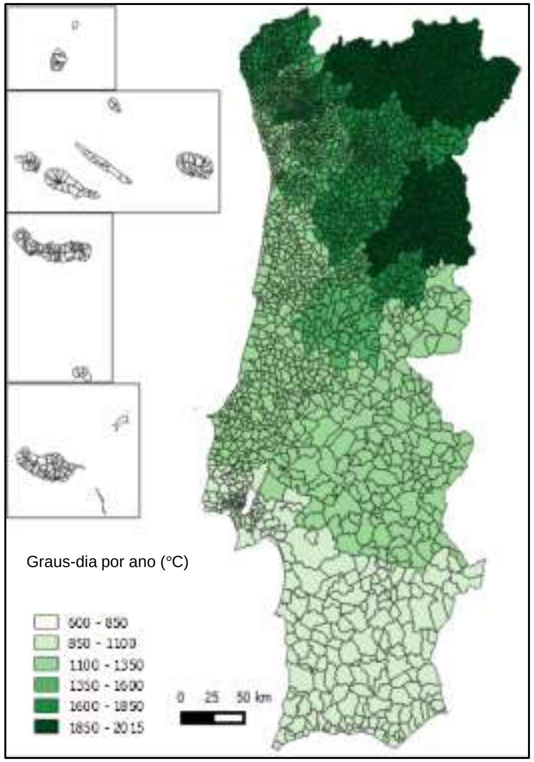


Fig. 18 - Heating degree days for Portugal (Palma et al., 2019)

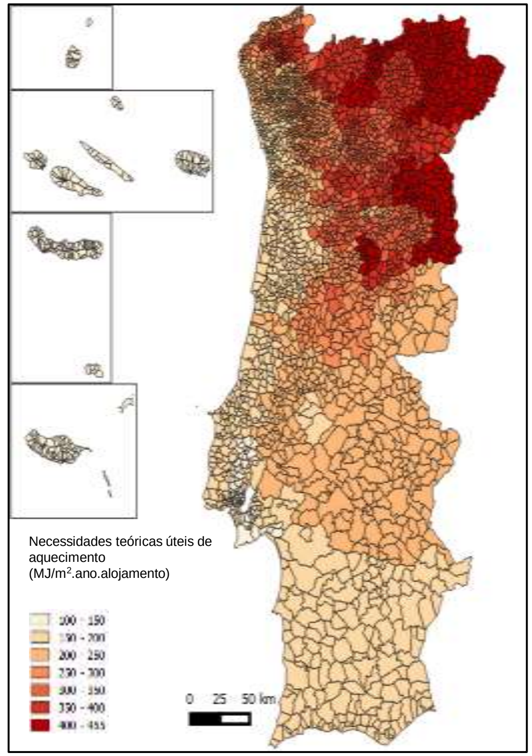


Fig. 19 - Heating needs per sqm (Palma et al., 2019)

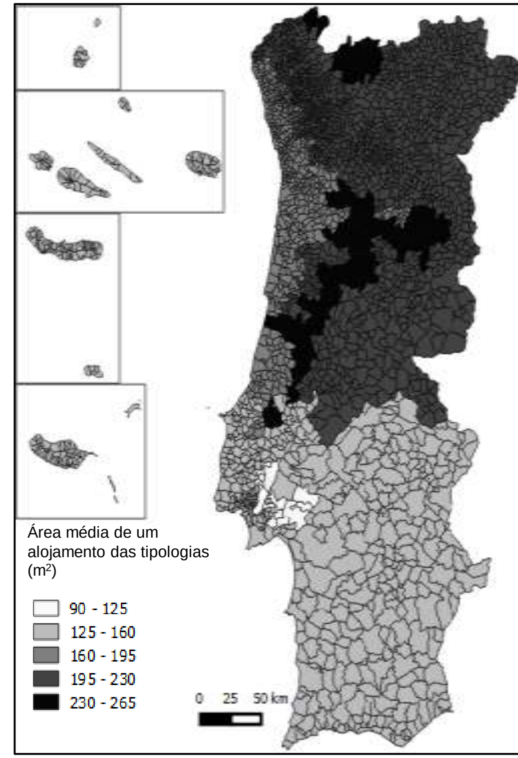


Fig. 20 - Average household area in Portugal (Palma et al., 2019)

Source: Palma, P., Gouveia, J.P., Simoes, S. G. (2019). Mapping the energy performance gap of dwelling stock at high-resolution scale: Implications for thermal comfort in Portuguese households. Energy and Buildings 190, pp.246-261. https://doi.org/10.1016/j.enbuild.2019.03.002

Space Heating and Cooling III – Buildings Archetypes #9

Table 3- Heating and cooling needs for different buildings archetypes in Portugal

Heating needs (Nic) (kWh/m²·year)			
Household Type	**Households pre 1990**	**Households between 1990 and 2005**	**Households post 2005**
Single House North	267,40	139,52	95,30
Multi--Apartment North	102,43	94,51	91,32
Single house/multi--apartment South	80,71	67,05	52,53
Cooling needs (Nvc) (kWh/m²·year)			
Household Type	**Households pre 1990**	**Households between 1990 and 2005**	**Households post 2005**
Single House North	8,26	9,55	10,31
Multi--Apartment North	6,88	8,34	8,82
Single house/multi--apartment South	15,54	16,46	16,86

Note: The estimated values follow the approach of the Thermal Performance of Building (RCCTE). The conditions of comfort for the heating season were set at 20°C while cooling to station were 25°C and 50% relative humidity (Gouveia *et al.*, 2012)

Space Heating and Cooling IV – Buildings Archetypes #96

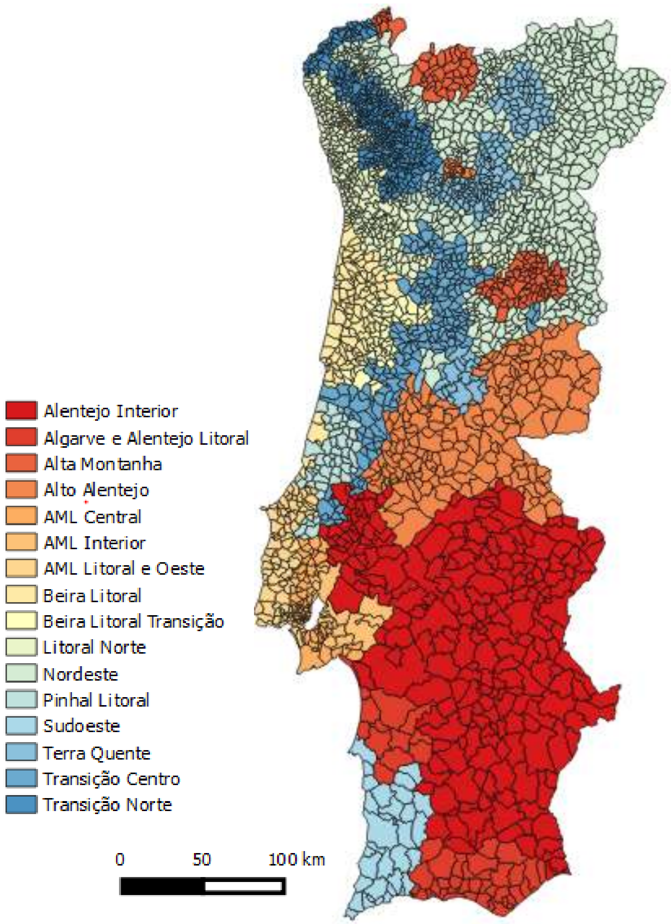
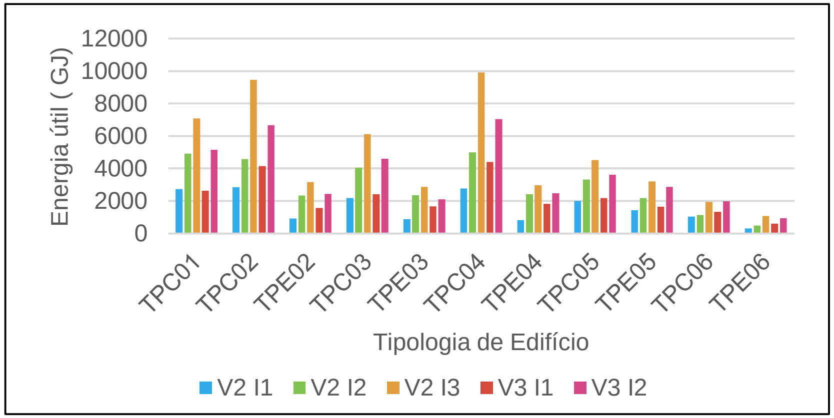


Fig. 21 - Portuguese regions for buildings archetypes definition (Adapted from Lopes, 2010)



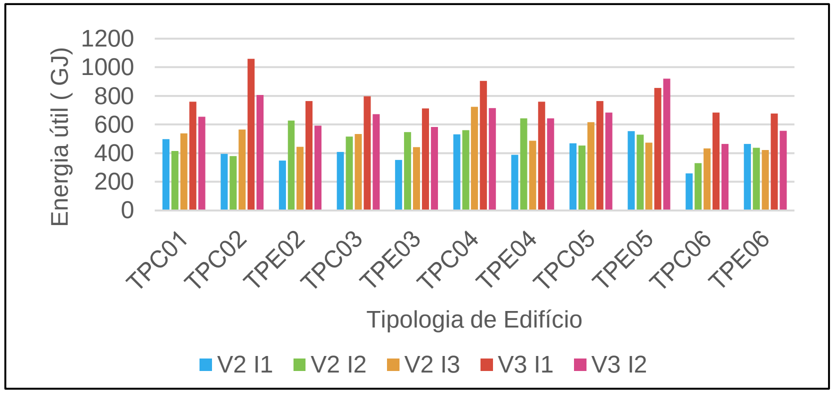


Fig. 22 - Space heating (top) and coolling (bottom) needs by archetype for each climate zone (Palma, 2017)

Note: The estimated values follow the approach of the new thermal perfomance regulation (REH. 2013)

Space Heating and Cooling V – Buildings Archetypes

Space Heating and Cooling VI –

Buildings Archetypes #10/#27

General
- Location
- Period of construction
- Foot print area
- Average household area
- Frequency

Geometry
- Type of building
- Number of floors
- Number of dwellings
- Height
- Room in the roof

Equipment Ownership
- Refrigerators
- Coolers
- Washing machines (clothes, dishes)
- Fireplaces
- Solar thermal panels
- Air Conditioning
- Computers

Occupation
- Number of occupants
- Average income
- Occupation schedule
- Type of room heated

Construction
- Bearing Structure
- Exterior wall type
- Roof type
- Wall insulation
- Glass type
- Window framing

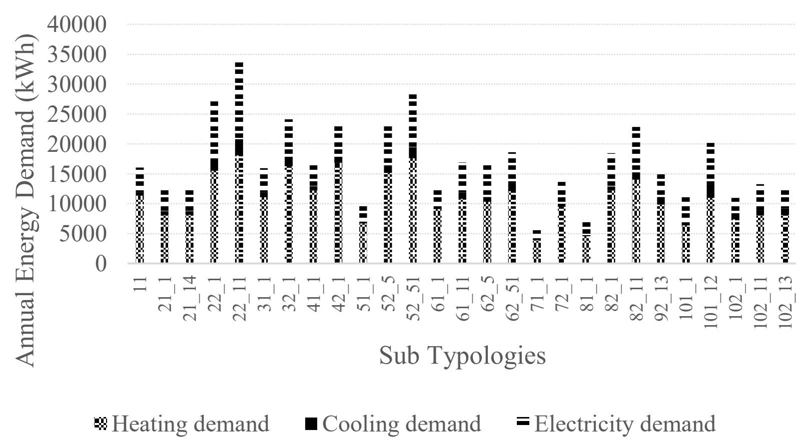


Fig. 23 – Heating, cooling and electricity demand by buildings sub typology for the city of Évora (Source: INSMART project

Note: The estimated values were calculated on Energy Plus

Domestic Hot Water (DHW)

Total energy needed for DHW for the year *n* (kWh/year)

=

Persons per household in the year *n*

X

daily average water consumption for DHW (40 liters/person/day)

X

temperature increase needed to reach the reference temperature (60°C)

X

number of consumption days

X

ownership rate of DWH equipment (%)

X

number of households in the year *n* for each location, and type

Source: Gouveia, J.P.; Fortes, P.; Seixas, J. (2012). Projections of Energy Services Demand for Residential Buildings: Insights from a Bottom-up Methodology. Energy 47 (2012) 430-442.

Lighting

Useful energy for each light bulb for 2005 *(E_l)* was obtained through the electricity consumption for lighting in 2005, and taking into account the market share and efficiencies of each type of light bulbs.

Based on this value and considering that the useful energy per light bulb remains constant for the future, it was used the following equation:

$$I_n = E_l \times HabT_n \times LB_n$$

(LB_n) –number of light bulbs per households

Source: Gouveia, J.P.; Fortes, P.; Seixas, J. (2012). Projections of Energy Services Demand for Residential Buildings: Insights from a Bottom-up Methodology. *Energy 47 (2012) 430-442.*

Main Assumptions I

Table 4 – Main Assumptions for energy demand scenarios (REN, 2009)

Parâmetro	Designação	2005	2010	2015	2020	2025	2030	Cenário
Pop_n (milhares de pessoas)	População anual	10.570	10.634	10.594	10.497	10.363	10.211	CT
			10.684	10.699	10.658	10.586	10.510	CM
DF_n (pessoas/fogo)	Dimensão média anual das famílias	2,7	2,6	2,5	2,4	2,3	2,2	CT
			2,5	2,35	2,2	2,1	2,0	CM
$HabT_n$ (milhares de fogos	Fogos (1ª Habitação) totais existentes no ano *n*	3.915	4.090	4.238	4.374	4.506	4.642	CT
			4.273	4.553	4.845	5.041	5.255	CM
FT_n (milhares de fogos	Fogos totais existentes no ano *n*	5.470	5.715	5.921	6.111	6.295	6.485	CT
			6.196	6.601	7.025	7.310	7.620	CM
$RHabT,FT_{2005}$	Número de habitações por família	1,40						CT
		1,45						CM

CT – Cenário Tendencial; CM – Cenário Mudança

Source: Seixas, J., Gouveia, J.P., Fortes, P., Procura de Energia para o ano de 2030, CENSE, FCT-UNL, 2009. Partly funded by REN, SA.

Main Assumptions II

Table 5 – Main Assumptions for energy demand scenarios (RNC, 2018)

Cenário 'Comunidades'	Unidades	2011	2015	2020	2030	2040	2050
População residente	Ind. - Milhares	10 557,60	10 358,10	10 007,85	9 284,33	8 460,65	7 467,95
Taxa de crescimento da população	%	0,19	-0,41	-0,69	-0,75	-0,92	-1,24
Índice de dependência total	%	51,33	53	56	66	87	106
Taxa da população urbana	%	50,78	53,68	53,68	53,68	53,68	53,68
Dimensão média dos agregados domésticos privados	Unidades	2,60	2,50	2,4	2,3	2,2	2,1
PIB (base=2011)	Euro - Milhares	176 166 578	179 809 061	197 935 126	208 057 555	218 697 645	229 881 872
Taxa de crescimento PIB	%	-1,83	1,82	2,00	0,50	0,50	0,50
PIB per capita	Euro - Milhares	16 686	17 359	19 778	22 410	25 849	30 782
Taxa de crescimento PIB per capita	%		0,99	2,64	1,26	1,44	1,76
VAB	Euro - Milhões	154 243	156 839	189 668	199 368	209 563	220 280
VAB energia	Euro - Milhões	3 503	5 143	4 931	5 184	5 449	5 727
VAB indústrias extrativas	Euro - Milhões	650	501	648	681	716	753
VAB indústrias transformadoras	Euro - Milhões	18 326	19 857	20 827	21 892	23 011	24 188
VAB transportes	Euro - Milhões	8 489	9 070	10 801	11 353	11 934	12 544

Source: RNC2050 Project (2018) , Get2C, FCT--NOVA

Other Assumptions

Table 6 – Other assumptions for computers and TVS for energy demand scenarios

	Parâmetro	Designação	2005	Fonte de informação
Socio Economic Characteristics	**Ptv (nº)**	Número de televisões por habitação	1,5	Considerando os valores de (Bertoldi e Atanasiu, 2007); (Remodece, 2006)
	P_{lcd} (%)	Taxa de posse de televisões LCD	1,5	(Bertoldi e Atanasiu, 2007)
	P_{plasma} (%)	Taxa de posse de televisões de plasma	0,5	
	P_{crt} (%)	Taxa de posse de televisões CRT	98	
Technology Characteristics	**EU_{lcd} (W)**	Consumo de energia útil de televisões LCD em utilização	135	**Média de consumos (Worten, 2009); (PNAEE, 2008); (Remodece, 2008)**
	EU_{plasma} (W)	Consumo de energia útil de televisões de plasma em utilização	438	
	EU_{crt} (W)	Consumo de energia útil de televisões CRT em utilização	160	
Behavior	**Utvs (horas/dia)**	Horas diárias de televisões em utilização	3.35	(Bertoldi e Atanasiu, 2007)
	SBtvs (horas/dia)	Horas diárias de televisões em *stand by*	20.65	
Technology Characteristics	**ESB_{lcd} (W)**	Consumo de energia útil de televisões LCD em *stand by*	1.86	
	ESB_{plasma} (W)	Consumo de energia útil de televisões de plasma em *stand by*	1.86	
	ESB_{crt} (W)	Consumo de energia útil de televisões de CRT em *stand by*	6.18	

Results I

Table 7 – Energy services demand results (PJ) for the different end uses for the residential sector (Trend scenario)

	2005	2010	2015	2020	2025	2030	Δ(2030/2005)
Aquecimento de Espaços	19,81	24,15	28,38	32,62	36,91	41,32	109%
Arrefecimento de Espaços	1,49	2,30	3,20	4,15	5,16	6,23	318%
Aquecimento de Águas Sanitárias	14,25	14,63	14,57	14,44	14,25	14,04	-1%
Cozinha	20,34	21,29	22,06	22,77	23,45	24,16	19%
Refrigeração	12,7	13,73	14,47	14,93	15,38	15,84	25%
Máquinas de Lavar Loiça	1,44	1,77	2,10	2,17	2,52	2,89	101%
Máquinas de Lavar Roupa e Lavar e Secar Roupa	3,90	4,38	4,68	4,88	5,02	5,17	33%
Máquinas de Secar Roupa	0,82	1,17	1,40	1,64	1,89	2,15	162%
Iluminação	8,29	9,12	10,23	11,37	12,55	13,80	66%
Televisões	5,13	-					-
Computadores	5,50	-					-
Outros Equipamentos Eléctricos	3,21	3,70	4,29	5,02	5,80	6,80	112%

Source: Seixas, J., Gouveia, J.P., Fortes, P., Procura de Energia para o ano de 2030, CENSE, FCT–-UNL, 2009. Partly funded by REN, SA.

Results II

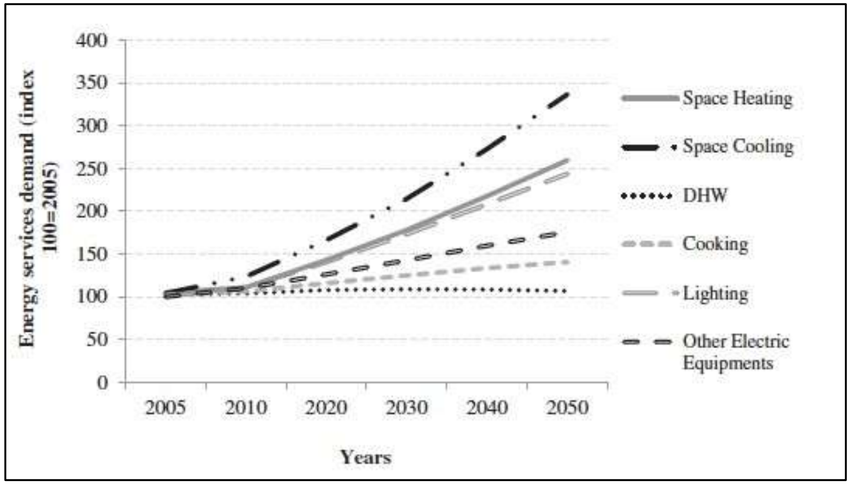


Fig 25 – Energy Services demand trends for the different end-uses until 2050 (REF scenario)

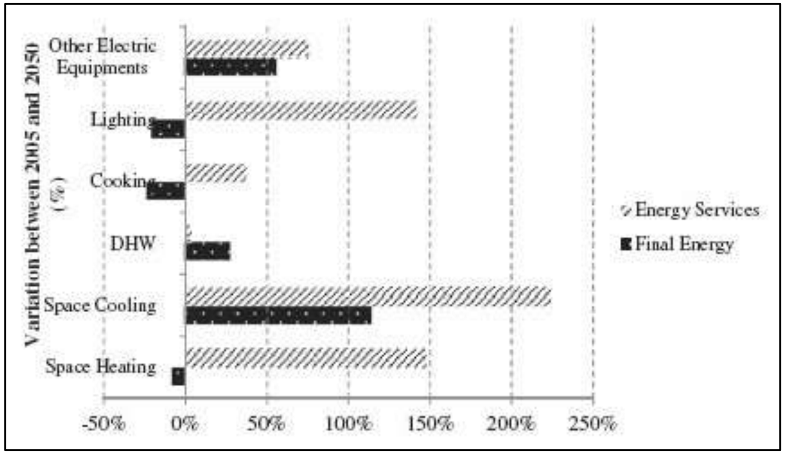


Fig 26 – Comparison between the evolution of the demand for ES and Final energy between 2005 and 2050 for REF

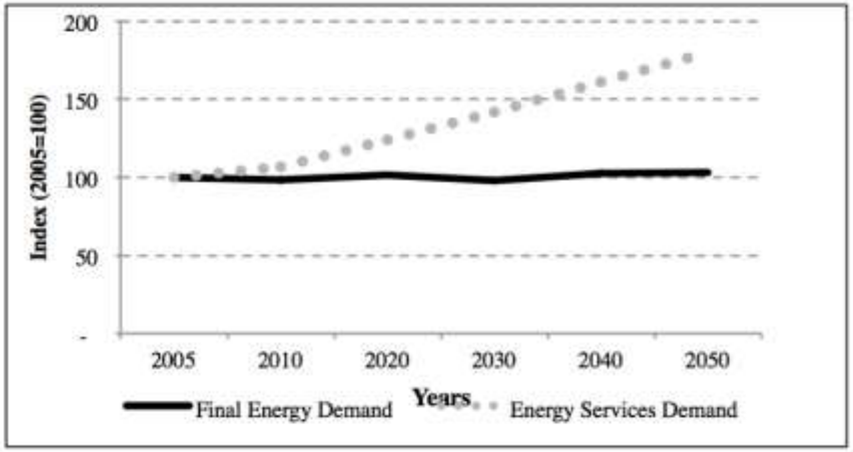


Fig 27-- Energy services and final energy trends between 2005 and 2050 for REF

Source: Gouveia, J.P.; Fortes, P.; Seixas, J. (2012). Projections of Energy Services Demand for Residential Buildings: Insights from a Bottom-up Methodology. *Energy 47 (2012) 430-442.*

Uncertainties I

Energy Services demand projections → vary substantially according to the assumptions considered and the uncertainty of the future socio-economic development.

Table 8 – Sensitivity analysis's from space heating and water heating parameters (Gouveia et al. (2012) - Energy)

End–Uses	Parameter	Variations to Reference Scenario	Impact in 2050 on energy services demand
Space Heating	Households Area	• Half of the growth rate from REF scenario • Constant in the 2010 average areas • Double of the growth rate from REF scenario	–8% to +18%
	Specific energy needs of new households	• –30% to +30% of the REF figures	–6% to +6%
	Thermal Comfort	• Constant in the 2005 figure (10%) • Increase of 1.5, 2, 2.5 and 3% each 5 years over the 2005 figure	–47% to +84%
Water Heating	Ownership rate	• Constant at the 2010 figure (i.e. 98%) • Increase to 99% in 2015 and the constant until 2050	–2.5 to –1%
	Temperature increase	• –10% to +10% of the REF figure (between 40.5°C to 49.5°C)	–10% to +10%
	Daily average water consumption	• –10% to 50% of the REF (i.e. 36 to 60 liters)	–10% to +50%
	Number of water consumption days	• –5% to +70% of the REF scenario figures (i.e. 173 days to 310 days)	–5% to +70%
	Persons per household	• Constant from the 2010 figures • Double of the growth rate from REF • Half of the growth rate from REF scenario	–25% to +32%

Uncertainties II

Heating and cooling demand –uncertainty associated with the increase of thermal comfort overcomes the uncertainty on the expansion in household area and heating and cooling needs due to thermal behavior of buildings.

Water heating –uncertainties on the assumptions for the future is stronger in the expectations of the social structure of a household and on the consumer behavior. This has an impact that could vary from --25% to 70% in the energy service demand of 2050 compared to REF.

Source: Gouveia, J.P. et al (2012) Energy

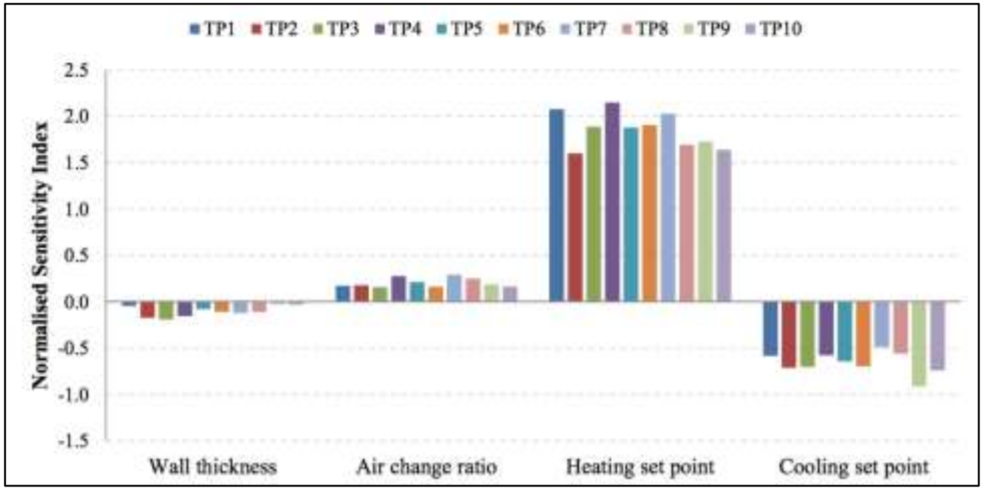


Fig. 28 - Normalized sensitivity indexes for each of the typologies (mean of all sub-typologies models) (source: EU INSMART project, 2016)

Energy Demand – By Consumer type

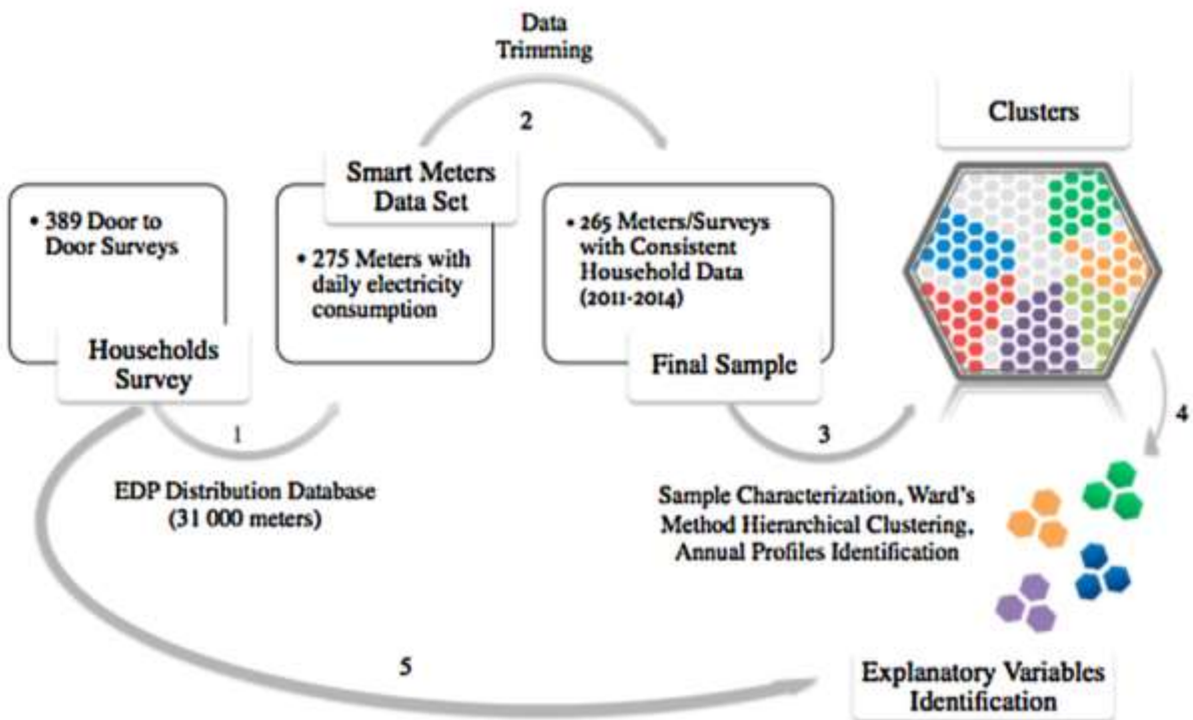


Fig. 29 – Methodology to identify and characterize distinct consumer groups

Source: Gouveia, J.P., Seixas, J. (2016). Unraveling electricity consumption profiles in households through clusters: Combining smart meters and door-to-door surveys. *Energy and Buildings. 116, 666–676.*

Energy Demand – By Consumer type I

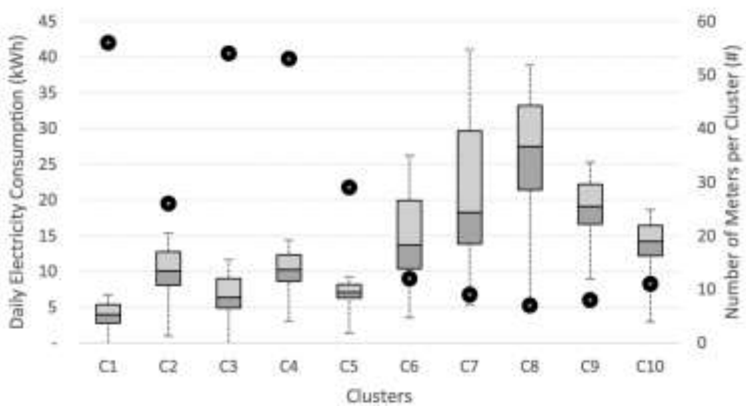
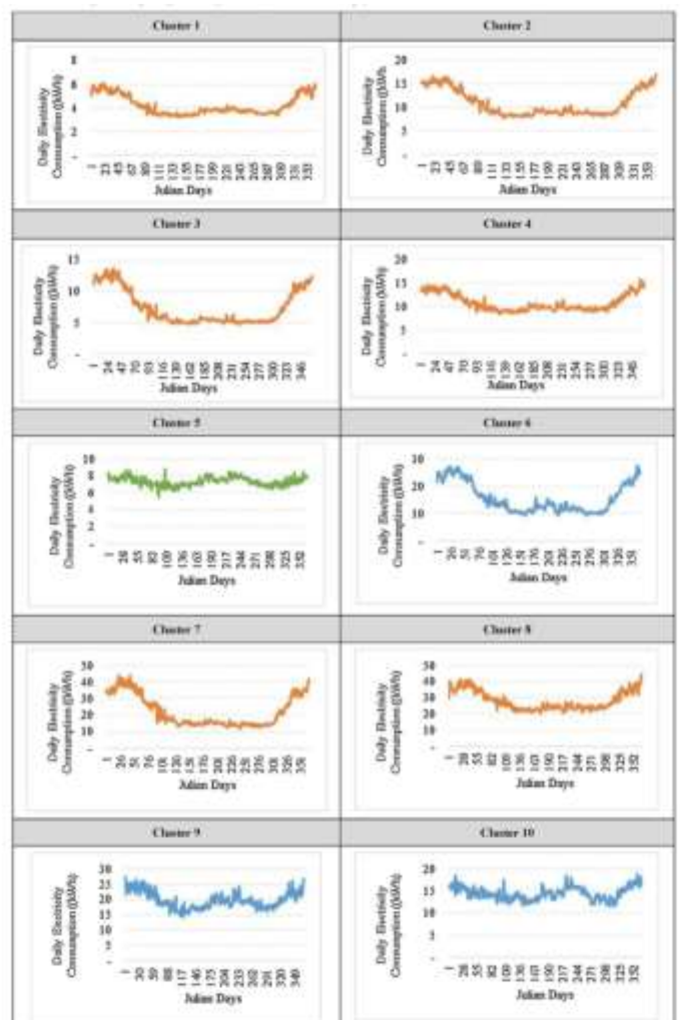


Fig. 30 - Box and whisker plot with consumers clusters distribution and number of meters per cluster.

Table 9 - Annual electricity consumption profiles by cluster (2011–2014 average).



Source: Gouveia, J.P. and Seixas, J. (2016). Energy and Buildings

Energy Demand – By Consumer type II

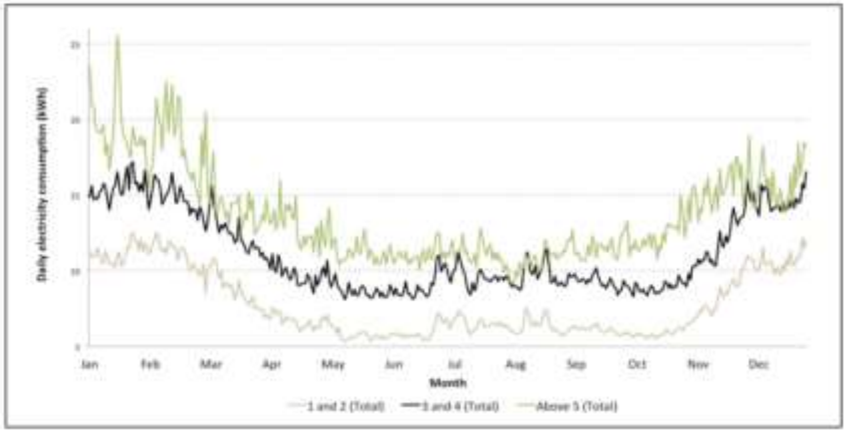


Fig. 31 - Daily average electricity consumption disclosed for the number of persons per household

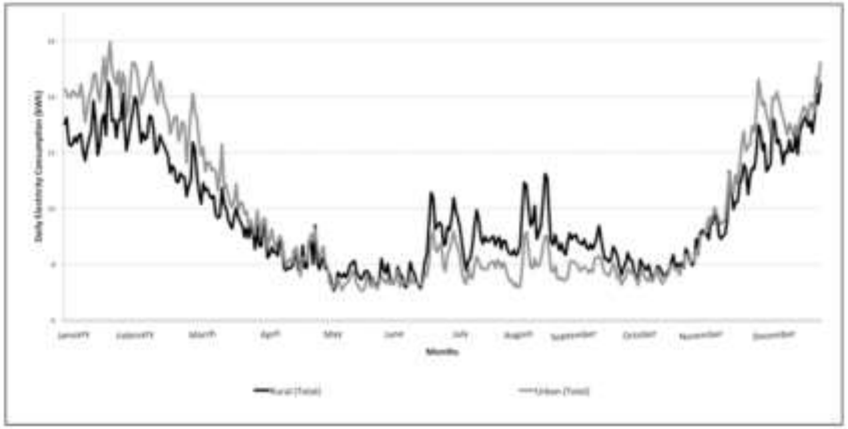


Fig.32 - Daily average electricity consumption for rural and urban houses

Source: Gouveia, J.P., Seixas, J., Mendes, L., Shiming, L. (2015). Looking Deeper into Residential Electricity Consumption Profiles: The Case of Évora. 12th International Conference on the European Energy Market, Lisbon, 19-22 May 2015, Portugal. doi: 10.1109/EEM.2015.7216723

Zooming in - Consumption Profiles

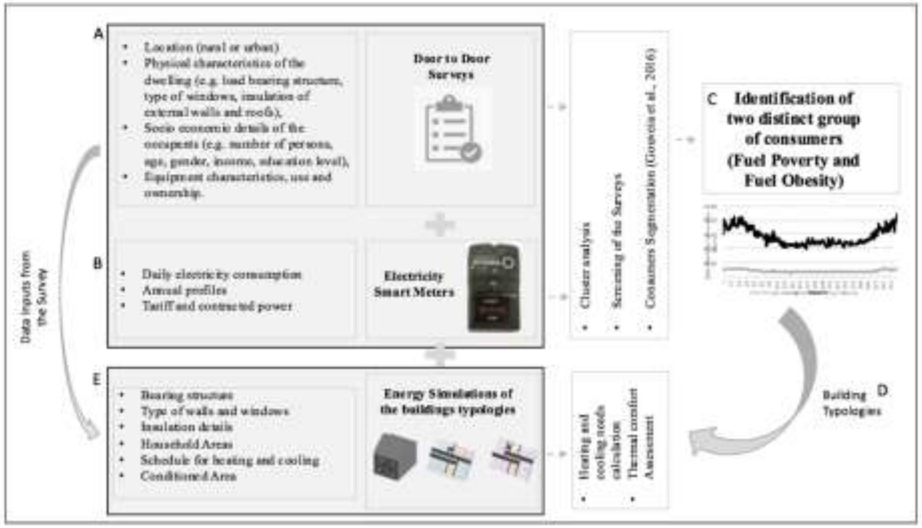


Fig. 33 - Overall methodology to identify contrasting consumers and to assess their thermal comfort gap

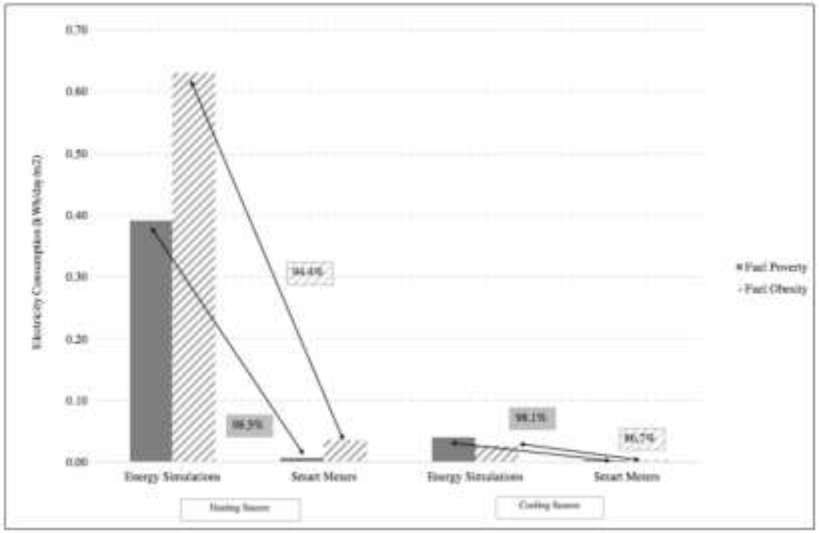


Fig. 34 - Heating and cooling thermal performance gaps for both consumer groups

Source: Gouveia, J.P., Seixas, J. Long, G. Mining Households's energy data to disclose fuel poverty: lessons for Southern Europe. *Journal of Cleaner Production. 178 (2018). 534-550.*

Zooming in - Consumer Behavior

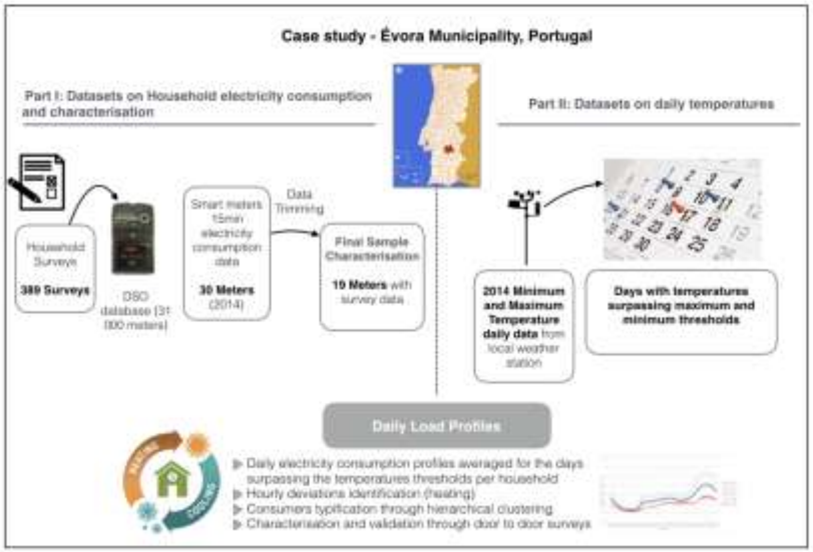


Fig. 35 - Overall methodology and data used

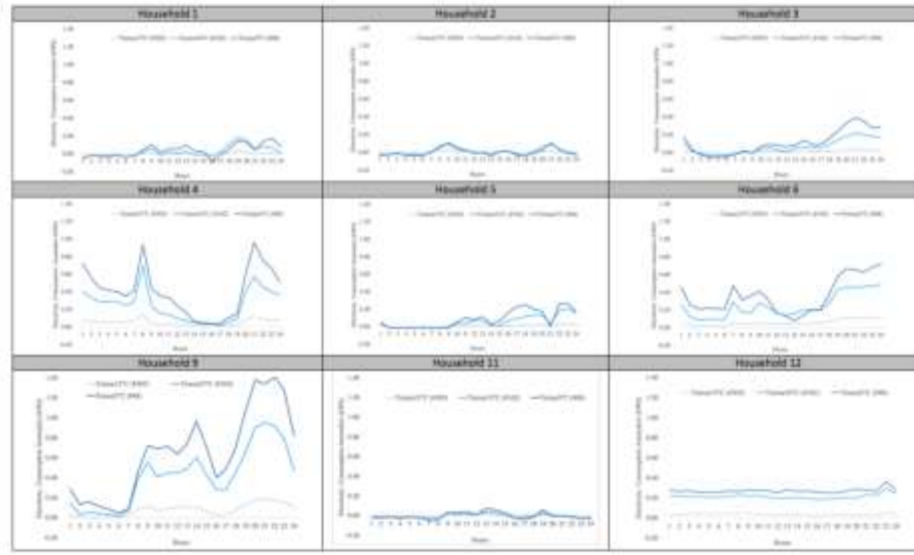


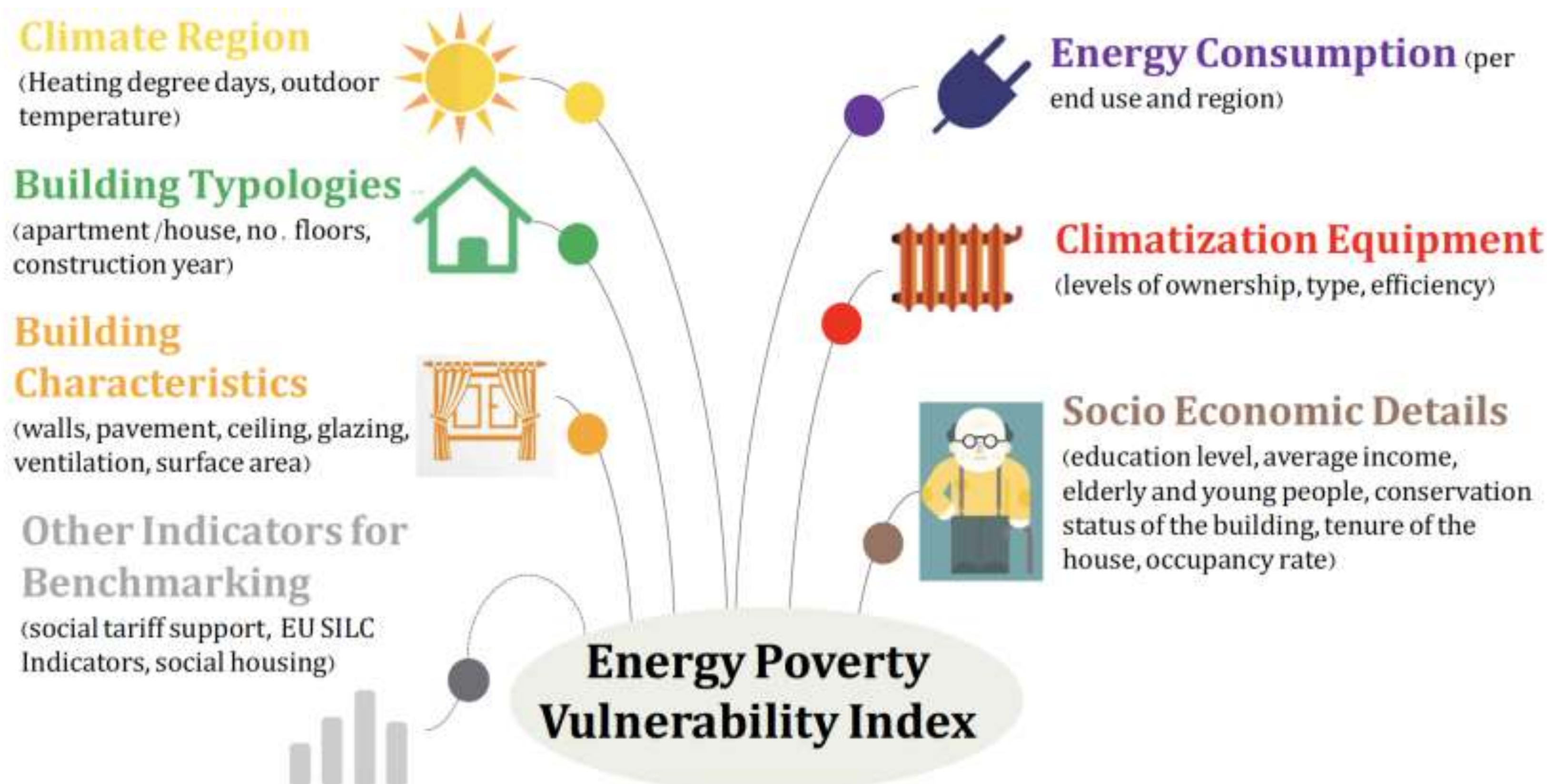
Fig. 36 - Heating season hourly consumption anomalies for the sampled household

Source: Gouveia, J.P., Seixas, J. Long, G. Mining Households's energy data to disclose fuel poverty: lessons for Southern Europe. *Journal of Cleaner Production. 178 (2018). 534-550.*

Energy Poverty Assessment

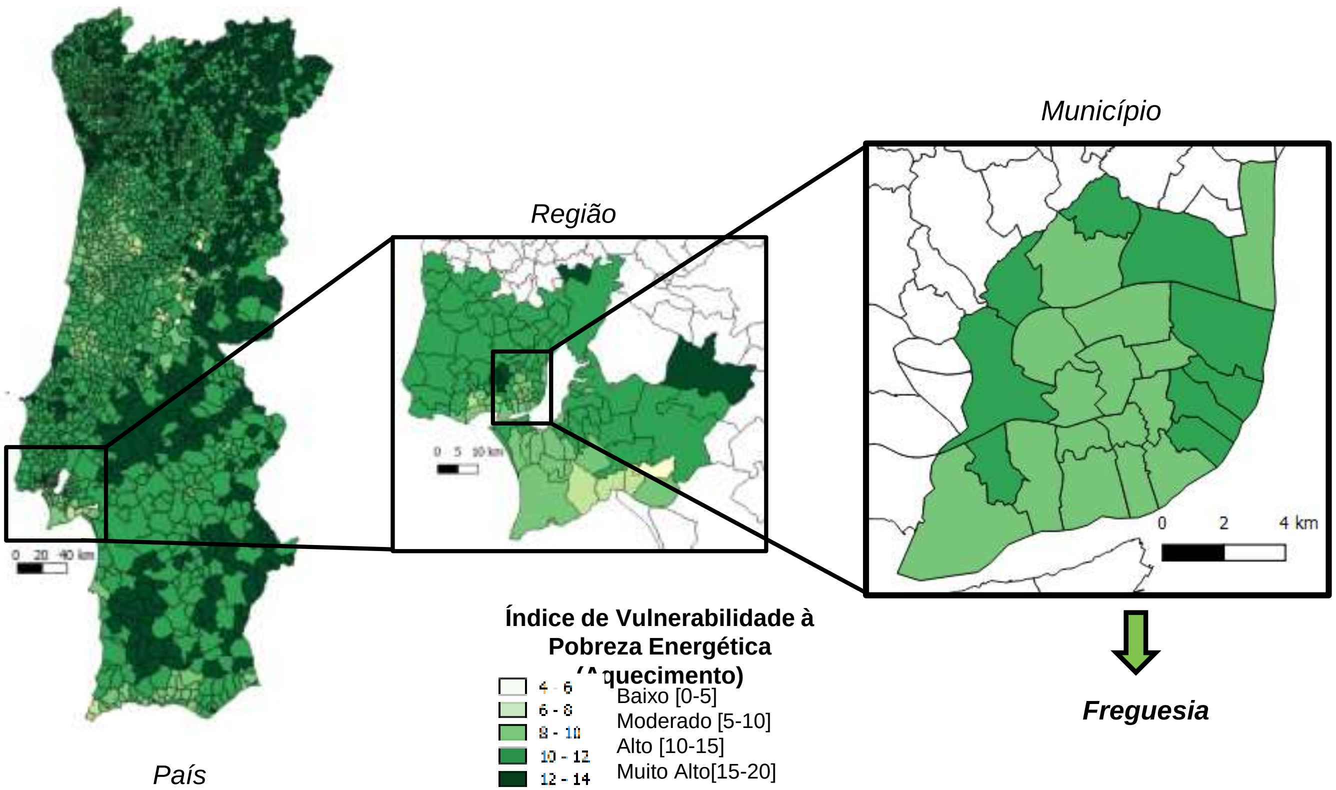
Develop a novel high resolution spatial scale composite index to calculate and map energy poor regions and identify hotspots for action, by combining socio-economic details of the population with building's characteristics and energy performance.

Methodology for classification and Assessment

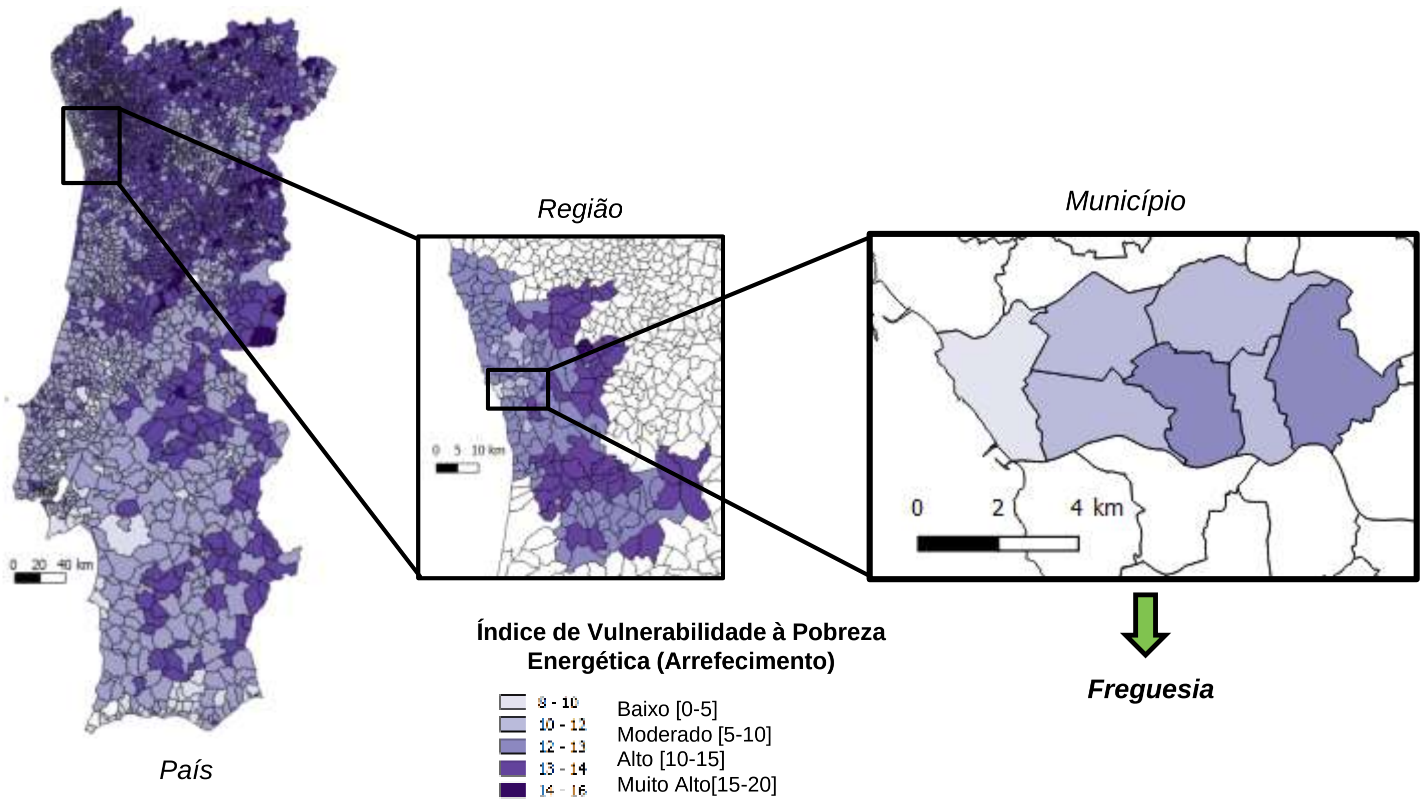


Gouveia, J.P., Palma, P., Simoes, S. (2019). Energy Poverty Vulnerability Index: A multidimensional tool to identify hotspots for local action. *Energy Reports. Volume 5, November 2019, Pages 187-201*

Energy Poverty – Winter Vulnerability



Energy Poverty – Summer Vulnerability



Services Sector

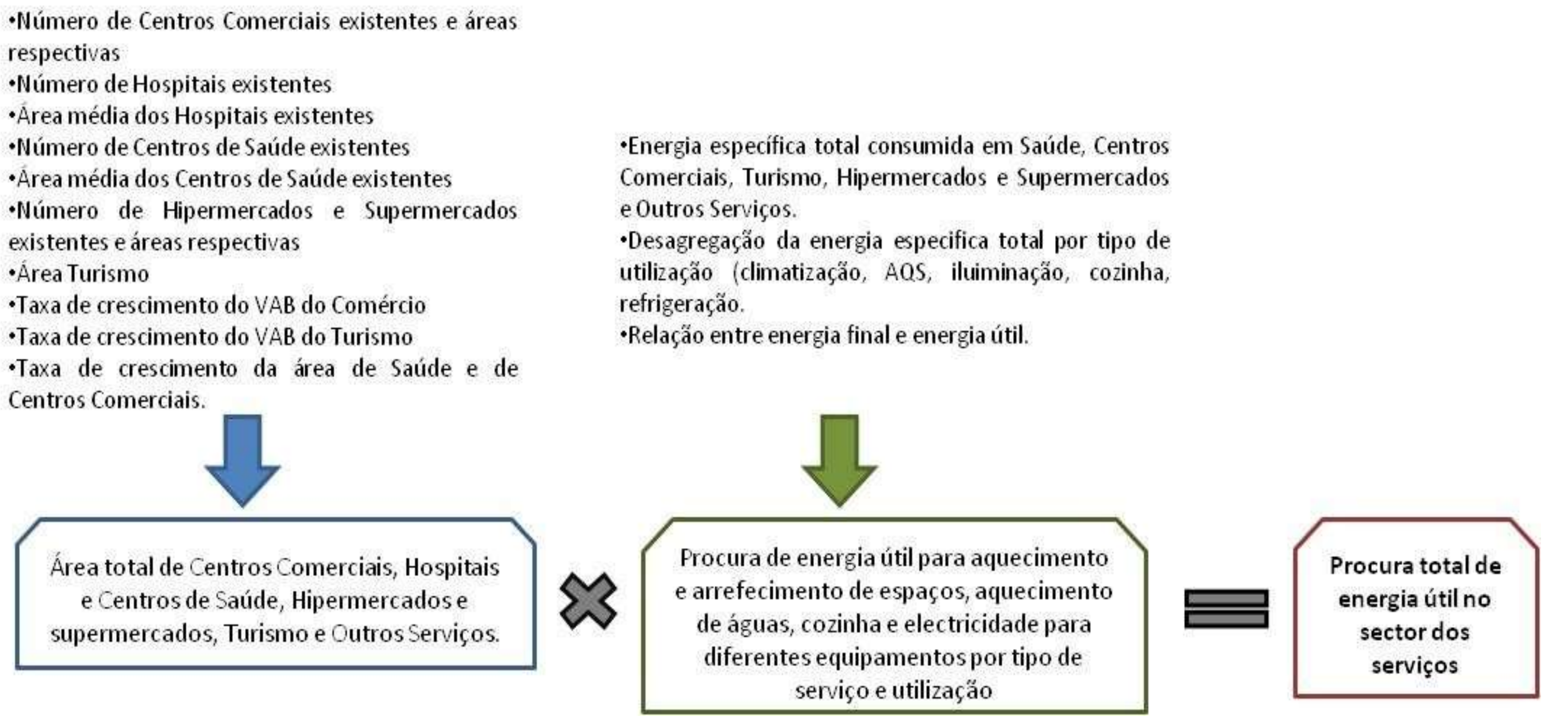


Fig. 37 – Demand generation methodology for the Services Sector

Source: Seixas, J., Gouveia, J., Fortes, P., Procura de Energia para o ano de 2030, CENSE, FCT–UNL, 2009. Partially funded by REN, SA.

Results I

Table 10 – Energy services demand results (PJ) for the different end uses for the commercial sector (Trend scenario)

	2005	2010	2015	2020	2025	2030	Δ(2030/2005)
Aquecimento de Espaços	31,94	33,17	35,46	38,13	40,93	43,90	37%
Arrefecimento de Espaços	10,50	11,78	12,98	13,93	14,94	16,01	52%
Aquecimento de Águas Sanitárias	11,66	11,87	12,56	13,50	14,49	15,53	33%
Cozinha	3,39	3,61	3,90	4,18	4,49	4,80	42%
Refrigeração	7,04	7,43	7,97	8,61	9,29	10,01	42%
Iluminação	68,56	75,00	82,19	88,20	94,54	101,25	48%
Outros Equipamentos Eléctricos	13,59	14,14	15,12	16,23	17,41	18,64	37%
Iluminação Pública	11,02	14,75	19,74	20,74	21,80	22,91	108%

Source: Seixas, J., Gouveia, J., Fortes, P., Procura de Energia para o ano de 2030, CENSE, FCT–UNL, 2009. Partly funded by REN, SA.

Results II

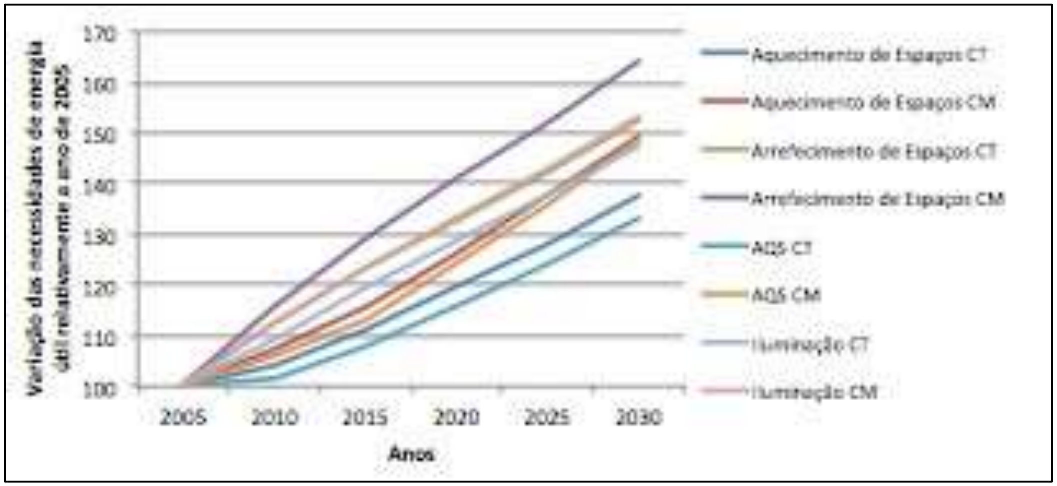


Fig. 38 – Variation of energy services demand for different end uses between 2005 and 2030

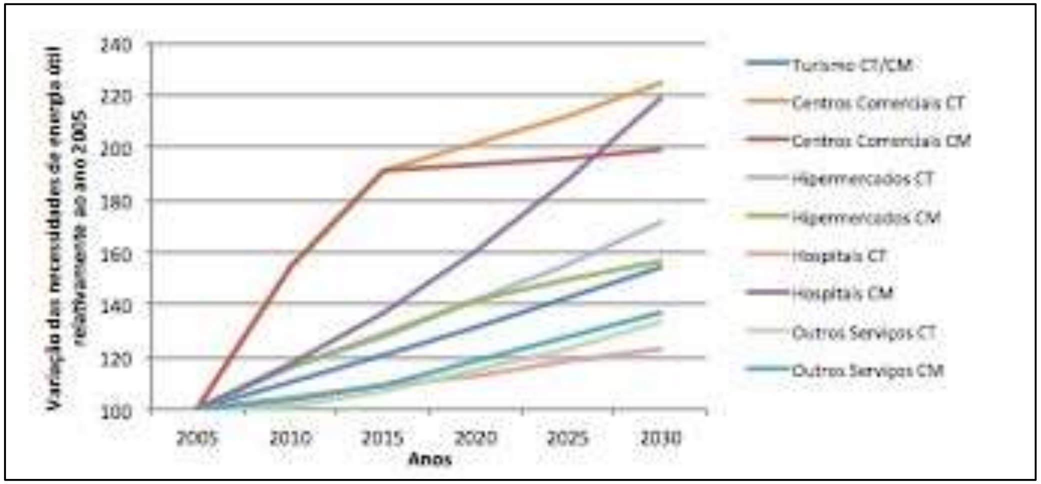


Fig. 39 – Variation of energy services demand for the different commercial subsectorsbbetween 2005 and 2030

Industry Sectors

$$DEM_{n,i} = DEM_{n-1,i} \times (1 + DRGR_n \times ELASI_i) \times (1 + PRGR_{n,i} \times ELASP) \times (1 - AEEI_i) \qquad (38)$$

Sendo **DEM_n** – Procura anual (t) de materiais ou energia por sector industrial (i), sendo 2005 o ano base;

$DRGR_n$ – Taxa de crescimento anual VAB sectorial

$ELASI_i$ – Elasticidade procura-rendimento por sector industrial (i);

ELASP – Elasticidade procura-preço;

$AEEI_i$ – Eficiência Autónoma da Indústria (i);

$PRGR_n$ – Taxa de crescimento anual do preço de energia total por sector industrial (i).

Fig. 40 – Demand generation methodology for the Industry Sectors

Sectors: Cement, Iron and Steel, Ceramics, glass, pulp and paper other industries.

Results

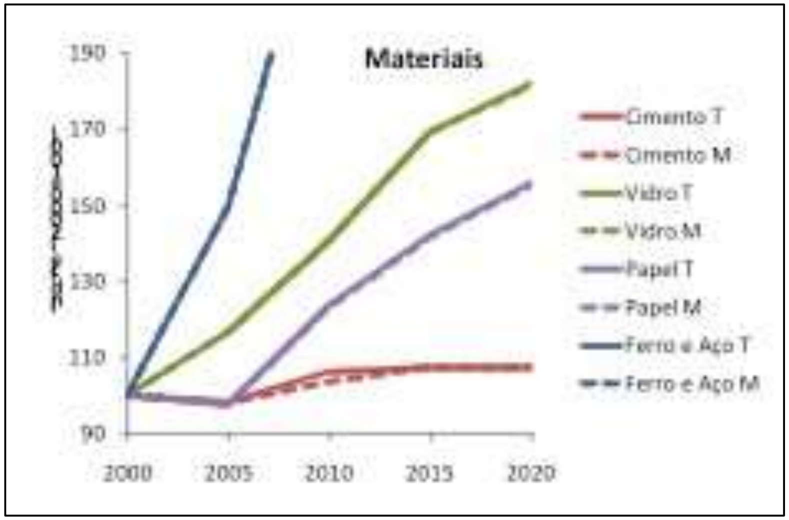


Fig. 41 – Variation of materials demand for different industry subsectors between 2005 and 2030

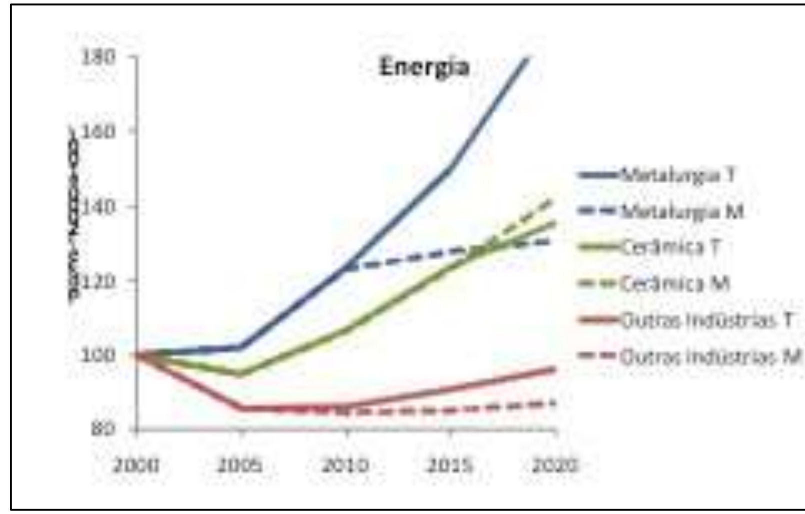


Fig. 42 – Variation of energy demand for different industry subsectors between 2005 and 2030

Transport Sector

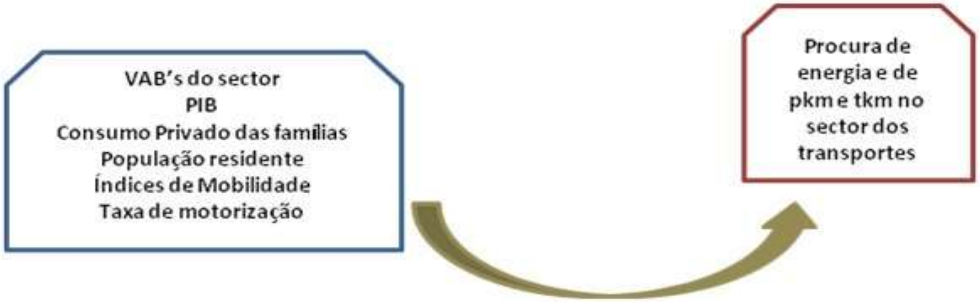
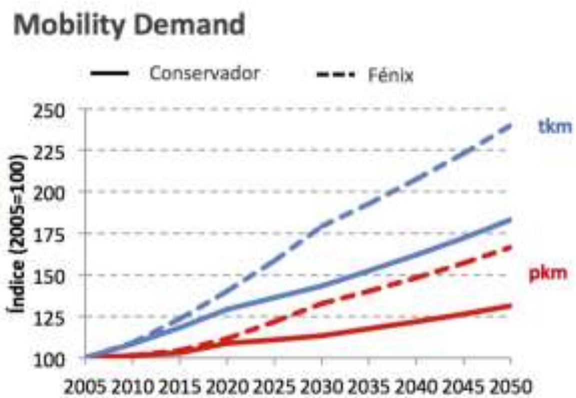
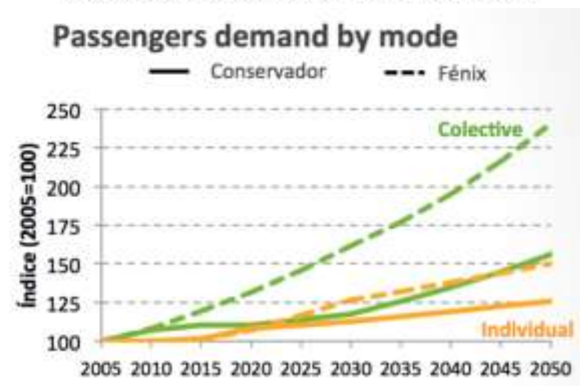


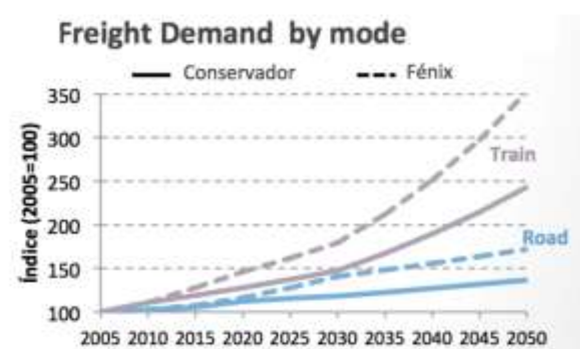
Fig. 43 – Demand generation methodology for the Transport Sector

Private cars and motorbikes; Freight and passengers road and railway.

Results







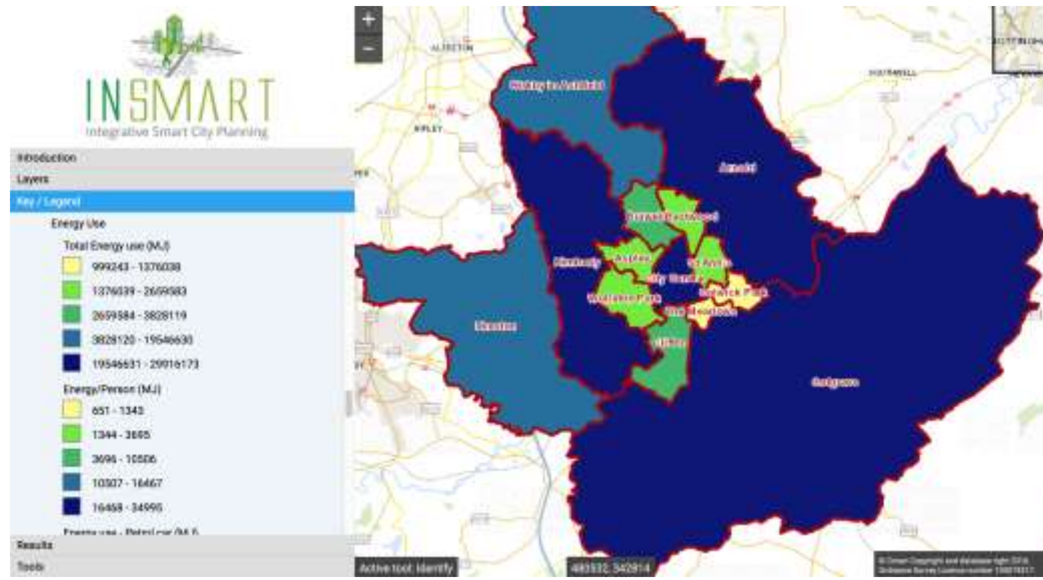


Fig. 44 – Mobility demand for Portugal (left) and energy demand for Nottingham by city district (top) (Source: EU INSMART project, www.insmartenergy.com)

Source: Roadmap Portugal 2050: análise das novas tecnologias energéticas nacionais e cenarização do seu impacto no sistema energético nacional. E.Value SA. Lisboa 2010.

DRAWDOWN

Drawdown is that point in time when the concentration of greenhouse gases in the atmosphere begins to decline on a year-to-year basis.

***Drawdown* maps, measures, models, and describes the 100 most substantive solutions to global warming.**

Eighty of the solutions in this book already exist and are scaling to become competitive alternatives to now dominant, high-emitting technologies.

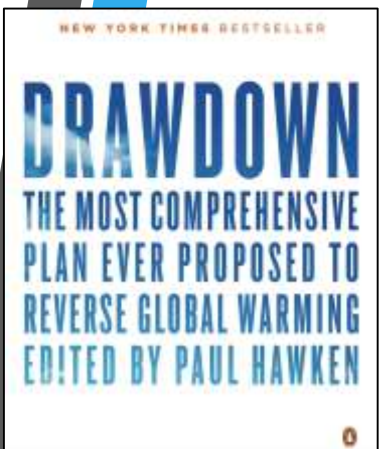
They are economically viable, proven to reduce greenhouse gas emissions or sequester carbon dioxide, and have the potential to spread throughout the world.

http://www.drawdown.org

"We call it a plan, but we also say we didn't make the plan. We found the plan". Paul Hawken

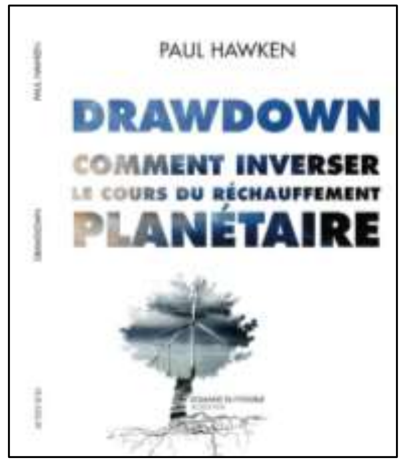
Poster (upper half) presenting Drawdown solutions all on one sheet – a 'periodic table' o

DRAWDOWN

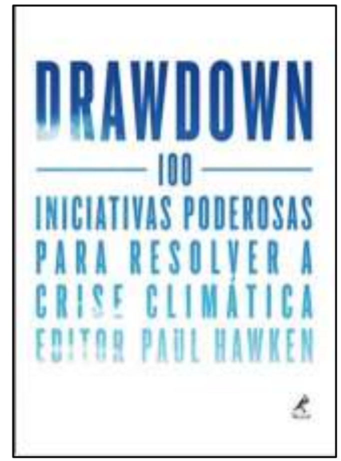


US Version

UK Version



FR Version



PT/BR Version

Dutch Version

https://www.drawdown.org/

ENERGY
ROOFTOP SOLAR

#15

RANKING AND RESULTS BY 2050

17.81 GIGATONS REDUCED CO2	$1.07 TRILLION NET COST	$4.82 TRILLION LIFETIME SAVINGS

The year was 1884, when the first solar array appeared on a rooftop in New York City. Experimentalist Charles Fritts installed it after discovering that a thin layer of selenium on a metal plate could produce a current of electricity when exposed to light. How light could turn on lights, he and his solar-pioneering contemporaries did not know, for the mechanics were not understood until the early twentieth century when, among other breakthroughs, Albert Einstein published his revolutionary work on what are now called photons. Though the scientific establishment of Fritts' day believed power generation depended on heat, Fritts was convinced that "photoelectric" modules would wind up competing with coal-fired power plants. The first such plant had been brought online by Thomas Edison just two years earlier, also in New York City.

Today, solar is replacing electricity generated from coal as well as from natural gas. It is replacing kerosene lamps and diesel generators in places where people lack access to the power grid, true for more than a billion people around the world. While society grapples with electricity's pollution in some places and its absence in others, the mysterious waves and particles of the sun's light continuously strike the surface of the planet with an energy more than ten thousand times the world's total use. Small-scale photovoltaic systems, typically sited on rooftops, are playing a significant role in harnessing that light, the most abundant resource on earth. When photons strike the thin wafers of silicon crystal within a vacuum-sealed solar panel, they knock electrons loose and produce an electrical circuit. These subatomic particles are the only moving parts in a solar panel, which requires no fuel.

While solar photovoltaics (PV) provide less than 2 percent of the world's electricity at present, PV has seen exponential growth over the past decade. In 2015 distributed systems of less than 100 kilowatts accounted for roughly 30 percent of solar PV capacity installed worldwide. In Germany, one of the world's solar leaders, the majority of photovoltaic capacity is on rooftops, which dot 1.5 million systems. In Bangladesh, population 157 million, more than 3.6 million home solar systems have been installed. Fully 15 percent of Australian homes have them. Transforming a square meter of rooftop into a miniature power station is proving irresistible.

An Uros mother and her two daughters live on one of the 42 floating islands made of totora reeds on Lake Titicaca. Their delight upon receiving their first solar panel is infectious. Installed at an elevation of 12,507 feet, the panel will replace kerosene and provide electricity to her family for the first time. As high tech as solar may be, it is a perfect cultural match. The Uru People know themselves as Lupihaques, Sons of the Sun.

Roof modules are spreading around the world because of their affordability. Solar PV has benefited from a virtuous cycle of falling costs, driven by incentives to accelerate its development and implementation, economies of scale in manufacturing, advances in panel technology, and innovative approaches for end-user financing—such as the third-party ownership arrangements that have helped mainstream solar in the United States. As demand has grown and production has risen to meet it, prices have dropped; as prices have dropped, demand has grown further. A PV manufacturing boom in China has helped unleash a torrent of inexpensive panels around the world. But hard costs are only one side of the expense equation. The soft costs of financing, acquisition, permitting, and installation can be half the cost of a rooftop system and have not seen the same dip as panels themselves. That is part of the reason rooftop solar is more expensive than its utility-scale kin. Nonetheless, small-scale PV already generates electricity more cheaply than it can be brought from the grid in some parts of the United States, in many small island states, and in countries including Australia, Denmark, Germany, Italy, and Spain.

The advantages of rooftop solar extend far beyond price. While the production of PV panels, like any manufacturing process, involves emissions, they generate electricity without emitting greenhouse gases or air pollution—with the infinite resource of sunlight as their sole input. When placed on a grid-connected roof, they produce energy at the site of consumption, avoiding the inevitable losses of grid transmission. They can help utilities meet broader demand by feeding unused electricity into the grid, especially in summer, when solar is humming and electricity needs run high. This "net metering" arrangement, selling excess electricity back to the grid, can make solar panels financially feasible for homeowners, offsetting the electricity they buy at night or when the sun is not shining.

Numerous studies show that the financial benefit of rooftop PV runs both ways. By having it as part of an energy-generation portfolio, utilities can avoid the capital costs of additional coal or gas plants, for which their customers would otherwise have to pay, and broader society is spared the environmental and public health impacts. Added PV supply at times of highest electricity demand can also curb the use of expensive and polluting peak generation. Some utilities reject this proposition and posit contradictory claims of rooftop PV being a "free rider," as they aim to block the rise of distributed solar and its impact on their revenue and profitability. Others accept its inevitability and are trying to shift their business models accordingly. For all involved, the need for a grid "commons" continues, so utilities, regulators, and stakeholders of all stripes are evolving approaches to cover that cost.

The first solar array installed by Charles Fritts in 1884 in New York City. Fritts built the first solar panels in 1881, reporting that the current was "continuous, constant and of considerable force not only by exposure to

Off the grid, rooftop panels can bring electricity to rural parts of low-income countries. Just as mobile phones leapfrogged installation of landlines and made communication more democratic, solar systems eliminate the need for large-scale, centralized power grids. High-income countries dominated investment in distributed solar until 2014, but now countries such as Chile, China, India, and South Africa have joined in. It means rooftop PV is accelerating access to affordable, clean electricity and thereby becoming a powerful tool for eliminating poverty. It is also creating jobs and energizing local economies. In Bangladesh alone, those 3.6 million home solar systems have generated 115,000 direct jobs and fifty thousand more downstream.

Since the late nineteenth century, human beings in many places have relied on centralized plants that burn fossil fuels and send electricity out to a system of cables, towers, and poles. As households adopt rooftop solar (increasingly accompanied and enabled by distributed energy storage), they transform generation and its ownership, shifting away from utility monopolies and making power production their own. As electric vehicles also spread, "gassing up" can be done at home, supplanting oil companies. With producer and user as one, energy gets democratized. Charles Fritts had this vision in the 1880s, as he looked out over the rooftops of New York City. Today, that vision is increasingly coming to fruition. ◆

IMPACT: *Our analysis assumes rooftop solar PV will grow from .4 percent of electricity generation globally to 7 percent by 2050. That growth can avoid 16.4 gigatons of emissions. Implementation costs continue to decrease. Operating costs, will save $2.87 trillion in home energy costs over thirty years.*

DRAWDOWN

Electricity Generation

Wind Offshore

Food

Silvopasture

Women and Girls

Educating Girls

Materials

Alternative Cements

Land Use

Afforestation

Buildings and Cities

Bike Infrastructure

Transport

Electric Vehicles

Coming Attractions

Autonomous Vehicles

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Each solution is modeled based on a comparison between a reference case, assuming little change over the next thirty years, and three scenarios reflecting increasingly more accelerated global adoption.

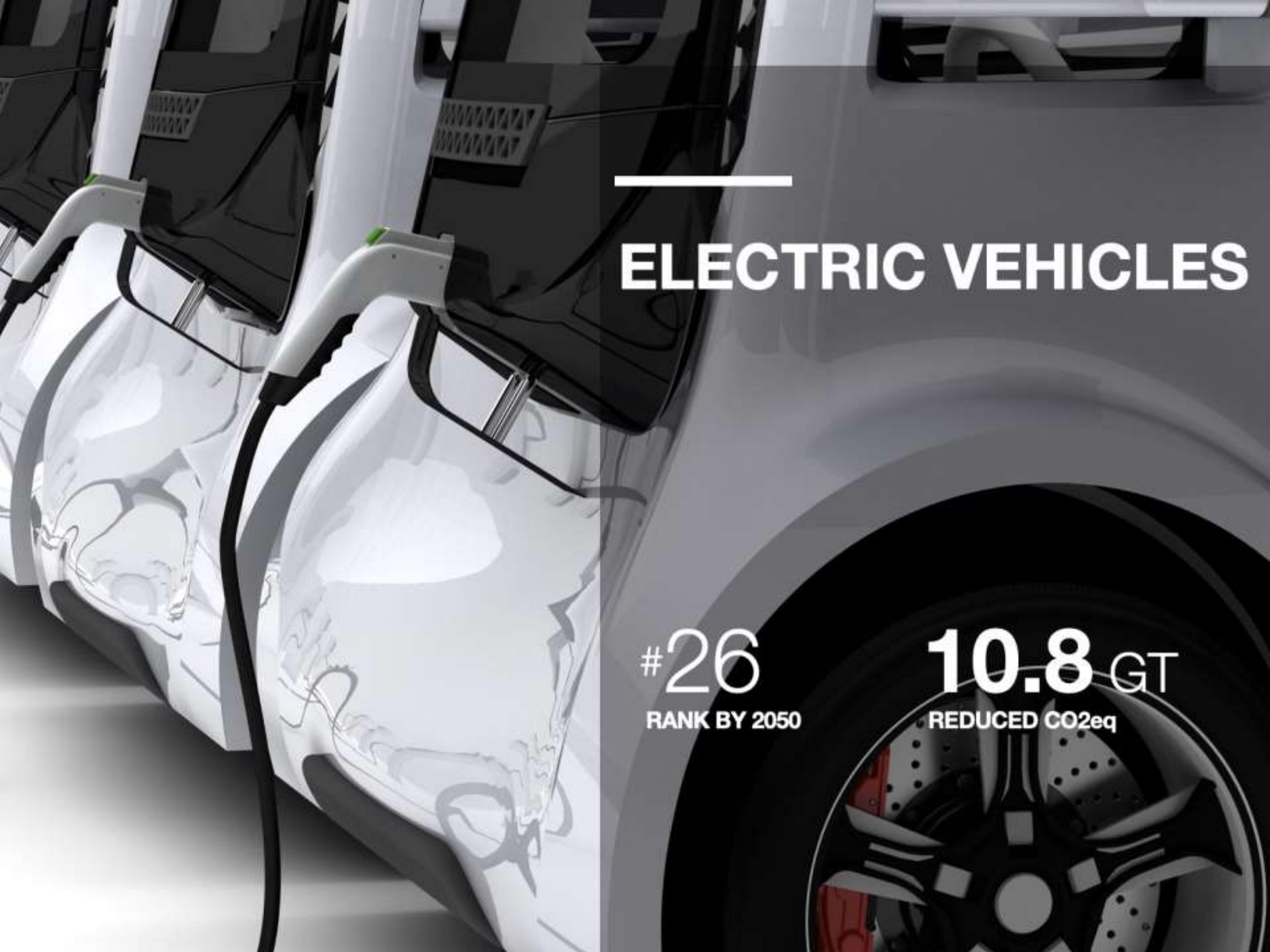
- **Plausible Scenario:** *the case in which solutions on the Drawdown list are adopted at a realistically vigorous rate over the time period under investigation, adjusting for estimated economic and population growth.*
- **Drawdown Scenario:** *the case in which the adoption of solutions is optimized to achieve drawdown by 2050.*
- **Optimum Scenario:** *the case in which solutions achieve their maximum potential, fully replacing conventional technologies and practices within a limited, competitive market.*

The data derived from models was then inputted into sector-level integration models to generate final results for all solutions within an in global system.


REDUCED
FOOD WASTE
#3
RANK BY 2050
70.53 GT
REDUCED CO2eq


WIND TURBINES (OFFSHORE)
#22
RANK BY 2050
14.1 GT
REDUCED CO2eq

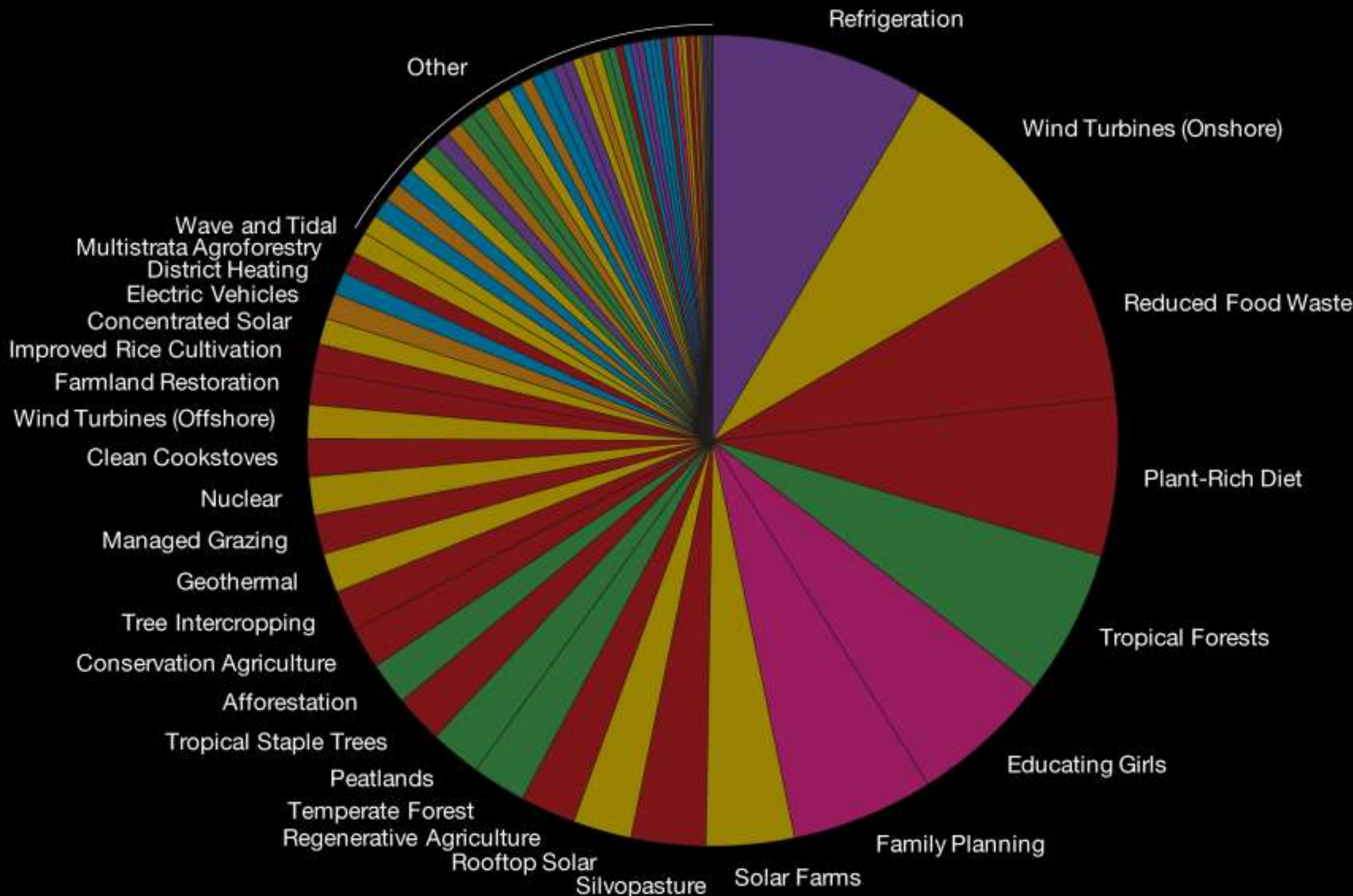

FOREST PROTECTION
#38
RANK BY 2050
6.2 GT
REDUCED CO2eq


ELECTRIC VEHICLES
#26
RANK BY 2050
10.8 GT
REDUCED CO2eq

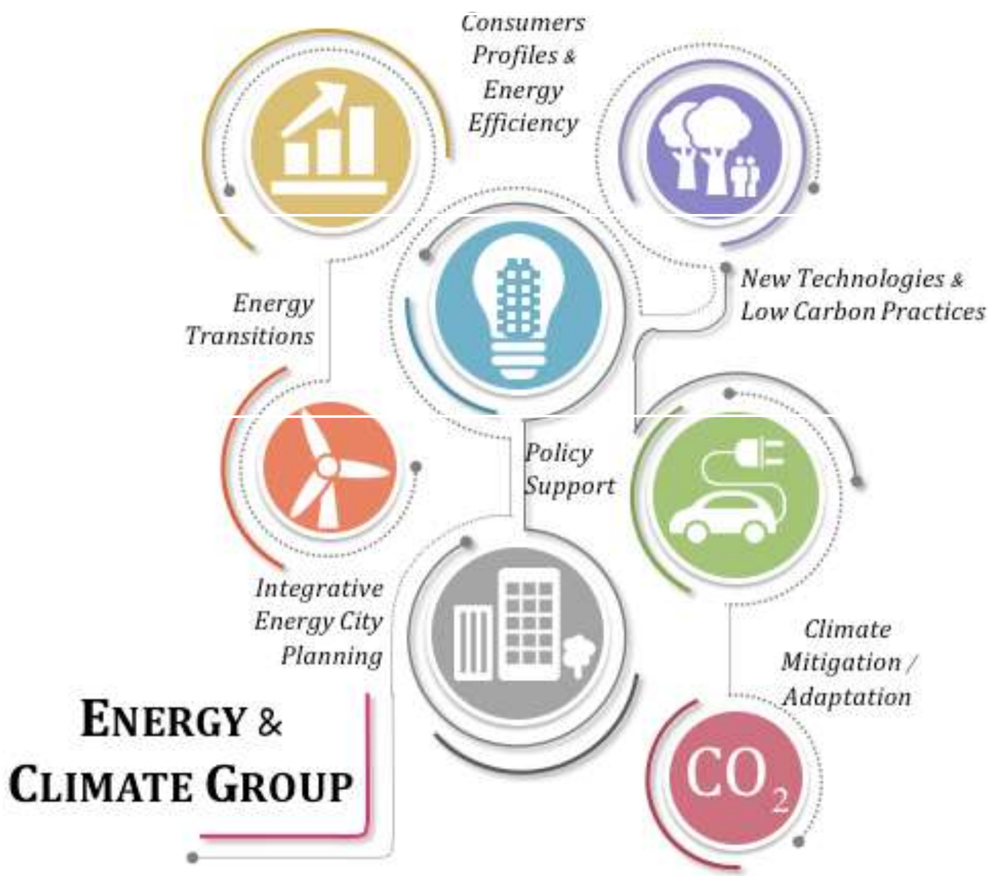
DRAWDOWN

Solution	RANKING	Plausible Scenario GIGATONS REDUCED	RANKING	Drawdown Scenario GIGATONS REDUCED	RANKING	Optimum Scenario GIGATONS REDUCED
Refrigerant Management	1	89.74	2	96.49	3	96.49
Wind Turbines (Onshore)	2	84.60	1	146.50	1	139.31
Reduced Food Waste	3	70.53	4	83.03	4	92.89
Plant-Rich Diet	4	66.11	5	78.65	5	87.86
Tropical Forests	5	61.23	3	89.00	2	105.60
Educating Girls	6	59.60	7	59.60	8	59.60
Family Planning	7	59.60	8	59.60	9	59.60
Solar Farms	8	39.90	6	64.60	7	60.48
Silvopasture	9	31.19	9	47.50	6	63.81
Rooftop Solar	10	24.60	10	43.10	13	40.34
Regenerative Agriculture	11	23.15	14	32.23	15	32.08
Temperate Forests	12	22.61	12	34.70	11	42.62
Peatlands	13	21.57	13	33.51	14	36.59
Tropical Staple Trees	14	20.19	15	31.50	10	46.70
Afforestation	15	18.06	11	41.61	12	41.61
Total (all 80 solutions)		**1053.05**		**1442.27**		**1612.89**

Drawdown



Refrigeration
Wind Turbines (Onshore)
Reduced Food Waste
Plant-Rich Diet
Tropical Forests
Educating Girls
Family Planning
Solar Farms
Silvopasture
Rooftop Solar
Regenerative Agriculture
Temperate Forest
Peatlands
Tropical Staple Trees
Afforestation
Conservation Agriculture
Tree Intercropping
Geothermal
Managed Grazing
Nuclear
Clean Cookstoves
Wind Turbines (Offshore)
Farmland Restoration
Improved Rice Cultivation
Concentrated Solar
Electric Vehicles
District Heating
Multistrata Agroforestry
Wave and Tidal
Other



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