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DEMAND RESPONSE: A BUZZWORD OR A SUSTAINABILITY DRIVER?

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ENERGIA PARA A SUSTENTABILIDADE ENERGY FOR SUSTAINABILITY

INESC Coimbra

Rio Maior MAIOR FUTURO

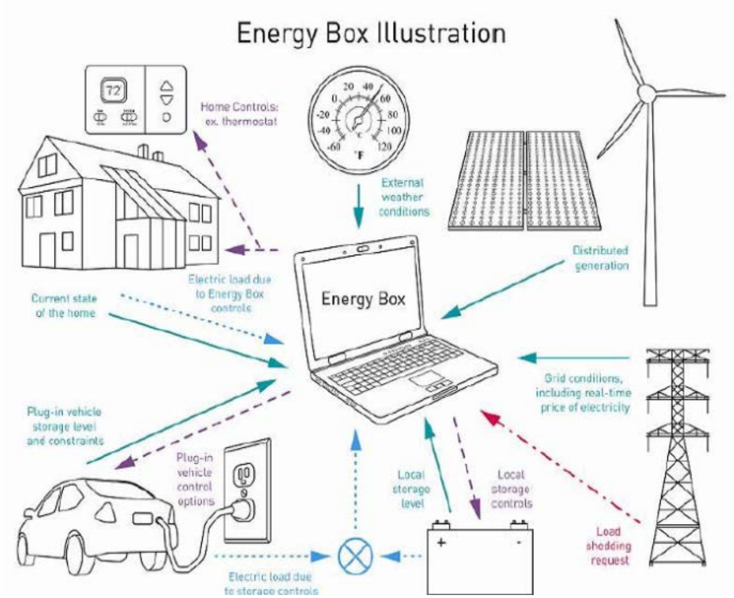
Abstract

- Demand response (DR) has been referred to as a valuable option in a smart grid environment towards efficient use of resources;
- Demand response requires automated reaction capabilities on the consumer side, by means of smart meters, to price variations and/or to DSO requests.
- **The present work aims at contributing to help the DSO, public authorities and society at large, to assess whether demand response based on price elasticity can reduce the environmental impact of electricity consumption, adding environmental value to the smart grid.**

Introduction (I)

- It will be used a residential demand response device based on the Energy Box (EB) concept proposed by (Livengood & Larson, 2009) and the DR methodology and results from (Miguel, et al., 2014).
- A methodology proposal for assessing the environmental impact is presented, considering EB deployments covering 20 to 100% of households in a city, considering the current energy matrix framework for electricity generation in Portugal.

Livengood, D. & Larson, R., 2009. The Energy Box: Locally Automated Optimal Control of Residential Electricity Usage. *Service Science 1*, Volume 1, pp. 1-16.



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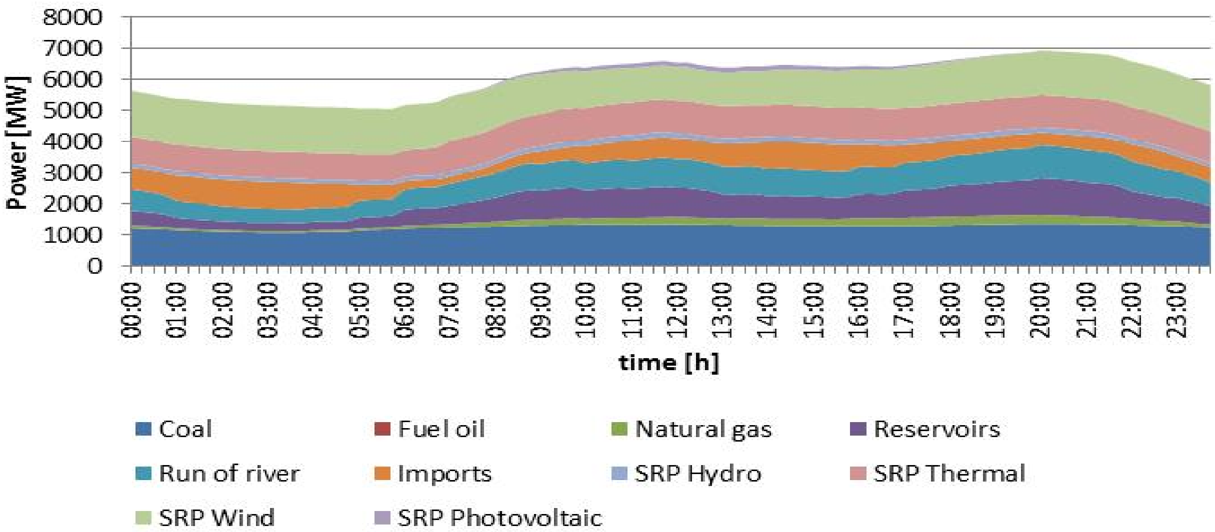
Generation of electricity/ The Portuguese energy matrix



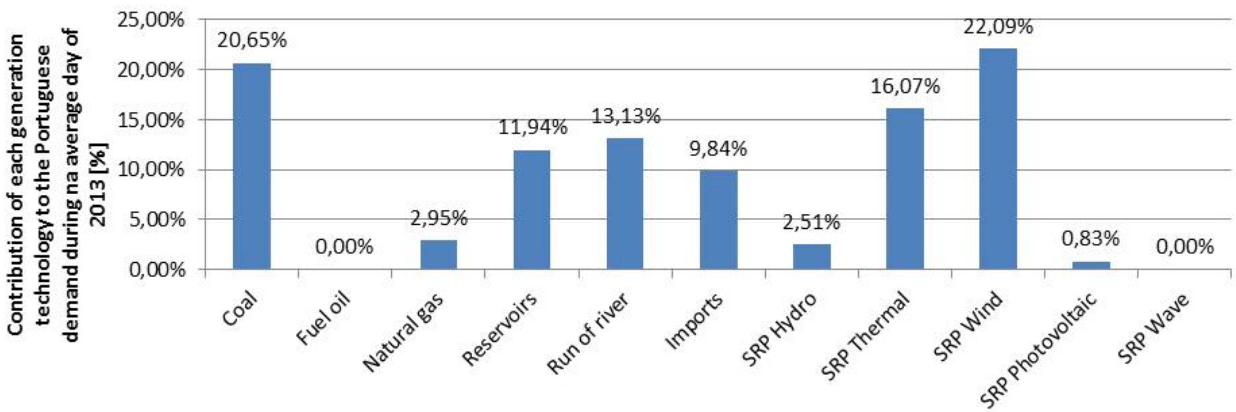


Figure 1 and Figure 2 - Evolution of the contribution of each generation technology to the Portuguese demand during an average day of 2013, in value and percentage, Source REN.

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Generation of electricity/ Environmental impact and European commitments

- In 23 October 2014, EU leaders agreed to a greenhouse gas reduction target of at least 40% compared to 1990.

- This target is inserted in the 2030 framework for climate and energy policies (European Council, 2014) that also sets a target of increasing the share of renewable energy to at least 27% of the EU's energy consumption by 2030, also increasing energy savings in 27% during the same period.

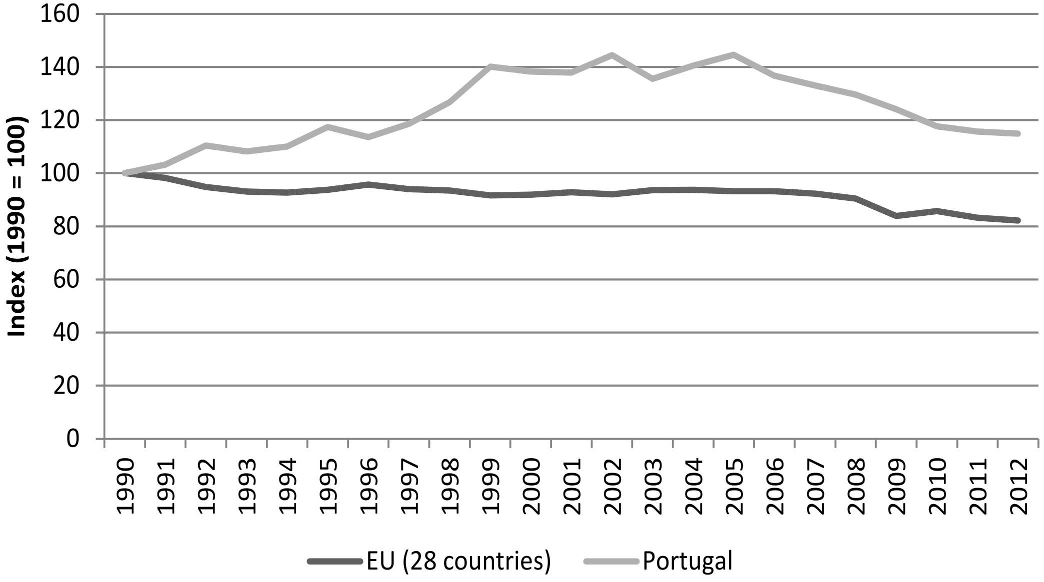

Figure 3 - Greenhouse gas emissions, base year 1990 (Eurostat, 2014).

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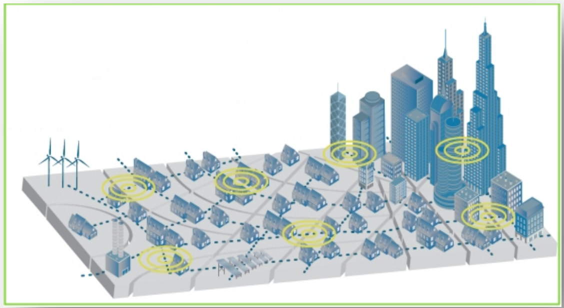
Household energy usage in the city of Coimbra



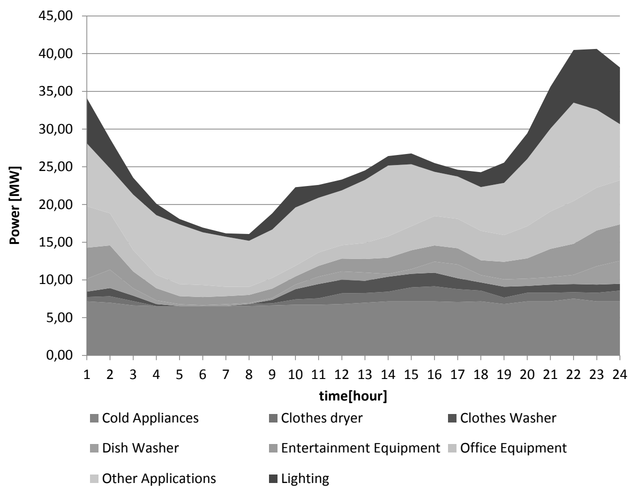


Table 1 - Type of load by possibility of control (Ribeiro, 2012).

Type of loads [%]							
Type I			Type II		Type III		
Clothes Washer	Dish Washer	Clothes dryer	Lighting	Cold Appliances	Office	Entertainment	Other
3.94	4.05	3.48	10.68	26.65	12.21	9.01	29.98
		11.46		37.33			51.21

Table 2 - Electrical energy consumption in the City of Coimbra in the year 2010 (PORDATA, 2013)

City	Average Electrical Consumption per household [kWh/year]	# Electricity Consumers	Total domestic consumption (kWh)
Coimbra	2,966.10	76,642	227,327,836.20

Estimation of the distribution of electrical energy for the average day for the city of Coimbra with loads represented by decreasing regularity of the standard deviation (Miguel, et al., 2013).

Demand Response at a city scale (I)

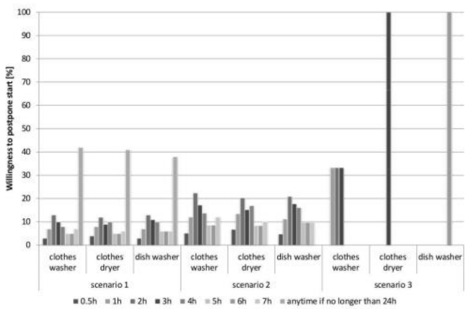


Figure 4 - Willingness to postpone start [%] for the considered appliances, scenario 1 based on (Mert, 2008) (SMART-A), scenario 2 adapted from (Mert, 2008) without the possibility to postpone start 24h, scenario 3 adapted from (Jamasb & Pollitt, 2011).

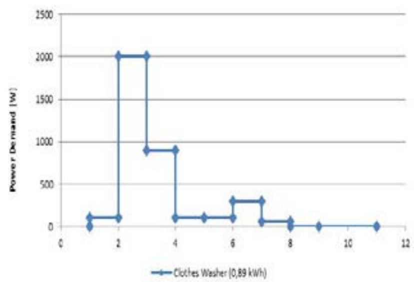


Figure 30 - General Pattern of a Power Demand Curve of a washing machine cycle in 1/4 hour steps (Stamminger, 2008) (SMART-A).

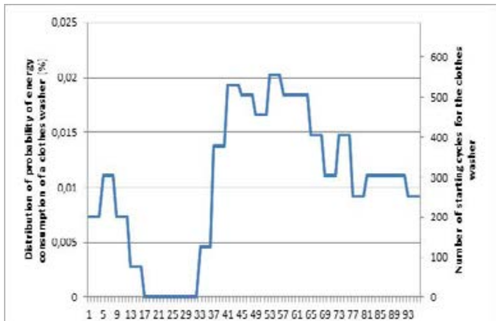


Figure 31 - Probability of energy consumption and number of cycles for the average day of a clothes washer in the City of Coimbra.

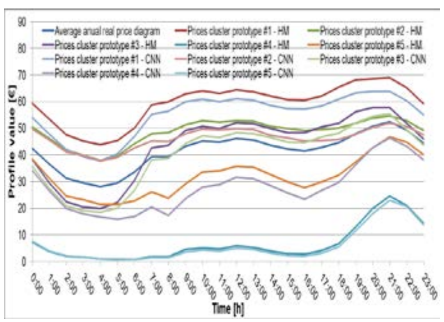
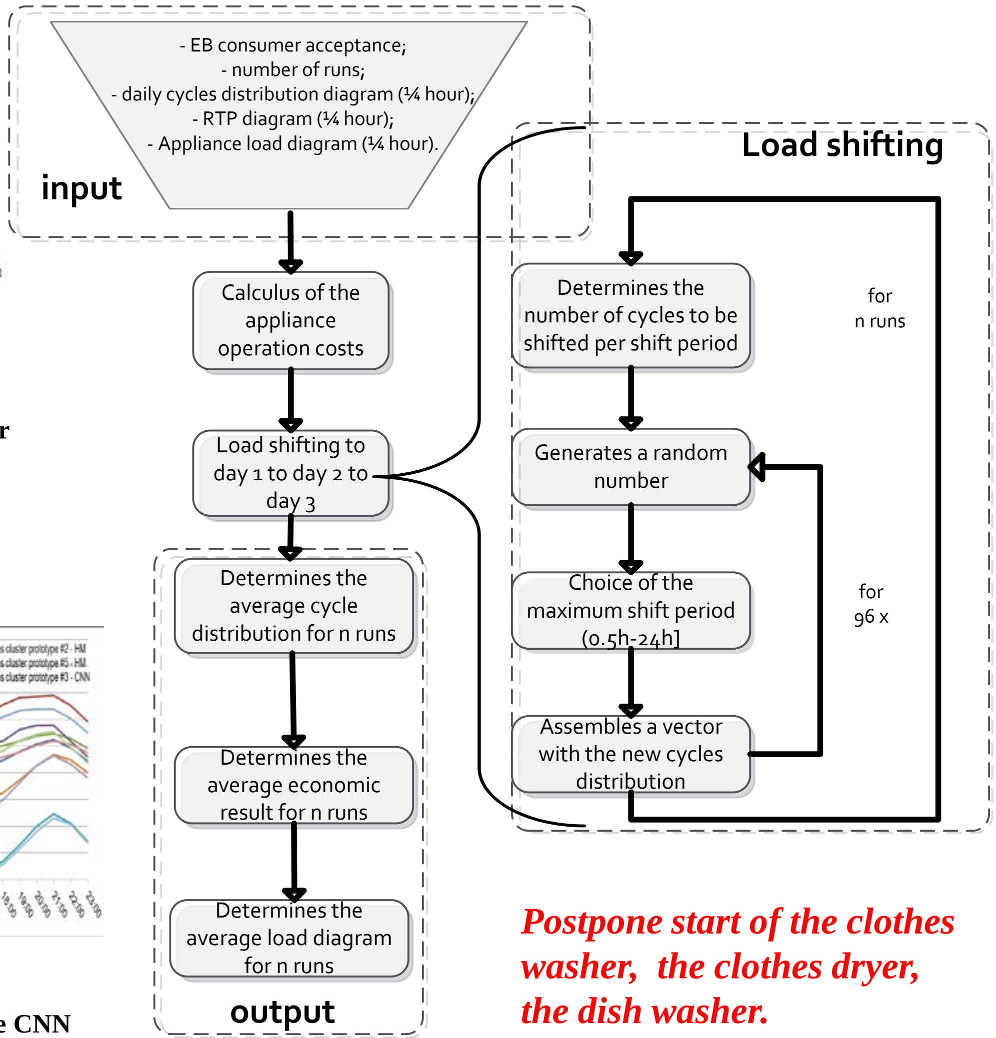


Figure 49 – Clustering price prototypes for the HM and the CNN method, for the 2012 year.



Postpone start of the clothes washer, the clothes dryer, the dish washer.

Figure 5 - Structure of the simulation routine for demand response (Miguel, et al., 2014).

Demand Response at a city scale (II)

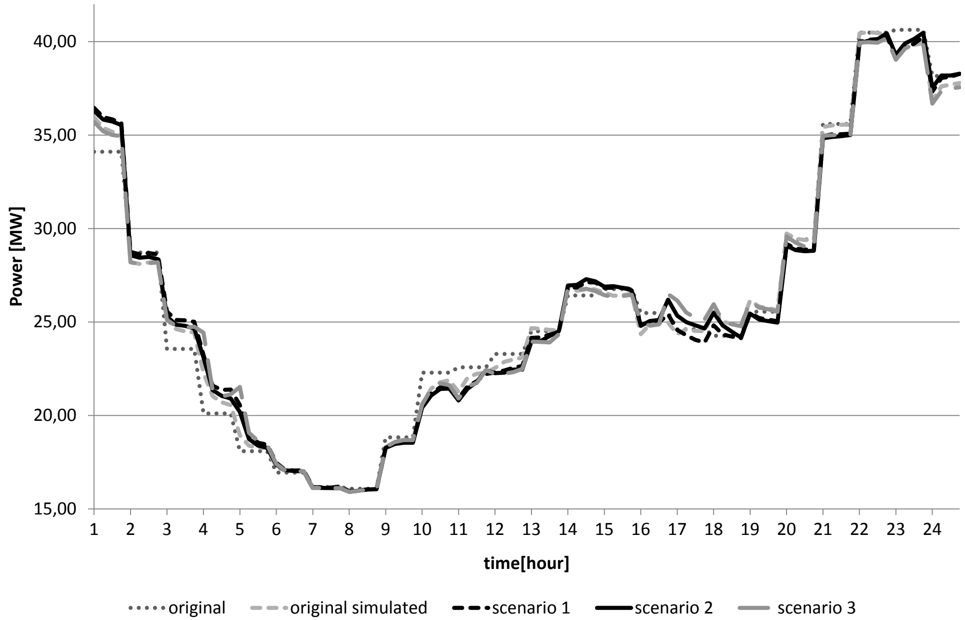


Figure 6 -Example of a 20% deployment simulation of the Energy Box in the city of Coimbra, with three scenarios with distinct consumer tolerances (Miguel, et al., 2014).

Figure 7 – Range of the power delivery and rebound for a 20% deployment of the Energy Box in the city of Coimbra (Miguel, et al., 2014).

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Assessing the environmental impact of demand response (I)

DR Environmental Impact

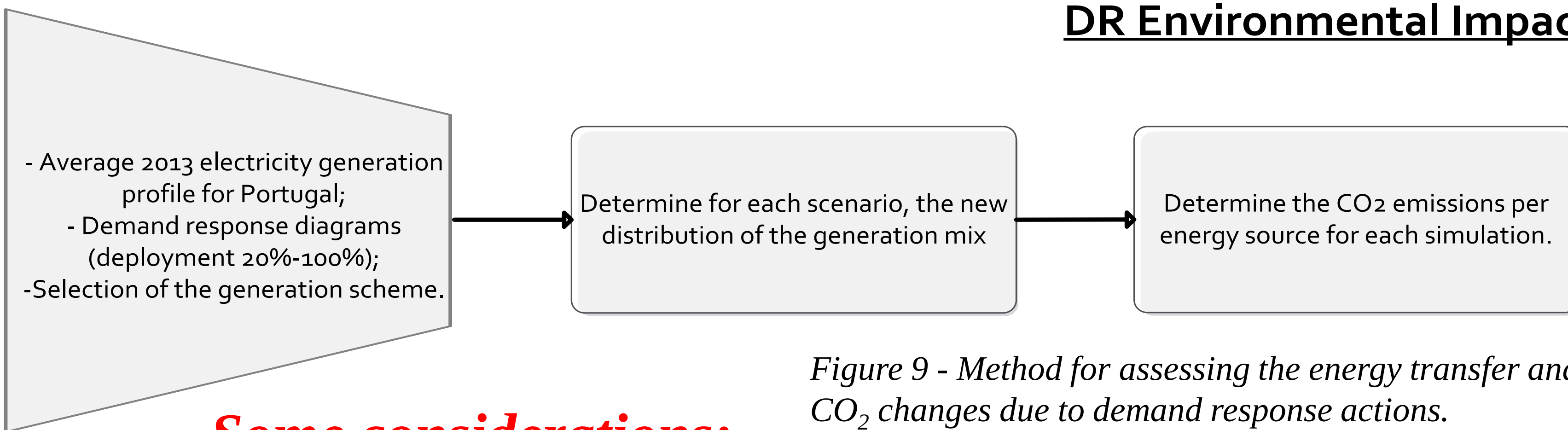

Figure 9 - Method for assessing the energy transfer and CO_2 changes due to demand response actions.

Some considerations:

- The output of renewable energy sources (Hydro – Run of River, SRP-Hydro, SRP-Wind and SRP-Solar), plus Imported electricity and SRP-Thermal is conserved equal to the average day simulation;

- The generation technologies and fuels that were affected by demand response actions were the following (3 Cases): Hydro-dam, Combined cycle gas turbine (CCGT), and Combined coal based steam turbine and CCGT.

Assessing the environmental impact of demand response (II)

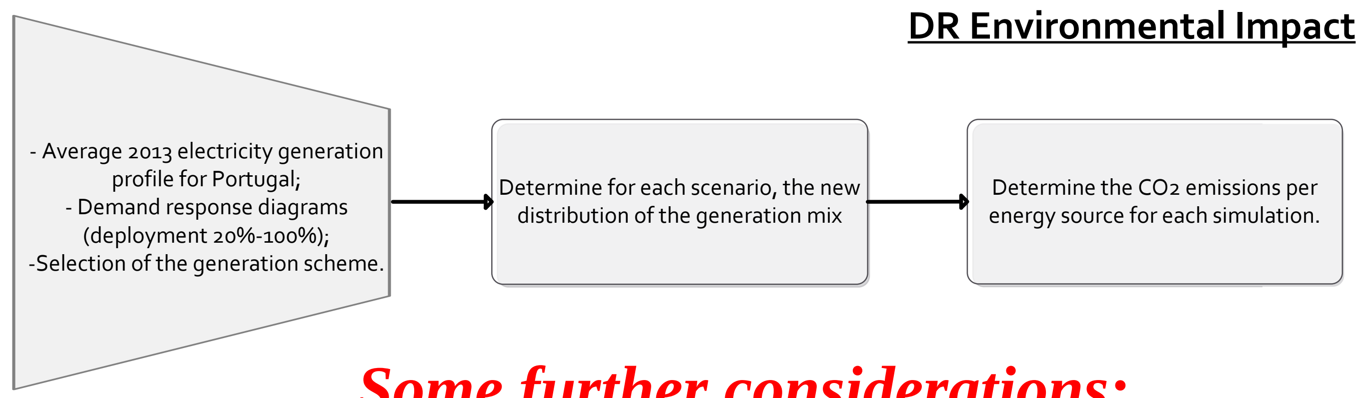

Figure 9 - Method for assessing the energy transfer and CO_2 changes due to demand response actions.

Some further considerations:

- The variations reflect changes in the composition of the generation mix resulting from demand response;
- Emissions can be calculated applying appropriate conversion factors to the energy outputs of the generation technologies at stake;
- The combination between simulations (12) and scenarios (3) with five deployment rates, from 20% to 100%, accounted for a total of 180 simulations.

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Calculating the reference of the environmental impact of Demand Response

Table 4 – Estimation of the contribution of each electricity generation technology for the average day of the city of Coimbra in the original simulated scenario (without DR) in [GJ/day].

	Energy [GJ/day]									
	Coal	Natural Gas	Hydro - Dam	Hydro - Run of River	Import	SRP - Hydro	SRP - Thermal	SRP - Wind	SRP - Solar	Total
Original simulated	461.35	65.12	266.26	294.72	223.58	55.76	358.74	499.55	16.38	2,241.45

Table 5 - CO_2 emissions for the original simulated scenario.

	Emissions [tCO_2e/day]		
	Coal	Natural Gas	Total
Average 2013 profile	108.99	7.59	116.58

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Case 1 - Using gas as the target for actions of the Energy Box

Table 6 - Statistical results for simulations of Demand Response for the city of Coimbra with gas generation technology used to compensate power demand fluctuations.

	Energy [GJ/day]					
	Increase in load demand			Decrease in load demand		
	Coal	Natural Gas	Total	Coal	Natural Gas	Total
Mean	442.61	85.21	2,242.80	445.73	79.71	2,240.42
Standard Error	1.39	1.43	0.09	3.05	2.97	0.17
Median	445.64	82.09	2,242.62	456.73	69.6	2,240.69
Standard Deviation	16.68	17.17	1.03	18.06	17.58	1.01
Variance	278.22	294.9	1.06	326.12	309.09	1.02
Minimum	399.47	65.13	2,241.46	409.52	63.98	2,237.27
Maximum	461.35	128.52	2,245.66	461.35	114.47	2,241.43
Number of simulations			145			35

Table 7 - Statistical results for simulations of Demand Response actions for the city of Coimbra, using gas generation technology to compensate power demand fluctuations.

	Emissions [tCO_2e/day]					
	Emissions increase			Emissions decrease		
	Coal	Natural Gas	Total	Coal	Natural Gas	Total
Mean	108.99	7.64	116.62	103.99	10.17	114.16
Standard Error	0	0.01	0	0.31	0.16	0.16
Median	108.99	7.63	116.62	104.38	9.98	114.44
Standard Deviation	0.02	0.04	0.02	3.89	1.96	1.94
Variance	0	0	0	15.13	3.84	3.78
Minimum	108.89	7.59	116.58	94.37	7.46	109.35
Maximum	108.99	7.78	116.67	108.99	14.98	116.58
Number of simulations			26			154

Table 8 - Case 1, generation technology shares, in %.

	Generation technology shares, in %	
EB deployment [%]	Coal	Natural gas
original simulated	20.58	2.91
20	20.58	2.91
40	20.39	3.11
60	19.91	3.61
80	19.30	4.23
100	18.65	4.90

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Case 2 - Using coal and gas as the target of the actions of the Energy Box

Table 9 - Statistical results of Demand Response for the city of Coimbra, with coal and gas generation technologies used to compensate power demand fluctuations.

	Energy [GJ/day]					
	Increase in load demand			Decrease in load demand		
	Coal	Natural Gas	Total	Coal	Natural Gas	Total
Mean	465.25	62.60	2,242.80	463.66	61.78	2,240.42
Standard Error	0.18	0.13	0.09	0.31	0.35	0.17
Median	465.02	62.96	2,242.62	462.98	62.39	2,240.69
Standard Deviation	2.16	1.53	1.03	1.81	2.10	1.01
Variance	4.68	2.35	1.06	3.27	4.42	1.02
Minimum	462.13	58.36	2,241.46	461.56	57.56	2,237.27
Maximum	472.35	64.73	2,245.67	468.65	64.38	2,241.43
Number of simulations	145			35		

Table 10 - Statistical results of simulations of Demand Response actions for the city of Coimbra, with coal and gas generation technologies used to compensate power demand fluctuations.

	Emissions [tCO_2e/day]					
	Emissions increase			Emissions decrease		
	Coal	Natural Gas	Total	Coal	Natural Gas	Total
Mean	109.87	7.28	117.15	109.22	7.24	116.47
Standard Error	0.04	0.01	0.03	0.06	0.07	0.02
Median	109.84	7.32	117.10	109.13	7.27	116.47
Standard Deviation	0.51	0.2	0.38	0.17	0.21	0.07
Variance	0.26	0.04	0.15	0.03	0.04	0
Minimum	109.13	6.71	116.61	109.04	6.83	116.38
Maximum	111.59	7.54	119.03	109.55	7.44	116.56
Number of simulations	172			8		

Table 11 – Case 2, generation technology shares, in %.

	Generation technology shares, in %	
EB deployment [%]	Coal	Natural gas
original simulated	20.58	2.91
20	20.63	2.86
40	20.68	2.82
60	20.73	2.78
80	20.79	2.75
100	20.84	2.70

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Case 3 - Using hydro-dam as the target of the Energy Box actions

Table 12 - Statistical results for simulations of Demand Response for the city of Coimbra, with hydro-dam generation technology used to compensate power demand fluctuations.

	Energy [GJ/day]					
	Increase in load demand			Decrease in load demand		
	Coal	Hydro - Dam	Total	Coal	Hydro - Dam	Total
Mean	461.08	267.88	2,242.8	460.88	265.7	2,240.42
Standard Error	0.08	0.12	0.09	0.19	0.17	0.17
Median	461.35	267.49	2,242.62	461.35	265.94	2,240.69
Standard Deviation	0.97	1.46	1.03	1.11	0.99	1.01
Variance	0.94	2.12	1.06	1.23	0.99	1.02
Minimum	454.76	266.27	2,241.46	457.26	263.70	2,237.27
Maximum	461.35	274.38	2,245.66	461.35	268.60	2,241.43
Number of simulations	145			35		

Table 13 - Statistical results of Demand Response actions for the city of Coimbra, with hydro-dam generation technology used to compensate power demand fluctuations.

	Emissions [tCO2e/day]			
	Emissions lowered to the level of the average day		Emissions decrease	
	Coal	Total	Coal	Total
Mean	108.99	116.58	108.67	116.26
Standard Error	0	0	0.07	0.07
Median	108.99	116.58	108.86	116.45
Standard Deviation	0	0	0.41	0.41
Variance			0.17	0.17
Minimum	108.99	116.58	107.44	115.03
Maximum			108.98	116.57
Number of simulations	140		40	

Table 14 – Case 3, generation technology shares, in %.

	Generation technology shares, in %		
EB deployment [%]	Coal	Natural gas	Hydro - Dam
original simulated	20.58	2,91	11.88%
20	20.58	2.90	12.02%
40	20.58	2.90	12.04%
60	20.57	2.90	12.05%
80	20.56	2.90	12.07%
100	20.51	2.90	12.12%

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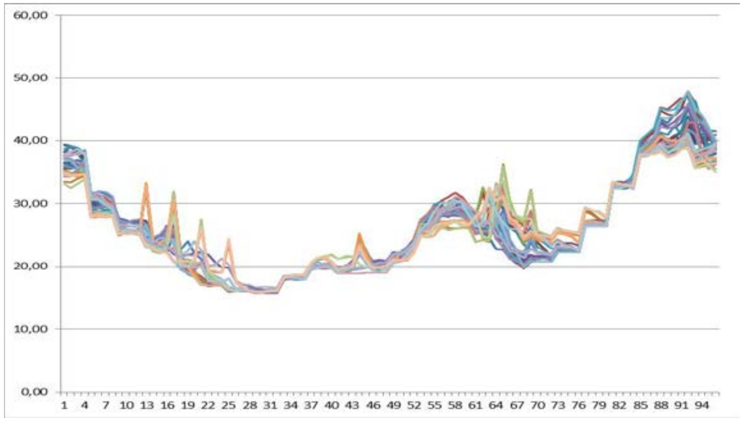
Conclusions (I)

- Demand response is not per se a tool for reducing CO_2 emissions;
- In the case of using gas as the target of the EB actions it can be highlighted that a 20% deployment of the EB does not produce a significant impact on the energy mix, gas and coal keeping their original shares.



Conclusions (II)

- By using coal and gas as the target of the EB actions and maintaining their original quarter-hour shares, a constant increase was verified in the share of coal, and a constant decrease of the share of gas for compensating the actions of the EB;
- The use of electricity generated in dams as the target of the EB actions is also an effective way to avoid CO_2 emissions increase.

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The end

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THANK YOU FOR YOUR TIME!
QUESTIONS AND SUGGESTIONS?

Demand Response: a buzzword or a sustainability driver?

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