Technical potential of smart grids: an assessment of load shifting actions in France

Laurent MEUNIER[‡]
Eric VIDALENC[§]

International Energy Workshop, Stanford (CA), July 2011

Abstract

In the context of ever more complex power generation systems, smart grids are expected to help match power supply and demand. In particular, they should help smooth the load curve, which in turn may help reduce the power generation capacity needed and mitigate carbon emissions. However, this should not be taken for granted and that is why we assess the impact of peak load shifting actions both on the load curve and on carbon emissions. As shown in a previous paper, assuming that the operating grid is effectively "smart", i.e. information on inflows and outflows is fully available, non-disruptive shifts in time of given appliances could have led up to an estimated 1.8 gigawatts (henceforth GW) decrease in the yearly peak load and about 100,000 tons of CO_2 in France in 2008. Yet, given France's generation power system peculiarity, it cannot be assumed that shaving peak-hours load *necessarily* entails a decrease in greenhouse gases (henceforth GHG) emissions in any circumstances. In other words, the analysis needs to be carried on and this is where the twofold contribution of the present paper lies. It first supplements the estimation of non-disruptive shifts in time of appliances uses, by considering additional appliances; secondly, electricity imports and exports are taken into account. The former path clearly helps smooth the load curve up to 3 GW, but does not help reduce carbon emissions more than 110 kt. Still worse, carbon emissions variation is uncertain when taking into account european generation power systems integration.

Keywords: load curve, installed capacity, carbon emissions.
JEL: Q41.

[‡]ADEME, laurent.meunier@ademe.fr, 27 Avenue Louis Vicat - 75747 Paris - France - Tél. : 33 1 47 65 21 - Fax. : 33 1 47 65 21 61

[§]ADEME, eric.vidalenc@ademe.fr, 27 Avenue Louis Vicat - 75747 Paris - France - Tél. : 33 1 47 65 21 - Fax. : 33 1 47 65 21 61

1 Introduction

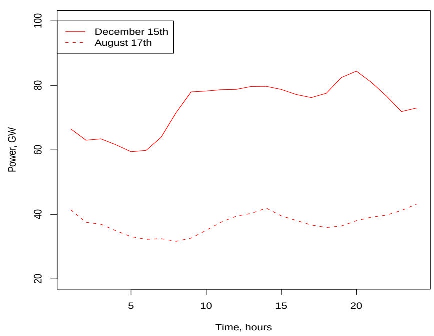
Power generation producers and transmission operators have to deal with a set of constraints in order to match supply and demand at all times. Economic contraints such as using the smallest capacity, and technical constraints such as assuring a reserve capacity are certainly among the most important ones. In addition, enforced carbon emissions mitigation policies as well as renewable power development makes demand and supply matching an increasingly complex issue. The purpose of smart grids is precisely to help deal with this complexity in order to manage both inflows and outflows more efficiently. Smart grids are thus expected to bring substantial welfare gains, which arouses hopes. Indeed, both the number and the size of investment programs in the field into both their creation and development currently implemented are a testament of the current political will towards smart grids development. Think for instance of France's €250M investment plan on smart grids or the US$3.4bn Smart Grid Investment Grant within the American Reinvestment Recovery Act. Yet, their technical relevance still has to be proved. The purpose of this paper is to help answer the two following questions: first, to what extent is it sensibly possible to smooth the load curve? Secondly what are the consequences on the needed installed power capacity and CO_2 emissions? Hence, we do not deal with the different types of possible smart grids, nor does it deal with the modalities of use (e.g. real-time pricing, remote control of appliances, etc.), and nor does it finally deal with the costs incurred to create and develop them.
In this paper, *smart grid* means *any means enabling, in particular through information flows, action on the load curve*. Moreover, we focus on the *technical potential* of shifts in time of some given appliances uses, *as if* in the context of an effectively operating smart grid. An assessment of such a technical potential has been partially performed on French data in a previous paper (see MEUNIER and VIDALENC, 2011), which considered shifts in time of given appliances usages in order to smooth the load curve. The estimated gains in 2008 in terms of installed capacity and GHG emissions were respectively slightly lower than 1.8 gigawatts (henceforth GW) and about 100 kilotons of CO_2 (henceforth $ktCO_2$). These quantities appear rather low, especially when compared with the gains due to a widespread use of the most efficient same appliances (about 1 $MtCO_2$). There still remains numerous issues to be adressed, among which the impacts if additional appliances are considered and those of power imports and exports. This is the twofold purpose of the present paper.

2 Smoothing the load curve: why and how?

In this paper, we focus on smoothing the load curve, which could bring substantial reductions in peak load as well as CO_2 emissions. Yet, the latter is true if both the spread between off-peak and peak loads on the one hand, and the one between off-peak and peak carbon contents on the other hand are significant. Hence, given its power generation system features, France is theoretically a country where relatively large gains are to be expected:

- There exists a significant gap between off-peak and peak loads

Figure 1 - Yearly peak and off-peak daily load curves, France, 2008



Source: Réseau de Transport d'Electricité (RTE)

Note first that in this paper, we consider year 2008 data. That year, the yearly lowest load was 31.4 GW, while the yearly peak load was 84.4 GW. Note that these figures refer to *extractions*, i.e. roughly generation minus transmission and distribution (henceforth T&D) losses. The amount of power actually generated and injected on the grid was equal to 92.4 GW during the annual hourly peak (source: RTE -the French transmission operator). These extrema are, above inter-year climate seasonality (which is clearly invisible on yearly data) the result of an *agregation* of seasonalities of different frequencies. First, inter-seasonal seasonality which reflects the fact that end-uses -in particular thermal ones- are heterogeneous across seasons. This is illustrated by *both* the spread between the curves of Figure 1 and their distinct shape. Secondly, consumption paths are heterogeneous across types of days (i.e. weekdays, Saturday and Sunday). Finally, the daily sequence of activities leads to 2-peak-shaped daily load curves, as illustrated by the shape Since the installed capacity is sized to match peak-hours consumption, some capacity is at rest for many hours during the year, which entails huge costs.

Table 1: Summary statistics on peak and off-peak loads

	Peak load	Off-peak load	Daily peak/off-peak ratio	
	GW	GW	Mean	Standard-deviation
Year	84.42	31.36	1.36	0.086
Winter	84.42	45.76	1.35	0.085
Summer	59.95	31.36	1.35	0.085

Source: RTE

- The shares of nuclear power (76%) and hydro power (12%) are significant

  This fact makes France's power generation very peculiar, especially compared with its neighbouring countries [1]. As a consequence, French base production is both cost and carbon competitive.

- Thermal production is mainly used in seasonal (winter) peaks of consumption, as far as it is competitive Consequently, the variance of the carbon content is large: from close to 0 during the night to several hundreds gCO_2/kWh during peak hours

To conclude, high peak load carbon contents as well as costly under-used peaking units are two reasons to believe that smoothing the load curve may enhance significant gains.

2.1 How to smooth the load curve?

Smoothing the load curve consists of shifting some consumption from peak-hours to off-peak hours. In practice, we can achieve this by turning off -at least decreasing transfered power- some appliances at proper times. We consider the following appliances:

Table 2: French households equipment

Equipment	Market penetration	Start-time delay function	STDF usage frequency
Washing-machine	95% (stable)	42%	32% almost all the time
Dishwasher	50%	100%	
Electric water heater	12M	90% with overnight storage	
Refrigerator	>100% (stable)		
Tumble dryer	33.2%	100%	60% of washing-cycle

Source: Stamminger, 2009

1. <u>Washing-machines</u>

   In 2008, 95% of French households were equipped with washing-machines, of which 42% with a start-time-delay-functioned (henceforth stdf) washing-machine. Moreover, 32% of them use the latter function "almost all the time" (see Stamminger, 2009). Our assumption is the following one: among

[1]See section 4 for further details

households equipped with stdf washing-machines, only the use of those owned by households *not* already using "all the time" the stdf can be shifted. Note that this possibly overestimates the actual potential, since some households might use the function "sometimes". Yet, as far as we know, no data is available to estimate the number of households programing their washing-machine to operate during peak-hours. On the other hand, we do not consider any shift concerning households not equipped with start-time delay function washing-machine whereas some washing-machines at least could be easily turned on and off, at convenient times, for instance by the transmission operator's remote controll. This clearly underestimates the possible decrease in power demand due to using washing-machines at a given time period t.

2. <u>Dish-washers</u>

   Since 100% of dish-washers are equipped with a stdf, we consider that 100% of the consumption of dish-washers during peak hours could be shifted to low-consumption periods of time.

3. <u>Electric Water Heaters</u>

   About 90% of electric water heaters uses overnight storage. Yet, in theory, it could be 100%, without any additionnal energy efficiency gain. The difference is certainly due to some ill-tuning. Thus, we assume that the consumption due to the use of electric water heaters at a given time period could be decreased by 100%.

4. <u>Refridgerators</u>

   We assume, based on Stadler's results on refridgerators thermal cycles (see Stadler, 2009) that it is possible to cut by 75% for as long as 57 minutes the power transfered to refridgerators without increasing the inner temperature above a certain harmful threshold. This is yet conditioned by an *increase* in power -amounting to half the former decrease- during the previous hour in order to store "heat" (cold actually) and the next one to catch up with the targeted temperature.

5. <u>Tumble dryers</u>

   A one-hour shift in power transfered to tumble dryers is also considered. Notice finally that we excluded space heating from our analysis, since it would change drammatically the results, given the order of magnitude of electric space heating consumption.

To conclude, let the reader be reminded that in this paper, we assess the technical potential of *non-disruptive* shifts in time of some appliances uses and its impacts. Therefore, one difficult part in this analysis is to gage whether or not turning off a given appliance at a given time is *actually* non-disruptive. As a consequence, we have to keep in mind that we may overestimate the impacts if we assume unrealistically optimistic (i.e. large) consumption shifts.

3 Power consumption and generation databases

3.1 Consumption

We used the $CHARTER^{TM}$ database (see [5]), which provides for the *estimated* real (i.e. not taking climate variations into account) French hourly power consumption for the entire year of 2008, per appliance (e.g. washing-machines, space heating, hot water, etc.); per demand sector (57 sectors, among which: households in detached homes; households in multi-family buildings, shops, industries, etc.); per type of day (3 types: weekday, Saturday, and finally Sunday and vacation); and finally per month.
The dataset was built from surveys of representative households and companies, the aggregation of which yields the estimated national hourly load curve. For further details, see [5]. Notice that we focus in this paper on the residential and services sectors, leaving aside industry and agriculture. This is firstly due to a lack of data as far as peak-hours consumption shaving potential is concerned. Furthermore, some demand management actions, i.e. actions aiming either at shifting demand from one time to another, or

at decreasing consumption (pricing, agreements, etc.) have been implemented in the industry. Finally, agriculture does not appear to be an important focus for smart grids development, given its relatively low consumption (approximately 10 TWh in 2008, or about 2% of the total power consumption, see MEDDAT/SOes, 2009, Bilan de l'Énergie 2008).

3.2 Power generation mix

The following table gives French power generation features:

Table 3: French power generation system

	Capacity GW	Generation TWh	Type	Carbon content gCO_2/kWh
Nuclear	63.3	418.3	Base	0
Hydro	25.3	68.0	Base and peaks	0
Fossil fuel thermal	24.6	53.1	Semi-base and peaks	[360;960]
Other renewables	4.3	9.7	Intermittent	0
Total	117.6	549.7		

Source: RTE

We use the public database of RTE, which decomposes the yearly production into *hourly* levels of production, total consumption, possible imports and exports, and the power generation mix. As a result, for all hours of the year 2008 we can identify the power generation mix, made up of: nuclear power; hydro power; coal- and gas-fired thermal power; oil-fired thermal power plus peaking units output (mainly storage-and-pump plants); remaining types of power generation (mainly combined heat power generation, henceforth CHP and renewables but hydro).

4 Methodology and assumptions

We conduct our analysis given the following sequence:

1. Reconstructing the hourly consumption for the 8784 hours of the (leap) year 2008, by matching types of day with real calendar days;
2. Estimating the potential for decreasing hourly consumption for some targeted hours;
3. Estimating the possible shifts in production;
4. Estimating the impact first on the installed capacity, and then on GHG emissions.

It is noteworthy that our analysis relies on *simulation*, and in no way upon optimisation.

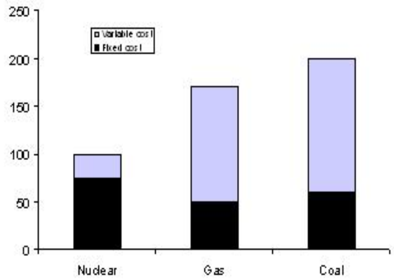
4.1 Potential for decreasing hourly consumption

For each day, we determine the six hours during which consumption is highest, and for each of them, the *possible* non-disruptive shifts in appliances time of use: first considering the possible decrease in hourly consumption of the three first appliances - i.e. washing-machines, dish-washers and water heaters; then refridgerators; finally tumble dryers. Subsequently, the power transfered to the three first appliances are to be shifted to the six hours during which demand is lowest, while the power of the other two appliances are to be shifted to the previous and to the next hours (refridgerators); to the next hour (tumble dryers).

4.2 Power generation modulation

First notice that since only shifts in time of use are considered, there are no energy savings. In other words, the total consumption remains constant. Moreover, production modulation is based on a technico-economic analysis (see [7]).

Figure 2 - Base-production costs



Source: French Ministry of Energy (DGEC)

Thus, nuclear power proved to be the most competitive means of production when operated for between 6,000 and 8,784 hours; then, coal-fired power plants between 4,000 and 6,700 hours; finally, gas-fired power plants between 2,000 and 4,700 hours. Last but not least, oil-fired peaking units production cost is equal to several times that of nuclear (source: French Ministry of Energy/DGEC, Programmation Pluriannuelle des Investissements, 2009).
Production modulation will be considered in two cases: first, the national grid; then, France's and its neighbouring countries. To respond to the decrease in consumption, the power generation mix is considered according to the following order of priority: first oil-fired power plants, and then coal- and gas-fired power plants. Accordingly, in order to increase off-peak production, we consider the reverse order: first coal and gas, and then oil. Note that some potential is lost because we do not consider the modulation of the other types of plants. The reason why nuclear and renewable energies (i.e. hydraulic, wind, solar and biomass) are not considered is because these means of production are either intermittent (e.g., wind and solar), or cost-competitive (i.e. nuclear and hydro).

5 Results

5.1 Case 1: considering the French generation mix

The constraints to be fulfilled for this case to make sense are the following. First, the shift in consumption from time t to time s can neither exceed the combustible fuel-fired power generation of that time t (C_1, see below), nor can it exceed the possible increase in combustible fuel-fired power generation at time s (i.e. the difference between installed capacity and production at time s, c_2). The third constraint ensures that we do not create a new peak. At most, we flatten the peak load, possibly becoming a plateau of 3 hours, i.e. $t_{max}-1, t_{max}, t_{max}+1$, with (d, t_{max}) being the time period when consumption is highest during day d.

$$\begin{cases} S'_{d,t} \le Q_{c\&g,d,t} + Q_{oil,d,t} \qquad (c_1) \\ S'_{d,t} \le (K_{c\&g} - Q_{c\&g,d,s}) + (K_{oil} - Q_{oil,d,s}) \qquad (c_2) \\ \forall t = \{t_{max}-1, t_{max}+1\}, \quad R'_{d,t} \le 2 * \{[(C_{d,t_{max}} - (S_{d,t_{max}} - C_{rf,d,t_{max}} - C_{sl,d,t_{max}})] - [C_{d,t} - S_{d,t}]\} \qquad (c_3) \end{cases}$$

Where:

- $S'_{d,t}$ ($S_{d,t}$) represents the *actual* (respectively *possible*) shift in consumption from time t to another time period s;
- $Q_{c\&g,d,t}$ ($Q_{oil,d,t}$) represents the coal- & gas-fired power generation (respectively oil-fired) at time t of day d;
- $K_{c\&g}$ ($K_{c\&g}$)is the installed capacity of coal- & gas-fired power plants (respectively oil);
- $R'_{d,t+i}$ represents the *actual* shift (if any) of refridgerators and tumble dryers to t's preceding and following period of time;
- t_{max} represents the daily peak time period, for a given day

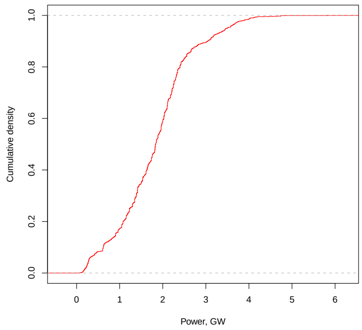
Table 4: Impacts of shifts in consumption

	Unit	Quantity
Decrease in yearly peak load	GW	2.99
Total potential shifted consumption	GWh	6,536
Total actual shifted consumption	GWh	3,440
Decrease in oil-fired power generation	GWh	767
Increase in coal- & gas-fired power generation	GWh	767
Decrease in CO_2 emissions	kt	109

Reading note: the potential shifted consumption is the sum over time of all possible shifts, regardless of (c_1), (c_2) and (c_3). On the contrary, the actual shifted potential is determined taking into account the constraints.

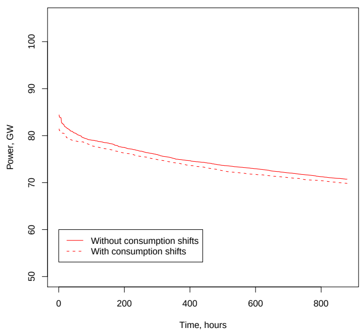
The results presented in table 4 are to be compared with France's overall consumption (485 TWh in 2008), and the annual peak load, i.e. 92 GW in 2008 on the coldest day of the year (note: 96.3 GW in 2010). This yearly peak load is decreased by 3 GW, which is significant from the grid manager perspective. Moreover, the shift is effecive since for about 40% of peak hours, the decrease in consumption is greater than 2 GW, as shown by the cumulative distribution of the decreases in consumption during peak hours:

Figure 3 - Cumulative distribution of decreases in consumption



Moreover, the yearly peak/off-peak load ratio falls from 1.36 to 1.24, and the winter and summer peaks -though to a lesser extent) are both lower than the observed peaks without consumption shifts. The impact on the yearly load duration curve -for the top-10% peak hours- is the following one:

Figure 4 - Load duration curves



Concerning GHG emissions, thanks to a $142 gC0_2/kWh$ difference between oil- and coal&gas-fired generation power carbon contents[2], 109 ktCO_2 could have been avoided by shifting 767 GWh of oil-fired power generation during peak hours to coal&gas-fired power generation during off-peaks hours. This estimated CO_2 emissions reduction amounts to about 0.3% of the annual power generation emissions (slightly greater

[2]The average CO_2 content of coal&gas-fired production (i.e. 658 g/kWh) is the mean of each type of plant (i.e. coal and gas) carbon contents, weighted by their respective annual production in 2008

than 30 Mt of CO_2 in 2008, source: French Ministry of Environment/SOeS).At this point, it should be noticed that there are two potential biases concerning CO_2 emissions gains. First, the CO_2 content of the annual composite average coal- and gas-fuelled power production (i.e. $658g/kWh$) is the mean of coal- and gas-fired power production CO_2 content, weighted by their respective annual production. Yet, considering current modulation in France, coal-fuelled power plants and then gas-fuelled power plants would be turned off when shaving peak hours demand (recall that the CO_2 content of French coal-fuelled power amounts to 960 g CO_2/kWh). On the contrary, gas-fuelled production and then coal-fuelled production would be increased during off-peaks hours (the content of gas-fuelled power is equal to 360g/kWh). In so doing, we underestimate the average CO_2 content of jointed coal-and gas-fired power production which is shaved during peak hours, and overestimate the average content of the additional production during off-peaks hours. Therefore, we underestimate this gain. On the other hand, the average CO_2 content of extreme peak production (i.e. 800 g/kWh) is overestimated since the extreme peak production means is made up of oil-fuelled power plants and storage-and-pump power plants. As the content of the former is equal to 800 g/kWh, whereas the content of the latter is close to zero, we overestimate the related gain. However, as no distinction is drawn in RTE data, on the one hand, between gas- and coal-fired power productions, and on the other hand between oil-fired and storage-and-pump plants, we can not go further. To conclude, these results show that the overall impact can be quite significant on the load curve, but remain relatively weak with regard to CO_2 emissions.

5.2 Case 2: taking interconnections into account

5.2.1 The issue

In the previous section, the carbon emissions reduction were estimated with no account taken of imports and exports between France and its main neighbouring countries, namely the United Kingdom, Belgium, Germany, Switzerland, Italy and Spain. The previous estimates relied on the assumption that *French* oil-fired power stations were turned-off and then *French* coal & gas power stations, without any impact on imports and exports. This is a very strong assumption, not to say unrealistic. First, there are possible local constraints upon the grid equilibrium preventing to turn off oil-fired power plants. Secondly, shaving peak loads may lead power stations in a neighbouring country to be turned off. In such a case, we can say very little about carbon emissions.

Interconnections and generation mixes

The first point worth noting is that interconnections between west-european countries are significant. The second issue concerns generation mix heterogeneity across countries. This is shown in the following table:

Table 5: Interconnection capacities, contractuals flows between France and neigbouring countries and production mixes

	Interconnections			Production					Emissions
	Capacity GW	Imports GWh	Exports GWh	Nuclear GWh	Hydro GWh	Combustible fuels GWh	Others GWh	Total GWH	Average factor gCO_2/kWh
Belgium	3.4	1,879	10,871	43,359	1,743	34,957	908	80,967	249
Switzerland	3.2	7,689	26,069	26,132	37,560	3,150	48	66,890	27
Germany	2.7	18,969	6,385	142,220	25,705	380,334	59,027	607,286	441
Italy	2.6	1,814	19,607	0	46,221	247,943	10,206	304,370	398
United-Kingdom	2.0	1,409	12,743	46,752	8,940	301,913	6,018	369,623	487
Spain	1.3	3,002	5,753	56,427	20,399	183,700	26,841	287,367	326

Source: ENTSOE, RTE and IEA

Note that taking into account interconnections amounts to relax constraints (c_1) and (c_2), i.e. to shave as much as possible regardless of french combustible fuels power and capacities. The results are the one summarised in the following table:

Unsurprinsingly, there is an increase in actual consumption shifts, from 3,998 to 5,898 GWh. However, the yearly peak load is not decreased above 3 GW. More interstingly, why is the result in terms of CO_2 undetermined? First, shaving peak loads to a greater extent than combustible fuel fired power generation

Table 6: Results, considering interconnections

	Unit	Quantity
Decrease in yearly peak load	GW	2.99
Potential shift in consumption	GWh	6,536
Shift in consumption [3]	GWh	5,346
Decrease in oil-fired power generation	GWh	767
Increase in coal- & gas-fired power generation	GWh	?
Increase in exports	GWh	1906
Decrease in CO_2 emissions	kt	?

will lead France to *export* nuclear and hydro power during peak hours. As far as off-peak hours are concerned, either there is an increase in *French* coal & gas power generation or an increase in imports from neighbouring countries, or both increase. If there are no imports, the increase in consumption during off-peak hours is matched by an increase in French coal&gas-fired power. In the opposite case, the matching is performed thanks to imports. Secondly, since we did not find hourly generation mix for the countries considered in the analysis, we had to rely on the yearly average carbon content of imported electricity in order to estimate carbon emissions variation of these consumptions shifts. Those are summarised in the following table:

Table 7: Impact on CO_2 emissions in extreme scenarios

	Carbon contents	Peak hours load variations	Off-peak hours load variations	
			Case 1	Case 2
	gCO_2/kWh	GWh	GWh	GWh
Oil	800	-767	0	0
French coal&gas	658	-2673	+ 5,346	0
Imports	329	0	0	+ 5,346
Exports	0	+1,906	0	0
Consumption shifts		-5,346	+ 5,346	+ 5,346

Shifting peak hours consumption 5,898 GWh to off-peak hours would have lead in both cases to a 1,906 GWh increase in exports during peak hours along with a 767 GWh decrease in oil-fired power and a 2,673 decrease in coal&gas power. In terms of carbon emissions, it is a 2,372,434 tons of CO_2 increase. Then, the matching during off-peak hours would either be performed through a 5,898 GWh increase in domestic coal and gas power (hence a 3,517,668 tons increase in CO_2 emissions); or through a 5,898 GWh increase in imports (hence a 1,758,834 tons increase in CO_2 emissions). In the first case, this would lead to a net increase in CO_2 emissions by 1,145,234 tons; by 613,600 tons in the second case.
These results seem disapointing and all the more so as assumptions are particularly favorable.

5.3 What about energy efficiency?

Potential gains are considered on the basis of current average consumption of these appliances and the best available equipments. It is worth noting that the CO_2 gains are evaluated on the basis of historic uses emission factors :40 g CO_2/kWh for thermal uses; 60 g/kWh for washing- machines, dishwashers and tumble-dryers (see [1]). Thus, the estimated reduction in CO_2 emissions is much greater compared

Table 8: Evaluation of energy efficiency gains

	Per-unit consumption		Total consumption		Gains	
Appliance	Average	Best equipment[4]	Average	Best equipment	Energy savings	CO_2 abatement
	kWh	GWh	GWh	GWh	GWh	kt
Washing-machine	169	120	4,259	1,270	2,989	179
Dishwasher	273	272	3,621	3,607	13	1
Water heater	1,920	730	23,328	7,978	15,350	614
Refridferators	253	140	6,644	3,676	2,967	119
Tumble-dryers	408	321	3,593	2,827	766	46
Total						959

to the previous estimates (i.e. 100 kt). Yet, these figures are not perfectly comparable to the previous ones. They rather aim at giving the reader an idea of the potential of energy efficiency compare to smart grids development.

6 Conclusion

As far as smart grid technical relevance is concerned, this paper reports some interesting results. First, there seems to exist a real potential for smoothing the load curve. Indeed, we estimated a 3 GW-decrease in the 2008 top-peak hour consumption. As small as it appears, this is significant in the transmission operator perspective. Moreover, considering the French generation mix only could have lead to a rough 100 ktons decrease of carbon emissions. Yet, when we do take into account interconnections with neighbouring countries, we can hardly prove that carbon emissions would be significantly reduced. Carbon emissions reductions appear even lower when compared to energy efficiency actions.
Indeed, it turned out that in the short run, energy efficiency is likely to bring greater gains than load shitfing actions, at least as far as CO_2 emissions are concerned (about 1Mt CO_2 versus 100 kt $C02$ in the most favorable case). However, smart grids are likely to develop alongside energy efficiency actions. Indeed, they are complementary: smart grids help optimise energy flows within a given system, yet that system's energy efficiency will be critical to achieving ambitious reductions in GHG emissions. Actually, we saw that smart grids could bring considerable reductions in power consumption -a determinant of electric power system sizing- but the gains in CO_2 emissions will be all the more so high as the difference in carbon content between peak and off-peak hours generation mix is higher. Thus, emissions could even be increased by peak-shaving actions, for example in the case of lignite-fuelled power in base periods and gas-fired power during semi-base and peak periods.
To conclude, energy efficiency lays the foundations of the energy system, and smart grids are likely to help address current and forthcoming challenges, such as incorporating an increasing quantity of renewable energy and demand variations. Indeed, this is where seems to lie the real potential of smart grids.

References

[1] ADEME. Le compteur linky: analyse des benefices pour l'environnement, 2010.

[2] ADEME. Reseaux intelligents et stockage de l'energie, rapport interemdiaire, 2010.

[3] ADEME-EDF. Note sur le contenu carbone du kwh electrique par usage en france, 2005.

[4] International Energy Agency. Carbon dioxyde emissions from fuel combustion, highlights, 2010.

[5] Commissariat General au Developpement Durable/SOeS. Bilan de l'energie 2008, 2009.

[6] Energies Demain. Charter modelling of charge, 2010.

[7] DGEC. Programmation pluriannuelle des investissements de production d'electricite, 2009.

[8] Armines Energies Demain. Projet probat4, rapport de la phase 2 : Mecanismes pour maitriser la demande d'electricite, 2010.

[9] Enertech. Consommation des appareils electrodomestiques performants, 2008.

[10] Meunier L. and Vidalenc E. Smart grids versus energy efficiency: which one first? In *ECEE 2011 Summer Study Proceedings*, 2011.

[11] RTE. 2008 electrical energy statistics for france, 2009.

[12] RTE. Bilan previsionnel, 2009.

[13] Sonnenschein M. Stadler M., Krause W. and Vogel U. Modelling and evaluation of control schemes for enhancing load shift of electricity demand for cooling devices. *Environmental Modelling and Software*, September 2009.

[14] Stamminger. Synergy potential of smart appliances, 2009.