Cooking in the night: peak electricity demand and people's activity in France and Great Britain

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Paper prepared for DEMAND Centre Conference, Lancaster, 13-15 April 2016

Summary

The study of energy demand diversity and evolution relies on buildings and appliances qualities, their environment and the performance of specific practices. However, in spite of the widely agreed fact energy is consumed in and for the performance of practices, researches continuously struggle to show a significant relationship between different doings and the variations in energy consumption measured on a large scale. Even if the direct link between the use of specific appliances and their energy consumption can be measured, it seems this link blurs into the complexity of the many practices performed over a year or across large samples of consumers, letting only steady infrastructures and shared contingency mark the shape of demand.

Still social practices can have large scale or regular structures based on repetition, synchronisation or sequencing, that should not just result into a random noise. In this research we look for the energy footprint of practices which are widely shared, highly regular, and key markers in the social organisation: eating practices. After showing the winter evening peak in electricity demand results from seasonal lighting overlapping with a fixed time activity peak, we studied the regional timing of this social synchronisation. The distribution of cooking times was studied across several time scales (week days, seasons) and areas (Great Britain, France and French regions). This comparison reveals a significant link between the time of the evening electricity demand peak and the time and synchronisation of cooking.

Continuously matching energy generation and demand in time is at the heart electric systems because of their very little storage capacity. This balance generally relies on the diversity and flexibility of the power sources that respond to demand. In addition, there's always been attempts to intervene on the demand side, by means of prices reflecting varying generation and transport costs (Yakubovitch, 2005), information, automation or direct load control. Increasing shares of inevitable renewable sources in the generation mix, in association with the rise of smart grids, renew the need and expectations for demand side management (Strengers, 2013, Torriti, 2016). In particular, consumers are expected to change their behaviours and adapt to the system needs, avoid peak times and absorb energy overcapacities.

However, these interventions and injunctions to change behaviour, tend to ignore the nature of the practical arrangements to be changed, the fabric of everyday life as it is today, what people have in their hands, and how it relates to energy consumption. If most researchers agree that knowing demand is about understanding what energy is finally consumed for, either focusing on consumers or social practices (Janda, 2011, Shove and Walker, 2015), empirical researches struggle to measure the precise role of consumers actions and daily life in the amount of energy they consume. The study of energy demand diversity and evolutions mainly takes into account buildings and appliances efficiency, environmental constraints and consumers' doings (occupation, activity, gesture or appliance usage). Most of the time it fails to show any significant relationship between different doings and the variations in energy consumption measured on a large scale (Cayla et al., 2010, Cayla, 2011, Morley and Hazas, 2011, Huebner et al., 2015). Even if the direct link between the use of specific appliances and their energy consumption can be measured (Durand-Daubin, 2013), it seems this link blurs into the complexity of the many practices performed over a year or across large samples of consumers, letting only steady infrastructures and shared contingency (i.e. seasons) shape energy demand. More ambitious measurement campaigns involving energy consumption and people activities are currently under way (Grünevald and Layberry, 2015), and should help to understand how and where the link between practices and energy consumption gets lost.

Still, social practices have regular structures based on repetition, synchronisation or sequencing, that can develop on a large scale, and should not just result into a random noise. In this research, we look for the energy footprint of practices which are widely shared, highly regular, and key markers in the social organisation: eating practices (Southerton et al. 2011, Isaksson and Ellegård, 2015, De Saint Pol, 2006). For this purpose, instead of collecting tailored data, implying high costs and difficult generalisation, we make an attempt to link people doings and electric consumption at a regional level based on public data only. Twenty five different areas for which people activities as declared in national time use surveys and electric load curves reported by transport grid operators were studied: Great Britain, France (Continental), and the 22 French regions. A prior study explored the quantitative identification of distinct eating practices based on the above mentioned time use surveys data (Durand-Daubin and

Anderson, 2014). Different types of meals were defined in terms of time, durations, secondary activities, participants and places. Surrounding activities allowed to specify the meanings and constraints attached to each type of them. The distributions of these practices were studied across several time scales (week days, seasons, and decades from 1974 to 2010) and areas (UK, France and regions).

The present paper focuses on the link between people activities around diner time and the evening peak observed in the electric system load curve in both countries. A number of studies already described this peak in terms of seasonality and underlying usage of appliances or energy services (heating, lighting, cooking…). It's known to be rooted in the residential sector (Poignant and Sido, 2011), to be highly seasonal, peaking in winter and disappearing in summer, as a result of being essentially made of lighting, which demand varies directly with sunset times (Boßmann et al., 2015, Pigenet, 2009). It's also often associated with the rise of active occupancy between the times when people go back home and when they go to sleep (M.A.López-Rodríguez et al., 2011), or with the overlapping of tertiary buildings and residential houses lighting demand, when people are in transition between these two locations according to Pigenet. Still more systematic analysis are needed to understand the role of these different factors.

Our question is: can we explain variations in peak demand with variations in people activities? In that perspective we start with the description of electric peaks so as to identify variations between seasons and areas, and define which of them are likely to be explained by people doings, as opposed to environmental contingencies. Then the variations in cooking, eating, television and home occupancy across regions are compared with electric peaks to assess which activities have the most impact on the shaping of the peak. Then we relate back the differences in the timing of these activities to the various eating practices earlier defined.

A seasonal peak: evening electric demand in Great Britain and France

In both countries, daily load curves reveal a similar shape with a low consumption in the early morning, a plateau from 8AM to 4PM and a peak in the evening (figure 1). However a number of structural differences can be noticed. The level of electric consumption is 50% higher in France. This difference obviously remains when expressing this consumption level by inhabitants. It comes from a higher electrification of space heating in the residential and services areas, and of the specific industrial processes in France, while more gas is used in Great Britain. In both countries, the level of electric consumption is higher in winter, all day long, due to the need for more light as a result of a lower sun. But this phenomenon is much stronger in France due to electric space heating demand increasing on colder days. In addition, in the same country, August shows a very low level with a slower increase in the morning, which is the sign of a high rate of workers on holidays.

Regarding the daily dynamic, electric consumption drops regularly at night in Great Britain, while resistance points are observed in France where a peak at 11PM reveals the massive use of automated electric hot water tanks, in association with off peak tariffs. A last difference is the observed drop in consumption before the evening peak arises in France, while the peak directly builds up from the plateau in Great Britain. This drop results in a lower relative spread between the minimum and maximum demand of the day (28% in France vs. 49% in Great Britain).

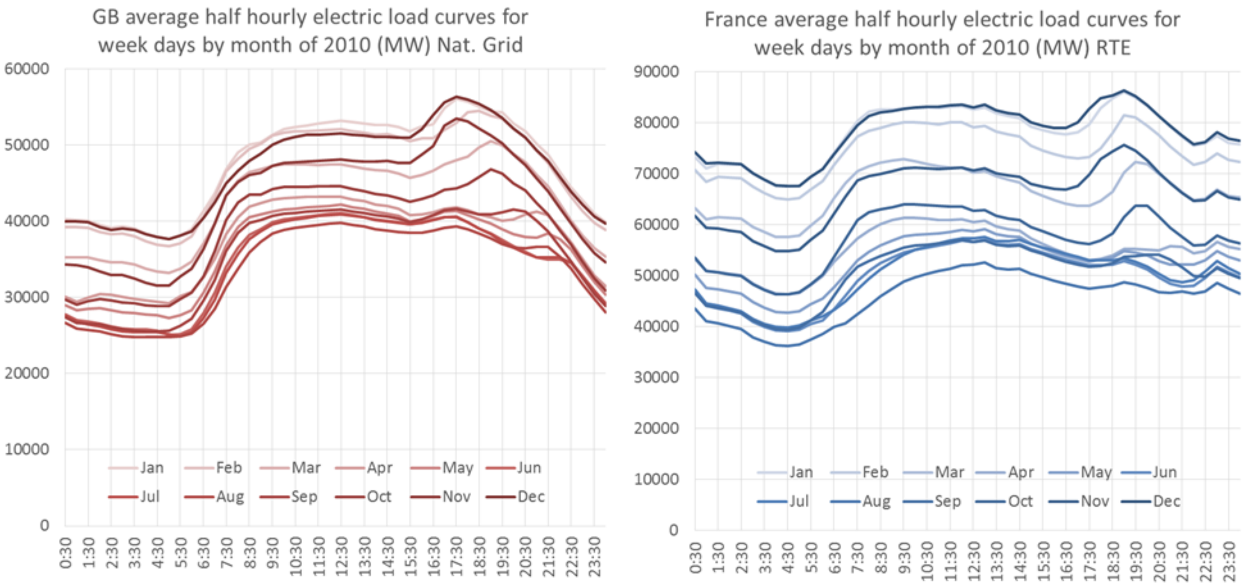

Fig 1: Seasonal daily electricity total demand in Great Britain and France

A possible footprint of the lunch break can be spotted in both countries. This trace is quite feeble but more remarkable in France. In happens at 12:30AM and 1:00PM respectively in Great Britain and France. In this case it's also preceded and followed by a small drop. Lunch peaks appear more clearly during the week-end days, when it's less drowned into work demand (services, industry and agriculture). Because of the weak intensity of this signal, it seems more difficult to study variations in the midday peak than in the evening peak.

In both countries, the maximum demand is observed in the early evening of Decembre and January, at 5:30 PM in Great Britain and 7:00 PM in France, while the sun sets respectively around 4:00 (Birmingham) and 5:00 (Bourges). With respect to sunlight, the peak occurs 30 minutes later in France. In both cases, the seasonal evolution shows the appearance of a lighting peak around 9:30PM in August. This peak grows and moves earlier each month until its maximum in Decembre, then it moves back later and flattens until July. This dynamic clearly follows the seasonal changes in the sunset time: the peak grows when darkness coincides with more activities or more places in use (Pigenet, 2009). Interestingly this peak of activity can already be identified during the summer months, especially on the GB curves, before it's swallowed and magnified by lighting demand when the night comes early enough. Contrary to the light demand, this peak is fixed over the entire year at 5:30 PM and 7:00 PM (6:00 with respect to the sun) as mentioned earlier.

As a preliminary conclusion the evening peak results from the amount of overlapping between a seasonal environmental contingency (night) and a social phenomenon which depends on the country but is fixed across the year. In the next sections we address the question of the practices that could possibly influence the building and timing of this all year fixed peak.

A regular social synchronisation: people activities in the early evening

In this section we analyse activity data from time use surveys to understand which social phenomena contribute to the shaping of the evening peak at this specific time.

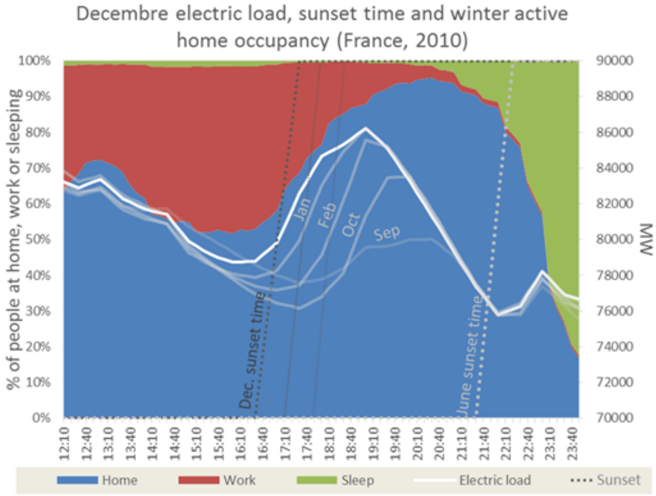

Fig 2: Seasonal light demand and active occupancy

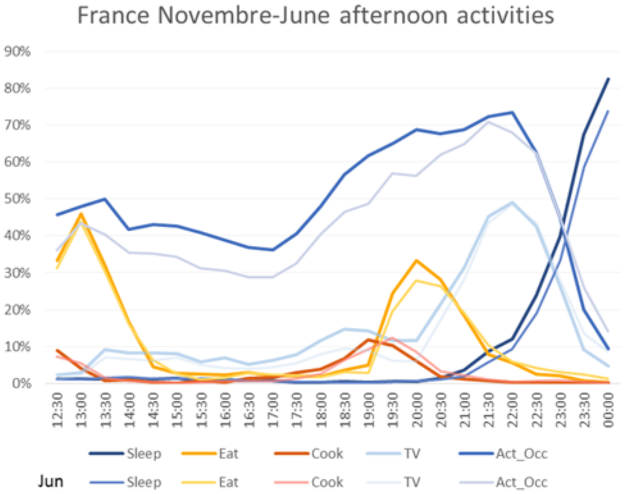

Fig 3: Seasonal variation in activities

In France, the superposition of electric consumption, people declared locations and sleeping time from noon to midnight provides a first assessment of the relationship between peak demand and the main periods of the evening (figure 2).

Lifting monthly electric loads at the level of the Decembre one helps to read how peak demand rises according to when the sun sets, which doesn't give us much information regarding when the underlying activity requiring lighting starts. On the contrary, the decline of the peak follows exactly the same dynamic, at the same time, all year round, which indicates the end of a regular activity peak.

Activity main periods on the other side do not vary much across the year (figure 3). In June, active occupancy is lower, especially during the day, people taking advantage of the good weather. Cooking and spleeping happen slightly later. When compared to electric demand (Figure 2), it clearly apears active occupancy does not coincide with electric demand, which declines in the first part of the active occupancy period, 90 minutes before it peaks. Earlier, the transition from workplaces to homes peaks around 5:30 PM. It is nearly achieved at 7:00 when electric demand peaks, which doesn't support a key role of this phenomenon in the peak, but does not discard it completely.

The results produced here based on the French example are stricly the same in the case of Great Britain. They tend to indicate specific activities distinguish the early part of the active occupancy period from the later. They also lead us not to consider the rising dynamic of the winter demand peak which is shaped by the night coming and would not allow the distinction of specific practices. Consequently, in the next paragraph we compare the activities in the beginning and in the end of the evening in relation with the time of the fixed peak.

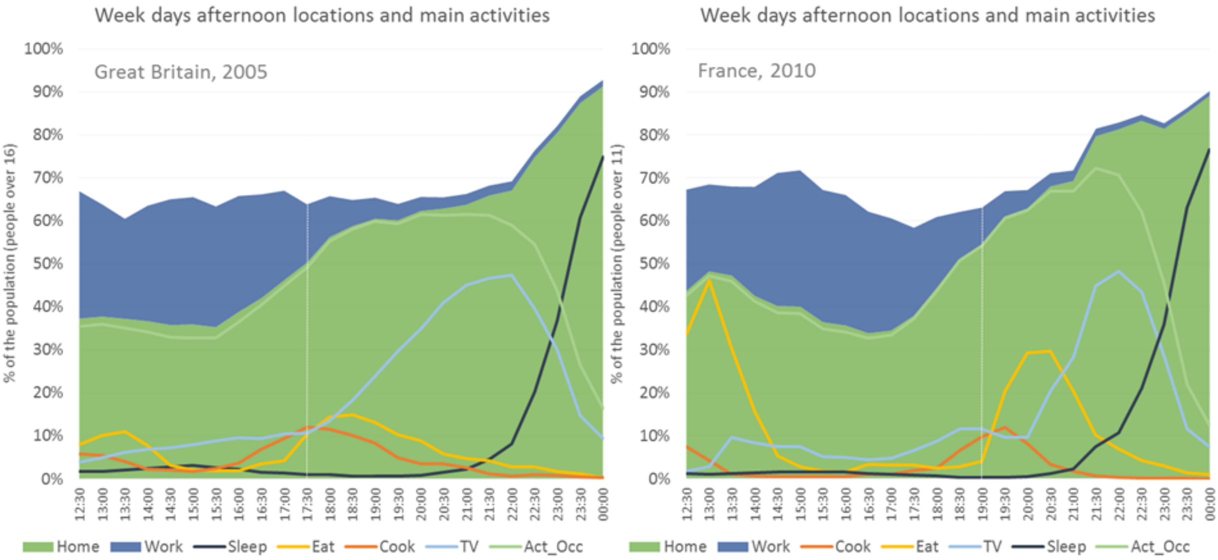

Fig 4: Home occupancy cooking and eating in both countries, by season or month (% in time)

On the two charts above comparing people activities on week days, from noon to midnight, in Great Britain and France, the white vertical line marks the time of the all year daily electric peak, the white area stands for the locations other than workplace and home (Figure 4). In both countries the second part of the day is paced by eight steps:

- 1) preparing lunch, 2) lunch,
- 3) going back home part 1
- 4) preparing diner, 5) diner
- 6) watching TV
- 7) going back home part 2
- 8) going to bed

Apart from the very last step (8), the dynamic of these activities differ a lot between Great Britain, in which they overlap smoothly and France where they draw clear dedicated times.

At noon, lunch gathers more than 45% of the French population in the 30 minutes from 12:30 to 1:00PM, when the British peak only reaches 12% half an our later. The French lunch relies partly on people going back home for lunch, and not only on the more developed canteens in France (Southerton et al., 2011). This difference is repeated later for diner, but French people do not reach the level of synchronicity they do for lunch. Diner peaks at 8:00 in France, two hours after their counterparts, leaving a wide period of four hours and a half with barely no eating activity. In between there is still a small bump revealing tea break and “goûter” between 4:00 and 5:00 in both countries. These marked meal times, and their strong conservation in France against international trends are well described by De Saint-Pol (2006).

Cooking or more general food preparation precede meals. This activity is again more concentrated in France, but we notice the overall amount of time dedicated to food preparation for diner is very large in Great Britain. This is not intuitively consistent with the results produced when uniquely associating cooking and eating episodes in a household which concluded to a third less cooked diners in Great Britain than in France (Durand-Daubin and Anderson, 2014).

Interestingly, watching TV is also more structured in France than in Great-Britain. The times of the 1:00PM and 8:00PM news are clearly visible on the French curve, while the smooth British curve reveals no particular event. There is also a little drop in the TV activity when cooking and diner come, showing some competition between these activities.

Overall the active occupancy period looks much more squeezed in France. While people go to bed at the same time as in Great Britain (from 10PM, with no consideration of the difference regarding sun time), they start leaving work from 5:30PM versus 4PM. As a result the three main activities of the evening are chained in a much shorter period. During the same period, British people tend to go out later, many of them (30%) finally finding their way back between 10:00 and midnight, when 80% of French people were at home at 9:30 producing a high peak of active home occupancy at that time.

In both countries the electric demand peak happens in the first part of the active occupancy period when people are cooking and eating, then the second part is dedicated to watching TV, which comes along with a clear decline in electric consumption. Given the role of lighting in the winter peak, and the dim light required for the practice of watching TV, it could be interesting to dig further that relationship.

In the last part we analyse the variations in cooking times and electricity peak across the former 22 French administrative regions, to assess the role of this activity in the timing of the fixed peak.

A peak set on cooking: regional electric demand and cooking times

In this part we try to confirm there is a relationship between activities in the beginning of the evening and electricity peak demand at a fixed time of the day, all year. For that purpose we need groups of people with varying activity times and measured electric loads. French regions can be both identified in the national time use survey, and in the data produced by the French electricity transport operator RTE.

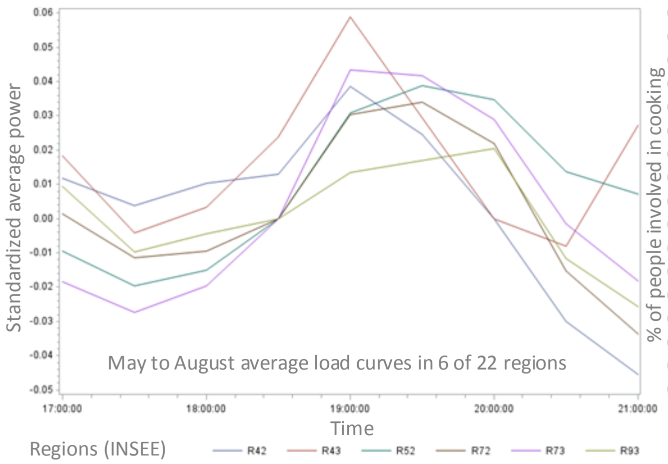

Fig 5: Standardized regional load curves

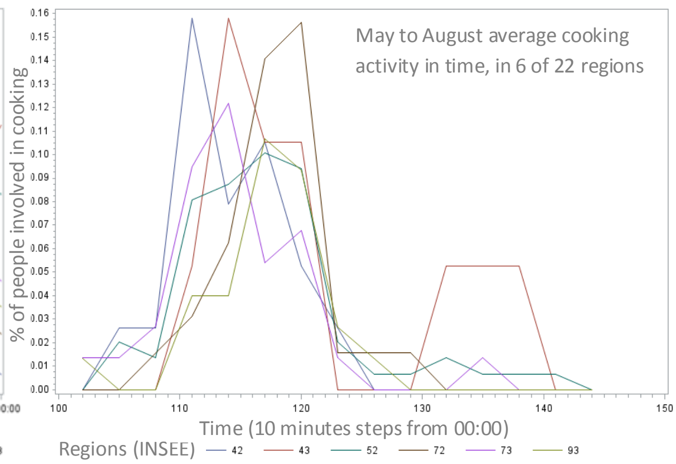

Fig 6: % of people involved in cooking by region

Electric power demand is first centred and normalised by region to avoid any global size effect. The granularity of the electric data being one power value every 30 minutes, it's difficult to catch the exact time of the peak and catch small variations between regions (Figure 5). To make the comparison possible, we consider the shape of the peak. For this purpose we measure if it's skewed toward earlier or later times. More specifically we compute the mean time of the peak weighted by the power from one hour before and after the peak. The same measurement is applied to the activities declared in the diaries (Figure 6).

However we don't want the measure to catch differences in sunset time between regions, for that reason the peak is analysed from May to August, when it's marked enough, and does not interfere with the lighting peak (figure 1). This way we ensure to catch the fixed peak.

Then we test the statistical significance of the correlations between these activity times and electric demand across regions (table 1).

	Cooking	Eating	TV	Active Occupancy
Correlation	0,50	0,34	0,19	0,02
p-value	0,0208*	0,1349	0,4213	0,9179

Tab 1: Peak time correlations with activities by region

From these results we see that the regions cooking earlier have an earlier electric peak demand. This relation can be observed on figure 7 in which each dot stands for a region. This doesn't necessarily means that this peak is the direct consumption of cooking, but at least cooking time is a good marker of different practices and activity patterns that result into different consumptions. Also, taking the cooking electrification rate by region (which does vary) in account in the modelling of the peak time and amplitude does not show any significant link.

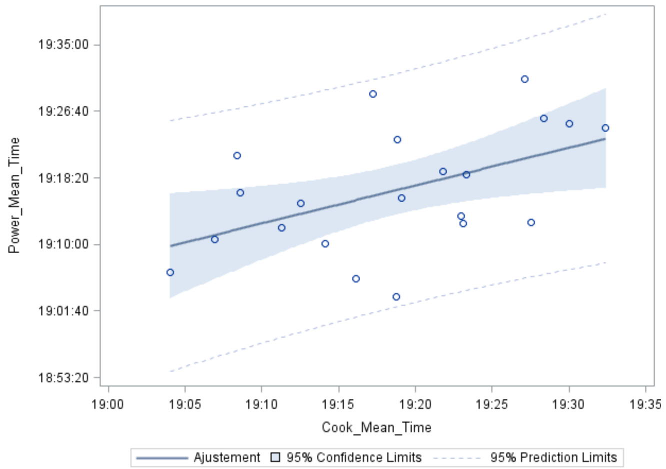

Fig 7: Cooking time by region vs. Peak time by region

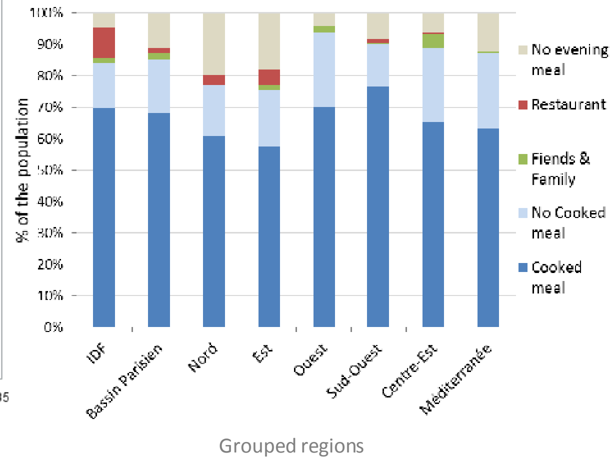

Fig 8: Diner types by grouped regions

The earliest regions on the left are Alsace and Loraine, in the East of France. On the opposite side, the latest regions are Île-de-France (Paris area), Languedoc Roussillon (Mediterranee), Aquitaine (South West) and Poitou Charentes (West). Later cooking in the South and West seems partly related to geographical situations, and again sun times. However this relation is not direct but mediated by cultural differences. This explains the link is not systematic. In addition to the time of cooking, these cultural variations are also associated with different types of evening meals, with or without cooking, at home or outside, as shown on Figure 8. In particular, in the East (Est) a large part of the population is not declaring any cooked meal in the evening which can be linked to the light and cold meals taken in this part of France, closer to the Germanic culture (Hauser, 2012). Some of the diner practices are linked to the urban and socio-demographic structures of the territory. This is the case for the frequent diners at restaurant in Île-de-France (IDF), where urban density and incomes are the highest.

Conclusion

A first description of daily activities and electric consumption patterns in France and Great Britain points at a number of similarities both in the succession of cooking eating and television between work and sleep, and in the consumption peak rising in the beginning of the active home occupancy period. The electric peak translates the overlapping of the night coming earlier in winter and a peak of activity requiring light at a fixed time all year round, marking some sort of social synchronisation.

The analysis of these daily dynamics also reveal differences between the two countries, that translate more specific interactions between people individual activities and various institutions or norms. It seems time is much more structured in France, where time slots are dedicated to specific activities. This is the case for meals, with a very high level of organised synchronisation for the lunch break in the middle of the work period, and another peak for the evening meal. This is also true for television, which is centrally synchronised by the national news at 1:00PM and 8:00PM. In this country, time for machines is also remotely controlled and centrally automated as the hot water tank electric peak shows between 10:30 and 11:00PM. Comparatively, activities in Great Britain are more spread, and changes are smoother. The global timing is also very different with a much shorter evening in France, leaving work later, but more people going out in Great Britain.

Some differences still exist within each county. Differences in domestic activities and electric demand across France were compared to identify the links between activities and consumption time patterns. Lighting needs alone do not explain the peak. Active home occupancy does not correlate with electric demand. The time of cooking is correlated with when the electric peak occurs, showing how distinct practices, as part of local cultures or permitted by specific infrastructures, involve different shapes of energy demand. This way, we successfully managed to make a link between what final consumers do and the related energy consumption at a regional aggregated level. Interestingly, this link distinguishes between shared and synchronised ways of doing, a common cooking time, rather than independent individual behaviours. In that sense, we compared the energy implications of distinct practices and not those of individual performances.

Looking back at the intervention aiming at the mitigation of peak demand, this study clarifies how this phenomenon is framed by contingent environmental factor and shared norms and practices, limiting a lot the effect of individual actions compared to social transformations.

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