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ORIGINAL ARTICLE

Time-shifting laundry practices in a smart grid perspective: a cross-cultural analysis of Pakistani and Danish middle-class households

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Abstract Future smart infrastructure development, in both developing and developed countries, is hinged on demand management and response strategies with consumers actively involved in time-shifting electricity consumption for improved efficiency. This paper presents a qualitative, interview-based, comparative study of how homeowners adapt their practices to the changing systems of electricity provision in two countries, Pakistan and Denmark. It reveals that household practices like laundering are flexible, highly contextualised and embedded in the wider socio-material and cultural context. In Denmark, time-shifting of laundering in households with photovoltaics is done voluntarily and closely interwoven with the temporal rhythms of the common dual-income household, as well as the natural cycles of the sun and weather, and is in most cases based on some degree of automation. In Pakistan, blackout schedules dictate time-shifting of most practices. Large family sizes and nuanced clothing make laundering more complex, socially bound and time-consuming; however, joint family systems, provision of house-staff and outsourcing make it more time-flexible and less dependent on automation and electricity-use. Using theories on temporalities of practices in a cross-cultural analysis highlights the significance of local socio-material and cultural context in the performance, bundling and synchronisation of practices. While practice theories prove useful in cross-cultural comparison of temporalities of household practices and demand, further theory development is needed to conceptualise practices as shared or socially differentiated entities in varying cultural contexts. This has implications for demand management policies proposed in smart-grid transitions as well as in the possible cross-cultural transfer of smart technology and demand response strategies.

Keywords Smart infrastructure · Developing countries · Developed countries · Time-shifting · Electricity consumption · Household practices

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Introduction

Demand side management is at the core of climate change mitigation and realisation of future energy targets. The globally converging and growing energy demand, significant shift towards intermittent and distributed renewable generation and the imminent integration of 'smart' systems have highlighted the need for demand management and effective demand response (Torriti et al. 2010; Walker 2014).

Massive investments in advanced metering infrastructures (AMI) as part of the future smart grid have become evident globally in the last decennium (Darby 2010; Buchanan et al. 2015). Such infrastructure development plans, in both developed and developing

countries, are based on the changing perception of energy supply and demand, with reliance on end-users as more active participants in demand management through time-shifting of their electricity loads or even as 'prosumers' (Ellsworth-Krebs and Reid 2016), that is households that produce as well as consume energy. Such infrastructure developments are part of future policies in both Denmark, a country which is at the forefront of 'smart' projects and Pakistan, a developing country that faces increasing gaps between its energy supply and demand.

However, the 'smart ontology' mainly constitutes demand policies that mediate transitions through rational individual choice based on information exchange and technological upgrades (Strengers 2013). These policies fail to capture the user's flexibility and limitations in making such transitions. Hence, a socio-technical approach in transitioning to a 'smart' energy provision system necessitates the consideration of the energy system not only as defining and shaping everyday routines and practices of households, but also in turn being shaped by these very practices (Shove et al. 2009; Shove and Walker 2014).

While understanding the flexibility of energy use in relation to household practices has formed the basis of empirical work in single case-studies (Strengers 2012, 2013; Powells et al. 2014; Higginson et al. 2014; Nicholls and Strengers 2015; Friis and Christensen 2016), comparative studies that analyse cross-cultural diversities in energy consumption and everyday practices like those of eating (Durand-Daubin and Anderson 2018), refrigerating/freezing (Rinkinen et al. 2017), reading (Southerton et al. 2012), comfort (Hansen et al. 2016; Heidenstrøm et al. 2013) and energy retrofitting (Bartiaux et al. 2014) are limited. Further still, comparative studies between countries in the West and East or in the Global North and South are almost non-existent. Among the few exceptions is Wilhite et al.'s (1996) cross-cultural study of Japan and Norway which juxtaposed similar material culture profiles in differing cultural contexts and exemplified how certain household practices are more firmly bound by local traditions and conventions than others. Cultural diversity in bathing practices in the Netherlands, India and Japan has been the focus of Matsuhashi et al. (2009). Through the comparison of significantly different cultural practices, they highlight how exploring cultural diversity and variety in practices can inspire less resource-intensive solutions.

In the globally recognised aspirations for shift towards the smart grid, one key challenge is that while the same technology can be employed in smart infrastructure worldwide, its processing and operation cannot be assumed to be similar due to the 'social and cultural properties of infrastructures-in-use' (Shove et al. 2015, p. 279). Infrastructure as materiality co-constitutes specific practice formations in specific socio-material contexts. Based on historically contingent norms and standards, it is also generally designed to be relatively resilient (often developed for long-term) and so prefigures socio-material arrangements and temporalities of demand and shapes patterns of future energy transitions (Shove et al. 2015; Spurling 2018). A cross-cultural analysis can not only provide context-sensitive insights into the socio-culturally embedded nature of technology and infrastructure, but also help determine users' flexibility and consequently form policies for such smart developments to effectively produce sustainable transitions.

Research presented in this paper thus focuses on a comparative study of how homeowners adapt the temporalities of their practices to the changing systems of electricity provision in two countries, Pakistan and Denmark. Denmark's policy goal for shifting to 100% renewable resources by 2050 includes, among other things, establishing a smart grid, including rollout of smart meters that facilitate remote automated metering, and demand management policies for high percentages of intermittent wind power (Danish Government 2011, 2013). In Pakistan, contractual agreements for 'smart' meter rollout throughout the country are currently underway as a means to reduce fraud and distribution losses and improve accuracy in billing (Aslam et al. 2015). Net metering has recently been approved to encourage private investment in renewable microgeneration.[1] Currently, the common form of demand management undertaken in Pakistan is electricity load-shedding, where power is shut down intermittently for 4–8 h daily in urban areas.

Although these two countries have very different economic, climatic, geographic, socio-cultural and housing contexts, both have policy objectives of transitioning to some form of smart grid with promotion of microgeneration integration, which makes the

[1] See Irfan et al. (2017) for detailed review of opportunities and challenges of smart grid development and IRENA (2018) for renewable energy assessment of Pakistan.

comparison interesting. Comparing similar household practices in such diverse contexts provide greater insights into improved demand management and response strategies in each of the two countries, as well as more generally.

This paper aims to present an in-depth comparative analysis of laundry practices in middle-class households in Pakistan and Denmark to explore the relationship between practice temporalities, culture and consumption. It responds to Anderson's (2016) call for a comparative analysis of laundry practices across different climates and cultures for demand flexibility and builds on Mylan and Southerton's (2017) arguments of domestic laundering as a good example of the social ordering of practices at micro-macro levels. As a resource intensive practice (Chaudhry 2010; Gram-Hanssen 2014) that is considered to be flexible (Higginson et al. 2014; Powells et al. 2014), laundering also provides a good example for understanding time-shifting for improved demand response in a smart-grid transition.

Thus, through a cross-cultural analysis, the study seeks to examine the extent to which temporalities of practices are defined by the given socio-material and cultural context and what this means for smart infrastructure development. Based on the empirical work, the study also aims to determine the usefulness of theories of practices and temporalities in analysing time-shifting of practices in the context of different countries. It further examines how a practice-based approach can inform the possible transfer of smart infrastructure technology and demand response strategies from one culture to another. This discussion will then help formulate policy implications.

The theoretical framework that forms the basis of our comparative analysis is presented in Section 2, followed by the method adopted in Section 3. Findings of the analysis are presented in Section 4 with discussion in Section 5 and conclusions in Section 6.

Dynamics of household practices and energy demand

The sociology of consumption took a 'practice turn' (Schatzki et al. 2001) in contemporary social theory, shifting focus from the 'symbolic' to the 'routine' and 'habitual' character of consumption (e.g. Gronow and Warde 2001). Practices came to be understood as the 'temporally unfolding and spatially dispersed nexus of doings and sayings' (Schatzki 1996, p. 89) and that consumption takes place as 'a moment in almost every practice' (Warde 2005, p. 137). When practices take centre-stage, societal transition and change in consumption can be understood as the evolution of practices and their inherent links that are taking place within society (Schatzki et al. 2001; Warde 2005; Shove et al. 2012). The various interlinked and interconnected 'bundles' of loosely knit practices or 'complexes' of more tightly integrated and interdependent practices (Shove et al. 2012) compete for both time and resources. In this sense, the temporal rhythms of practices—the frequency, duration, sequencing and scheduling of daily routines—shape the temporal patterns of energy use in the household and on the aggregated, societal level (Shove et al. 2009).

According to Southerton (2009, 2012), temporalities of practices are highly influenced by culturally derived dispositions; that is, 'shared orientations towards the performance of practices' (Southerton 2012, p. 341). The term culture may in some understandings of theories of practices be in conflict with a practice-theoretical framework; however, in the present study, culture does not represent 'symbolic display, communication and presentation of self' (Warde 2014, p. 287).[2] Rather, it denotes the specific temporally, historically and regionally contingent socio-material settings shared by practice performances in a given context. Practice performances are shaped by tacit knowledge and embodied skills as well as sequences of activities guided by institutional and material scripts (Southerton 2012) and cultural constructs (Jack 2013). According to Warde (2013), rules and procedures configure cultural understandings of practices, which are produced and consolidated in cultural contexts. In analysing the global dissemination of social practices in different countries, cultures and communities, Shove and Pantzar (2005) contend that practices and associated cultures of consumption are always 'homegrown' (p. 62). Even though the transfer of certain technologies (or even knowledge and/or engagements) in the globalised world of today is inevitable, the emergence and evolution of practices is necessarily localised, in which cultural history plays an important part (Shove and Pantzar 2005).

Mylan and Southerton (2017) highlight a number of social mechanisms that order the performance of

[2] See Warde (2014) for detailed description of cultural analysis and its comparison with practice theory.

laundry practices at the personal, household and societal level, including social relations within the households (e.g. gender divisions of domestic labour) and cultural conventions that act as cultural ideals for laundering (e.g. softness and smell of freshly laundered clothes and convenience). Materiality is another social mechanism identified by Mylan and Southerton, but that has been elaborated further and in more detail by Spurling (2018), who focuses on the material dependencies of temporalities; accordingly, technologies and infrastructures are partially responsible for setting the temporal patterns of energy consumption by co-constituting the sequence, duration, frequency, and temporal location of various practices. Combining these two approaches, this paper focuses on understanding the role of socio-material settings in time-shifting of household practices.

Southerton (2003) provides insight into the temporality of everyday life, and how this orchestrates the timing of daily practices, with the concepts of 'hot spots' and 'cold spots'. These are essential components for time management of practice performances within allocated personal and collective rhythms that configure practices, such as institutional and seasonal timings (Southerton 2012). 'Hot spots' are the predictable periods of the day densely packed with activities that typically precede institutionally timed events, such as work, school or meal times. Such hot spots lie between loosely formed time periods, referred to as 'cold spots' that are perceived as 'quality time' and 'bonding time', filled with 'meaningful' (p. 19) social activities.

Walker (2014) contends that the rhythms of routine, energy-consuming activities, when combined and scaled up, form the resonant load profiles of grid infrastructures. Closely interrelated with these rhythms is the concept of synchronisation, which relates to 'the relationships between rhythms' (Walker 2014, p. 52) of practices. Walker identifies two types of synchronisations: social synchronisation formed by the socially shared rhythms of practices like cooking and eating. Such institutional and societal patterns of synchronisation become significant during peak demands. Walker notes that socially shared rhythms may have stronger or weaker bonds and vary in character between societies and cultures—a point of significance in the present comparative analysis. The second type of synchronisation is natural-social synchronisation formed by the linking of natural rhythms of especially the solar daylight hours to the social rhythms of practices, e.g. in sleeping.

Walker (2014) highlights the emergence of a second form of natural-social synchronisation brought about by the increasing focus on intermittent renewable energy into the energy supply mix. The changing systems of electricity provision thus provide an opportunity for investigating the flexibility of practices and, consequently, the shifting and shedding capacity of demand brought about by the 'un-braiding and re-braiding' (Trentmann 2009) of everyday practice rhythms. This then opens a discussion for improved demand management policies in the respective socio-material contexts.

Method

This study focuses on a comparative analysis of two significantly different socio-material contexts in order to explore their relationship with the temporalities of practices for demand response in future smart development. The research was undertaken with the assumption that comparing similar practices in considerably different socio-material contexts provides greater insights into the socio-culturally embedded nature of practice temporalities.

As such, a comparison of household practices in empirical case-studies from Pakistan and Denmark provided a viable option; both countries have national objectives for smart-grid transitions with changing electricity provision systems but differ considerably in their existing socio-cultural context and material infrastructure. The empirical case-studies of household practices and energy demand for the two countries were conducted separately and form part of earlier published work (Friis and Christensen 2016; Khalid and Sunikka-Blank 2017). The Pakistan study formed part of an on-going PhD research at the University of Cambridge, UK, whereas the Danish study formed part of a household smart grid study at Aalborg University in Denmark. The original empirical research was not designed with the objective of a cross-cultural comparison, but the two available datasets presented an excellent opportunity to compare time-shifting adaptability of household laundry practices under changing systems of electricity provision; the Danish households with microgeneration as a new form of energy provision and the Pakistani households with varying modes of electricity generation in an uncertain intermittent supply system. In both the Pakistani and Danish study, the empirical material focused on time-shifting and household energy consumption

more broadly. This empirical data was revisited and re-analysed for the purpose of this study with a view to compare and contrast time-shifting of practices. Consequently, this paper focuses on detailed comparison of laundry practices.

The Pakistani study consisted of ten middle-income households in Lahore. Ownership of urban housing stock in Pakistan is concentrated in the middle- and upper-income bracket and constitutes majority of the urban domestic energy demand (Ghani 2014). The interviewed houses in Lahore were detached, two-storey masonry structures with provision for house-staff, usually accommodating single or joint families (multi-generational family system is common in the culture). Houses were selected through strategic sampling on basis of variation in multiple means of electricity provision, including UPS (Uninterrupted Power Supply) systems, gas, diesel or petrol-run power generators and solar photovoltaics (PVs) in addition to utility power. Variation was also ensured in the type of family structure (single or joint family system), occupancy and education; all considered important sociodemographic factors that influence energy consumption. Data was collected through ten in-depth semi-structured interviews, with 21 interviewees, followed by walk-through house tours. Of these, six were joint family households with several generations living together (Table 1). Interviews were conducted in July–August 2016, which lasted for approx. 60–100 min. All interviews were recorded, translated from Urdu to English, transcribed, coded and analysed using NVivo.

From Denmark, 13 semi-structured interviews, with 20 interviewees, were conducted in middle-income households in two rural areas of Denmark. All households had PV installation in combination with either heat pump, an electric vehicle or localised storage batteries. Households were selected with the aim of maximising the diversity regarding household size, age and occupation.[3]

[3] Household selection was made in agreement with the two research partners (an electricity company and a public-private partnership working for decarbonising the local area) in two different areas: 31 houses took part in an EU-funded trial located on an island which tested a variety of smart-grid technologies in households. Of these, nine were selected for study, in which some combination of PVs with either storage battery or heat pump was found. Of the total 13 households that form part of this study, the remaining four (no. 10–14 in Table 2) were from another rural area, recruited on basis of PVs installed in combination with an EV.

The interviewed households in Denmark were primarily detached single-storey homes with single families, consistent with common family and housing structures in Denmark. Most households ended up being middle-class, dual-income families (only one family having parents younger than 30 years, as seen in Table 2), which reflects a demographic-based preference for investment in PVs. The interviews typically lasted for approx. 60 min and were conducted in Autumn 2016. All interviews were recorded, transcribed and later coded in NVivo.

Owing to the diverse nature of background variables and multifarious characteristics among the two datasets, a straight-forward comparison would necessitate a reductionist approach. The qualitative sample of each country, however, presents a rich account of practice performances within the specific context of middle-class families in rural Denmark and urban Lahore respectively. Furthermore, the close association of the authors with the respective culture ensured that the overarching sociocultural, political, economic and material frameworks were well understood, which formed the background for detailed empirical practice-based inquiry. Qualitative interviews are not meant for representative accounts of the studied subject, but provide rich and detailed descriptions of general value (Flyvbjerg 2006; Kvale 1996). Thus, the objective was to highlight the contextual significance of time-shifting everyday practices, for which even single examples that show variation would suffice.

Findings

The results of the analysis are presented, first, in terms of a general overview of the wide variations in the degree and extent to which homeowners adapt their daily routines to the changing electricity provision systems in the two contexts. This is then followed by a detailed comparative analysis of time-shifting of laundry practices.

A tale of two countries: general overview of electricity consumption

The primary reason for shifting and/or shedding of electricity consumption in Pakistan is the planned intermittent electricity supply system which results in daily power outages of 4–8 h. Rearrangements in energy-use practices to accommodate the shifting magnitude and

Table 1 Household and interview participant demographics from Pakistan

Interview label	Interview participants (pseudonyms)	Household composition	Age of interviewees (years)	Occupation	Electricity provision system
A	Mr. Asim Mrs. Asim	2 grandparents + 3 adult children + 2 grandchildren	60+ 51–60	Self-employed/businessman Housewife	Utility + Generator
	Arif		20–30	Mechanical Engr.	
B	Mrs. Bashir Bisma	2 adults +, 3 children	41–50 20–30	Housewife Student	Utility + UPS
C	Cyrus Mrs. Chishti	2 adults +, 2 children +, 1 house-servant	31–40 51–60	Unemployed Housewife	Utility + UPS
	Cemaal		20–30	Student	
D	Mrs. Dawood Duriya	3 grandparents + 3 adult children +2 grandchildren	51–60 51–60	Housewife Housewife	Utility + UPS
	Dua		31–40	Housewife	
E	Mrs. Ejaz	1 great- grandparent +, 2 grandparents +, 3 adult children +, 2 grandchildren +, 3 house-staff	51–60	Housewife	Utility + UPS
F	Mrs. Furqan Fareed	2 grandparents + 2 adult children +, 2 grandchildren +, 2 house-servants	51–60 31–40	Charity worker Self-employed/businessman	Utility + PV + generator
G	Mrs. Gulzar	2 adults +, 2 children +, 1 chauffer	31–40	Housewife	Utility + generator
H	Mr. Harris Mrs. Harris	2 adults +, 3 children + 1 house-maid	51–60 51–60	Agriculturist Small local business	Utility + PV + generator
I	Mrs. Imran Izza	2 grandparents +, 3 adult children +1 grandchild +, 3 house-staff	51–60 20–30	Housewife Housewife	Utility + generator
J	Mrs. Jamal Jamila	2 grandparents + 6 adult children +, 2 grandchildren + 1 house-maid	51–60 20–30	Housewife Student	Utility + PV + generator

frequency of load-shedding schedules are common. Rinkinen (2013) highlights two types of rearrangements in practices during disruptions in energy provision; an orientation to embrace disruptions and one of seeking continuation for 'normality'. In the Pakistani dataset, both these rearrangements are seen to occur simultaneously prompted by the long-term inconsistent power supply.

Although dependency on an intermittent supply has made homeowners more flexible in their practice performances by shifting and shedding of electricity loads, it has, however, led to the emergence of a new material culture in households, that of seeking continuation and stability in practices. This is evident in the plethora of power back-up systems, such as UPS (uninterrupted power supply) battery systems (which are highly inefficient and not subjected to any market regulations); diesel, petrol or gas-powered generators and, more recently, in the installation of PVs. While such equipment makes energy more 'material' and its use more 'tangible' to homeowners (Strengers 2012), it is also associated with convenience, a way of overriding the dependency and added complexity of time-shifting practices under the inconsistent power supply. The current energy regime not only dictates the temporal arrangement of practices in the interviewed households, but also at the wider community level; e.g. in determining when neighbours and friends can be visited and when grocery shopping can be done, depending on load-shedding schedules.

Contrary to the Pakistani sample, the interest in energy demand management and time shifting among Danish utilities and energy planners originates from growing shares of intermittent renewable energy production, specifically wind power, which now represents approx. 40% of the total Danish electricity consumption

Table 2 Household and Interview participant demographics from Denmark

Interview label	Interview participants (pseudonyms)	Household composition	Age of interviewees (years)	Occupation	Electricity provision system
1	Mr. Danielsen	2 adults +1 child	approx. 50	Blacksmith	PV
2	Mr. and Mrs. Larsen	2 adults +2 children	41–50	Electrician and secretary	PV + battery
3	Mrs. and Mr. Petersen	2 adults	61–70	Health care assistant and retired workman	PV + battery
4	Mr. and Mrs. Hansen	2 adults +2 children	51–60	Storehouse clerk and residential social worker	PV + battery
5	Mr. Beck	2 adults	approx. 60	Local director	PV + heat pump
6	Mr. Frederiksen	2 adult +1 child	approx. 60	Production manager	PV + heat pump
7	Mr. Thomsen	2 adults	approx. 70	Inseminator	PV + heat pump
8	Mr. and Mrs. Svendsen	2 adults +1 child	21–30	Haulage contractor and sales assistant	PV + heat pump
9	Mr. Olsen	1 adult	81–90	Retired technical director	PV + heat pump
10	Mr. and Mrs. Johansen	2 adults	71–80	Retired general labourer and head teacher	PV + EV + heat pump
11	Mr. and Mrs. Bertelsen	2 adults	61–70	Both retired school teachers	PV + EV + heat pump
12	Bjarne and Susanne Andersen	2 adults +2 children	41–50	Both professionals (project manager and planner)	PV + EV + heat pump
13	Mr. and Mrs. Brodersen	2 adults	51–60	Doctor and nurse	PV + EV + heat pump

(Danish Energy Agency 2017). This creates challenges of balancing electricity demand and supply due to the lack of synchronicity between production and consumption.

Up until 2012, Denmark witnessed a rapid growth in households installing PVs due to a favourable Danish tax regulation, which made it economically attractive to install PVs. This changed in 2012 with an hourly net metering scheme replacing annual net metering. Ten of the interviewed Danish households are on the hourly net metering scheme, and eight of these reported time-shifting some of their electricity-use practices to daylight hours to maximise use of self-produced electricity, thus providing an economic incentive for synchronising electricity consumption with PV production. However, in contrast to Pakistani households interviewed, the shifting of electricity-consuming practices is done on a voluntary basis, which has consequences for its penetration in practices as well as in society. This also means that time-shifting in Danish households is conditioned; several interviewees explained that if friends and family are visiting, dishwashing is not time-shifted.

In the Pakistani interviews, time-shifting was predominantly observed in practices related to comfort (ventilation and space heating/cooling), lighting and laundering (washing and ironing). In the Danish interviews, time shifting was especially brought up by interviewees in relation to practices of dishwashing and laundering. The following analysis will focus on and compare issues of time shifting laundering in the two contexts.

Time-shifting laundry practice in Pakistan

The intermittent electricity provision system was cited as the major reason for time-shifting of laundering practices by homeowners, who planned their daily routines and household chores around the power outage schedules;

> We had to schedule when to do the laundry according to power outage times. We think about every part of our routine based on when the light (meaning electricity) will be out and when it will come back. We have to manage our entire day according to it. Everyone has done that. (Interview A)

For homeowners who can afford to have microgeneration through PVs, time-shifting was not a priority. In fact, a major reason for PV installation was convenience of having 24-h electricity, comfort of

cooling and non-reliance on electricity load-shedding schedules for performing practices;

> Primary decision was definitely to get non-stop energy. We were getting 8-10 hours of load-shedding. 2.5 years back we installed them. My father and I am at work most of the day, but those at home had to face a lot of problems. Without energy, there is no life. Life just comes to a stand-still. Everyone has to wait for the electricity to come back- be it washing, cleaning, water coolers, even ironing... (Interview F)

Laundering in the Pakistani middle-class households interviewed is a complex practice, involving multifarious resources. In all ten interview households, along with the use of washing machines on a daily to fortnightly basis, hand washing was common, particularly for delicate fabrics or children's clothing. In addition, in five of the ten households, washing and/or ironing of larger items and gent's clothing was outsourced. This is understandable considering the nuances of materials, colours, quality and textures of fabrics, each with its unique washing requirements that make up the laundry in large middle-class families in Pakistani households, as indicated by Mrs. Gulzar:

> All the gents' clothes, towels and bedsheets go to the *dhobi* (outsourced to washermen). The children's and my clothes are washed at home … sometimes by hand, and sometimes by machine. The machine is used once weekly. It's manual. Normally clothes are washed by hand by the servant, usually in the morning around 11am. I operate the machine myself, overseeing the washing by the maid. In the machine, I wash daily routine clothes, the everyday things. But special or formal clothes are washed by hand. (Interview G)

Outsourcing or hand-washing by house-staff point to the social dynamics at play in laundering and highlight that there is no need for time-shifting activities that do not rely on household electricity. When compared with the Danish interviews, a key point of distinction was that ironing formed a substantial part of the laundering process in all Pakistani households interviewed. Unlike washing, which is generally assigned to a specific morning time-slot in most households, ironing was found to be more spread out. Three homeowners explicitly mentioned not using the iron in the evenings during peak hours to avoid higher electricity costs, while for the remaining households, timings for ironing very much depended on availability of house-staff or on a needs basis. Mrs. Gulzar:

> Ironing is done daily. These days it is used twice a day. All the clothes that are washed at home must be pressed. Once in the morning, around 10am, as per the amount of clothes. Then in the evening as well, around 5-6pm. It's done twice because of the heat, we generally have to change clothes twice daily, once in the morning and then once in the evening. In winters, its used only once, in the morning. (Interview G)

The wider cultural rhythms of society have a significant impact on the temporalities of everyday practices. A good example of this was provided by Mrs. Asim, who specifically avoids doing the laundry on Fridays, the day of congregational worship in Islam;

> Mrs. Asim: "I typically do the laundry daily, except for Fridays. We have a big family, so once daily is compulsory. On Fridays, I normally try not to use it."
> Interviewer: "Why is that so?"
> Mrs. Asim: "Because of the water issue. Everyone has to use water in the washrooms (because of Friday prayers) so I don't want there to be shortage. Also, all the attention is mostly concentrated on that. Even my cooking on Fridays starts after 3pm." (Interview A)

These examples show that laundering is a very complex and time-consuming process driven by social conventions of propriety and collective rhythms (Southerton 2012; Mylan and Southerton 2017) such as those of religious obligations, giving rise to social synchronisation (Walker 2014). In this sense, laundering is not so much a 'personal' practice based on individual rhythms but becomes more of a social practice even in its very performance; through integrating various stakeholders, maintaining specific social standards and pertaining to social rhythms.

In addition to the wider socio-cultural context, daily routines, practices and management of household chores in the interviewed households in Pakistan were also found to be dependent on the type of family structures, roles and responsibilities of the various household members and the provision of house-staff. All these factors determine when and where laundering takes place in the household;

> You can take it as … look … our electricity goes at 11:15am till 12:15pm, so we try to start it at around 12:30pm. It is definitely done in the morning because my maid comes around 11:45am, so we start the washing around 12:30. (Interview H)

The interviews indicated that the availability of house-staff played an important role in the temporalities of homeowners' practices. This has also been highlighted by Pfau-Effinger (2010), who compares the variations in arrangements of work and family life of southern European societies with their persisting tradition of a 'servant culture', with those of Scandinavian countries, where employed house-staff is frowned upon. Moreover, the availability of house-staff not only determines the temporal arrangement of practices in the interviewed households, but also influences the selection and use of appliances. Four of the ten interviewed households did their laundry using older, inefficient, semi-automatic washing machines and had no intentions of replacing them with newer, more energy efficient models as housemaids were responsible for laundering;

> My machine is semi-automatic. That's why throughout, the maid I have is the one who is responsible for doing the washing … It is extremely old … very old. Almost every other day we have this discussion that it needs to be changed, it needs to be changed, but then I say that as long as it is in the hands of the housemaid … my friends tell me to discard it and be rid of the housemaid and to buy my own automatic machine … for one thing, I don't want to fire the housemaid, because she has been working here for a very long time. She proclaims that if you deduct my chores, I will leave you. I want to keep on doing these chores … as it helps increase her salary. That is why I don't buy an automatic …. (Interview H)

Since practices are dependent on such household dynamics, the availability of house-staff and the family structuring ensure temporal flexibility of practices, diffusing hot spots (Southerton 2003) in time and space.

However, due to constraints of load-shedding schedules and time management required for the successful completion of chores, homeowners often talked about the sequencing and synchronisation required for performing practices. Four of the ten households specifically mentioned wanting a place for their washing machine in close proximity to their kitchen, as they preferred undertaking both practices simultaneously. Since in most cases, laundering was delegated to housemaids, it became easier for housewives to do the cooking while supervising the laundering;

> …. we selected the design for this house given the ideals and priorities of the time … I remember wanting the laundry area to be made adjacent to the kitchen. So that my washing and ironing area is right next door but separate. (Interview H)

Thus, temporal and spatial conditioning of practices gives rise to unexpected 'coupling constraints' (Ropke and Christensen 2013, p. 54), which are then overcome by bundling (Shove et al. 2012) otherwise unrelated practices.

One critical trend that was observed in the Pakistani middle-class households interviewed was the gendered performance of practices that are time-shifted. Predominantly in the interviewed households, laundering, ironing and cleaning practices were performed by females, whereas the selection and purchase of household appliances and control of thermostat settings (e.g. in refrigerators and air-conditioners) were male-dominated practices;

> Mr. Fareed: " … my father and I, we are out most of the day, so everything in the house is being managed by the ladies of the house. We only come into play where some facilitation is required … In most cases, if an equipment (must be bought) or energy decision must be made, it comes from us, but what is required, comes from them … These are the decisions that we make … if they want a TV in their room, they would tell us that they want a TV, and we have to give it to them." (Interview F)

Hence, although men were seen to have more technical know-how, females were responsible for most of the time-shifting of practices to avoid 'peaky' (Strengers 2012) evening electricity use such as in managing laundering and ironing practices.

Time-shifting laundry practice in Denmark

Among the various practices analysed in the Danish sample, it was found that laundering and dishwashing were being time-shifted by most households;

> We also become more conscious about it, at the time we got the solar cells (PVs) … to consume power when we produced it ourselves … So, washing (laundering) and dishwashing, it was when the sun was shining …. (Interview 5)

Asked about the reasons for time-shifting electricity consuming practices, most interviewees refer to the economic benefit of being on the hourly net metering scheme; meaning that the PV power should ideally be consumed within the same hour it is produced. In addition, some homeowners liked the idea of using their 'own' electricity, which relates to notions of being independent and self-reliant with energy;

> Yes but, it is this mixture … It is about economy, but also this satisfaction with saying … What we are doing now, it's something we have produced our own power for … and what's weighting most, I don't really know …. (Interview 5)

Moreover, a few interviewees referred to environmental reasons like saving the environment or contributing to the "green wave" (Interview 6), that is, the transition of the energy system away from fossil fuels. However, environmental concerns seem much less prevalent compared to the attractiveness of using one's own energy, being self-reliant and (in particular) saving money.

In explaining why they chose to time-shift dishwashing and laundering specifically, several of the households taking part in the EU-funded trial referred to this being recommended by the project owners at a common information meeting at the start of the trial. This indicates that the trial setting also played a role in the participants' active engagement in time-shifting practices.

The time-shifting of electricity-use practices was closely interwoven with and dependent on the temporal rhythms of family life and household composition. In this regard, differences in time-shifting were found in households constrained by collective and institutional rhythms of school or work as opposed to those that were not. Predominantly, for those households where one or both (if a couple) adults were staying at home regularly during the daylight hours, e.g. due to retirement or one of the adults having night-shift work, the washing machine was started manually during the day. Mr. Thomsen, who is retired and typically stays at home during daytime hours provided one such example:

> Interviewer: "Okay, so … both washing machine and dishwasher are running during the daytime?"
> Mr. Thomsen: "Yes, that's the general rule."
> Interviewer: "Do you have a timer that you use?"
> Mr. Thomsen: "No, we are starting it (manually)"
> Interviewer: "It's because you are at home that you can do that?"
> Mr. Thomsen: "Yes, exactly." (Interview 7)

However, for those interviewed households in which the adult(s) are away from home during daylight hours (typically because of work), the washing machine is generally either started in the morning (before they leave for work) or timers are set so that it starts in the middle of the day. Clothes are dried by hanging or using the dryer in the evening, once the homeowner's return;

> Then (name of wife) leaves in the morning, so she can say (decide) … it (the washing machine) should start in 6 hours … or eight or 12 hours …. (Interview 5)

The interviews show that for dual-income households with daytime jobs, the time-shifting of laundering is highly dependent on automation and on the machines' capacity to run a full washing cycle independent of intervention (see also Friis and Christensen 2016 for similar observations related to households' time-shifting energy consumption according to a static time-of-use trial). The use of timing devices for time-shifting practices has been found in other studies in the Global North (e.g. Mylan and Southerton 2017). In the Danish households interviewed, with only one exception, no specific reference to ironing being time-shifted was made. This is not surprising, as the type of clothing culture prevalent does not require much ironing.

A point of significance highlighted during the interviews was how homeowners sometimes time-shifted (or postponed time-shifting) their laundering practices in relation to the weather forecast. By looking at the forecast for the next day, homeowners could decide whether enough solar energy would be produced to power the washing machine (or dishwasher);

> If it has been cloudy or rainy weather, then we are not washing that day … As we are only two (persons) in the house, we do not need to run the dishwasher every day … we are trying to make it match with that the sun is shining …. (Interview 5)

These examples highlight how a household of only two members makes it less complicated to postpone laundering compared to households with children. This was also evident in the greater consistency of time-shifting practices in households without children living at home and, in particular, in homes with one or both partners retired from work, which alleviates the constraints of collective institutional rhythms otherwise imposed. The everyday life of households with children living at home are typically more time-pressured and with more distinct hot spots (Southerton 2003) during the day (especially if it is a dual income family). Therefore, the time-shifting flexibility of these households is generally limited, as previously demonstrated by Nicholls and Strengers (2015) and Friis and Christensen (2016).

Another important aspect highlighted in the interviews was how time-shifting of laundering was not only related to concerns of synchronisation with PV power production, but also how sunshine and dry weather were associated with the possibility of hanging clothes outside. Dry and sunny weather was not only good for producing electricity but also for drying clothes. This simultaneity between peaking PV power production and ideal conditions for air-drying clothes was also hinted at by Mrs. Petersen, who explained that they typically postponed laundering if they knew the weather would be good the next day, but that postponing laundering might be as much about good conditions for air-drying as it is about synchronising electricity production and consumption;

> Especially if it is fine weather, the clothes are brought out to be hung … It's probably more the weather I'm thinking about, that it can be dried (outside). (Interview 3)

These examples indicate that the habit of synchronising laundering with sunny weather is not entirely new, and that the introduction of PVs rather strengthens, or 'taps into', an existing habit than introduces a (completely) new routine. These findings also point to the importance of natural-social synchronisation (Walker 2014).

The use of automation for time-shifting laundering was also seen to be dependent on seasonal regimes, as in the interview with the Svendsen couple. As both the household members had daytime jobs, they would shift between starting the washing machine manually in summers and using timers in winters. The difference was determined by the annual sun cycle with the sun rising early in the morning in summers, but later during winters. Since Mr. Svendsen typically got up at 2:30–5:30 am, he would load and start the washing machine before he left for work in summers. His wife, who got up later, would hang the clothes before leaving at 8:30 am. However, during the winters, Mr. Svendsen would set the timer so that the machine started in the middle of the day (when no one was home), and his wife would hang the clothes upon arriving home in the late afternoon.

During weekends, the institutional rhythm of paid work is absent in most families, which could imply a higher degree of flexibility in time-shifting consumption. This was indicated by the Svendsen couple, who mentioned postponing laundering generally to weekends. This also hinted at the gendered role of time-shifting. Mr. Svendsen explained how, on weekends, he typically followed the electricity production of PVs more consistently by reading the display of the inverter frequently, and if there was high electricity production, he suggested that his wife do the laundry:

> Mr. Svendsen: " … I'm just making sure that if we are having some laundry, that it gets started …
> Mrs. Svendsen: "And then it is me who have to get it started (laughing) … "
> Mr. Svendsen: "If she is having something that needs to be ironed, then she might as well do it then … Everything, that use power, it should be when the sun is shining … "
> Interviewer (speaking to Mrs. Svendsen): "Are you doing it, then?"
> Mrs. Svendsen: "Sometimes, yes … (Laughs) Sometimes I just say 'okay, okay, boss' … Or 'okay, okay, darling' … But it is not something I'm devoted to, if I'm going to be honest … " (Interview 8)

This example substantiates a gendering with regard to performance of practices that are time-shifted, with a female dominance as observed in similar studies (Treas and Drobnič 2010; Ellegård and Palm 2011; Torriti et al. 2015; Anderson 2016). Even though male interviewees also regularly took part in doing parts of the laundering, they were typically more engaged in monitoring the energy flows of the home and promoting synchronisation with the PV power production.

Discussion

The cross-cultural analysis of time-shifting everyday practices highlights the significance of developing future smart grid solutions and intelligent transitions with an understanding of the cultural and socio-material context of practices. The study shows that homeowners' practices are influenced by the varying electricity provision systems and, at the same time, highly contextualised and embedded within the wider socio-material and cultural context.

In Denmark, in the dual-income middle-class households interviewed, time-shifting laundering becomes difficult without timers and automation. In households with children, the practice becomes even more tightly bound in hotspots and wider institutional rhythms. While institutional rhythms are found to play a greater role in defining household practices in the Danish interviews, the existing infrastructure with intermittent electricity supply greatly shapes practice temporalities in the Pakistani case. In the Pakistani sample, large family sizes and wider range of clothing materials mean that laundering and ironing is a much more complex, socially bound and time-consuming process. However, the joint family system, provision of house-staff and outsourcing make laundering more flexible. Interestingly, this very system limits the applicability and usefulness of automation for demand management in Pakistan.

In the Danish households interviewed, the use of PV microgeneration for laundering through natural-social synchronisation means that the natural cycles of the sun and weather become an important constraint for homeowners. In the Pakistani interviewed households, laundering is predominantly a daytime activity, but requires flexibility and increased time for completion due to load-shedding schedules, hence often carried out simultaneously with cooking, creating new bundles and synchronisation in space-time between otherwise seemingly unrelated practices. In both Pakistan and Denmark, laundering is a female-dominated activity, which highlights the role that gender plays in management of practices and time-shifting.

An important point of contest in the two contexts is the volition of undertaking time-shifting of practices. In the Pakistani context, homeowners are bound to act in response to the administrative set-up of the intermittent energy supply, whether by shifting or shedding their electricity-use or by incorporating back-up systems like PVs to get the convenience and comfort of 24-h electricity; in contrast, the uptake of renewable microgeneration and time shifting are voluntary in Danish middle-class households and mostly motivated by ideas of saving money or increasing self-sufficiency. These differences affect the degree to which practices are time-shifted. In the Danish context, social obligations such as accommodating guests and visitors takes precedence over time-shifting; in comparison, the fixed load-shedding schedules in Pakistan have become an ingrained part of home life as well as community life. Visiting friends, grocery shopping or laundering are confined by the set schedules of the electricity provision system. Thus, the question of the extent of volition in demand management and response strategies, and how this reflects on local socio-material and cultural contexts, is important in policy frameworks for successful smart grid design. This also reinforces the co-constitutive and mutually shaping nature of temporality and materiality (here technology and infrastructure) in practice, as highlighted by Spurling (2018).

In the present cross-cultural analysis, using a practice-theoretical framework helped focus on the specific doings and in finding similarities across cultures in how practices formed bundles and synchronised with other practices. At the same time, it helped reveal differences in the ways in which this was achieved. Practice theories, specifically applied within studies of temporality, are not yet widely used in cross-cultural analysis. This study suggests, however, that they might be useful, as they bring to focus aspects of the local context which might otherwise be taken for granted. The 'systems of practice' (Watson 2012) that define laundering in the Pakistani interviews are formed of very different elements of know-how, technologies, rules and engagements than in the interviewed households in Denmark. In addition, the respective socio-material setting results in very different timings, durations, frequencies and sequencing of performances. This can be seen, for instance, in the role of household staff and joint multi-generational households in the Pakistani interviews, compared to dual income, nuclear families in the interviewed households in Denmark, that determine time constraints and importance of institutional rhythms.

Having said that, applying practice theory to a cross-cultural comparison raises certain theoretical questions about the analytical boundaries of practice. If we concur with Shove and Pantzar's (2005) theorisation that practices can be thought of as socially and regionally situated performance, the present study would suggest that Pakistani and Danish interviewed households are, in fact, involved

in two different practices, although with some ingredients in common. Even though similar ideas of cleanliness and washing might be at the core of laundry practices wherever they are situated, the different culturally and historically contingent socio-material settings result in different practices with different temporalities. Hence, further theoretical development in a cross-cultural context is needed to determine when a practice can be thought of as a 'collective convention' (Shove 2003, p. 395) with shared understandings, and at what point do practices become socially differentiated entities.

Taking a practice-based approach to cross-cultural analysis further reveals that in smart infrastructure development, technology transfer alone from one country to another might not work. Narrowly defined demand management policies focusing only on technological appropriation and/or behaviour change through information fail to produce effective demand reduction (Shove and Walker 2010; Strengers 2013; Naus et al. 2014). For example, the empirical research shows how some Pakistani homeowners are reluctant to replace their old semi-automatic washing machines with more efficient automatic ones because of existing practices of labour division between homeowners and housemaids. The research shows that technology is embedded within practices which are also formed of other elements, including know-how, knowledge and engagements, which differ and interlink in different ways in varying contexts. The current study suggests that the effective 'diffusion' (Shove and Pantzar 2005, p. 57) of smart infrastructure that is predominantly developed in the Global North to countries like Pakistan in the Global South would require a reframing of the existing electricity consuming practices. This would entail a transfer or (better still) broadening of other elements of the practice, as a form of 'reinvention' (Shove and Pantzar 2005, p. 60) to incorporate different modes of engagement, practical and institutionalised understandings, in addition to technology transfer for improved efficiency and demand response. This presents a much greater challenge than the simple transfer of technology, including better understanding of the appropriation and adaptation of smart infrastructure within the specific socio-cultural context.

Conclusion

This paper used practice theories to analyse time-shifting of middle-class household practices and the resulting electricity consumption in the two significantly different cultural contexts of Pakistan and Denmark. While limited to a single sample in each context, the application of this theoretical approach to a cross-cultural context helped uncover the links between micro-level mundane household practices like laundering and the broader macro-level socio-material settings. The study revealed that time-shifting of laundering is not only dependent on material infrastructures of electricity provision, but also on social systems like joint family structures, 'servant culture' and clothing that is culturally and climatically appropriate. While practice theories were found to be useful in analysing temporalities of household practices in a cross-cultural context, further development is needed to conceptualise practices as shared or socially differentiated entities in varying local contexts in increasingly globalised future smart development goals.

The cross-cultural study illustrated how deeper and more direct connections are being forged between the changing electricity provision systems and daily household practices. These have implications for the shifting and shedding of electricity demand that can be expected and, consequently, the solutions proposed in smart-grid transitions as well as in the possible cross-cultural transfer of smart technology and demand response strategies.

For achieving energy savings and load shifting, different demand response strategies need to be developed for Pakistan and Denmark with regard to their wider systems of practice. While demand response strategies cannot be transferred between the two contexts in a simple way, there are still important lessons to be learned from the cross-cultural analysis. While the comparative study highlights the socio-culturally embedded nature of practices and their temporal-material arrangements, it also gives insight into alternative pathways that can inspire contextually derived, less resource-intensive and more temporally flexible forms of demand. It also provides indication of strategies that may or may not prove successful in a specific context.

In the Pakistani middle-class households interviewed, smart infrastructure development based on automated systems and state-of-the-art appliances may not work. Instead, further encouragement of service-driven practices, like outsourcing laundering facilities, might be useful. In addition, since most washing takes place in the morning and early afternoon periods, along with cooking, demand response strategies need to focus on shifting ironing practices, as they are more

resource intensive (as compared to the Danish case) and are often carried out in the peaky evening times. Learning from the study of Denmark, smart infrastructure development can focus on renewable microgeneration as a tool for self-sufficiency and can encourage utilisation of self-generated energy for household chores like laundering. This is supported by the hourly net metering scheme in Denmark, which incentivises consumption within the same hour of production. A similar approach could be encouraged in Pakistan with the recently launched local net metering regulations.

In the Danish sample, smart infrastructure design should focus on automated solutions for demand response, as these become essential for time-shifting, especially in dual-income households with children. Learning from the Pakistani experiences, one possible way that time-shifting could be made easier in Denmark is through encouragement of joint outsourcing or community-based facilities for laundering. This could, in turn, be supported by co-housing facilities that could further help reduce per capita consumption of single-occupancy households, which are becoming more common in Denmark. Moreover, in such joint or community-based facilities, certain domestic practices can be shifted to the service sector; in this way, the timing of laundering can be better controlled by implementing service sector demand response through smart infrastructure.

Some might question the relevance of comparing such different contexts like Pakistan and Denmark, but we believe that comparing such socio-culturally contrasting contexts is an effective way to make the established cultural and material structures, institutions and practices 'visible'. This is proven by the analysis of household practices that was undertaken in each case separately prior to this comparative study (Friis and Christensen 2016; Khalid and Sunikka-Blank 2017). While the individual studies highlighted significant characteristics of household practices, it was only through the comparative analysis that certain features of practice temporalities were brought to light. For example, in the Danish case, the key importance of the dual-income family and automated washing machines for the temporal organisation and time-shifting of laundering practices were made visible by contrasting with the Pakistani case. In the Pakistani sample, the importance of servant culture in practice temporalities and use of appliances, in addition to the greater consumption of ironing as a significant part of laundering in contrast to the Danish case, were clearly highlighted. More importantly, the comparison emphasised that alternative socio-material arrangements exist can show greater temporal flexibility and challenge existing norms and standards. For instance, the Pakistani sample that has been subject to time-shifting for decades shows that time-shifting and adapting to changing energy systems is both doable and realistic for Denmark, albeit as appropriated within the specific socio-cultural context.

As mentioned earlier, the empirical study was not originally designed for comparison and so presents limitations to the theoretically derived inferences regarding the transfer of smart infrastructure technology. However, the examination of the temporalities of practices in each case is based on empirical evidence that reveal their strong interlinks and interdependence on socio-cultural norms and existing infrastructure. We strongly encourage further empirical research on the implementation and exchange of demand response strategies in smart grid development, specifically to address the gap in cross-cultural comparative studies that focus on socio-technical transitions. Furthermore, the cross-cultural comparison highlights how constraints of time-shifting are strongly embedded in family structures, and as these are expected to continuously change in the future of both Pakistan and Denmark, we are also reminded of how these constraints are never set in stone.

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Compliance with ethical standards

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