Grid interactive affordable housing - a grid-management policy opportunity for distribution licensees in India

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***Abstract*—This paper provides a position statement for a grid interactive affordable housing programme called CELLULAR presently concluding its scoping phase. The study has so far balanced the technical, regulatory and financial aspects of socio-technical solutions that are practical and inexpensive. Later phases will deploy urban living labs which will site and test technology, decarbonization policy, regulatory sandboxes, urban land-use planning, human and social factors, financing innovations, and higher penetration of onsite RE. If successful, the programme would offer diverse benefits to affordable housing occupants, grid operators and builders. Observed efficacy of tested interventions will be pursued in a scale-up phase intending technical support for energy sector policy reform.**

***Keywords*—disruptive innovations, affordable housing, electricity distribution, demand side management, living lab**

I. Introduction

To date, very few Housing For All (PMAY-U policy) building developments have pursued Efficient Building (ENS building code) certification, and onsite renewables have very low uptake. India has pressing needs for reliable power supply as it has recently completed connecting all households for 1.4 billion people - but not yet for 24/7 supply and often only 300W [1]. India's electricity is heavily subsidised and so keeping electricity affordable is essential, but this constraint creates revenue challenges for electricity distribution companies (DISCOMs). Passive building design strategies, coupled with onsite renewable energy generation, demand-response/load management opportunities, and tariff design therefore have the potential for improving affordable housing while reducing energy costs and related GHG emissions. This potential has attracted researchers from two organisations and their donor to launch CELLULAR - Clean Energy Living Lab for Urban Low Carbon Affordable Residences. This paper is a position statement on the status of this new programme.

Implementing policies to best effect for the industry, DISCOMs, markets and building occupants is increasingly urgent as unchecked heating effects of global warming are anticipated to contribute to mortality of 10% of all deaths in India by 2100 [2] – we suggest that safe affordable housing should become critical disaster infrastructure. Rapid progress can only happen in a coordinated manner with clean energy provision relying on grid improvements and on-site solar and small wind generators – in turn provided by buildings and their occupants interacting with the grid – that is, grid interactive housing. There are also improvements in health, productivity, cost of living and other outcomes for more efficient buildings (for example: [3], [4]). Improving building performance and integrating with the grid could also hasten electrification and the conversion of cooking systems from propane and high particulate matter and CO biomass fires to electric stoves, a particularly serious health risk [1].

The importance of testing human factors means that innovators and governments alike can learn what will actually work and scale, rather than perpetuating the building-energy gap between as-designed and as-occupied energy use [5] [6]. Grid interactivity brings another layer to this situation as future DISCOMs will likely rely on cooperation from millions of occupants in heating events to prevent blackouts due to grid congestion. Space cooling in buildings (which constitutes around 33% of total electricity consumption in India) was ~135 TWh in 2017-18, and projections show that this will increase by a factor of four (to ~585 TWh) in the next two decades. Increasing use of air conditioners is already contributing to blackouts outside India (for example in Australia, [7]) where demand reduction bounties are being tested during high demand [8].

Household income and energy use have been found to be quite strongly correlated (for example in the UK [9]). At the same time, low-income Indian households are upwardly mobile: 8.5% of India's population moved up from the vulnerable category to middle class and 13.9% improved in status from poor to vulnerable up to the year 2010 [10]. Indians more generally have high expectations of upward mobility [11]. For those most vulnerable, 40% of energy distributed to informal settlements is lost with scheduled blackouts making refrigeration and other continuous energy uses impossible [12].

The study will have at least three phases. The present scoping phase runs to July 2022. Our methodology in the second phase from late 2022 is to deploy up to three sited *living labs* where we have convened supportive occupants, builders, and all levels of government. The study will seek dedicated funding for additionalities at all sites. At the time of writing these are initially in the states Gujarat, Karnataka and Maharashtra where we have engaged with the stakeholders already. A third phase of this work anticipates scale up of successful interventions to many other sites before 2030.

II. Living Lab Design

Living labs allow design interventions to be tested in situ so that adapted human social practices [13] can also be observed. Improvements in energy services and in grid interactivity will only be successful if they don't interrupt occupant's lives, do not require high energy literacy, have correct incentives operating, and can be seen to work in-situ. In India, there are few resources to deeply integrate improvements into households with little if any financial surplus, or time to learn and adapt. Such living lab research recognises that occupants:

- …are the experts on the products and services that will best meet their needs and preferences.
- …represent an under-tapped source of ideas and creativity.
- …involvement in shaping changes in their own lives extends the democratic space. [14]

From the side of DISCOMS, partners and educational institutions, labs:

- manage stakeholder cooperation
- lead to the pooling of complementary resources
- research the whole innovation process from conception to effective application in the real world
- encourage the sharing of innovations
- give end-users and communities more power in change processes and thereby deepen democracy
- make innovation more visible to those who need to help it along.[14]

The technologies in scope include:

- Changed demand: Buildings are entirely electrified to use grid energy; and, permanent energy-demand aware features that reduce energy demand via promoting energy efficiency (both for envelope and machines/devices).
- Connected and smart systems: Energy-demand technologies such as smart meters, building automation systems, sensors and others which support owners and occupants.
- Systems which rely on Distributed Energy Resources (DER) as a behind-the-meter solution such as onsite solar with batteries and vehicle to grid technologies potentially as despatchable generation and loads
- DISCOM facing controls: building infrastructure or appliances that send information such as smart meters or can actually be directly controlled such as header tank pumping.
- Systems which rely on cooperation and behaviour change of building occupants such as aligning solar generation with cooking, occupant energy curtailment advised by DISCOMs and so on.

Adjusting social practices such as introducing cooking on an induction stove during the solar day can see grid demand greatly reduced where there is onsite solar, and the typical evening demand peak reduced. CELLULAR will also explore the socialization of behavior change for which community-creation trials have been more successful (eg: [15]), long lasting and have demonstrated self-sustaining benefits (eg: EcoTeams [16]) and it will explore institutional design around sharing a limited resource [17].

Solutions under consideration:

- DISCOM-facilitated rooftop solar and small wind turbines (reproducing a BSES trial in Delhi [18]).
- Multifamily occupants sharing power from solar and small wind turbines via special metering (following AllumeEnergy.com)
- DISCOM-controlled HVAC and heat pumps for water heating (following from [19])
- 2-3-4wheeler charging and freight charging as a new social enterprise run by the building occupants through innovative business cases.
- Virtual power plant commons and socialisation of shared energy (from [20], [21]) along with DISCOM-messaging and demand reduction bounties (for example: [8]).

III. Conclusions and Future Work

The study covers at least four aspects of progressive energy use: the demand-side opportunities for resilience and affordability (energy reliability) and building efficiency (the building envelope); opportunities for energy utilities to coordinate with building occupants for energy efficiency (efficient devices and time-of-use); and, the potential for the formation of energy communities (groups of occupants who cooperate to make the best use of energy).

While India is not a large per-household user of energy and is largely not a cool climate country, the goal of building energy design is to cap or limit the growth in energy from quite a low base. The potential benefits to the users and grid operators via the bidirectional flow of electrons and value should be substantial as well as other health and wellbeing benefits for affordable housing occupants. The outcomes are intended to form technical support for further policy implementation in India.

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REFERENCES

[1] R. Kumar et al., “Electric Cooking The Way Forward,” India Smart Grid Forum (ISGF), 2020.

[2] T. A. Carleton et al., “Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits,” National Bureau of Economic Research, Jul. 2020. doi: 10.3386/w27599.

[3] P. Bragge, L. Nita, L. Pattuwage, A. Waddell, and A. Lennox, “Co-benefits of sustainable building and implications for Southeast Asia,” Monash Sustainable Development Institute, 2021.

[4] P. Graham, “Adopting decarbonization policies in the buildings & construction sector: Costs and Benefits,” United Nations Environment Programme, 2019.

[5] P. de Wilde, “Building performance gaps: A commentary,” Academia Letters, Mar. 2021, doi: 10.20935/al815.

[6] S. Hu, D. Yan, E. Azar, and F. Guo, “A systematic review of occupant behavior in building energy policy,” Build. Environ., vol. 175, p. 106807, May 2020, doi: 10.1016/j.buildenv.2020.106807.

[7] CarbonTrackAU, “Why the recent heat wave caused outages, and what it means for you,” Feb. 05, 2019. https://carbontrack.com.au/blog/why-the-recent-heat-wave-caused-outages-and-what-it-means-for-you/ (accessed Jan. 09, 2022).

[8] ARENA, “Powershop Australia Demand Response Program,” ARENA, Nov. 30, 2017. https://arena.gov.au/projects/powershop-australia-demand-response-program/ (accessed Jan. 10, 2022).

[9] M. Büchs and S. V. Schnepf, “Who emits most? Associations between socio-economic factors and UK households’ home energy, transport, indirect and total CO2 emissions,” Ecol. Econ., vol. 90, pp. 114–123, Jun. 2013, doi: 10.1016/j.ecolecon.2013.03.007.

[10] M. Rama, T. Béteille, J. L. Newman, and Y. Li, Addressing Inequality in South Asia. World Bank Publications, 2014. [Online]. Available: https://play.google.com/store/books/details?id=qobjBAAAQBAJ

[11] SAP, “GLOBALIZATION 4.0 + The Human Experience Presented to the World Economic Forum,” SAP, 2019.

[12] Mahila Housing Trust, Jan. 04, 2022.

[13] E. Shove and G. Walker, “What Is Energy For? Social Practice and Energy Demand,” Theory, Culture & Society, vol. 31, no. 5, pp. 41–58, Sep. 2014, doi: 10.1177/0263276414536746.

[14] R. Salter and S. White, “Collaborative research in the real world: Review of Living Laboratories,” Australian Low Carbon Living Cooperative Research Centre, RP3005, 2013. Accessed: Jan. 10, 2022. [Online]. Available: http://www.lowcarbonlivingcrc.com.au/resources/crc-publications/reports/collaborative-research-real-world-review-living-laboratories

[15] A. V. Moere, M. Tomitsch, M. Hoinkis, E. Trefz, S. Johansen, and A. Jones, “Comparative Feedback in the Street: Exposing Residential Energy Consumption on House Façades,” in Human-Computer Interaction – INTERACT 2011, Sep. 2011, pp. 470–488. doi: 10.1007/978-3-642-23774-4_39.

[16] H. Staats, P. Harland, and H. A. M. Wilke, “Effecting Durable Change: A Team Approach to Improve Environmental Behavior in the Household,” Environ. Behav., vol. 36, no. 3, pp. 341–367, May 2004, doi: 10.1177/0013916503260163.

[17] E. Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action, vol. 1. The Edinburgh Building, Cambridge, CB2 2RU, UKK: University of Cambridge Press, 1990. [Online]. Available: http://wtf.tw/ref/ostrom_1990.pdf

[18] TNN, “Discoms to hand-hold residents to boost rooftop solar power in Delhi,” Times Of India, Nov. 03, 2020. https://timesofindia.indiatimes.com/city/delhi/discoms-to-hand-hold-residents-to-boost-rooftop-solar-power/articleshow/79008048.cms (accessed Jan. 10, 2022).

[19] O. O. Osunmuyiwa, A. D. Peacock, S. R. Payne, P. Vigneswara Ilavarasan, and D. P. Jenkins, “Divergent imaginaries? Co-producing practitioner and householder perspective to cooling demand response in India,” Energy Policy, vol. 152, p. 112222, May 2021, doi: 10.1016/j.enpol.2021.112222.

[20] P. Hansen, G. M. Morrison, A. Zaman, and X. Liu, “Smart technology needs smarter management: Disentangling the dynamics of digitalism in the governance of shared solar energy in Australia,” Energy Research & Social Science, vol. 60, p. 101322, Feb. 2020, doi: 10.1016/j.erss.2019.101322.

[21] C. Burton, C. Ryan, B. Rismanchi, and S. Candy, “Urban shared energy systems and behaviour change − simulating a common pooled resource problem,” Smart and Sustainable Built Environment, vol. 9, no. 1, pp. 17–26, Jan. 2019, doi: 10.1108/SASBE-01-2019-0013.