

Operating-Envelopes-Aware Decentralized Welfare Maximization for Energy Communities

Ahmed S. Alahmed[†], Guido Cavraro[‡], Andrey Bernstein[‡], and Lang Tong[†]

[†] *School of Electrical and Computer Engineering, Cornell University, Ithaca, NY*

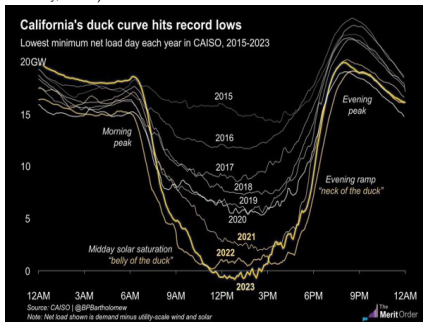
[‡] *Power System Engineering Center, National Renewable Energy Laboratory, Golden, CO*

[†] {asa278,lt35}@cornell.edu, [‡] {gcavraro,abernste}@nrel.gov

2023-09-05

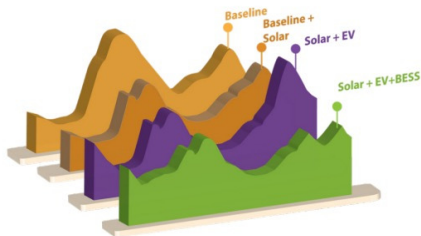
Operating envelopes for a decentralized grid with increased bi-directionality

- Induced by the declining installation costs and increasing efficiency, BTM DER are being integrated with higher capacities, which increases the level of energy exports and imports.
 - Nearly, 75% of households in the U.S. are **ineligible** for rooftop solar installations (Source: A guide to community solar: Utility, Private, and non-profit project development, National Renewable Energy Laboratory, 2010.)



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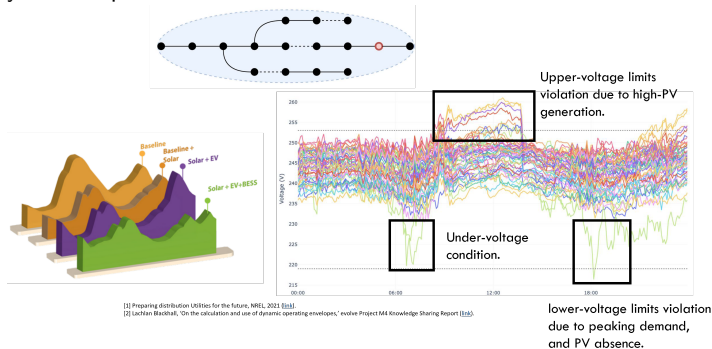
- Induced by the declining installation costs and increasing efficiency, BTM DER are being integrated with higher capacities, which increases the level of energy exports and imports.
- This is compounded by the fact that there is likely a mismatch between the intervals of peak DER imports and exports. **BTM renewable PV peaks in midday**, whereas **EV charging** is likely to occur **early to mid-evening**.



Source: Preparing Distribution Utilities for the future, NREL, 2021

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- Such **un-coordinated DER** which are also neither *controllable* nor *visible* by the DSO can result in dynamic two-way energy flows that threaten the physical or operational limits of the distribution networks.



[1] Preparing distribution Utilities for the future, NREL, 2021 [133]

[2] Lachlan Backhal, 'On the calculation and use of dynamic operating envelopes,' evolve Project M4 Knowledge Sharing Report [126].

lower-voltage limits violation due to peaking demand, and PV absence.

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- Dynamic operating envelopes (OEs) are proposed to enable DSOs to ensure network integrity (i.e., voltage and thermal limits), without directly controlling BTM DER or aggregators.

Dynamic Operating Envelopes (OEs)

Time-varying **export** and **import** limits at prosumers' PCC.

Energy Communities: Enablers of wider DER accessibility and aggregation

Energy Communities

An energy community is a coalition of a group of customers who pool and aggregate their resources and perform energy and monetary transactions with the DSO as a single entity behind a PCC.

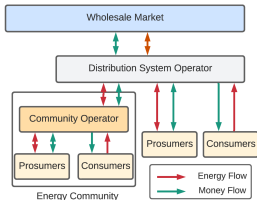


Figure: Standalone customer.

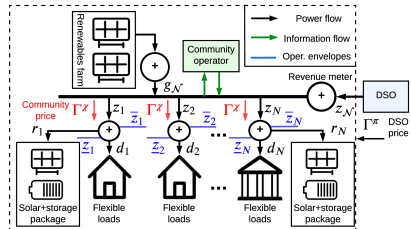


Figure: Energy community framework.

Problem statement: How can a community operator devise a market mechanism that's

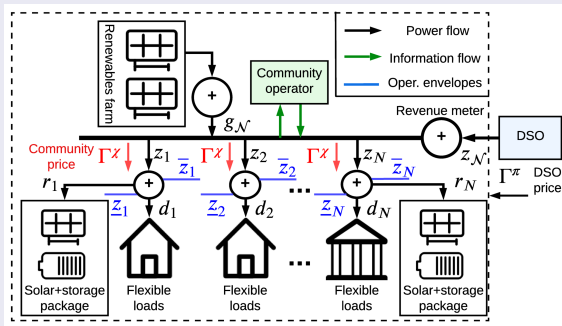
- OEs and resource-aware.
- Competitive to the DSO.
- Privacy-preserving.
- Welfare-maximizing.
- Just and fair.
- Non-discriminatory.

Contributions/Summary of Results

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We propose OEs-aware, prosumer-centric, and efficient energy community through mechanism design. The proposed market mechanism:

- 1 incorporates the DSO-imposed OEs, ensuring a network-aware community operation.

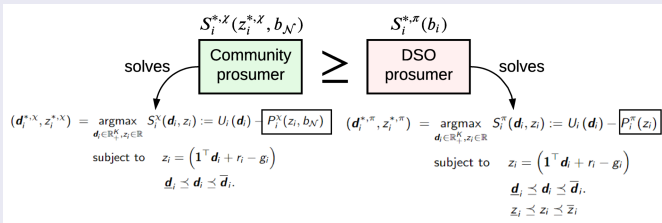


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We propose OEs-aware, prosumer-centric, and efficient energy community through mechanism design. The proposed market mechanism:

- 1 incorporates the DSO-imposed OEs, ensuring a network-aware community operation.
- 2 guarantees surplus levels to its members higher than the maximum attainable surplus under standalone settings.

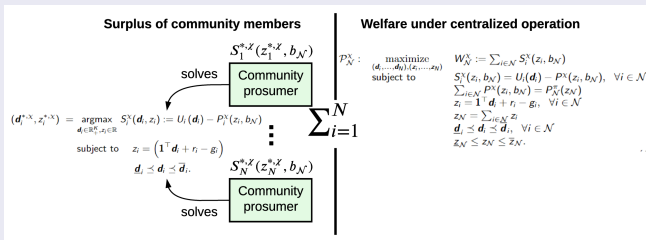


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- 3 decentrally achieves welfare optimality.



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- 2 guarantees surplus levels to its members higher than the maximum attainable surplus under standalone settings.
- 3 decentrally achieves welfare optimality.
- 4 *just* and *fair* for all community members, i.e., the market mechanism satisfies the *cost-causation principle*.
 - It is worth noting that many allocation rules do not satisfy the *cost-causation principle*, including the *equal surplus division*, *proportional rule*, and *Shapley value*.