ADAPTIVE ENERGY SYSTEMS IN DISASTER STRUCK REGIONS

ARHAM SHAH, PARSHWA PATEL, YASH KHANDELWAL
(ARHAM2@ILLINOIS.EDU/PARSHWA2@ILLINOIS.EDU/YASHK4@ILLINOIS.EDU)

key problems

- Disasters cause power shortages for critical infrastructure.
- Renewable energy is underused in crises.
- Decentralized, real-time energy trading is essential.
- Hospitals and shelters must be prioritized.

SDG GOALS ACHIEVED

- 11 SUSTAINABLE CITIES AND COMMUNITIES
- 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
- 7 AFFORDABLE AND CLEAN ENERGY

Reliable access to energy is vital during **economic, social, natural, or man-made disasters**. Ensuring **uninterrupted energy to critical locations in these** moments underscores the importance of achieving energy independence.

algorithms

Access to energy is vital during crises. Peer-to-peer energy which utilize batteries, solar and a grid connection would allow trading with renewable producers (i) to supply energy (Eij) to critical nodes (j) within microgrids.

A blockchain-secured system, integrating transport, pricing, and market equilibrium algorithms, optimizes distribution by prioritizing high-importance zones (Wj), minimizing losses (Lij), and managing battery usage (Bt) efficiently. This scalable approach ensures energy security with minimal hardware.

$$\text{Maximize: } \sum_{t} \sum_{i,j} W_j \cdot \left(E_{ij} - L_{ij} \cdot E_{ij}\right) - C_{\text{battery}} \cdot \sum_{t} B_t$$

smart contracts

Smart contracts power blockchain-based peer-to-peer energy trading, automating secure, real-time transactions.
Key features:

- **Automation:** Align energy supply with demand based on pricing.
- **Incentives:** Promote off-peak use and grid participation.
- **Dynamic Pricing:** Adjust prices and process payments instantly.
- **Dispute Resolution:** Resolve issues transparently with predefined rules.
- **Tokenization:** Convert energy into tradable blockchain assets.

Smart contracts ensure energy trading is **secure, scalable, and cost-effective**.

technical factors

- Shifting the power of decision in their hands of the producer
- Utilizing blockchain to transfer information in the marketplace to restrict double-counting
- Enable disaster struck areas to prioritize areas of refuge such as hospitals in Ukraine and Puerto Rico

"I got goosebumps twice hearing about the potential of your idea" said an industry professional with 25 years in this business

- A decentralized grid needs a decentralized purchasing decision for maximum benefits
- For a for-profit model in the US, such a model can leverage the spike pricing model to improve profits from solar power by 40%
- The ability to store energy would allow the means for having stored energy for hours with lower production
- Mathematical problem modelled as Linear Optimization, can be focused on energy savings or energy security

"A decentralized grid deserves decentralized price points, and we are at that inflection point" said a post-doctorate professional in the field

economical factors

BATTERIES

STORAGE SOLUTIONS

- **Low Cost:** Lead-acid batteries are cost-effective and widely available.
- **Reliability:** Proven dependability in disaster scenarios for temporary storage.
- **Scalability:** Easily deployed for small-scale and community microgrids.
- Other uses: Beneficial during regular operations as well.

IOT HARDWARE

SMART DEVICES

- **Affordable Solutions:** Lead-acid batteries combined with Management systems to direct the flow of energy and maintain battery health.
- **Accessibility:** Batteries are available in remote and underserved regions.
- **Compatibility:** Supports integration with renewable energy systems like solar panels into the grid

INFRASTRUCTURE

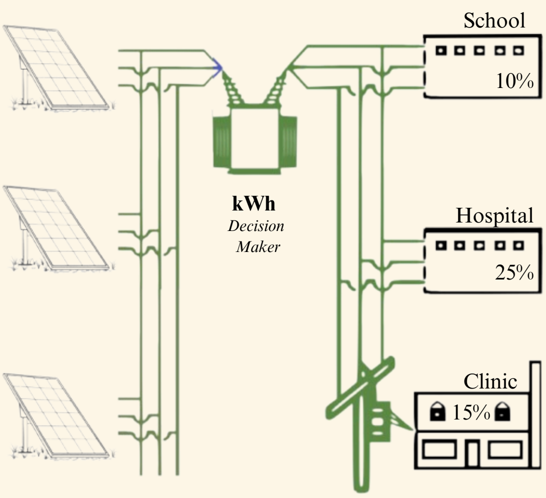
GRID MANAGEMENT

- **Cost Efficiency:** Smart Energy Systems allow for the energy trade
- **Energy Security:** Grid Connectivity to batteries/solar to transport energy
- **Sustainability:** Facilitates renewable integration for long-term disaster resilience.

social factors

We must engage receptive communities to ensure there are enough energy producers who are able to support energy transport. Key factors include:

- **Awareness and Education:** Use workshops and demos to familiarize people with energy trading and blockchain.
- **Early Adopters:** Focus on tech-savvy users with solar panels or batteries to drive adoption.
- **Reliable Networks:** Start in urban or suburban areas with established renewable programs.
- **Supportive Demographics:** Target sustainability-conscious or cost-saving-oriented individuals.
- **Local Partnerships:** Collaborate with community groups, governments, and solar companies to build trust.



Starting small and expanding as benefits are recognized ensures a socially adaptable solution.

government policies (US)

FERC Order 2222: Allows Distributed Energy Resources (DERs) to participate in energy wholesale markets

FERC Order 888: Transmission lines owned by utility companies must provide 3rd party access

FERC Order 889: OASIS (Open Access Same-Time Information System) - Centralized platform with real-time information for capacities and prices

FERC Order 2222: DERs can participate in the wholesale energy markets

Investment Tax Credits (ITC): 30% project setup cost can be deducted on federal taxes

PJM & MISO: Regional Transmission Organizations under FERC Order 2000 that regulate companies that operate transmission lines

Net Metering (For DERs set up before Jan 1, 2025): 1:1 credit for each unit of electricity produced that can be used to offset the electricity bills by property owners. Credits can be used for costs in all the sections: Supply, Delivery, Taxes and Fees.

Net Metering (For DERs set up after Jan 1, 2025): Credits for electricity generated would be usable only for the Supply section of electric bills. However, energy producers will be provided a $300 rebate for each kW of the setup (Distributed Generation Rebate).

Renewable Energy Credits (RECs): Illinois Shines provides 1 REC for 1 MWh of energy generated. RECs can be used to generate additional revenue for producers and can be bought by companies looking to meet renewable energy requirements

conclusion

- Access to electricity is essential for disaster recovery, powering critical infrastructure like **hospitals and shelters.**
- **Decentralized microgrids** and **peer-to-peer trading** empower communities and improve resilience.
- **Underutilized renewable energy** can be optimized through **adaptive systems** and selective usage during crises.
- **Blockchain** and **smart contracts** enable secure, efficient, and transparent **energy transactions**.
- These systems also **optimize energy use** and costs during non-disaster periods, **promoting sustainability**.

Securing Ukraine's Energy with Green and Decentralized Solutions
Published 11/19/2024 Updated 11/19/2024

ISABEL FRASER SCIENCE SEP 27, 2024 5:14 AM
Ukraine Is Decentralizing Energy Production

RMI
https://rmi.org › hurricane-proof-energy-for-puerto-rico
Hurricane-Proof Energy for Puerto Rico

Energy News Network
https://energynews.us › 2023/03/17 › in-puerto-rico-ad...
Puerto Ricans want clean energy to be local

Pioneering Disaster-Resilient Energy Solutions: Government to Launch MES Pilot Program in Typhoon-Prone Areas
Posted on April 16, 2024 by ResilientPH

Department of Energy (.gov)
https://www.energy.gov › gdo › puerto-rico-grid-resilien...
Puerto Rico Grid Resilience and Transitions

Decentralized Energy Powers Ukraine's Resilience Against Russia
Published Nov 20, 2024 at 8:09 AM EST

NREL
Haiti Builds a Path to a Clean, Resilient Energy Future

acknowledgement

We sincerely thank **Matt Luallen** (mluallen@illinois.edu), **Karan Singh** (karan@pragmaticai.dev)**, John Holz** (jbholz@aol.com), **Dr. Jordon Eccles** (jordan.eccles@gmail.com), **Bob Norris** (wrnorris@illinois.edu), and **John Thode** (jthode@illinois.edu) for their guidance and support in helping us move our idea forward. The feedback and insights have been incredibly valuable, and we truly appreciate the time you took to assist us.

references

1. Kleinman Center for Energy Policy, "Empowering Puerto Rico: A Proactive Approach to Addressing a Fragile Energy System," authored by Bianca Montañez, published June 13, 2023. Accessed from Kleinman Center for Energy Policy, "Empowering Puerto Rico: A Proactive Approach to Addressing a Fragile Energy System," authored by Bianca Montañez, published June 13, 2023. Accessed from https://kleinmanenergy.upenn.edu..
2. Resilient Energy. "Resilient Energy Networks: Advancing Decentralized Solutions for Sustainable Energy." Published 2023. Accessed from Kleinman Center for Energy Policy, "Empowering Puerto Rico: A Proactive Approach to Addressing a Fragile Energy System," authored by Bianca Montañez, published June 13, 2023. Accessed from https://kleinmanenergy.upenn.edu..
3. The Green Block. "Harnessing the Power of Blockchain for Renewable Energy: Revolutionizing Adoption, Trading, and Peer-to-Peer Sharing." Published 2023. Accessed from Kleinman Center for Energy Policy, "Empowering Puerto Rico: A Proactive Approach to Addressing a Fragile Energy System," authored by Bianca Montañez, published June 13, 2023. Accessed from https://kleinmanenergy.upenn.edu..

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN