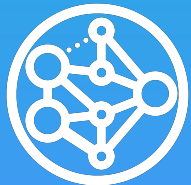


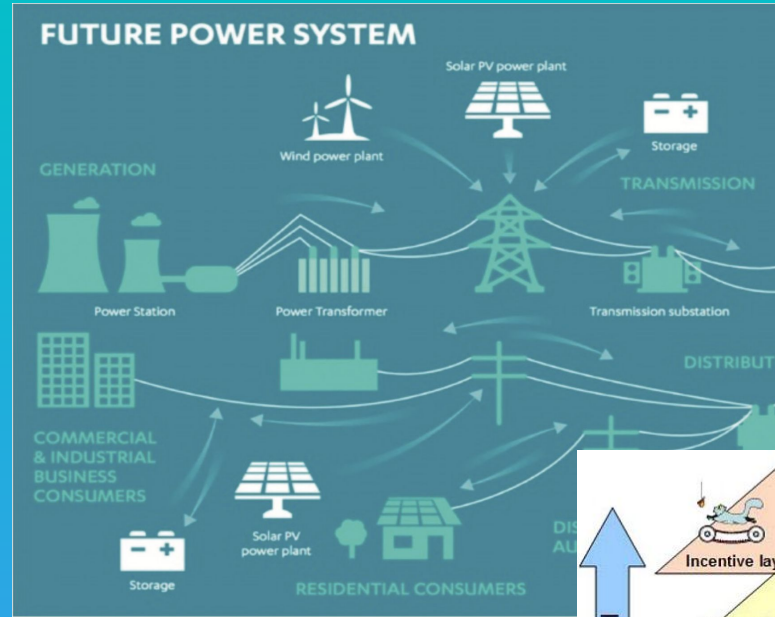
A scalable protocol for  
transactive energy coordination



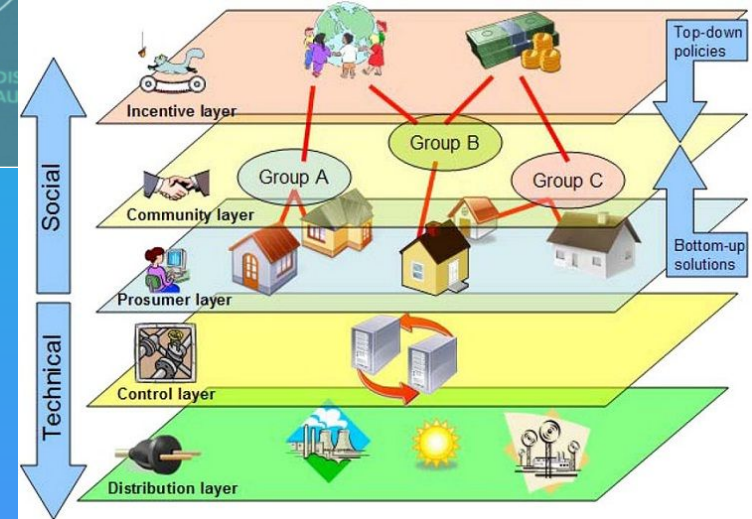
Plurigrind

[plurigrind.xyz](https://plurigrind.xyz)  
[gm@plurigrind.xyz](mailto:gm@plurigrind.xyz)

Energy Systems are rapidly **transitioning** from centralized resources to distributed energy resources



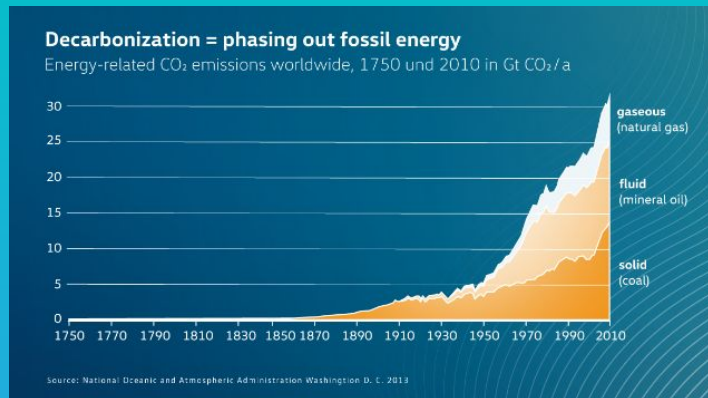
A key challenge is their **integration**, **coordination**, as well as **bidirectionality** as generators and consumers at an unprecedented scale.



# Right now

**Coordination of grid-edge resources** can make a major contribution to **power system decarbonisation** (critical for keeping anthropogenic warming below 1.5 °C above pre-industrial levels).


Example: Oslo, leading in decarbonization currently 60% to their 2030 goal of 95% carbon neutral due to coordination at several scales



# Decentralized DERMS are missing “parts”

A review of thousands of papers on this subject revealed acute gaps in

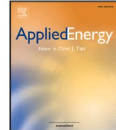
- **Privacy**
- **Demand side coordination** specifically on the retail side
- **Interoperability** and
- **Data availability** throughout grid networks
- **Assurance mechanisms** to faithfully execute the scientific planning of the grid




Contents lists available at ScienceDirect

## Applied Energy

journal homepage: [www.elsevier.com/locate/apenergy](http://www.elsevier.com/locate/apenergy)



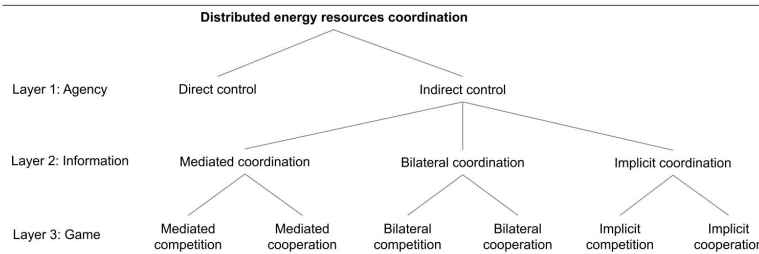


### Coordination of resources at the edge of the electricity grid: Systematic review and taxonomy

Flora Charbonnier<sup>a,\*</sup>, Thomas Morstyn<sup>b</sup>, Malcolm D. McCulloch<sup>a</sup>

<sup>a</sup> Department of Engineering Science, University of Oxford, UK  
<sup>b</sup> School of Engineering, University of Edinburgh, UK

#### GRAPHICAL ABSTRACT



```
graph TD
    A[Distributed energy resources coordination] --> B[Direct control]
    A --> C[Indirect control]
    C --> D[Mediated coordination]
    C --> E[Bilateral coordination]
    C --> F[Implicit coordination]
    D --> G[Mediated competition]
    D --> H[Mediated cooperation]
    E --> I[Bilateral competition]
    E --> J[Bilateral cooperation]
    F --> K[Implicit competition]
    F --> L[Implicit cooperation]
```

Layer 1: Agency

Layer 2: Information

Layer 3: Game

#### ARTICLE INFO

**Keywords:**  
Coordination  
Renewable energy  
Peer-to-peer energy trading  
Transactive energy  
Smart grids

#### ABSTRACT

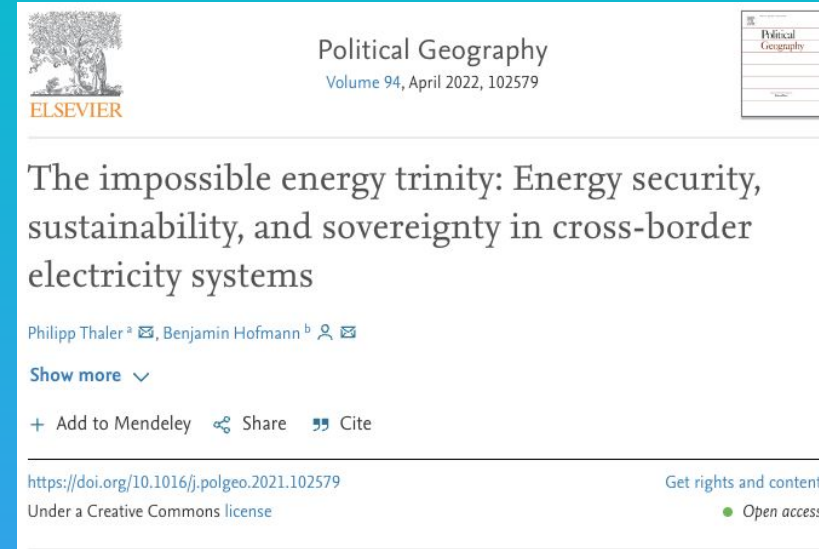
This paper proposes a novel taxonomy of coordination strategies for distributed energy resources at the edge of the electricity grid, based on a systematic analysis of key literature trends. The coordination of distributed energy resources such as decentralised generation and flexibility sources is critical for decarbonising electricity and achieving climate goals. The literature on the topic is growing exponentially; however, there is ambiguity in the terminology used to date. We seek to resolve this lack of clarity by synthesising the categories of



We strongly believe that Digital Public Goods for bootstrapping, expanding and operating systems of distributed renewable energy resources ☀️🗣️ cannot be proprietary or opaque.

Nationstates have mostly failed in their legitimacy and ability to address climate change

They need to be replaced with better ontologies that have more dynamism and are better aligned with material fact of energy systems and energy markets.





# Existing Solutions

Anode Labs manages the React Network, a blockchain-based protocol that pays users to make their battery storage available to utilities during peak energy usage.

Utilities pay for access to the aggregated storage capacity available on the React Network using its tokens. The proceeds of the sale are split between Anode Labs and the battery owner.



Holy Cross Partnership

## Anode Labs

Anode Labs is a technology company committed to building a more stable, sustainable, and abundant energy system for humanity.

Our projects include:

- [React Network](#) - the next-generation energy cooperative
- [Energy Flexibility Tariff Database](#) - an open-source database of national DR incentives

[Contact Us](#)



SolarSandy's Own Your Power initiative helps people lower their energy bills by owning their power and installing solar panels.

### React Network

ORGANIZATION

Summary Financials

About

React Network aims to modernize the national power grid by creating a community owned network connecting energy storage assets.

Austin, Texas, United States


Highlights

Total Funding Amount \$4.2M

Investors 8

Open source  
and open model  
code bases exist  
around the  
world and are  
funded by a  
variety of  
sources

NREL SIP, GENX



Search NREL.gov

SEARCH

Energy Analysis

Research ▾ Staff Publications **Data & Tools**

» Energy Analysis » Scalable Integrated Infrastructure Planning Model


## Scalable Integrated Infrastructure Planning Model

NREL created the Scalable Integrated Infrastructure Planning (SIIP) modeling framework to effectively build, solve, and analyze the scheduling problems and dynamic simulations of quasi-static infrastructure systems.

To meet the needs of evolving energy infrastructure systems, the SIIP model develops a foundation to fundamentally advance the nation's ability to model individual and integrated infrastructure systems at a range of spatial and temporal scales.

### Capabilities

The SIIP model applies NREL's capabilities in advanced computer



## We used GenX to showcase the promise and potential of “stakeholder-driven modeling”

- **What we did:** used GenX to perform our own portfolio modeling based on the 2021 IRP jointly filed by two Kentucky utilities, relying on public data.
- **We addressed key stakeholder concerns, including:**
  1. Limited consideration of technology cost forecasts.
  2. No treatment of endogenous unit retirement.
  3. No year-by-year modeling.
- **Compared to the utilities' IRP we found:**
  1. Increased renewables, more storage, and less gas to achieve reliable, long-term resource portfolios.
  2. Opportunities for earlier, cost-effective coal plant retirement and replacement.
  3. An immediate opportunity for new solar and delayed role for new gas generation.



### Power Planning to the People

How Stakeholder-Driven Modeling Can Help Build a Better Grid



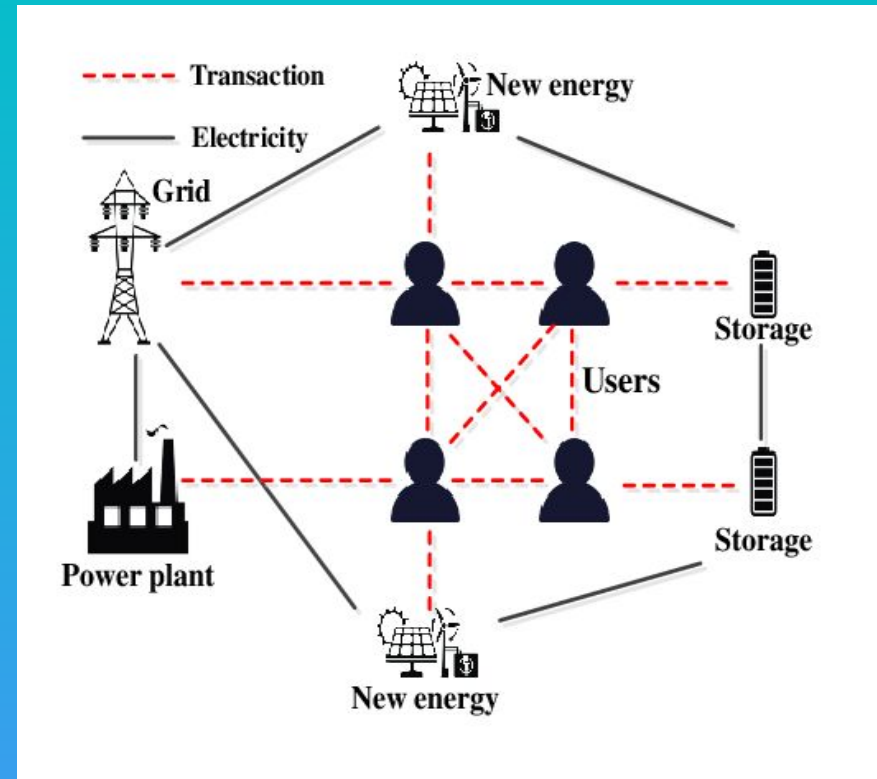
Copyright NREL | December 2020

# Plurigrid's protocol provides for totally new opportunities for transactive energy

New coordination paradigms and strategies -- driven by simulation of all the layers of (social, political, economic, physics)

Compliant and certified assurance mechanisms for industrial control systems

Cyberphysical standards (NREL++)





**Plurigrig Protocol** provides a scalable open mechanism for **anyone in the world** to start from scratch and participate in coordinated systems, for microgrids of all sizes and maturity levels

Anyone from individuals with an e-app on their phone, vans at burning man, industrial facilities to be able to participate in **two-way markets** and systems surrounding them, sustainable, effective expansion, maintenance, and resilience of energy resources and systems surrounding them.

Plurigrig's approach focuses on what is already recognized and validated to be the missing pieces on the frontiers of the emerging grid landscape

- Interoperability (through IBC)
- Data availability
- Privacy (through new computing techniques ZK / MPC etc.)
- P2P transactive energy incentive models



# Modeling and incentive simulation

## Phase 1 - Simulation

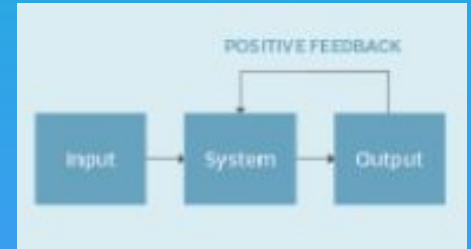
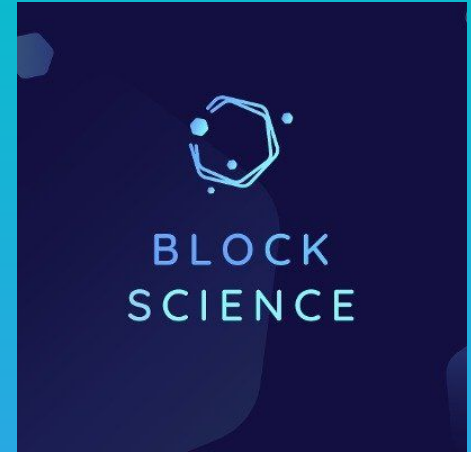
Plurigrid's superpower is the ability to model grid solutions and resources before deployment.

New simulation models must contain not just grid components, but politics, ecology, energy policy, physics, and incentive models.

## Phase 2 - Deployment

Simulation tools inform real-world deployments, creating a provable model that can be safely tested before deployment.

In the lab, new incentive models can be safely tested before going live.

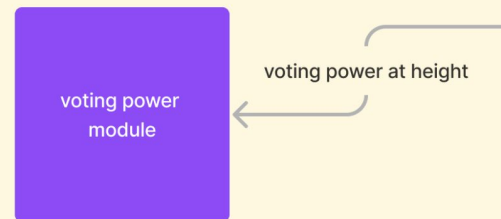


# Open games that find closed loop systems

- Enabling open games and simulation models on any data and grids connected to the protocol
- New governance models (dao-contracts), funding and ownership models (commons-contracts)
- Dynamical systems management for high availability (cadCAD.jl)
- Behavioral economic / mechanism design
- Retail demand side coordination - E-Apps show baskets of incentives available to E-Gens (prosumers)

## The voting module

### voting module semantics



PowerSimulationsDynamics.jl

Search docs

#### Simulation Execution

- Solvers
- Exploring the Solution
- Keyword Arguments

#### Tutorials

#### Models

#### Initialization

#### Small Signal

#### Reference Frames

#### Perturbations

#### Industrial Renewable Models

#### Simulation Execution

[Edit on GitHub](#)

## Executing a Simulation

After constructing the System data from `PowerSystems.jl` with its dynamic components, a `Simulation` structure must be constructed. Check the API for `Simulation` and `Simulation!` for its construction and available arguments.

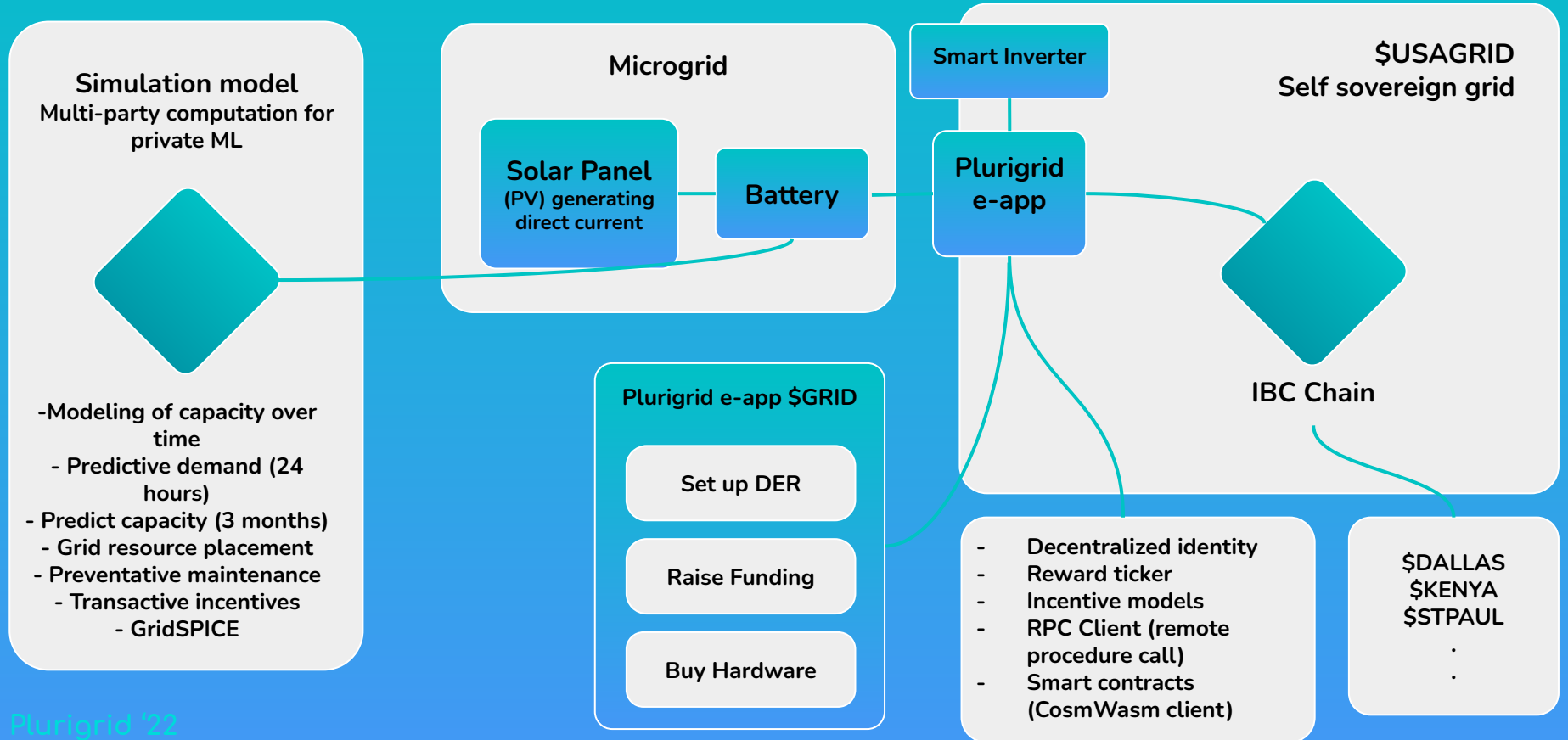
Once a `Simulation` is constructed and properly initialized, the `execute!` command is used to run the `Simulation`. If no perturbation was included, then a steady state simulation will be run over the time span defined. See the API of `execute!` for more details.

## Solvers

Solvers must be chosen accordingly depending on the type of model used in the `Simulation`. For example, a `Residual` model can be executed using Sundials IDA solver:

```
using Sundials
sim = Simulation(
  ResidualModel(),
  sys,
  pvd(),
  (0.0, 20.0),
  perturbation,
)
execute!(sim, IDA())
```

# Plurigridd Protocol and Platform for Transactive energy



# Roadmap

## 2023 Jan - Mar - Simulation Phase

- Extend cadCAD to simulate grid modeling
- Create gridSPICE (token incentive modeler)
- Create Commons Contracts (p-ABC)
- Google Cloud Anthos partnership
- Private testnet
- Public testnets
- Public goods NFT simulations

## 2023 Jun - Nov - Pilot Stage

- First physical Microgrid running Plurigrd protocol
- Testing and feedback
- Additional pilot projects deployed at universities and Microgrid sites
- Additional testing and feedback
- Predictive maintenance demo / private machine learning and digital twinning

## 2023 Nov - Jan - Growth Stage

- Smart inverter, solar and battery partnerships
- Deployment at additional sites, create case studies
- Prove scalability, privacy and security

## 2024 Jan - Jun - Scale Stage

- Go to Market through press channels, trade shows, website, word of mouth, podcasts, partnerships and conference speaking
- e-app partnerships and integration into Microgrid systems
- P2P Transactive energy market model, spot market trading based on unprecedented predictive modeling
- Public Goods bootstrapping for Kenya and other sites competitive with central resources



# Where are we today?

Numerous small capital commitments.

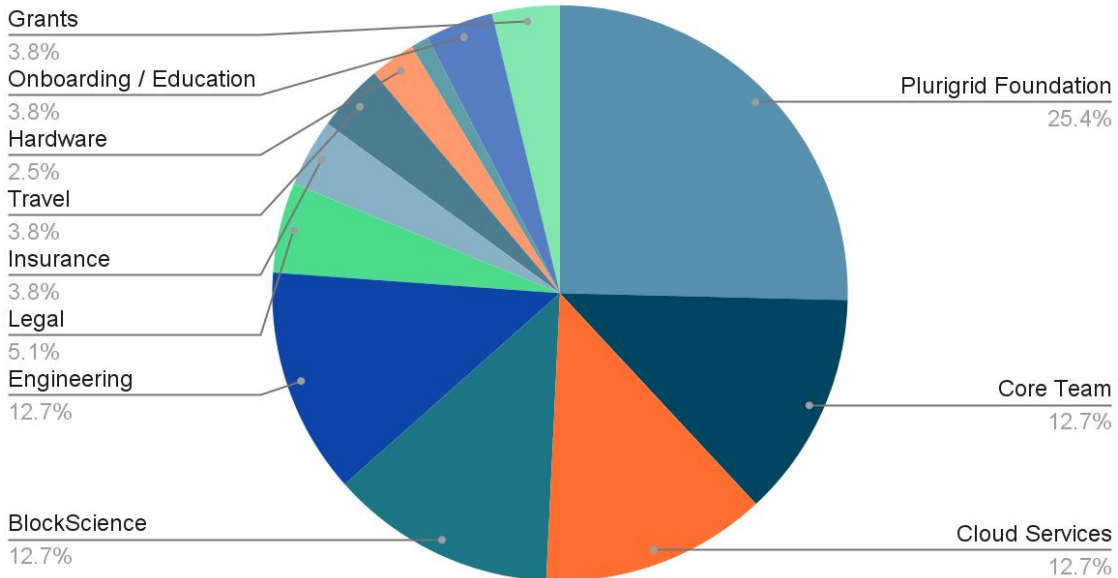
Looking for value-aligned leads or co-leads in regenerative finance and climate change who understand our unique mission.



Raising a SAFE  
- 1.5-2m at 10m

Looking for a lead  
or co-lead of  
750K.

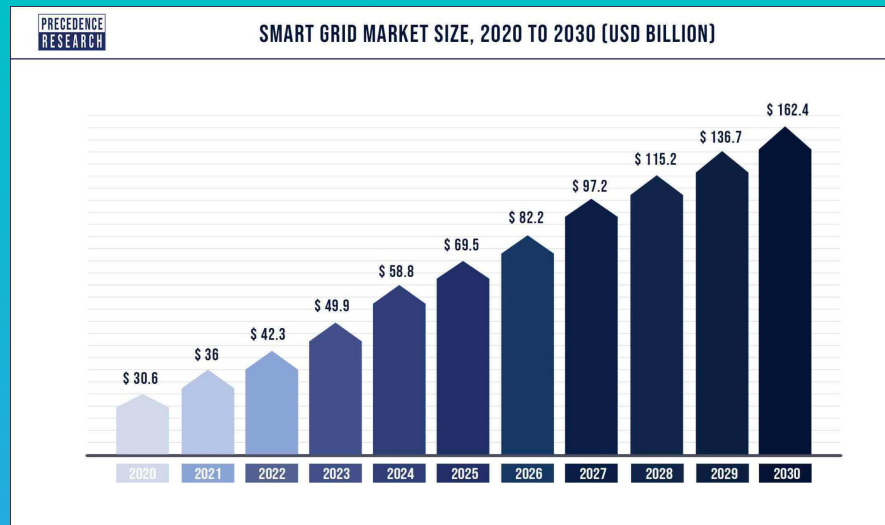
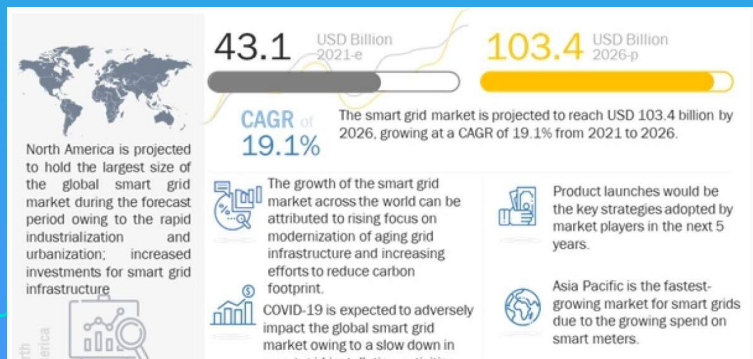
Breakdown of spend



By interoperating we can create better energy systems for everyone. Create new, better games for energy markets to play.

Self-sovereignty is critical. Plurgrid is applicable to the following markets:

- Emergency Services for wildfire response
- Emerging grid opportunities
- Existing centralized grids
- 774 million people without electricity
- The next billion people



Smart Grid Market Size to Hit USD 140.53 Billion by 2028 (CAGR of 21.9%)

Smart Grid Market Forecast Report 2021-2028

Power System Simulator Market Forecasted to Hit USD 1,461.8 Million by 2025 with 7.50% CAGR

Report by Market Research Future (MRFR)

Utility energy storage could approach **\$1 trillion** during the next 10-20 years.



# Plurigrd Team



## Barton Rhodes

Machine Learning  
Security DAO, Lacework,  
DaVita, Optfit, Hurricane Labs



## Amber Case

Exits: EverCharge / Geoloqi  
MIT Media Lab / Harvard  
Berkman



## Janita Chalam

IBC+ Smart Contracts  
Uber / Microsoft



## Michael Zargham

Complex Systems Scientist &  
Architect, cadCAD  
(Advisor and partner)

## Advisors

### Eric Alston

Constitutional Law  
Leeds School of Business, UC Boulder

### SJ Klein

Harvard Berkman Klein Center for  
Internet & Society

### Seth Frey

MetaGov

### Lynne Kiesling

Energy Economist

### Scott Moore

Co-Founder, GitCoin

### Jules Hedges

Applied Category Theory

## Partnerships

BlockScience

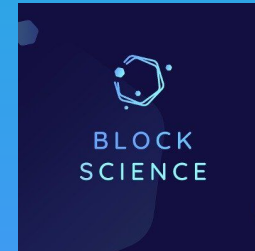
cadCAD

WindscapeAI

Anoma

Metagov

NREL



Thank you!



[plurigridd.xyz](https://plurigridd.xyz)  
[gm@plurigridd.xyz](mailto:gm@plurigridd.xyz)

# Appendix

# Appendix A | Resources

## Research

### **Coordination of resources at the edge of the electricity grid: Systematic review and taxonomy**

<https://www.sciencedirect.com/science/article/pii/S030626192200558X>

### **Electricity retail rate design in a decarbonizing economy: An analysis of time-of-use and critical peak pricing**

<https://energy.mit.edu/publication/electricity-retail-rate-design-in-a-decarbonizing-economy-an-analysis-of-time-of-use-and-critical-peak-pricing>

<https://energy.mit.edu/publication/electricity-retail-rate-design-in-a-decarbonizing-economy-an-analysis-of-time-of-use-and-critical-peak-pricing>



Applied Energy  
Volume 318, 15 July 2022, 119188



Coordination of resources at the edge of the  
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Flora Charbonnier<sup>a</sup>, Thomas Morstyn<sup>b</sup>, Malcolm D. McCulloch<sup>a</sup>

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<https://doi.org/10.1016/j.apenergy.2022.119188>

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# Scalability: Sovereign blockchains + IBC

The Inter-Blockchain Communication Protocol (IBC) allows independent blockchains to directly communicate and trade assets.

IBC enables independent blockchains to connect, transact, exchange tokens and other data, scale, and thrive in an interconnected network.

- IBC is what Plurigridd instances use to operate smart contracts, send and receive information from the grid to data models, and ensure information is private or public
- Because IBC is interoperable across multiple chains, each grid can have their own ledger mechanisms, and the network can achieve global scale.
- For larger grids, IBC powers the compositionality of working smaller grids.

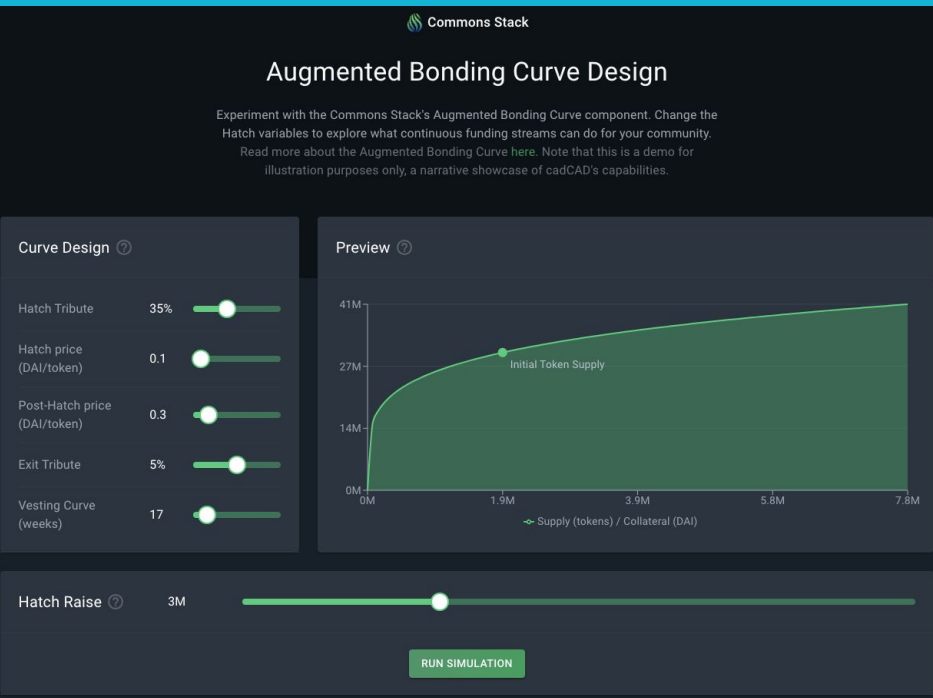
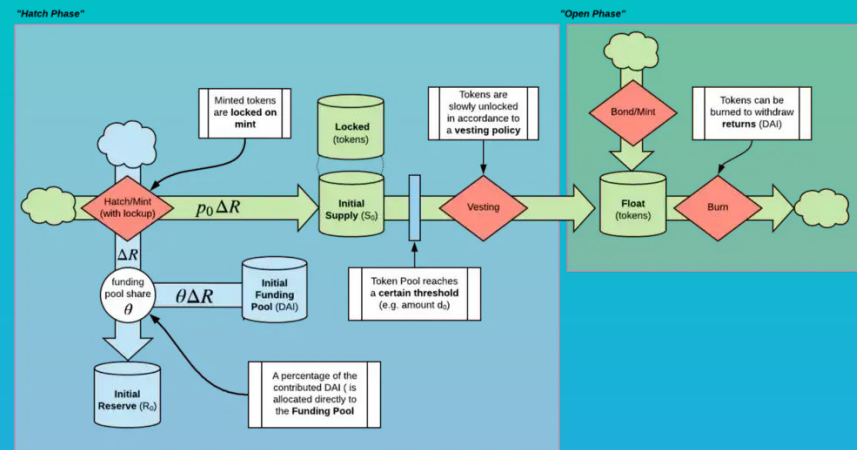
IBC and Plurigridd Protocol can allow grids to exist at any scale on sovereign blockchains. GridSPICE modeler can inform when to create a sovereign blockchain. Smart contracts, specifically commons contracts and dao-contracts are used to bootstrap smaller grids and allow for legal public funding of grid resources

Any number of microgrids can start up as an instance of a commons on a permissioned, public Plurigridd:

- Acquire a number of private permissions ledger instruments
- Over time, discover the value of coordination
- Evolve into sovereign blockspace across any number of chains, public and private, necessary to sustainably fulfill coordination needs of that given Plurigridd.

# cadCAD and BlockScience

Configuration at the edge: Microgrids themselves set incentive structures and have sovereign blockchains and hatch events



The image shows the header and main content of the TEC (Token Engineering Commons) website. The header includes the TEC logo, navigation links (MISSION, COMMUNITY, ECOSYSTEM, FORUM, GET INVOLVED), and a "GET \$TEC" button. The main content features the text "TOKEN ENGINEERING COMMONS" in large, stylized letters, followed by the tagline "Sustainable & Ethical Design for Token Ecosystems" and a "BUILD WITH US" button.

# Initial Deployment Targets

Mount Evans Outdoor Lab | Morrison CO

NREL Energy Systems Integration Facility

Kennedy Mountain Campus

University of St. Thomas Renewable  
Energy Facility in Minnesota - *Partnership  
with Xcel Energy\**

Steger Wilderness Center\*

Individual small, community-owned  
Microgrids



Starting with an idea for a home that also functions as a microgrid, NREL collaborated with Holy Cross Energy to create this home site .

*\* Advised by Professor Greg Mowry, Minnesota*

**Federal Grip  
Grid Resiliency Grant Application  
Submitted 2022-12-16**

**Electric Utility**

Poudre Valley Rural  
Electric Association

**Hardware and Software**

Eaton

Max Broadband

**Academic**

University of Denver

Washington State  
University

**Software and Analytics**

Resilient Entanglement

TerraNexum

**Federal Agency**

USDA Forest Service

Plurigrd