IIT Institute of Design

Microgrid as Civic Infrastructure

How will rewiring today's choices around electrical grids shape tomorrow's communities?

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SECTION 1

INTRODUCTION

Executive Summary

Electricity is an essential commodity in the twenty-first century. It is an asset that we are all intimately familiar with but don't think twice about until it's not there. When we plug our phone into an electric outlet while on the brink of death and receive that brilliant chime of confirmation, that sigh of relief is usually where our relationship with energy ends: Its usefulness in our everyday lives.

What lies behind the outlet is the electric grid are power plants, wires, batteries, utility poles, distribution lines, voltage converters, and transformers that are organized and orchestrated to keep America running. It is a system that has slowly evolved over the last 150 years, yet modern life continues to place new demands on it. In pushing it beyond its limit, we're starting to take notice of how it's holding us back:

- Increased blackouts across the nation.
- Continued reliance on non-renewable resources polluting the environment.
- Increased centralization and monopoly of the industry.

Rethinking how we generate and deliver energy, how it can withstand disruption, and most sharply, how it can serve and strengthen our communities has become the need of the hour. For as ingrained and pervasive as the grid is, it has immense potential to influence, shape, and transform how we organized our lives.

We are at a tipping point where we genuinely need to consider a radical transformation. We have been witnessing that complex, large-scale transformations such as energy transition can not be achieved through fragmented efforts but require a purposeful alignment of products, services, organizations and policies at all levels of systems. While this complexity resists long-term and strategic planning, design can help us envision more sustainable interactions rooted in energy infrastructure that can present us with new choices and opportunities.

With this mindset, we explored possible design interventions that build up on the existing work on the microgrid model at Illinois Institute of Technology (IIT) and Bronzeville as part of the Sustainable Solutions Workshop at IIT Institute of Design. In this report, we present a collection of these design interventions and the choices they enable for our shared future. We hope that in describing these emerging opportunity areas and how design can support such transition processes we can empower industry leaders, organizations and sustainability advocates to envision new pathways towards sustainable energy infrastructures.

We envision a paradigm shift to envision sustainable futures for our energy infrastructure where data-enabled intelligence can increase adaptive capacity, new capabilities are built to form collective energy stewardship, people have choices and control for how they participate in energy transition systems, and establish incentives mechanisms to advocate for the adoption of desired mental models.

Glossary of Terms

Affordance

An affordance is a tangible clue in a designed artifact that indicates a specific action that is enabled by the artifact.

Civic Infrastructure

The visible and invisible structures, spaces, assets, processes, contracts, norms, and networks that bind communities to self-organize and hold themselves collectively accountable for making purpose-driven choices.

Microgrid

A decentralized network of electricity users with diversified local sources of energy supply that can function independently but can also connect to a centralized national grid.

Prosumer

An informed individual who at the same time is both a consumer and producer of a specific product or service. Prosumers can be driven by self-service, collaboration, or economic interest.

Transaction

The modes of exchange of resources between agents within networked systems that are enabled by specific features of infrastructures.

Electric Energy Generation

The process of generating electric power from sources of primary energy which can be either renewable or nonrenewable.

Energy asymmetry

This occurs whenever some areas have more accessible and cheaper access to energy because of distribution, while others have none.

Energy resilience

A measurement of a healthy electric energy system's capacity to absorb disturbance and still maintain functional integrity.

Grid Fracture

Extreme weather or human-produced disasters that leave entire communities without access to the electric grid or an alternative means to access energy such as the disruptions caused by heat waves or Texas storms.

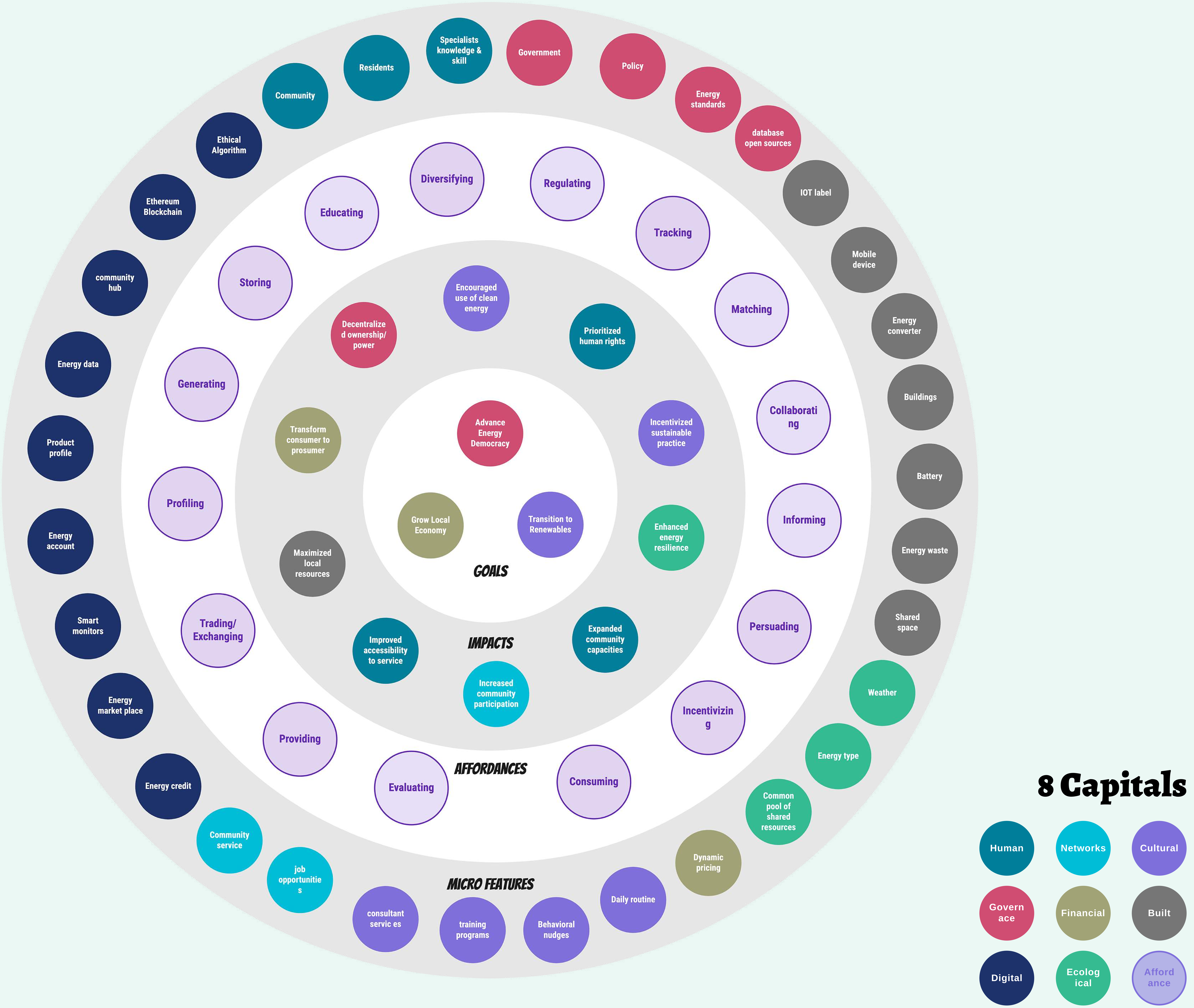
Small-mid scale institutions

Institutions that bring the community together, whose goal varies from electricity. They can bridge accessibility gaps and demonstrate environmentally and socially responsible practices around energy. For example, local businesses, community organizations, libraries, churches, grocery chains, restaurants, etc.

Problem Landscape: Future of the Grid

The transition to renewable energy has long been endorsed as the primary pathway of energy transformation to reduce CO2 emissions and mitigate climate change. However, electricity is consumed in our homes, offices, and elsewhere which relies on a crucial edifice, the electric grid. This reliance on an aging, increasingly unstable, underfunded infrastructure fundamentally threatens and obstructs our pursuit of transition to new, resilient, and sustainable energy futures. We are already experiencing the consequences of our unsustainable energy infrastructure in the form of weather-related power outages, increased costs of maintenance reflected in electricity bills and growing risks of cyber-attacks.

In the face of this challenge, consumer-driven sustainability narratives keep placing the onus on the end users to adopt sustainable practices and switch to energy-efficient products. However, it becomes increasingly clear that such large-scale transitions require a purposeful alignment of policies, utility companies, end users and other stakeholders in the form of infrastructural interventions that can enable more sustainable ways of sourcing, distributing and using energy. One such emerging infrastructure is the microgrid exemplified at Illinois Institute of Technology that combines renewable energy sources with intelligent and reliable energy distribution. While microgrid offers new grounds for transitioning to sustainable energy sources, it needs to be supported by the design of a new system of solutions that can open up new choices for various stakeholders to reap the potential benefits for the environment as well as the communities. The following pages illustrate the design processes and models we leveraged to challenge the old energy paradigm on all accounts of ownership, modes of exchange, and governance to encourage a transition to renewable sources of energy and produce equitable outcomes for all.



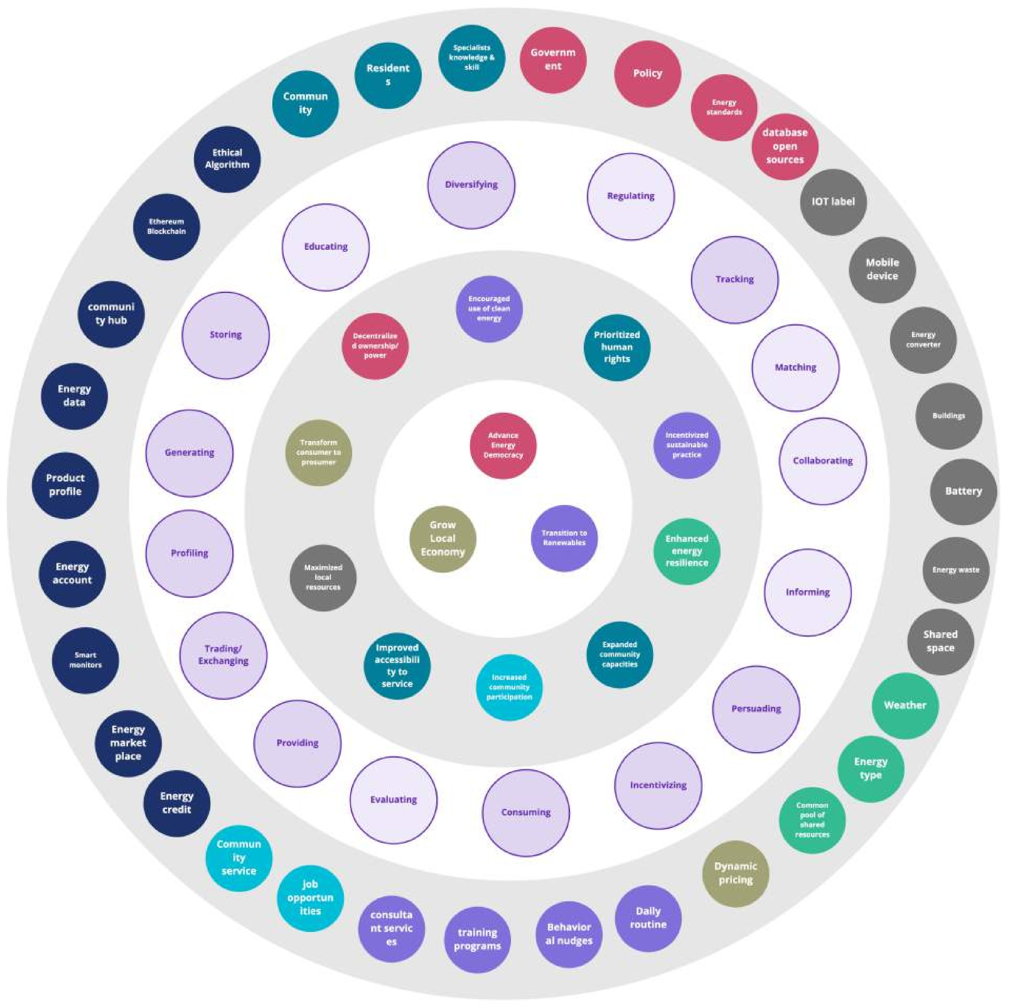
Generative Prototyping

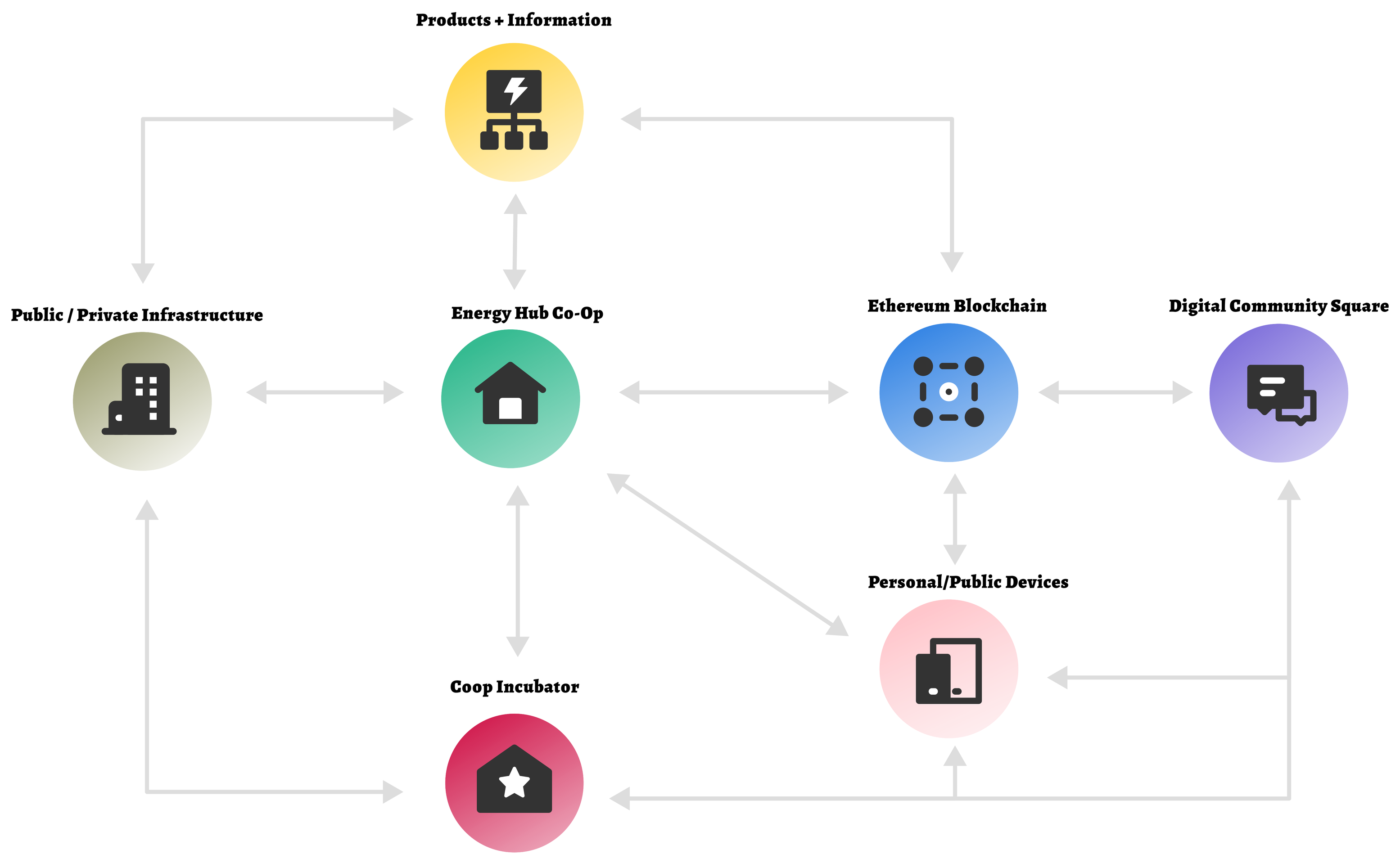
Generative prototyping is a design practice that focuses on experimentation and learning through doing. It relies on cycles of rapid iteration by building physical objects to communicate ideas, generate questions and provoke critique. These prototypes are used as tangible props to navigate the problem space, explore opportunity areas, envision new affordances, and surface ethical concerns.

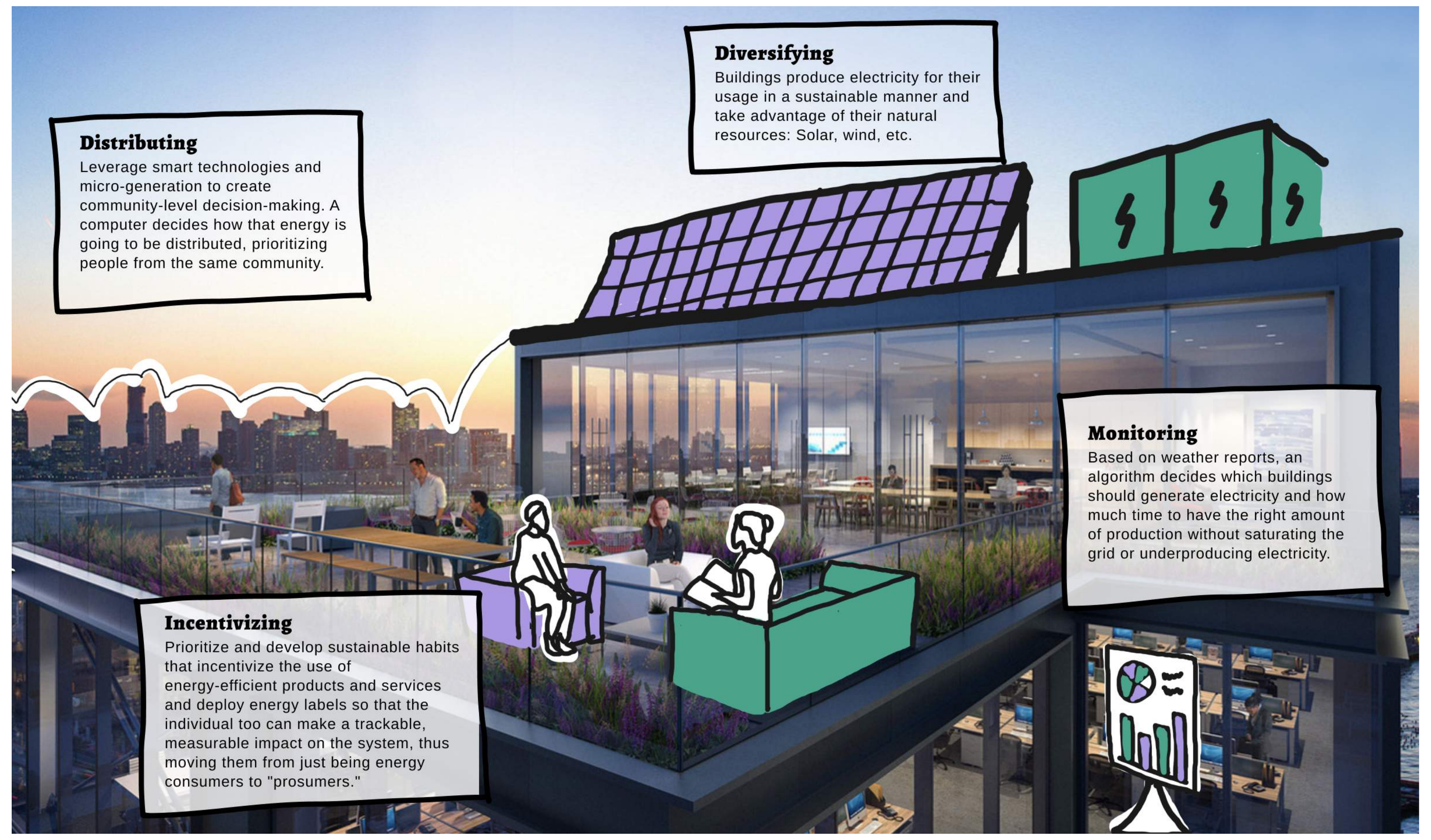
We adopted this process to understand the various aspects of infrastructures and explore sustainable solutions through different lenses such as equity, circular economy and anti-racism. We organized our process in multiple rounds of prototyping with mixed teams to create the conditions for collective exploration and cross-pollination of ideas. By renouncing ownership of solutions, we provoked an immediate exchange of perspectives, ideas and critique with minimum bias.

We used computation as a core ingredient of prototyping to explore the features needed to build collective intelligence as a means to increase the adaptive capacity of the infrastructure and to foster more equitable outcomes for the various users that carry the burden of our current energy paradigm. We also explored the possibilities of computation to support communities' and organizations' collective capacity to act towards open innovation.

Design Models







Anatomy of Infrastructure

Anatomy of Infrastructures is a design framework that helps identify the various tangible and intangible components that makeup infrastructures and explore their multiple, purpose-driven configurations. We used the Anatomy of Infrastructures to recognize the diverse resources that can be mobilized (components layer) to enable new interactions and exchanges (affordances) that lead to the impacts that users want to generate (indicators) when pursuing their purpose.

Archetypes

An archetype illustrates the transferable core logic of a designed solution defined by its goal, features, and affordances (the actions it enables us to take). It represents a purposeful combination of products, services, channels of communication, and data ecologies that will allow diverse agents to contribute to shared goals and envisions new variations of these features across different contexts.

Action Situation

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SECTION 2

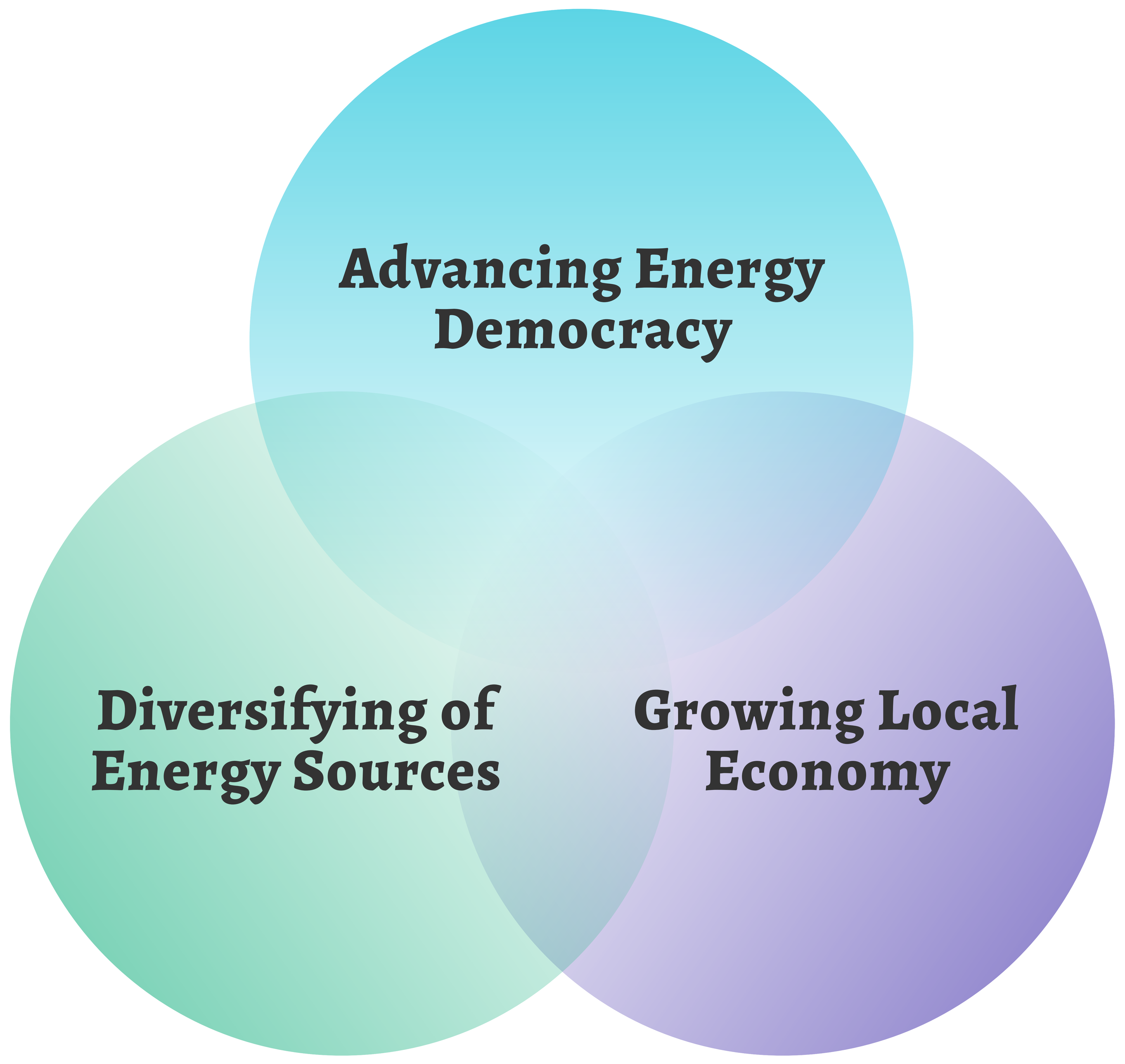
SYSTEM OF SOLUTIONS

System of Solutions

Envisioning the microgrid as civic infrastructure requires moving beyond its conception as a technical infrastructure to consider its socio-cultural dimension that is intertwined with the countless artifacts through which we source, distribute and regulate electricity. Unfolding the elements of microgrid a shared pool of tangible and intangible resources helped us envision new configurations of these resources that can activate new choices to support sustainability goals in the long-term. By integrating the lenses of equity, circular economy, behavioral design and anti-racism into our hands-on exploration we discovered new opportunity spaces that can activate the microgrid as a civic infrastructure.

Our exploration was centered on the new choices that will shape a new energy paradigm towards sustainable energy sourcing and equitable outcomes for communities. Our discoveries consolidated in three complementary themes that propose ways to recombine our shared resources through infrastructural design interventions.

The first theme is **diversifying energy sources** which is a key element of transitioning to renewable energy sources not only at the level of production, but also distribution and consumption. This diversification needs to be supported by new governance mechanisms that can decentralize energy generation and consumption. Such decentralization opens up a whole new set of opportunities for **growing local economy**, in the form of new non-monetary currencies and peer-to-peer exchanges. The rise of the local economy goes beyond just wealth generation and signals an essential switch in power dynamics and ownership. All of this requires the strengthening energy stewardship at the local community level - a core component of **advancing energy democracy**.



Diversifying Energy Sources

How might we encourage and enable more circular approaches in our production, consumption, and disposal of energy within the microgrid to minimize environmental disruption and ensure energy resilience?

GOALS

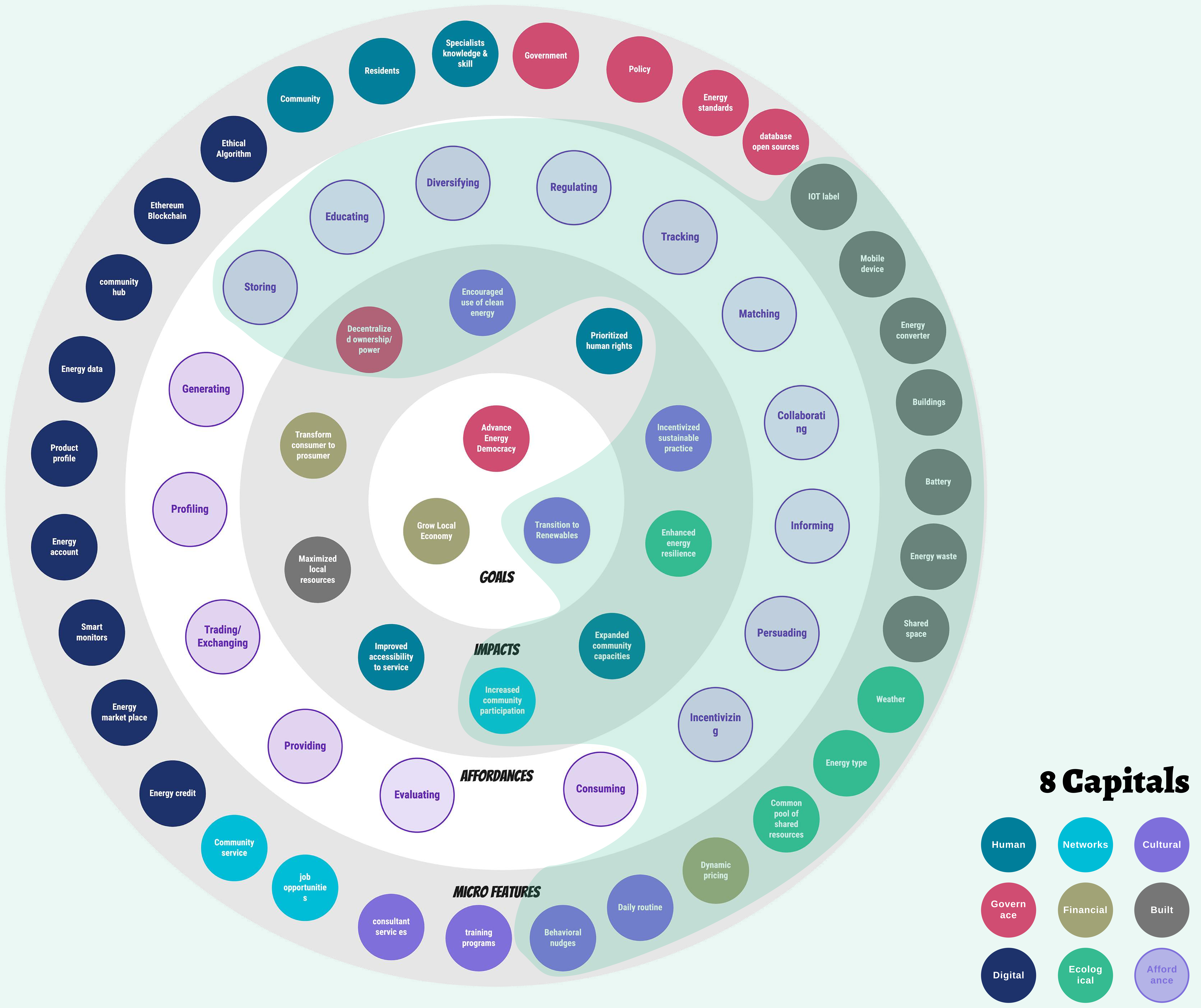
Minimize negative impacts in the environment by encouraging closed-loop energy cycles that can reduce waste.
Increase the capacity of the grid to absorb disturbances such as weather conditions or supply/demand

SYSTEM OF SOLUTIONS

Diversifying Energy Sources

While diversification of energy sources is a key component of transitioning to renewable energy sources, it needs to be supported by new mechanisms that can put circular economy principles into action. A circular approach to energy challenges the one-way production and consumption paradigm that dominates our energy infrastructure, to emphasize collective ownership of resources and mutual accountability between users and organizations from private and public sectors.

In this set of solutions we propose a tactical activation of existing resources such as spaces, technologies, cultures through new features that can advance collective stewardship of energy infrastructures. We combine multiple interventions at the production, distribution and consumption levels to incentivize collective ownership of energy generation and management. These interventions open up new choices for individuals, communities and organizations that can leverage different energy sources to increase local social and economic capital alongside energy resiliency.



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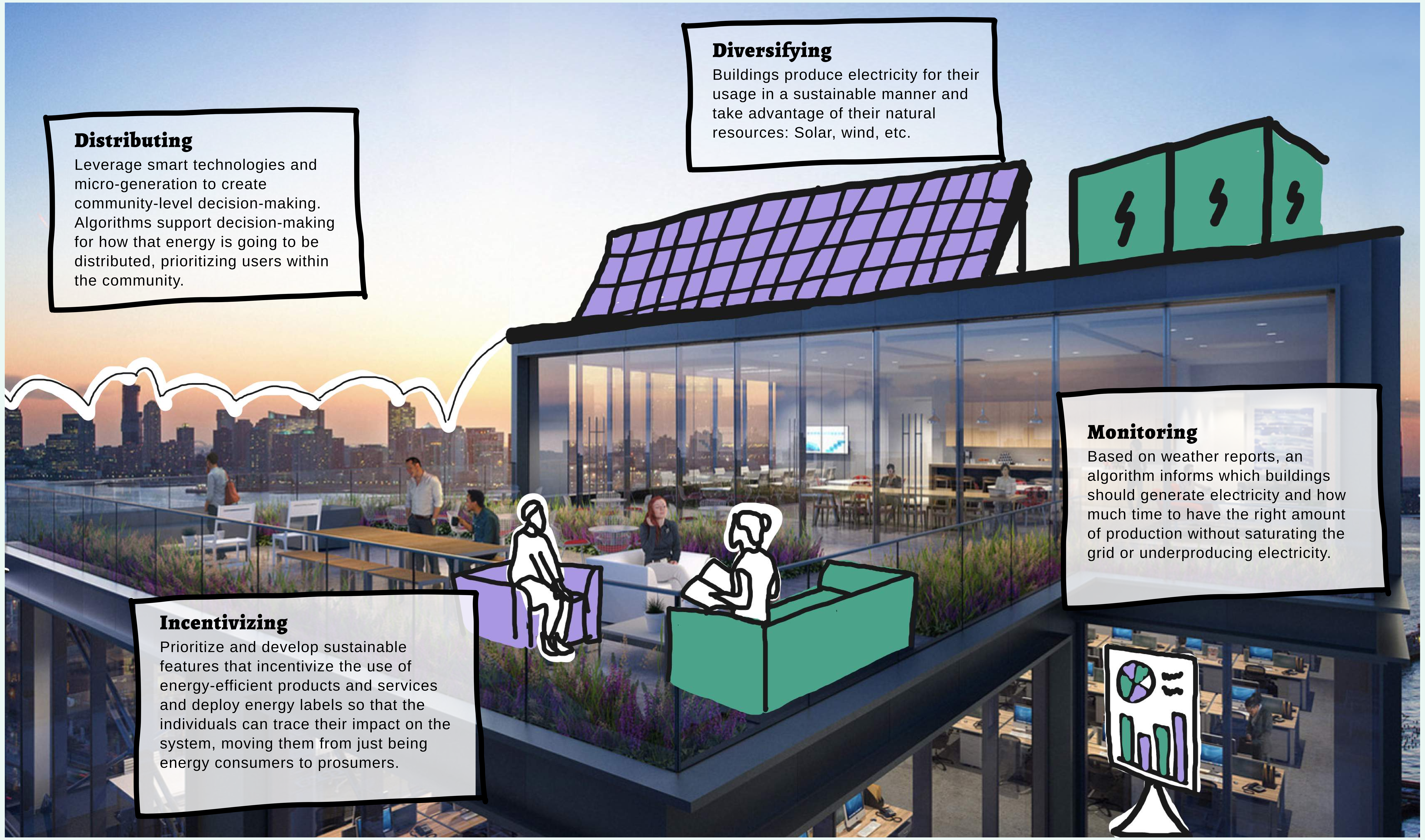


Buildings manage (produce, control, exchange, store, etc.) their energy to diversify energy sources. Buildings and communities prioritize sustainable generation by recycling the grey energy that is otherwise lost. They contribute the surplus generation to the community grid or purchase from the neighboring grids when demand exceeds supply. The interdependence of buildings for energy distribution contributes to energy resilience.

Archetype | Community Micro-Generation of Energy

Communities can repurpose their unused spaces such as roofs, empty lots, and yards to create their renewable energy micro-generation. Depending on the size, location, and type of energy being harvested, individuals can manage the system with smart technologies that monitor the infrastructure and report real-time data. Through the localization of knowledge and resources, the decision-making and implementation power for energy resources are in the hands of communities. Individuals can benefit from localized energy production through a lower cost on their bills, make a profit if they produce energy, enjoy a healthier outdoor environment with fewer pollutants, and confidently rely on a resilient energy supply.

Under-utilized Space

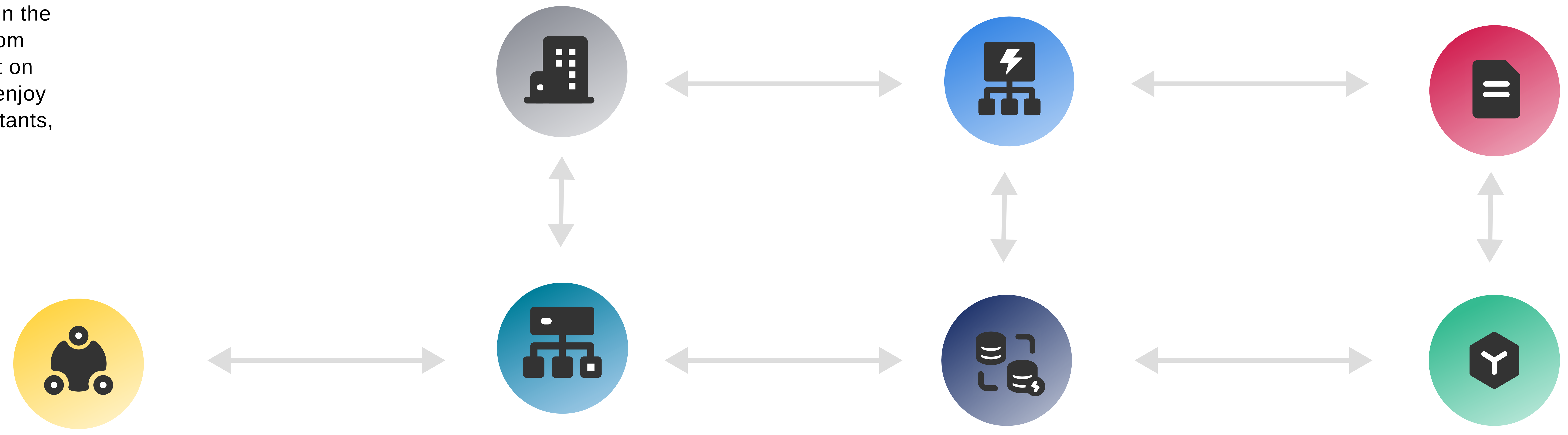
Individuals can leverage underutilized spaces like roofs, offices, and parking lots to create micro-generation sites. Typically underutilized spaces are used to build platforms, provide a community amenity, and support the local economy.

Micro-Generation of Energy

Residents generate energy at small and large scales. Available resources like wind, solar, and water are used to create energy that is better for the environment and people because it does not produce pollutants or other adverse effects from harvesting fossil fuels.

Community Energy Generation Policy

A policy framework that attracts investment by rewarding entrepreneurship and innovation and constraining inefficiency and waste. Create incentives that will encourage new energy consumers and support the transition to renewable energy.



Community Platform

Community platforms calculate how much grey energy is being produced city-wide. Potential energy sources are identified and located in real-time and are available to the whole community.

Distributed Production

Individuals and communities determine how to create energy in their homes, offices, and communities. Residents have more localized control over how they receive their power and create new economic opportunities through their energy generation.

Production and Consumption Data

Smart technologies support microsystems' and prosumers' ability to monitor their output and optimize their systems.

Energy Assessment Platform

Sensors collect data about the functionality of the system and environmental considerations. Sensors reduce the burden on residents by removing the need for continuously monitoring their microgeneration.

Growing Local Economy

How might we leverage the affordances of the microgrid to create new choice architectures that can activate local resources and grow local economies?

GOALS

Create platforms for participation with lowered barriers for entry and increased ability for active engagement.

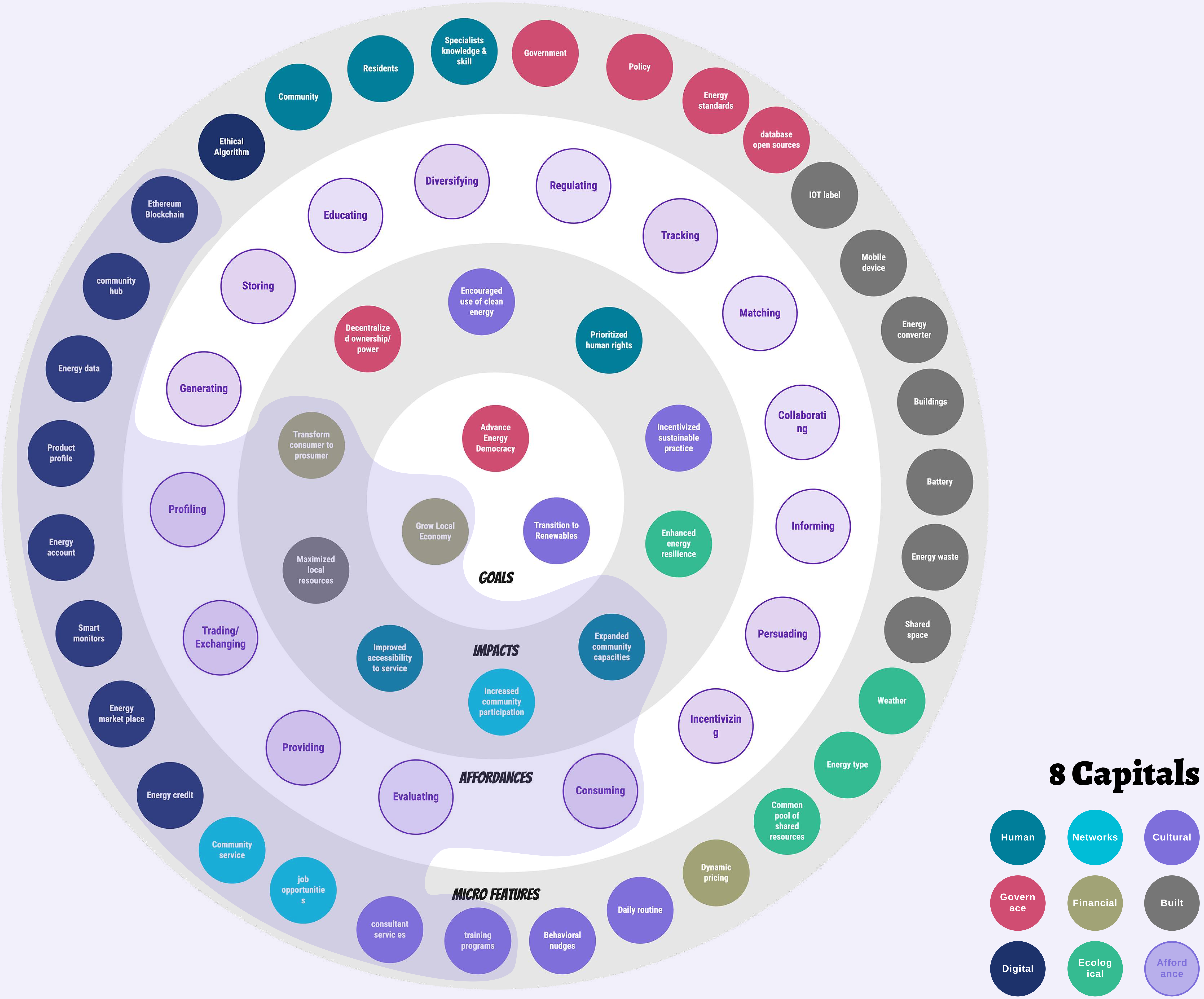
Increase local economy resiliency by expanding opportunities to exercise expertise, strengthen community ties and safeguard health and wellness of community members.

SYSTEM OF SOLUTIONS

Growing Local Economy

The microgrid as a civic infrastructure democratizes energy production and revitalizes new modes of transaction within local economies. In motivating the adoption of the microgrid and supporting technologies for transitioning to renewable energy, it is important to provide the community members with not only incentives but also the ability to make alternative choices and control their assets towards an increased ability to leverage local resources in innovative contexts of use.

Our sustainable solution creates opportunities for community residents to self-select options that suit them best and self-organize through the P2P networks and platforms. The suggested combination of interventions lead to diverse activations within the community by reducing the barriers to access quality services, creating marketplaces for energy trading, aiding financial planning and wealth generation, strengthening community ties or providing new contexts to obtain nourishment and protection from extreme weather elements. Additionally, the users are no longer passive consumers but prosumers, with the potential to collaborate, upskill, self-serve and monetise through their interactions and interchanges within their communities. The adoption of the described technologies thus, is increasing not only the resiliency of the power system but also that of the local economies.



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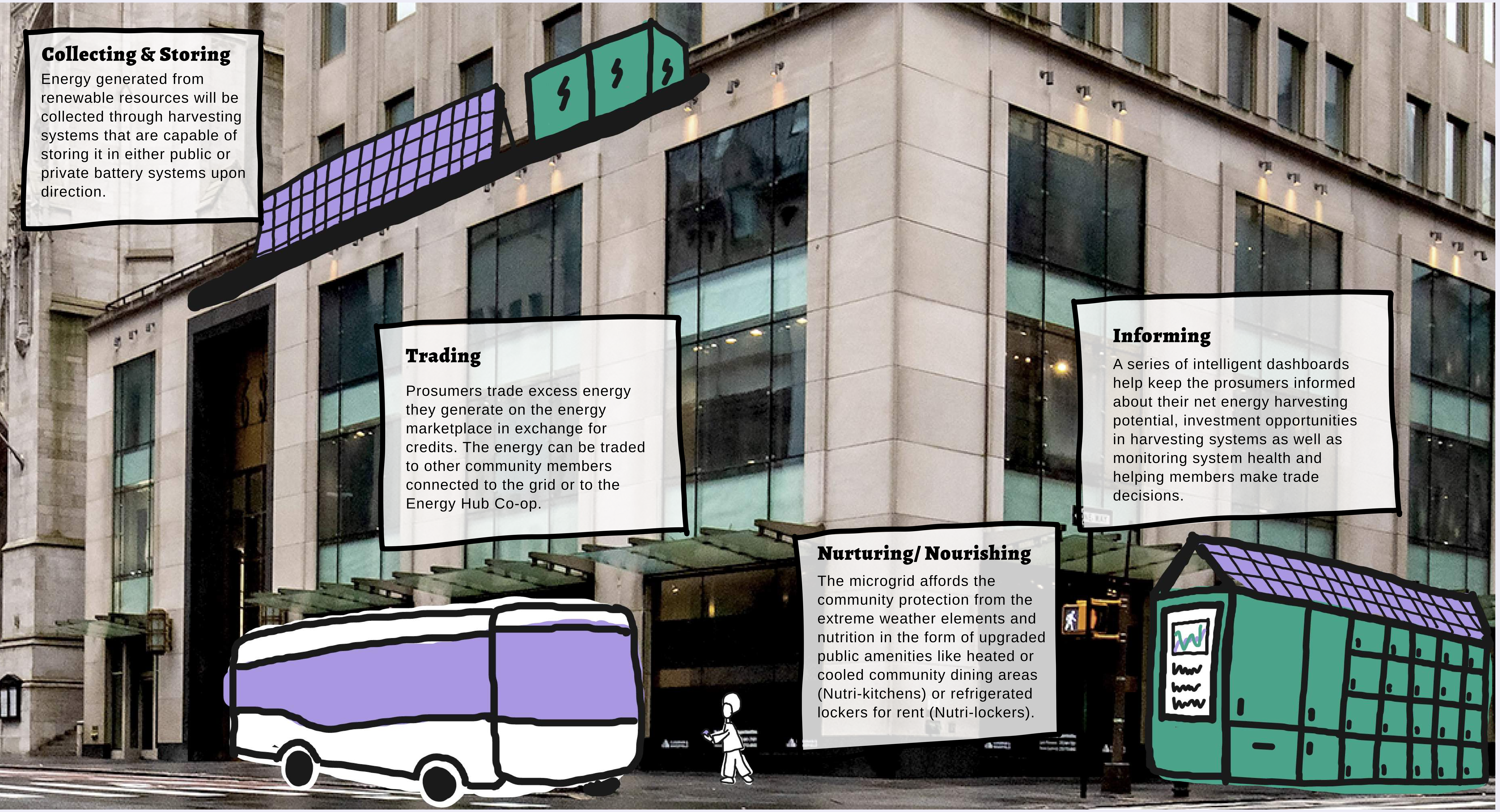

Collective capacity of community members and the economic potential of their assets are strengthened through the actions enabled by the Energy Hub Co-op. This people centered enterprise safeguards the networked system and marketplace platform transactions like matching, trading, buying or providing services (or energy). The hub enables new opportunities for community members to offer and advance their technical expertise in exchange for credits, which can in turn, be redeemed to acquire microgrid technologies or other services. Amongst the innovative community facing services provided, is neighborhood Nutri-kitchens — an amalgamation of food lockers, dining zones and self-help counters that allows for dignified access to nutrition for community members. Additionally, Energy Hub acts as an aggregator of local distributed energy resources when negotiating energy contracts with larger industrial or commercial consumers. This exchange helps build strategic partnerships between the community and the industries and can motivate reinvestment in these distributed economies.

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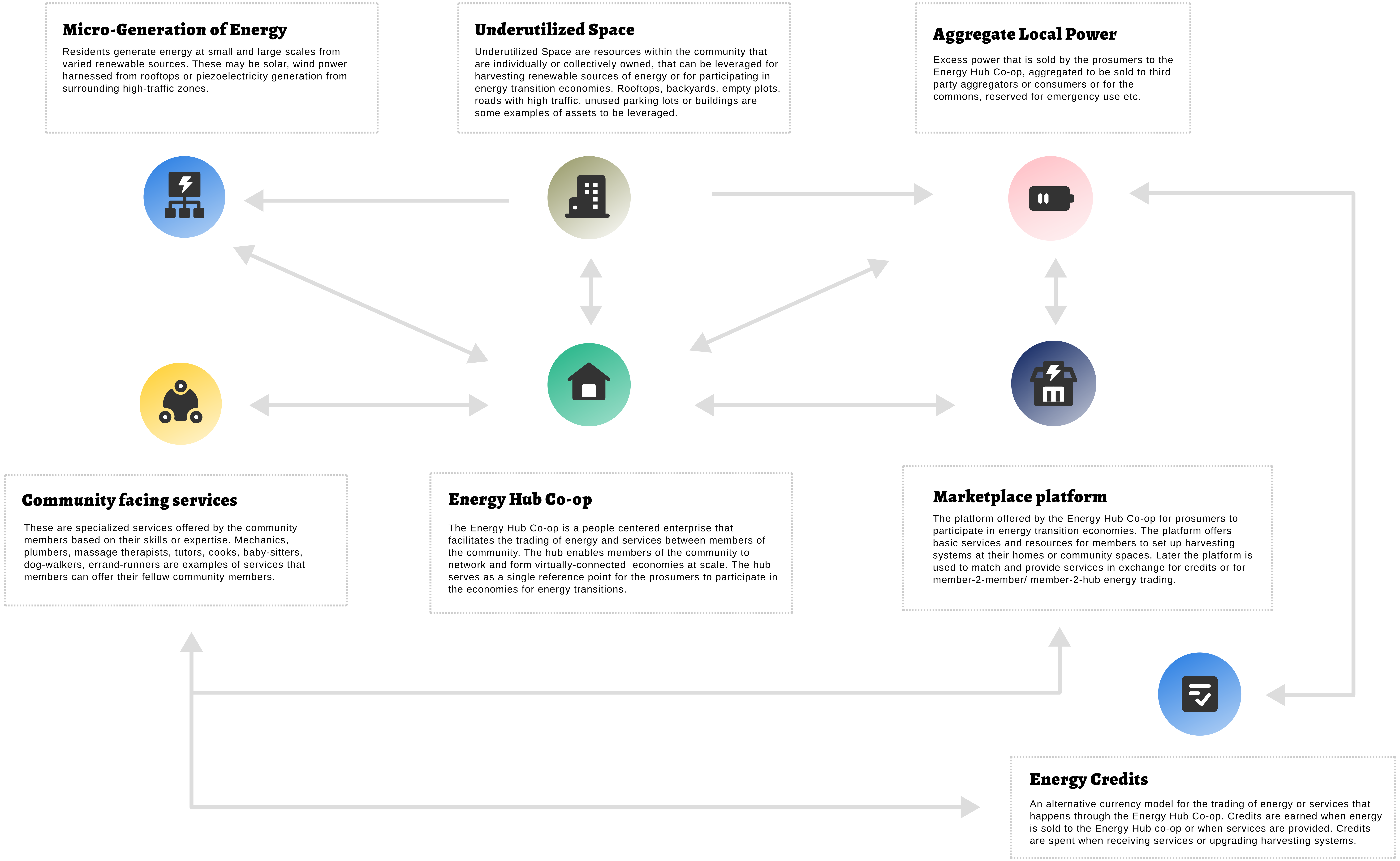


Advancing Energy Democracy

How might the microgrid incentivize more equitable modes of communal engagement?

GOALS

A gradual and calculated shift from wealth accumulation to shared ownership and community resources.

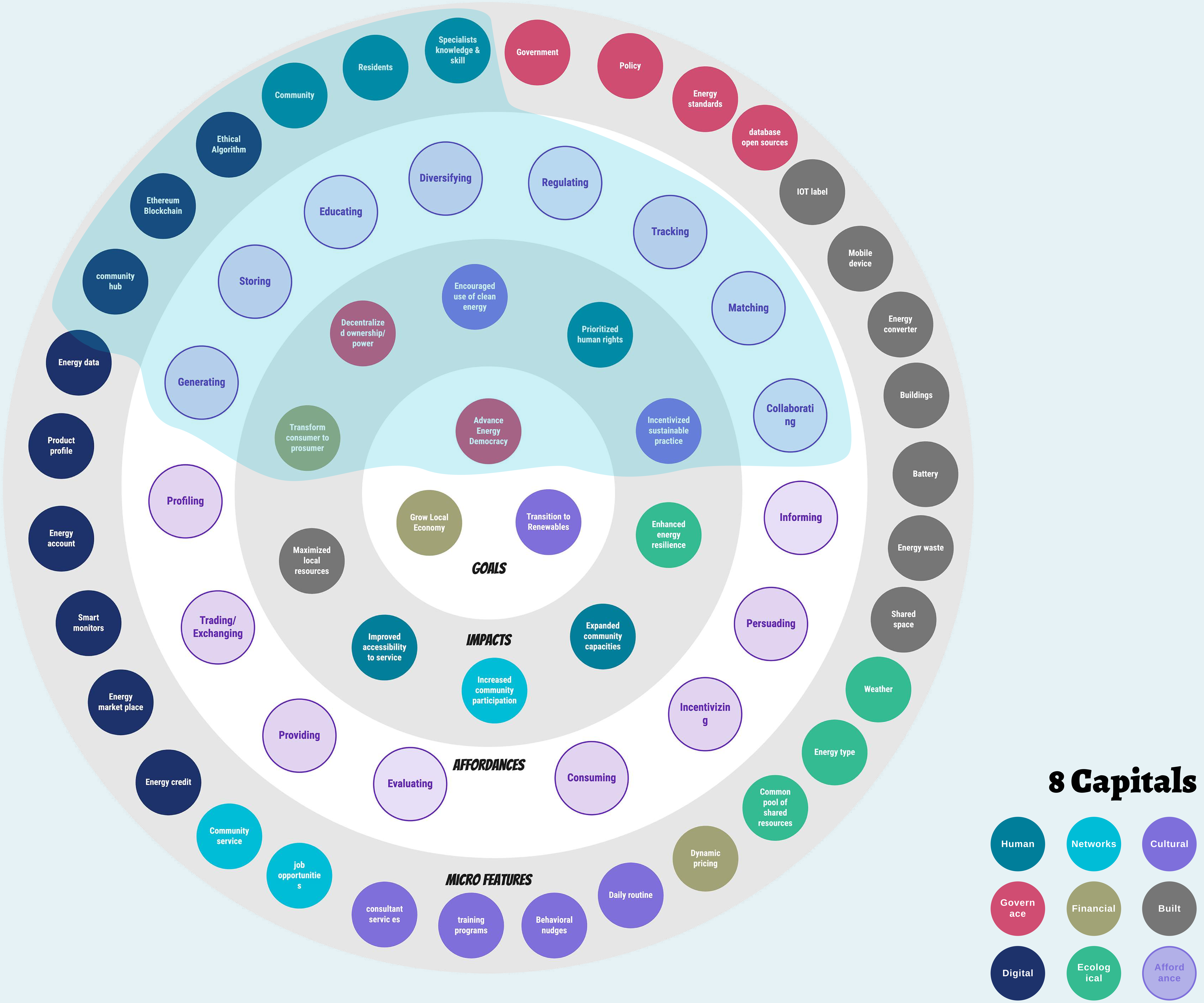
Ability to reclaim and restructure existing infrastructure to be more democratic and participatory.

Increase individual and communal self determination
Incentivize equitable modes of communal participation

Advancing Energy Democracy

The emerging affordances and capabilities that are revealed in the diversification of energy sources and the reimagining of local economic opportunities lead to a potential strengthening of civic engagement beyond just the energy sector. The shift to more localized decision-making along with decentralized ownership and exchange of resources advance democratization of energy production.

Incorporating participation from small-mid scale institutions creates a transition scale between the city utility and individual consumers for localized control and management. The decentralized nature of the microgrid favors a shift to hyperlocal systems in combination with computation-enabled governance mechanisms to reimagination of power structures that could increase the agency and resilience of a community. The success of this vision rests in part on developing the necessary capabilities, resources, and platforms that support a community's ability to understand, debate and participate actively in creation and evolution of their civic infrastructure. This set of solutions surfaces questions such as the balance between privacy and transparency, paths to universal data literacy, asynchronous autonomous modes of communal decision-making will shape idiosyncratic local governance structures that are dynamic, resilient and reflect the needs of those it serves.



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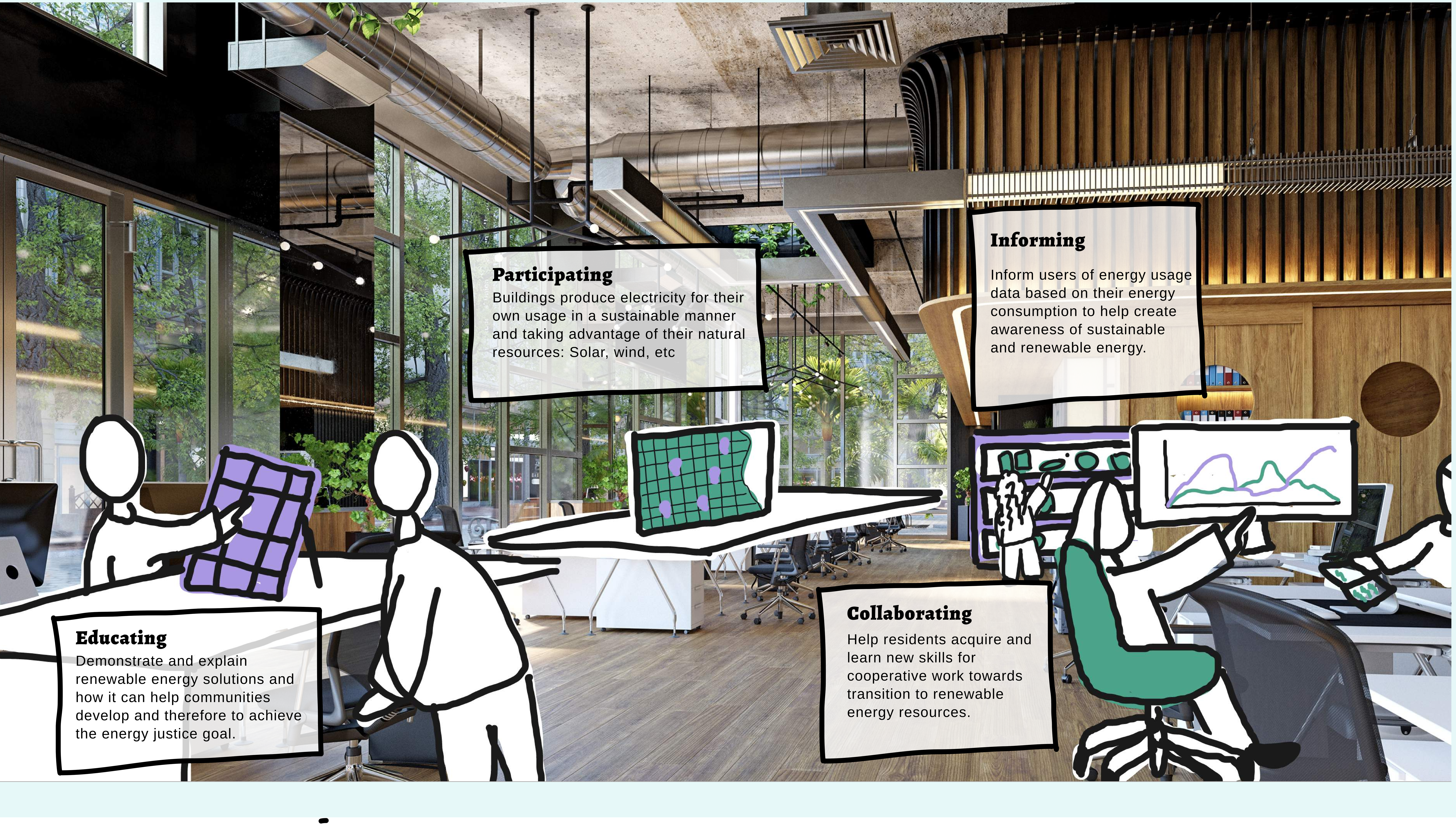
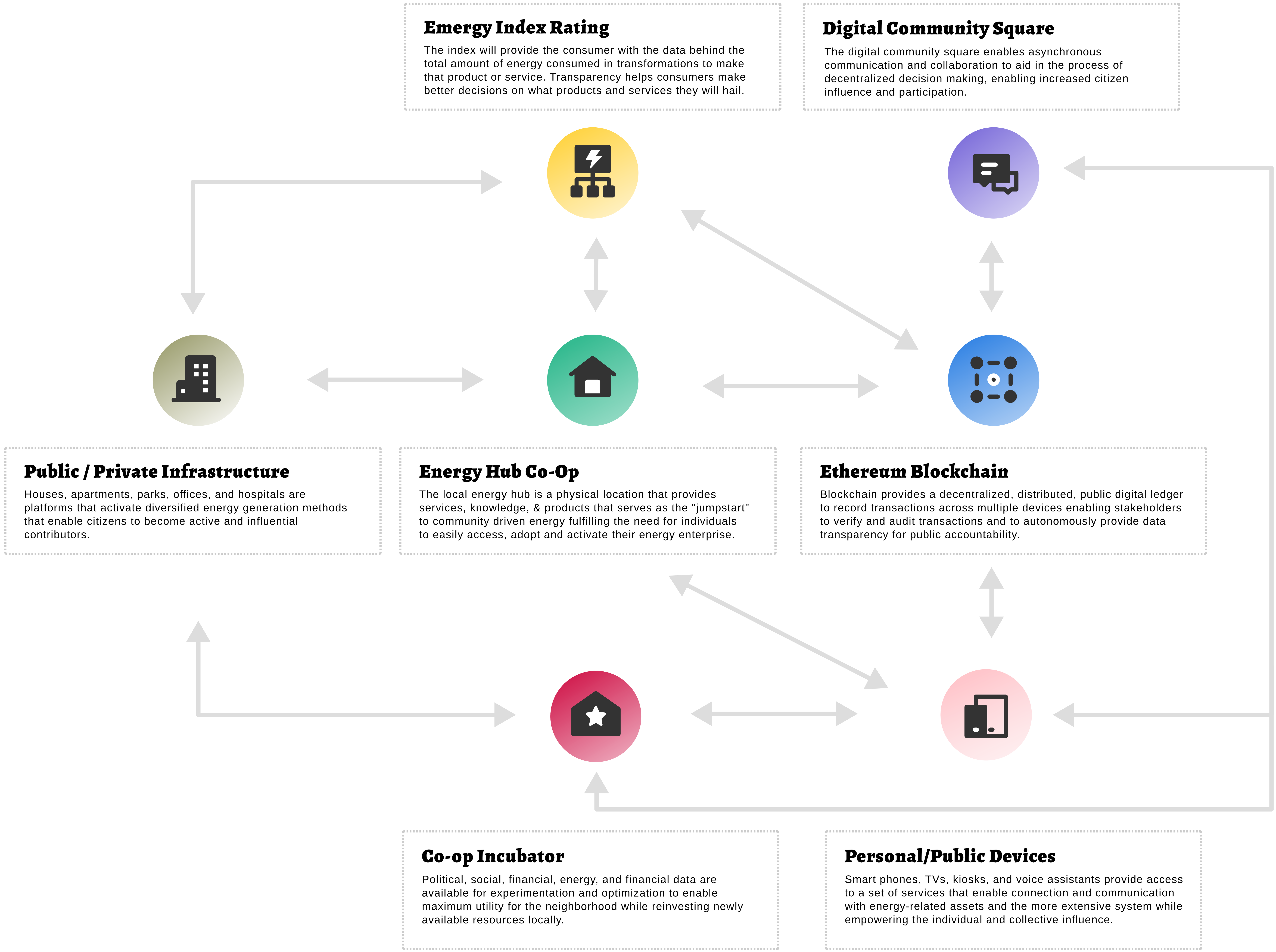


The new transaction and capabilities that are revealed in the local economy and diversification also open new possibilities in terms of governance structures towards civic participation. In our explorations, it became clear that a critical transaction revolved around education at all levels. Energy management and data literacy were critical skills that, if ignored, could continue to increase current system inequities. An energy co-op hub helps materialize and provide resources and services to help everyone gain access to skills and resources to make informed choices. Other institutions that could play key roles are digital community squares that aggregate and facilitate communal conversations and decision-making. The community increases collective resilience while providing pathways to innovate public and private partnerships where there is a space for open experimentation and further exploration around new services and ways to rethink resources.

Archetype

Building support structures that increase participation and engagement is crucial as it promotes an effective decentralized marketplace that is equitable and inclusive. This support is done through energy education: the Energy Hub Co-op is an institution whose purpose is to materialize and provide resources and services to community members to gain the skills and knowledge necessary to understand and exert their choices entirely. This safeguards every members' capability to engage in the open-source energy exchange. The Digital Community Square and its embedded algorithms afford the ability to visualize and conceptualize community data for the community members to experiment and reimagine new ways to address emerging needs. Finally, ethereum blockchain enables autonomous and asynchronous decision-making for policy-making through personal devices that act as passports.

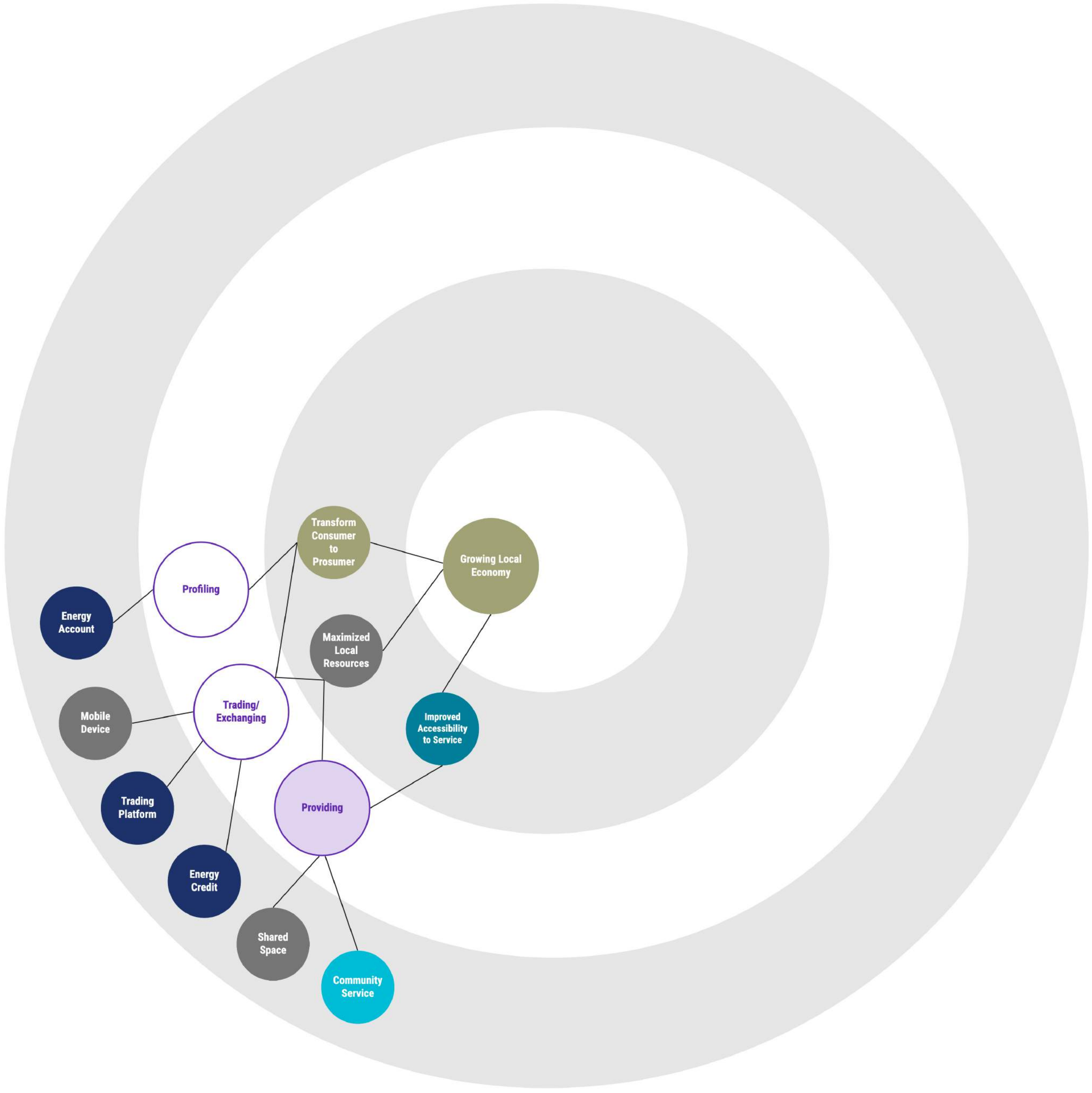


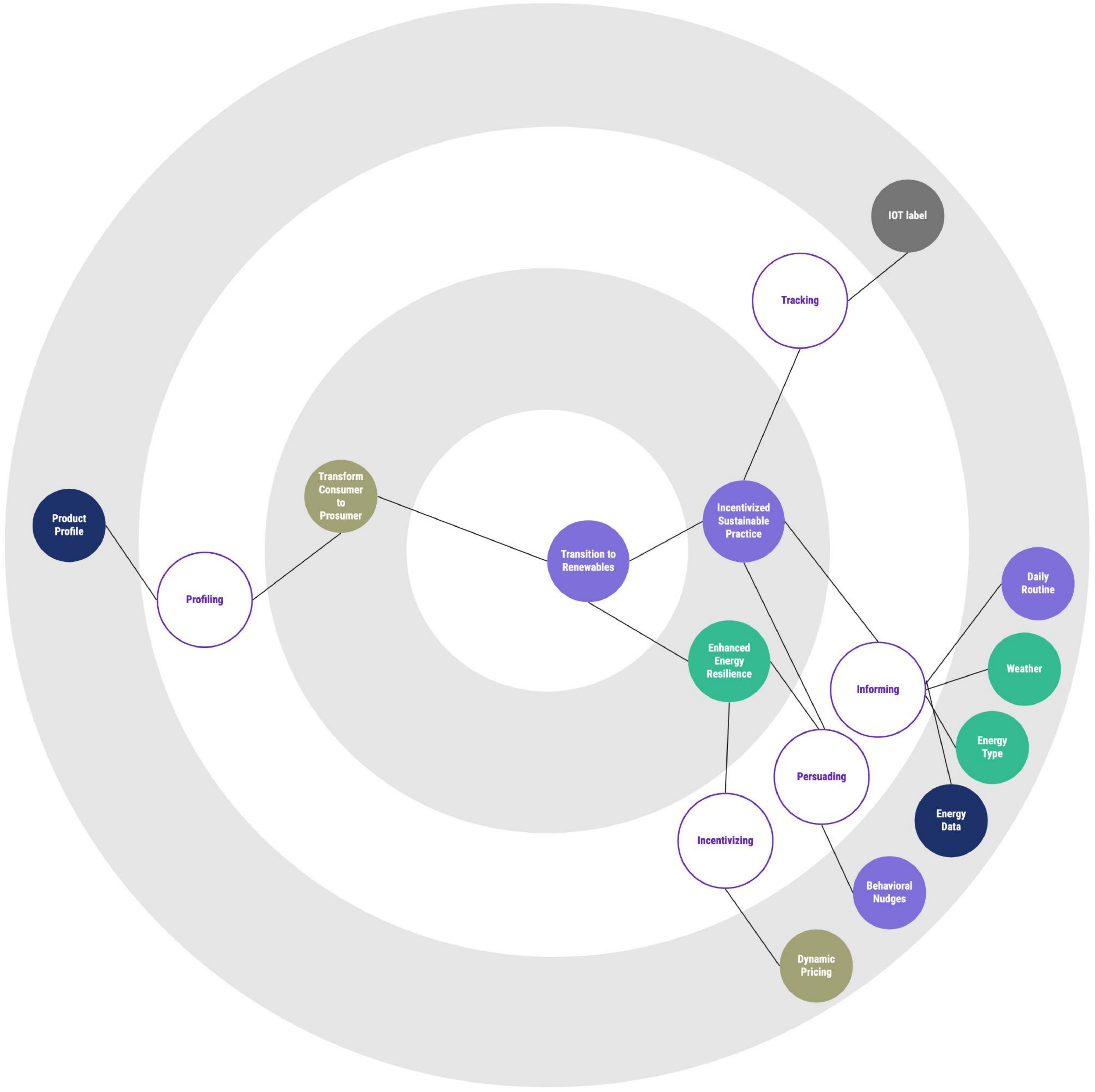
SECTION 3

Emerging Transactions

Emerging Transactions

The infrastructural interventions that we presented through the three thematic clusters of diversification of energy sources, growing local economy and advancing energy democracy proposed a collection of features that can activate microgrid as a civic infrastructure. While these features are essential to enable new actions, they can not contribute to the larger transition goals as isolated interventions. Their capacity to drive new energy paradigms resides in their unique configurations as infrastructures that can enable new modes of exchange of resources as emerging transactions. We identified five such transactions at the intersection of thematic clusters as characteristics of our system of solutions. These transactions demonstrate how new flows of resources can be enabled through purposeful orchestration of diverse features at all levels of infrastructures.





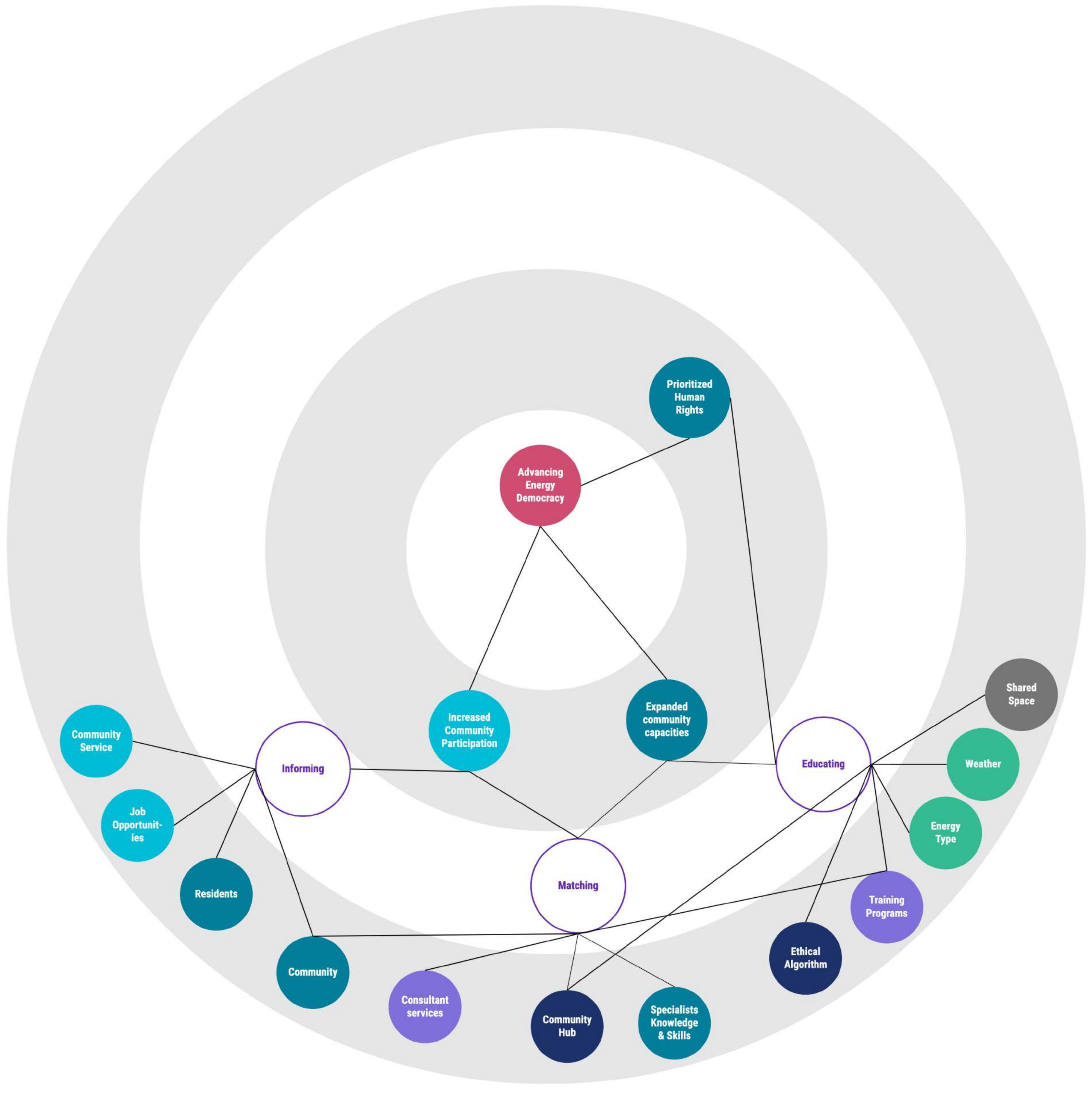
Community oriented trading

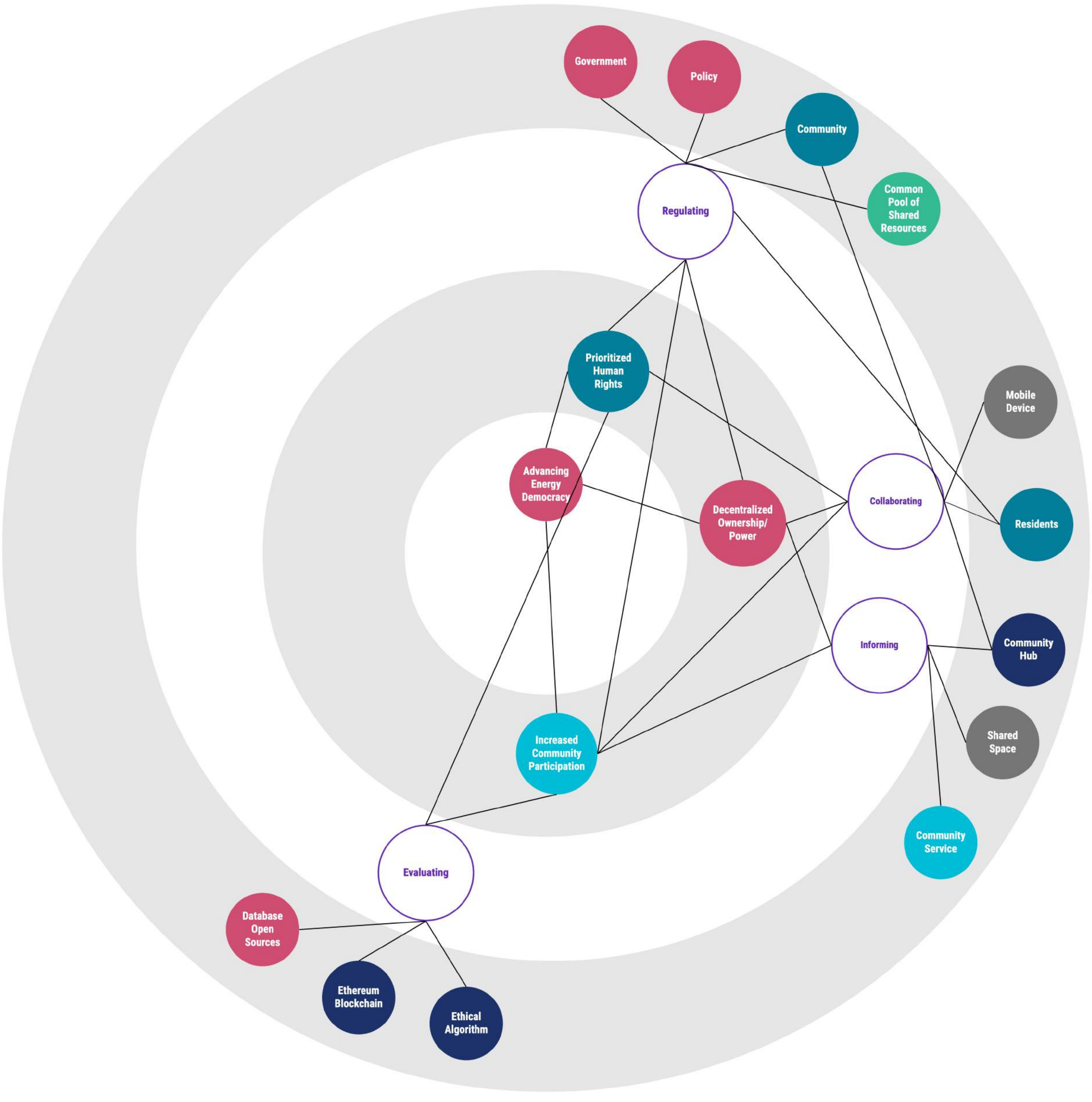
By providing an exchange platform for individuals and entities, community-based energy and service trading mobilizes local resources and optimizes the use of assets within communities. Residents can trade for essential services (such as public transportation) and support community programs (such as meal programs) with energy generated from private properties and shared community spaces. Residents are no longer passive consumers that buy from the monopolies. Instead, they will actively engage in and reshape the energy market for the good of their community.

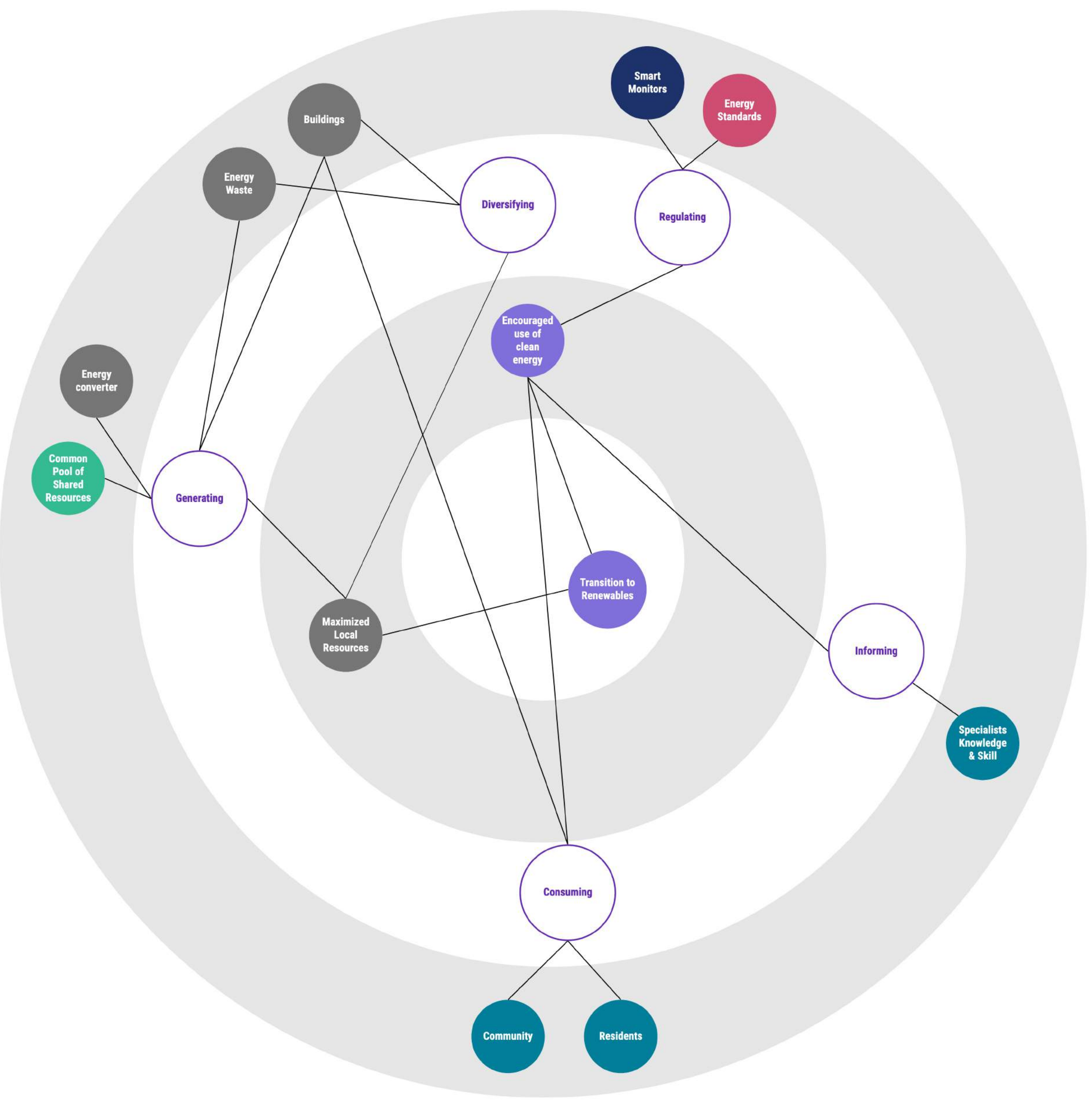
Informed and responsible consumption

With energy information collected throughout the supply chain, consumers are informed of the practice and the environmental impact embedded in their choices of products and services.

Real-time and historical data of appliance energy consumption and environmental factors are used to identify and predict energy consumption patterns at the household and region levels. The system guides consumers towards more desired and sustainable behaviors assisted with behavioral nudges and economic incentives.







Energy justice education

Energy justice education focuses on working to ensure a just transition to renewable for communities. It helps residents understand emerging affordances and capabilities revealed in the diversification of energy sources. We envision energy education beyond awareness of energy goals and resources to equip community members with the necessary expertise to mobilise and maintain their assets for collective energy stewardship.

By developing the necessary capabilities, resources, and platforms that support energy and humanity-related education, a community can increase its ability to understand, debate, and participate actively in the creation and evolution of the civic infrastructure, from energy generator installation to shaping economic opportunities.

Data-driven public/private collaboration

Localized decision-making structures and decentralized technological and financial platforms need to be supported by ethical algorithms, ethereum blockchain, and open source databases to support expanding energy democracy.

Increasing community participation could shape idiosyncratic, collaborative local governance structures, which helps build balance between privacy and transparency, paths to universal data literacy, and asynchronous autonomous modes of communal decision-making.

Diversified energy production

By transforming grey energy into usable electrical energy and utilizing unused spaces in buildings to generate power, communities diversify the pool of energy resources and integrate renewable sources of energy. The use of shared storage centers can allow them to increase energy resiliency in connection with neighboring grids. The community-based ownership of energy sources need to be supported by expert knowledge and skills to establish new energy standards and leverage computation for collective intelligence.

Actionable Insights and Future Directions

As we build new energy infrastructures, the mindsets and principles through which we design new interventions matter just as much as the object of these interventions. Here we present four key insights that characterize the paradigm shift to envision sustainable futures for our energy infrastructure.

Invest in data-enabled intelligence that can increase adaptive capacity

Appliance optimization systems should learn from and adapt to the emerging circumstances and address the need for information transparency and remove knowledge & expertise barriers for informed decision-making for all stakeholders. Technologies such as smart meters with embedded intelligence need to adopt dynamic and transferable data-collection mechanisms to respond to emerging needs in real time.

Provide new choices and entry points for active participation in energy transition

In order to encourage more sustainable ways of relating to energy, we need to present users with tools and technology that provide them with choice and power to engage in decision making rather than following prescriptive solutions. These include transparency of data-collection, making the consequences of actions visible to users and supporting them in making informed decisions that can benefit individuals as well as the environment.

Build new capabilities for collective energy stewardship

A key element of transitioning to distributed and collective decision-making in shaping energy futures is renouncing individual ownership and adopting self-organizing and interconnected governance mechanisms. While expanding microgeneration capabilities give more enable active engagement with energy production, this suggests new roles for utility providers such as managing energy credit systems, aggregating data repositories, insuring home and appliance security.

Establish incentive mechanisms to advocate the adoption of desired mental models

Without establishing new incentive mechanisms to support energy stewardship by communities, mere introduction of new features risks amplifying the inequities embedded in our current energy infrastructure. Features such as credit systems, energy labels and storage banks need to be coupled with incentives to bring back investment and present new opportunities for communities. In order to leverage the positive civic impact of the microgrid we need to adopt alternate mental models that can allow us to think of energy beyond just a commodity.

Looking forward

We hope that the collection of design models and interventions presented in this report can contribute to expanding the role of design in energy transitions and foster critical reflection on how we might shape a new energy paradigm that benefits not only the environment but also the people who are connected to the grid. It is essential to note that the solutions that we present in this report are not blueprints for navigating large-scale transitions but they aim to inform new approaches and spark debate at the countless intersections of the grid with our society.

We hope that the questions explored in this work can be further expanded through contextual inquiry and connections with the different stakeholders which was not possible due to the major limitations imposed by the ongoing COVID-19 pandemic.

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Acknowledgements

IIT Institute of Design is a graduate design school with a history of innovation. ID pioneered the development and dissemination of modern design from its founding in 1937 as the New Bauhaus in Chicago. Experimentation, rigorous methods, systems design, and strategy support ID’s current focus of preparing individuals and organizations to take on the world’s complex, fast-changing, and unpredictable problems such as competitiveness, digital media and learning, health and wellbeing, social innovation, and more.

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