# #Connect2Evolve Token Engineering Challenge

Digital economic activity in Senegal is driving the need for access to affordable electricity. Design a token economy around energy use and ownership of a newly installed smart solar microgrid to optimize energy production, value exchange, and positive impact to the community.

**Accompanying GitHub repo:**
**https://github.com/TokenEngineeringCommunity/TEcase1_Energy_Connect2Evolve**

**Remember, your goal is not to solve this system. It's too big a question and too open a system to solve. Pick a small piece and make it work really really well, and contribute to the token engineering ecosystem.**

## Table of Contents


The Setting 1
The Challenge 2
The Details! 5
Ecosystem Agents 5
Discretionary Decisions 5
Machine Agents (Mechanics/Output/Input) 7
Environment 8
The Flows of Value 9
Energy Layer 9
Value-Sharing Layer 10
The Data 12
Solartainer Operation Timeline 12
Solartainer Production Data 13
Solartainer Battery Data 13
Community Usage Data 13
Fee Structuring 14
Operations Data 14
Maintenance Schedule 14
Donations Data 14

# The Setting

Digital economic activity in Senegal is driving the need for access to affordable electricity.

The Solartainer® offers a solution. It is a self-contained solar smart microgrid, including solar panels, storage, satellite internet, and grid cabling. It is capable of bringing electricity, information, and financial services to off-grid rural villages with a population 4,000 people. This documentary gives more background on the solution.

Over 20 Solartainer® are currently powering villages with more than 100,000 people and counting. It’s a numbers game and comes down to cost-effectively scaling the funding side (cost of capital) and optimizing the impact of new and existing Solartainer® installations along the way.

#Connect2Evolve is an innovation project within Siemens driven by ingenuity and purpose. A community of innovators within Siemens started in 2016 with a vision that Electrification, Digitalization, and Automation can and must have positive impact on people’s lives — and an unstoppable curiosity how tokenization and new forms of decentralized organization play a role. Together with their network they are now planning a crowdfunding campaign to donate a Solartainer® to power a village in Senegal.

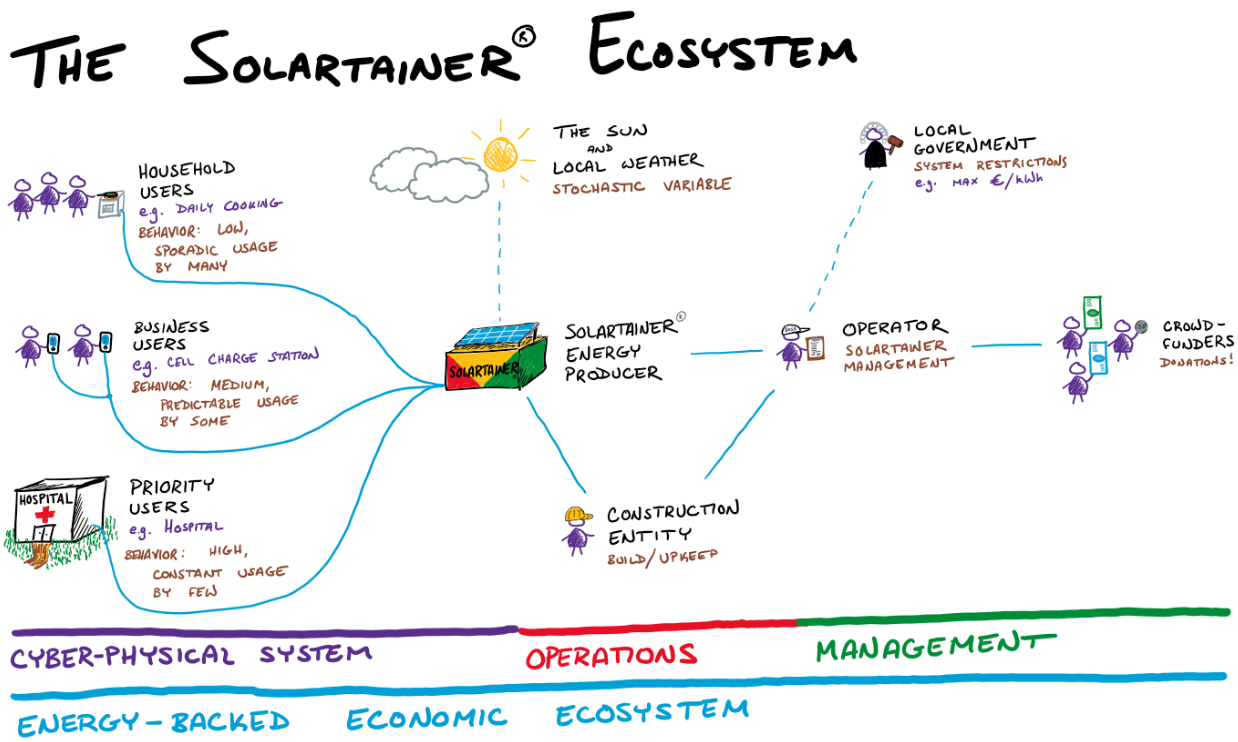
**This is where you come in.**
**How can we optimize the value and impact offered by this system?**

# The Challenge

As a token engineer, your first challenge is to forget about the token ;) and start thinking in systems. The Solartainer® Ecosystem is composed of:

- Decision-making Agents
- Flows of value created through energy consumption (information, energy, money)
- System-influencing mechanisms such as the market for the price of energy, or the tokenization of Solartainer ownership.

A diagram of the system's agents and how they interact is below:




Each of the decision-making agents have their own goals (i.e. optimization functions), spanning from making money to providing the most people possible with electricity. The ecosystem itself has a goal as well: how can it distribute the value it creates most effectively such that the system can sustain itself and fulfill its purpose of affordable access to clean energy.

For the challenge, you are provided with:

- **A System Definition**: The full document below gives you more background about each of the entities in the picture above, including their motivations, interactions, and exchange of value with other entities in the system.
- **A System Model**: A simple model of the flow of energy from Sun to Solartainer to user, with simple exchange mechanisms such as price-sensitive user purchase behavior and battery storage. The model is coded in python using cadCAD.

- **Energy Usage Data**: The model outputs generated energy data including hourly Solartainer® production capacity, user demand, and battery levels for whatever time period selected. Every run of the cadCAD model produces slightly different outputs, perfect for Monte Carlo simulations

And finally, your **challenge**:

***Design token mechanisms around energy use and system ownership of a newly installed microgrid to optimize energy production, value exchange, and impact to the community.***

This is a huge question and trying to answer the whole question will take lots of smart mini-solutions aggregated from many different sub-problems. Take this challenge and pick a sub-problem you want to solve. For example:

1. **Tokenizing Usage**: How can energy usage be tokenized? Should each kWh produced be represented as a token? Should tokens represent a ticket system which allows users to purchase a kWh at a market price? What will the token market look like at the micro-grid level, and how can it be integrated into a broader network?
2. **Incentivizing Ownership**: The Solartainer® starts off owning itself (benefit of being a donation!). Why and how should it distribute ownership of its own future energy production (and the money or value surplus it brings!) to the broader ecosystem? How can community ownership of the Solartainer® improve (optimize!) value flows in the network?
3. **Measuring Impact**: This Solartainer® installation wouldn't be possible without Siemens and their gaggle of crowdfunders. How can we measure the value of their donations and tie it to real energy production? How can we calculate and report each crowdfunder's share of impact? Can impact be tokenized?

Even if you solve just a very targeted question in the ecosystem, we'd love to hear your perspective on these three broader themes and how your solution fits in.

You and your team have a few options of how to tackle this challenge:

1. **cadCAD Modeling**: Use the pre-formulated cadCAD model as a structure, design and implement new agent behaviors / token mechanisms, and measure the outcomes
2. **General Modeling**: Use the data outputs of the provided model, build and measure a tokenized system of exchange outside of cadCAD
3. **Systems Design**: Take a step back from the data and construct a new system definition (e.g. stock and flow diagram or differential specification) of how a token economy would change system behaviors
4. **Bring Your Own Challenge:** Do any of the above for your own token engineering challenge (energy-related or otherwise!) using your own data, using this document and model design to guide your thinking

**Note that the challenges, the model, the data, and everything provided to you is meant to give you some guiding forces in the sandbox. Feel free to manipulate everything from the behaviors of the agents to the bounds of the system to express the point you and your team are trying to make. Just make sure to explain what you did and why!**

Your submission will be judged on a combination of your team's technical Innovation (idea), creativity of solution, execution (code or system definition), and polish (representation of solution and presentation).

Modeling and simulation will be done using cadCAD, a tool for complex systems design recently open-sourced by BlockScience. We'll be giving a workshop during the day on Saturday on how to design and build systems with cadCAD, and we'd recommend going through the tutorial available on their github repo before the weekend. **Search for TODO in the code for ideas of where to start!**

Full problem statement document is coming soon! Join our Token Engineering telegram for any questions: and check out our series of Token Engineering articles leading up to the hackathon.

And now, the details! WOOOOOOOOOOOOOOOOOO

# The Details!

## Ecosystem Agents

The system can be represented by the following decision-making entities:

**Discretionary decisions**:
1. Community
    a. As individual energy users [usage dimension]
    b. As community members [ownership dimension]
2. Solartainer Operator (Operates & Maintains Solartainer)
3. Construction Company (Builds & Deploys solartainer)
4. Crowdfunders

**Algorithmic decisions**:
5. Solartainer

**Stochastic/External decisions**:
6. The Sun and local weather
7. Government

### Discretionary Decisions

The goals of discretionary decision-making agents can be encoded with heuristic strategies derived from game theoretic, psychological decision sciences and/or behavioral economics literature or machine learned from past data (e.g. energy and mobile payment data) where the feature space is some characterization of the agent and system states, and the labels are the actions taken.

Below describes each of the relevant agents in our system and their motivations.

**Community**

Comprised of people who act as individual energy users [usage dimension] and as collective community members with influence on the system [ownership dimension].

There are different types (tiers) of users:
- Priority Users (e.g. hospital) with high, fairly-constant usage
- Business (e.g. cell phone charging business) with medium, predictable usage
- Household (e.g. stove, lights, and other appliances) with low, sporadic usage

Each of these energy users are represented by specific **energy consumption data**.

As individual energy users they want to have affordable access to electricity, as this increases their individual and community welfare. Their energy usage behavior is complex, but can be assumed to be somewhat price-sensitive and tied to their community's economic development. One can assume that energy users want electricity at the lowest cost possible - but beware of the mental cost a user incurs when they must think about their consumption.

Their goal can be subsumed as increasing welfare in the community, whilst some agents might be selfish or ignorant. Welfare in the community can be derived by energy data - **but how is up to you**.

**Solartainer Operator**

The operator is responsible for operations & maintenance of the Solartainer. The operator also manages electrical technicians and guards, and other day-to-day operational hurdles.

The goal of the operator is to maximize profits, by bringing down costs of financing, cost of operations and maintenance and by increasing revenues through energy sales and potentially adjacent business models, e.g. selling electrical equipment to community businesses.

The operator typically buys the Solartainer to operate, but any other arrangements are possible. Part of the financial model can include detailed scenario modeling and Monte-Carlo simulations of different operational models and contractual relationships.

In the hackathon for example, we are initially giving the Solartainer 100% its own ownership. How can it effectively distribute its ownership to ensure it creates value? Maybe the Solartainer should use tokens to incentivize the operator for optimal maintenance. This is similar to a leasing or franchise concept, where the owner is another legal entity.

Relevant costs / duties available in the **operations data**.

**Construction Company**

This is the entity that builds the Solartainer and sells to the owner. Typically, this entity employs a process called "build-operate-transfer," which takes about 2-3 months from construction, to shipping, to deployment, installation and initial operation and troubleshooting. After this period, the Solartainer is transferred to the local operator.

In our simplified system, the construction company can also be assumed to do maintenance on the system

The goal of construction company is to maximize profit by reducing costs and build time in order to scale the number of Solartainers produced. Not only is this company the innovation driver in construction but also in process, e.g. scouting for best deployment areas, knowledge transfer to local operators, etc.

Build-operate-transfer schedule is defined in the **operations data**.

**Crowdfunders**

These are the people who have donated various amounts to the crowd-funded Solartainer. Their goal is to have a positive impact with the amount they have available for charitable causes. They are eager to understand the impact of their donation.

Their behavior may be dependent whether it's the charitable time of the year ;) *Can you find other drivers and decide how to model them?*

Crowdfunder list with donated amounts is available in the **donations data**.

## Machine Agents (Mechanics/Output/Input)

In the following is the description of our machine agent: the Solartainer. Machines can and should be modelled as agents, if they have some ability to 'observe state and make decisions' e.g. anything with a decision/control system (includes sensors). This applies for the Solartainer, but only if the model is granular enough to be modeling a decision system associated with our system that we want to model. Its goals can be derived from the control-theoretic model, or the Solartainer can have inherently adaptive strategies, e.g. by encoding it as a reinforcement learning agent who will learn to do whatever they can to achieve their goals within the bounds of the action space.

**Solartainer**

The Solartainer is comprised of:

- Power generating solar panels (incl. smart inverters)
- Battery (incl. smart inverter)
- Smart metering / monitoring (and embedded controller)
- Distribution grid cables to cover the entire village
- Satellite Internet for remote maintenance but also available bandwidth to sell Internet services to the local community)

The Solartainer is represented by time-stamped energy production and battery usage data in the **energy consumption data**. Its output depends on the solar radiation (available solar potential), demand/usage (actual load by electrical equipment; but also when the local grid experiences high loads, the system will shed load as to protect remaining electrical equipment, and its components), and how well it is maintained (outages).

For the hackathon we propose that the Solartainer owns itself, after it got funded by the crowd to be built and deployed in the Senegal village. As it owns itself, it wants to produce as much energy as possible over its lifetime, and receive the value of exchanging that energy with the community. You can also think of a Solartainer as a species; it wants to be reproduced and have as many people with electricity as possible. Hence, it's goal is to be optimally used, maintained, and reproduce :)

*Note: Part of the challenge will be transferring this ownership to the community / operators / maintenance entities to ensure that it maximizes its future energy production.*

### Environment

A system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose, and expressed through its functioning. A complex system cannot be understood by understanding only these parts separately. A complex adaptive system, even adapts to changes posed by the environment and actions of agents in the system.

In the Power to the People case we have both instances: of a truly environmental exogenous process (weather) that affects an agent in our system (Solartainer) as well as an agent that we model as an exogenous process: the local government that can define the cap of electricity price per kWh.

**The Sun and Local Weather**

- Acts as a stochastic variable directly tied to the sun and weather patterns
- Represented by hourly energy production capacity of Solartainer available in the **energy consumption data**.

**Local Government**

- Represented by system restrictions, e.g. a price/kWh cap available in the **fee structuring**.
- *Note: Although not considered in our data, you could consider that the local government will benefit from the positive community influence and may accordingly change its policies over time*

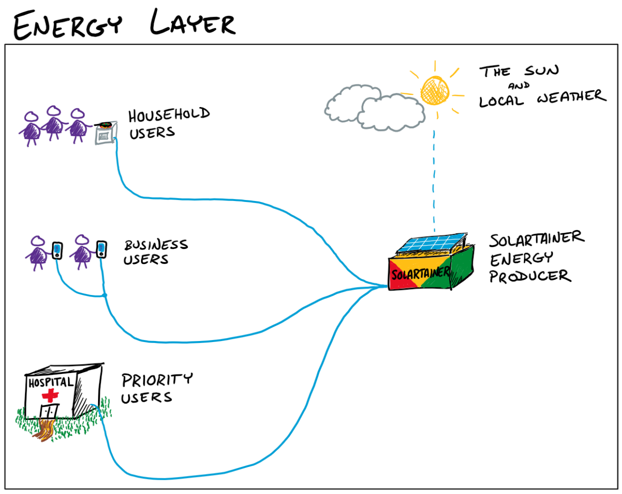
*Note: agents that we cannot or will not model entirely will be represented - if possible - by (generated or synthetic) data, e.g. energy user, operator, etc. When hackers want to model incentive mechanisms for optimal energy use, then we/they will need to model the energy user with assumptions on consumption patterns, and how different energy users will react differently to given incentives (e.g. household, business, hospital). Once we have access to data from the Solartainer we can use it to better model agents and scenarios.*

## The Flows of Value

The community microgrid in Senegal can be represented by building layers of flows of physical value eventually abstracted into digital value representations (hopefully tokens!). Each of the layers is described below:

## Energy Layer

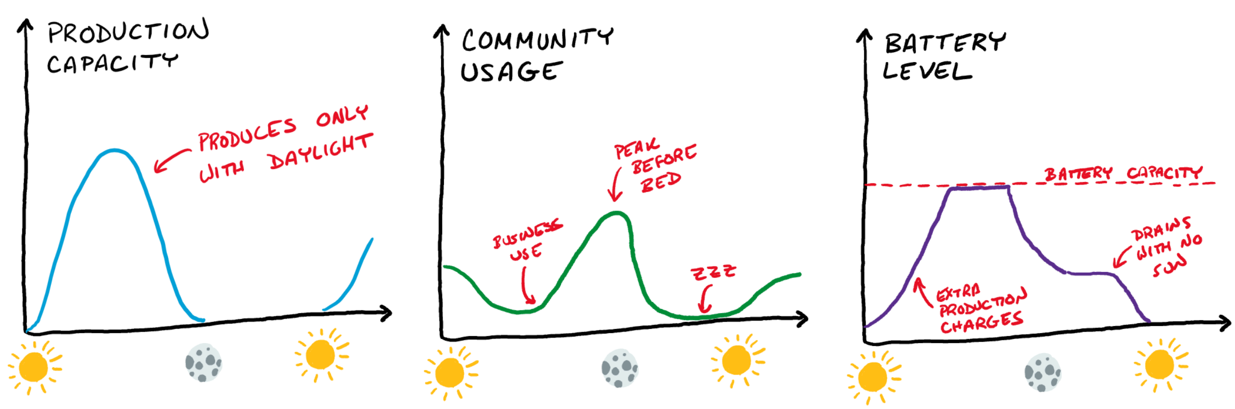
The energy layer represents the cyber-physical system of actual energy production and usage. It is the physical value of the system and includes the different users in the community, the Solartainer, and the Sun and local weather.




In the **Energy Layer**:

- **The Sun and Local Weather** provides stochastic inputs to the **Solartainer**
- **The Solartainer** provides energy to the **Community Users,** if the **Operator** takes good care of the Solartainer and their customers (community users). Any remaining energy production goes to the **Solartainer Battery** to be sold after solar production hours, if possible
- **The Community Users** use the energy for various purposes

Below is a depiction of generation, usage, and battery levels over the course of a typical sunny day:



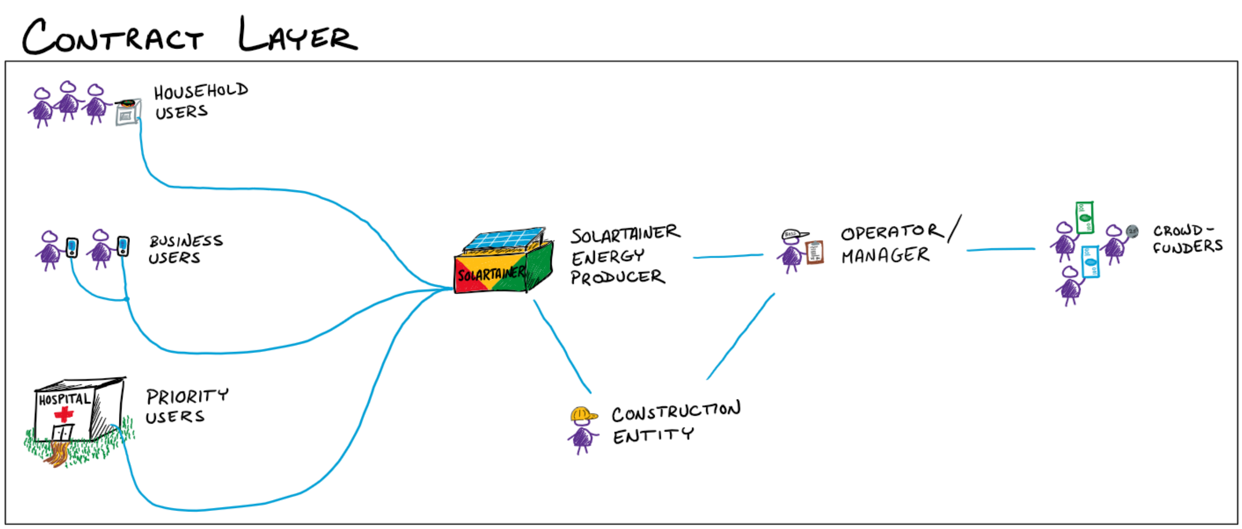

Note that the community usage will be limited by the production capacity of energy by the solartainer. The battery level will be equal to the difference between production and usage at any point in time. Any production that is not used and cannot be stored in the battery is lost.

## Value-Sharing Layer

The value-sharing layer is an abstraction of the energy layer and is a way to assign value in the system. It consists of every agent with the ability to make decisions that influence the network. The contract layer can be broken into two major inter-working concepts:

1. **Ownership Sub-Layer**: this sublayer describes who owns the **future value of energy production** of the Solartainer.
2. **Value Sub-Layer**: this sublayer describes when and how value (energy, money, impact, etc.) changes hands in the system.

The actual contracts that exist in the system will be a mixture of physical (traditional) contracts and Ethereum-based smart contracts (called Ricardian contracts. Meanwhile, interesting solutions exist that encompass both, such as lexon, zencode, and mattereum [in development]). As the system advances and we build fundamentals on which to build, the entire system could work on smart contracts.




In the **Ownership Sub-Layer**:

- The **Solartainer** begins with 100% of ownership of future energy production flows and the associated cash flows.
- What happens next is up to you! The goal is that ownership is distributed to the ecosystem effectively to **maximize the value of the system**, with the assumption that ownership distribution can be used to affect things like optimal usage or system upkeep.

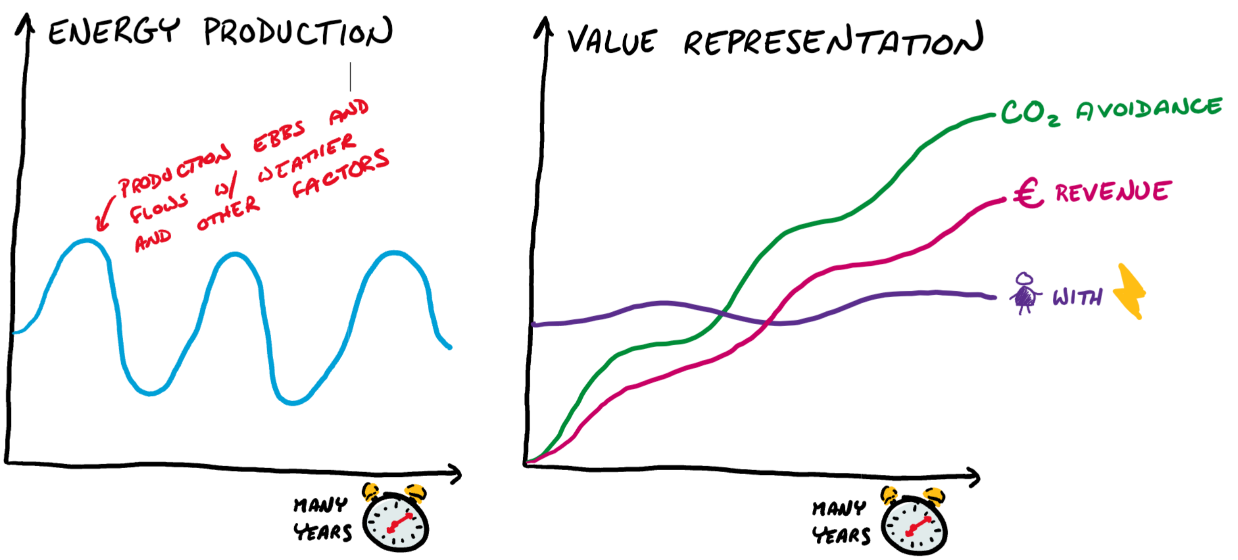
In the **Value Sub-Layer**:

- Funding
    - **The Crowd-funders** provide fiat currency to fund the development of the **Solartainer**. Each crowd-funder is responsible for some % of the Solartainer

being there, and receive the appropriate amount of **share of impact (can you tokenize?)** as a certificate.

- Energy Sale
  - **The Solartainer** sells energy to the **Community Users** either in fiat currency or token-based on some function of price per kWh *(up to you - how can you design a token economy here?)*.
  - **The Community Users** purchase energy, either with:
    - Fiat currency (current state of the model)
    - **Energy Tokens** (hopefully future state of the model) based on token/kWh exchange, ticket-based to purchase kWh at market price, or whatever other economic system you can imagine and model
  - The **Local Government** in this case imposes restrictions on energy purchasing, with a maximum purchase price of **EUR 0.13 per kWh**.
- Operations
  - The **Operator** receives some portion of revenue that acts as profit based on their costs of operation
  - The **Construction / Maintenance Company** receives some fee based on their services when used

The outcome of the contract layer is that the value (money, impact, etc.) exchanged by the consumption of energy is distributed appropriately based on the distribution of the **Ownership Tokens.** Below is a depiction of future energy production flows and how that translates into value. How that value is distributed against the ownership tokens will, once again, be up to you.




As depicted, energy production over a period of time translates into various types of value flows, including $CO_2$ Avoidance, Revenues, and People with Electricity. Note that some of these values (like $CO_2$ Avoidance) increase from 0 over time, and others stay relatively steady state (such as people with electricity). **What other value flows should be considered?**

# The Data

The following information and data is available in the provided data file. If data you believe you need isn't available or you have questions about the data, please ask the mentors and we'll either provide an assumption to use or ask you to create your own justified assumption.

**Timeframe**: 5 examples of 15 year periods (hourly granularity) are available in the github repo. Can be run for any time period based on cadCAD model inputs.

**Access**: In the github repo, the `data_pregenerated` folder has generated pickle files of dictionaries with the model outputs. Each run of your own outputs are generated and also output to the `data` folder. There are helper functions to save and load data in the 'Data Saving Helper Functions' section of the python notebook. **Keep in mind that these pre-generated data points are with the baseline initial conditions, you'll need to generate your own data by changing these initial conditions if wanted**.

## Solartainer Operation Timeline

**1st October 2019**
Solartainer construction begins.

**1st December 2019 - 1st January 2020**
Solartainer operation ramps up, maxing out at 400 connections after 1 month of infrastructure build-up. The system will go live all at once, to simplify modeling. The connections consist of:

- 320 household users
- 70 business users
- 10 priority users

**1st January 2020 - 1st January 2035**
15 years of usage projected before the system is assumed to go out of operation.

## Solartainer Production Data

The production data of the Solartainer acts as a stochastic input to the system. cadCAD will take in the attributes defined below and generate production capacity scenarios to be used in Monte Carlo simulation.

Data Components

- Production
    - kWh production capacity per hour (based on local weather patterns and generation efficiency)
    - Noise is added based on annual, daily, and hourly variances

- Degradation added
    - A discount rate on energy produced is in effect due to equipment degradation over time
    - Maintenance can 'restore' this discount rate, but comes with a cost

## Solartainer Battery Data

The Battery is used to collect and store any production not immediately consumed by the community. Stored energy can then be sold to the community at a later time at defined price.

Data Components

- Storage
    - Initial max storage capacity [kWh]
    - Battery Degradation over time (also improved by maintenance)
- Charging / Discharging
    - For the purposes of this exercise, can assume that charging / discharging is magical and there is no physical limit to the rate of charging / discharging. The battery can simply take all excess energy generated per time step until it is full.

## Community Usage Data

The Community usage data reflects the expected demand of individuals in the community from the solartainer based on inputs such as price, weather (and maybe you could add ownership!)

Data Components

- Components
    - Usage appetite per aggregated tier of user: household, business, priority [kWh / timestep] that varies over time and with noise
    - The usage data is somewhat price sensitive for certain tiers

Note that **total** community energy usage is assumed to stay constant throughout the year, at 160,000 kwh, split equally between the three usage tiers. Any consumption that is not consumed by clean energy in our model can be assumed to be diesel. The cost of diesel is **EUR 0.20 per kwh** (but see if you can come up with other, non-monetary costs like CO2!)

## Fee Structuring

Electricity cost is capped at **EUR 0.13 cents / kWh** used. The actual pricing mechanism is currently set as an input in the model, changing it over time will be up to you. The usage data is currently somewhat price sensitive, but feel free to change that sensitivity if you're able to explain why it better fits your model and its assumptions!

## Operations Data

Operator costs include security, management salaries, and other costs, and is represented by two numbers:

- Cost per kWh produced (trying to make modeling easier!) is **EUR 0.035 cents / kWh** for kWh that go directly to the user and 1.5x that for every kWh that has to be routed through the battery
- Cost per hour of operation is **EUR 0.10 cents per hour**, which is each timestep of the simulation

## Maintenance Schedule

Maintenance costs 300 EUR per call. It is assumed to restore production capacity and battery use to 100%.

## Financial Outcomes

The revenues, operating costs, and maintenance costs per time step are available in the output data structure

## Donations Data

Donations data is provided as a list of individual donators and their % share of the total Solartainer donation:

- Satoshi Nakamoto: 50.99% of donation
- Nikola Tesla: 25% of donation
- Grandma: 15% of donation
- Donald Trump: 0% of donation
- Colin Andrews: 0.01% of donation