spm 4530: Introduction to Agent Based Modeling

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Lecture goals

Understand what is an Agent, and what is an Agent Based Model
Understand the concepts of generative science
Understand how bottom up modeling is different from other modeling techniques

Modeling in general

All models are wrong, some are useful ! (Box 1979)

Model a problem, not a system!

A model is twice remove from reality !

- A simplified formalization of the modelers understanding of (a part of) reality

Three main schools of Agent thinking

Artificial Intelligence – AI
- Agents as autonomous identities solving problems

Multi-Agent Systems – MAS
- Distributed control of systems

Agent Based Modeling (and Simulation) – ABM(S)
- Simulating (real world) phenomena

We will follow the ABM(S) view !

Agents are :

Encapsulated
- clearly identifiable, with well-defined boundaries and interfaces;

Situated in a particular environment
- receive input through sensors and act through effectors;

Capable of flexible action
- respond to changes and act in anticipation;

Autonomous,
- meaning that they have control both over their internal state and over their own behavior;

Designed to meet objectives
- they attempt to fulfill a purpose, solve a problem, or achieve goals.

Jennings, N. (2000). On agent-based software engineering, Artificial Intelligence 117(2): 277–296.

Agent Based Model

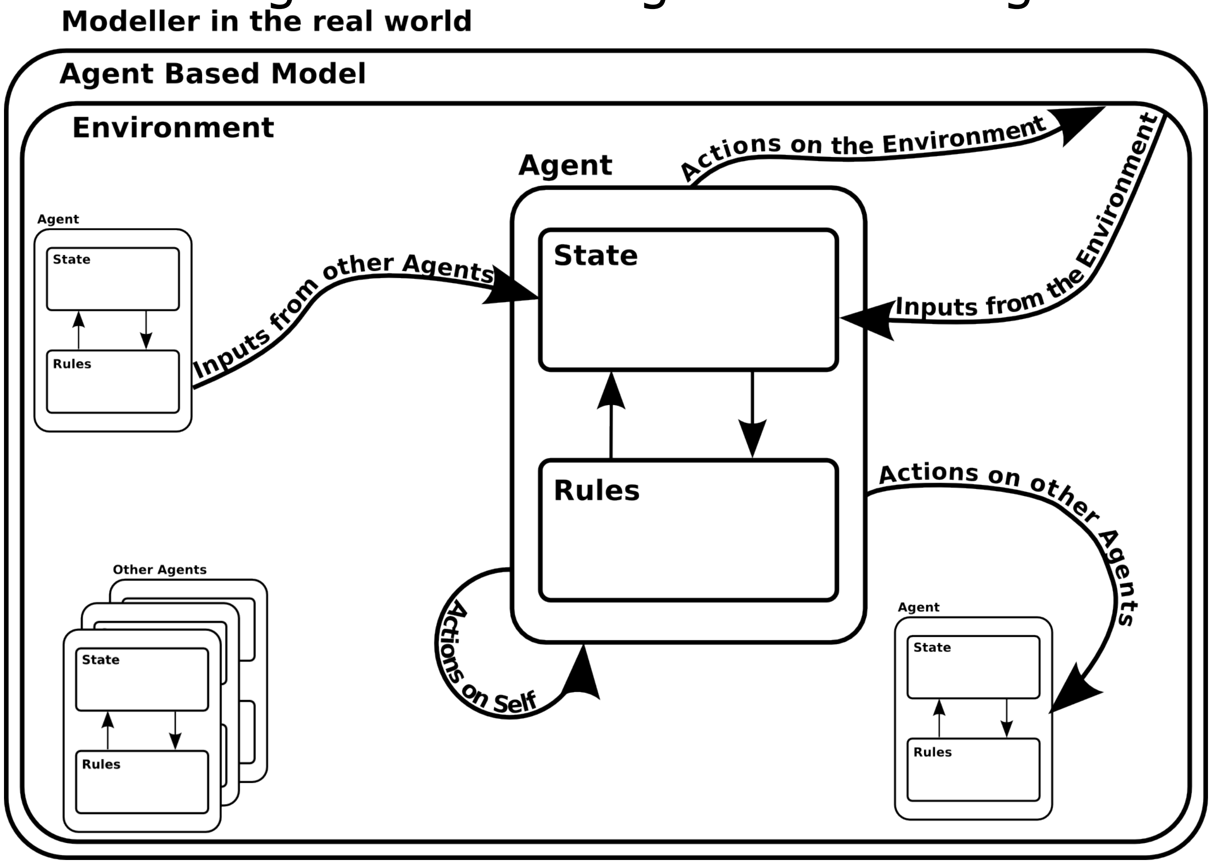
An Agent is a persistent thing which has some state we find worth representing, and which interacts with other agents, mutually modifying each other's states.

The components of an agent-based model are a collection of agents and their states, the rules governing the interactions of the agents and the environment within which they live.

C.R. Shalizi. Methods and techniques of complex systems science: An overview. *arXiv.org*, arXiv.org:nlin/0307015, 2006. URL http://www.citebase.org/abstract?id=oai:arXiv.org:nlin/0307015.

Agent

Agent is a thing that does things to other things



States

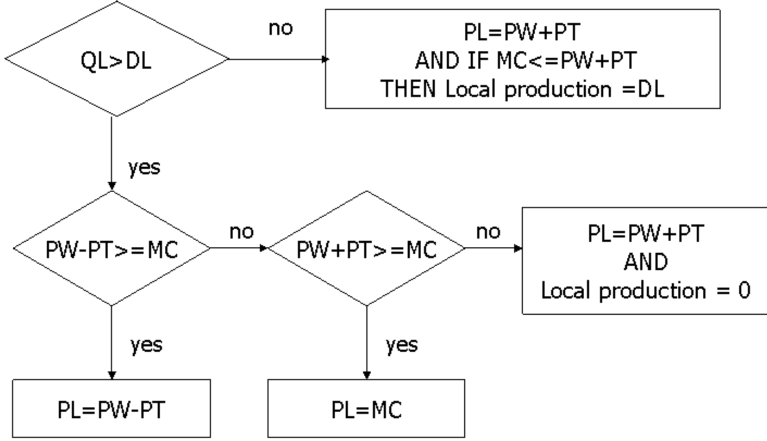
Agent state and behavior *and* Model state en behavior

Stuff that Agents knows or has (including memory)

- Can be private or public
- Can be static or dynamic and can depend on the Rules
- Eg:
  - Profits, Color,Location,

State of an agent is a composite
- of internal *and* local *and* global

Rules



Agents *"internal models"*

Decision and transformation rules → from inputs and states to action and behavior

Can be static or dynamic

Types of rules

Rule based
    nested if-then-else structures.

Multi Criteria Decision Making
    Options and weights

Inference engines
    expert systems,facts (states) and decision heuristic

Evolutionary Computing
    find a optimal solution in large solution space (GA)

Machine learning
    Neural Networks for recognizing patterns

Actions

Based on
- Other Agents
- States
- Rules

Agent will perform (or not perform) some action

Action can
- Affect other Agents
- Own state
- Own rule
- Environment

Behavior is the overall set of observable actions

Environment

What the Agent is in.

Provides the agents with information and structure

Everything that is *not* an Agent, but is relevant.

It affects the Agent, and Agent can affect it.

Structure :

- Soups
- Space (gfrid, GIS, etc...)
- Networks

Time

ABM take place in discrete time
Time progresses in ticks
Between two ticks, everything is assumed to happen in the same time, attempting to simulate the parallelism in real world
As computers are serial processing machines, the order of Agent iteration is very important.

Top-Down modeling

Start with the entire system

- Assumes that you know how the system behaves
- Formalize (encode) your understanding
- Try to replicate the observed regularity

System description is static

$$\frac{\partial u}{\partial t} + t\frac{\partial u}{\partial x} = 0.$$

$$g\frac{d^2u}{dx^2} + L\sin u = 0.$$

$$P_0(\cos\Theta) = 1$$

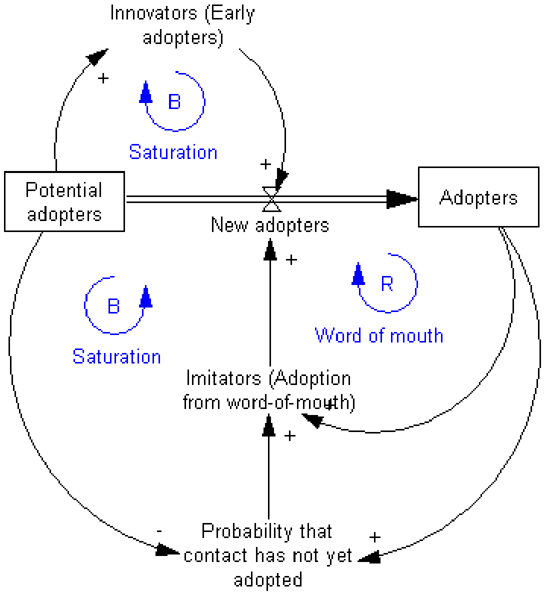
$$P_1(\cos\Theta) = \cos\Theta$$

$$P_2(\cos\Theta) = \frac{1}{2}(3\cos^2\Theta - 1)$$

$$P_3(\cos\Theta) = \frac{1}{2}(5\cos^3\Theta - 3\cos\Theta)$$

$$P_4(\cos\Theta) = \frac{1}{8}(35\cos^4\Theta - 30\cos^2\Theta + 3)$$

$$P_5(\cos\Theta) = \frac{1}{8}(63\cos^5\Theta - 70\cos^3\Theta + 15\cos\Theta)$$



Works fine as long as

You have good understanding of the system is in its entirety
You understand exactly how system components interact with each other.
Works great for complicated stuff, airplanes, chemical factories, busses and glue.

However, for complex stuff, like socio-technical systems, we need something else...

Generative Science

"If you did not grow it, you did not explain it!" (Epstein 1999)

build understanding from the bottom up !

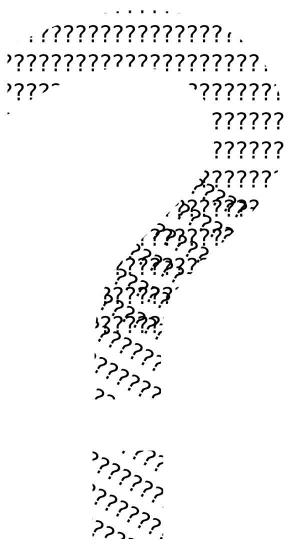
Central principle :

phenomena can be described in terms of interconnected networks of (relatively) simple units. Deterministic and finite rules and parameters of natural phenomena interact with each other to generate complex behavior

J.M. Epstein. Agent-based computational models and generative social science. *Complexity*, 4 (5):41-60, 1999.

Generativist Question

How could the decentralized local interactions of heterogeneous autonomous agents generate the given regularity?



Generativist Experiment

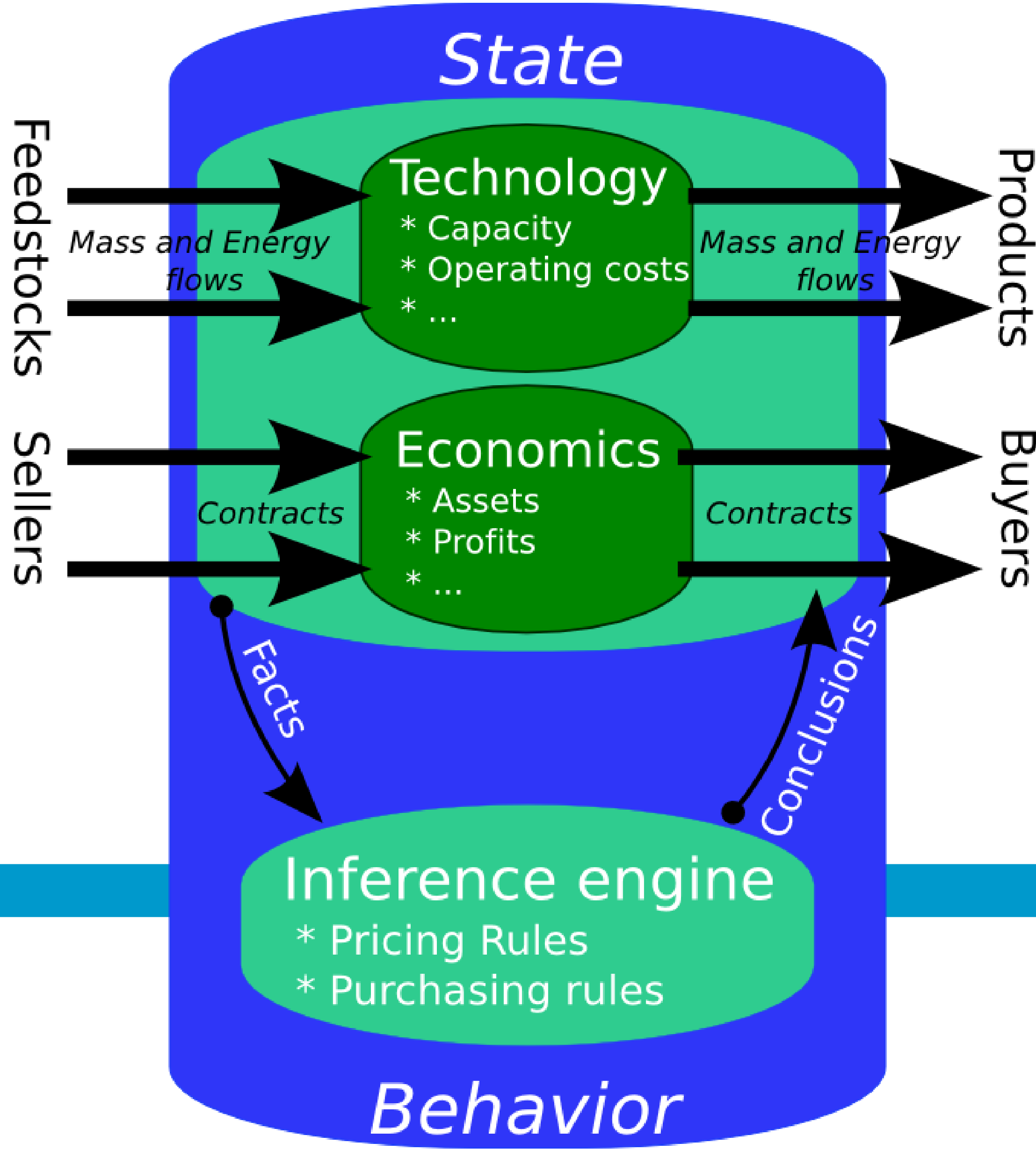
Situate an initial population of autonomous heterogeneous agents in a relevant spatial environment; allow them to interact according to simple local rules, and thereby generate - or ’grow’ - the macroscopic regularity from the bottom up.

Or, given a well understood, well described population of agents, what kinds of behavior are they capable of under different conditions

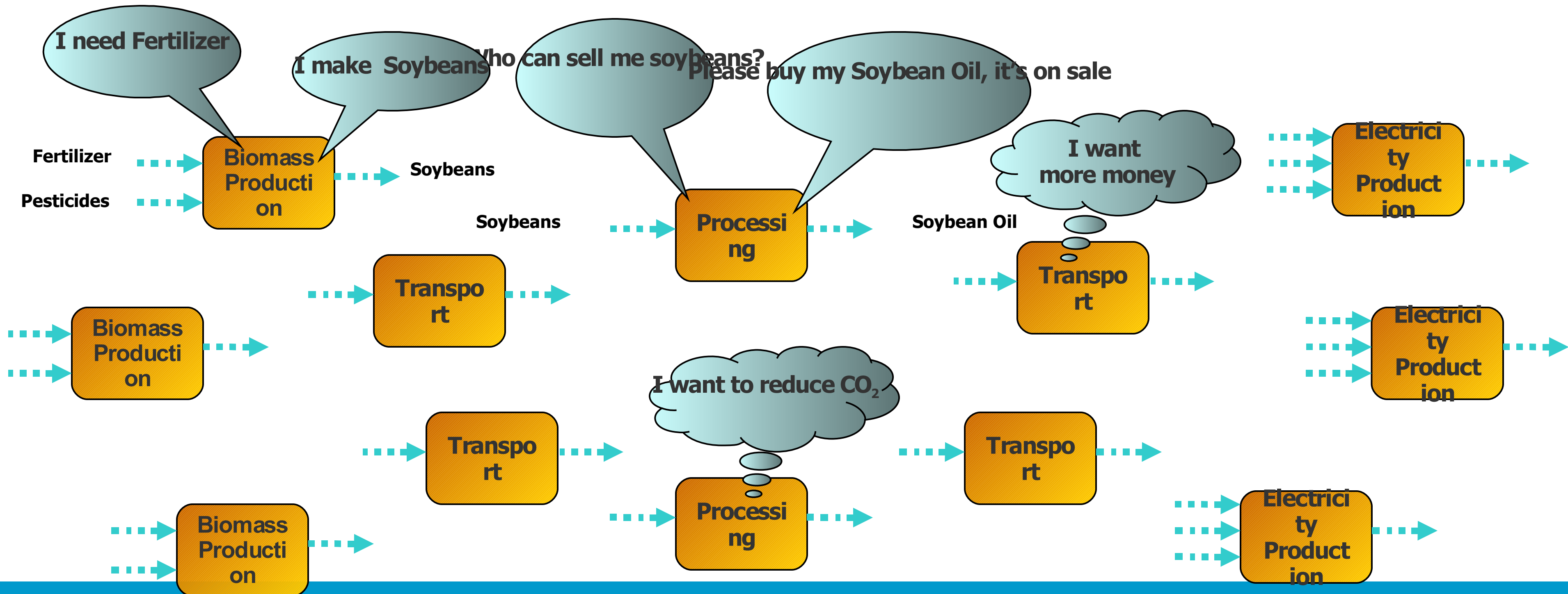
Observed regularity

Delfzijl industrial network

Firm as an Agent



Many different agents



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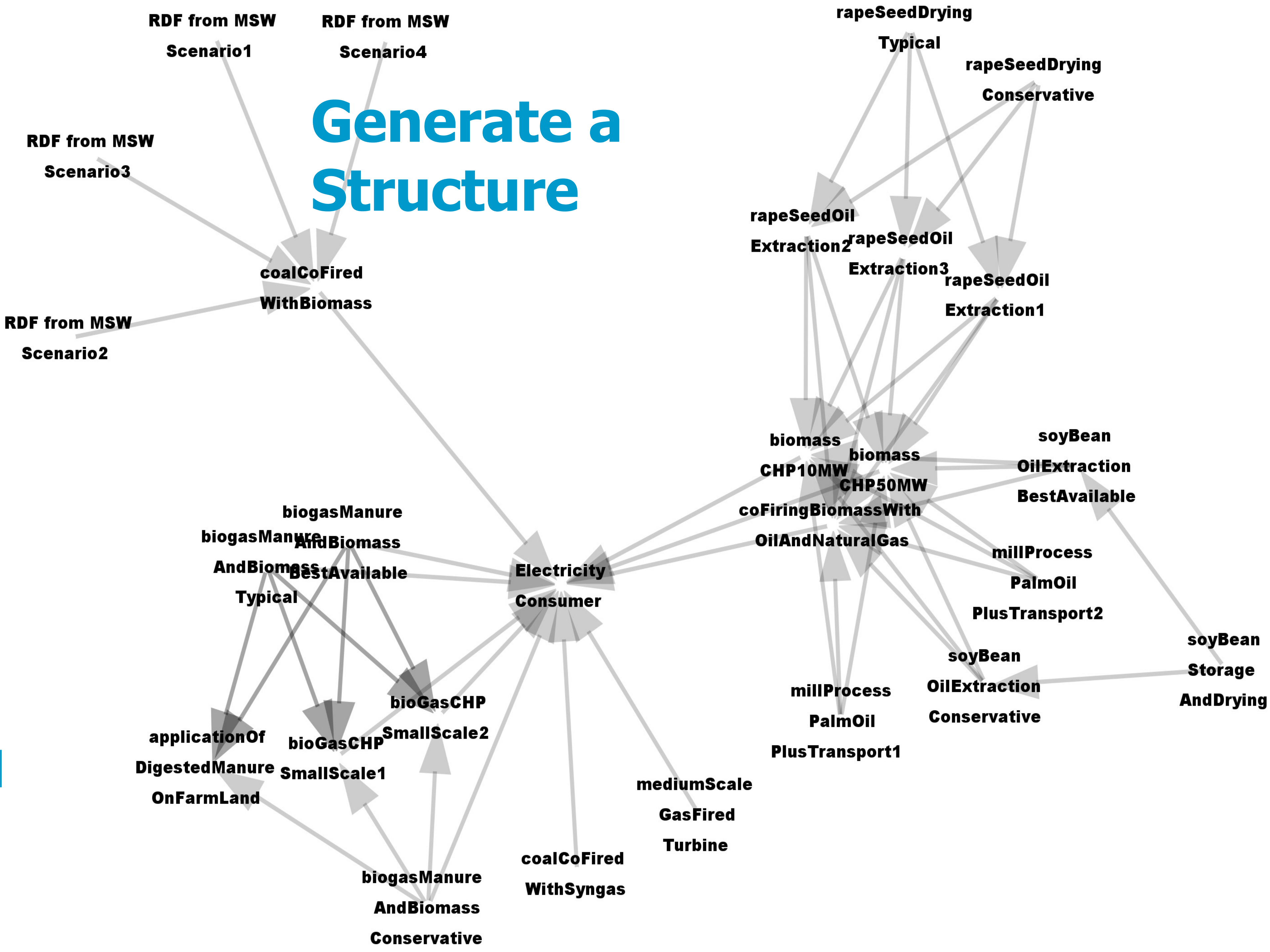
Generate a Structure



That matches an observed regularity