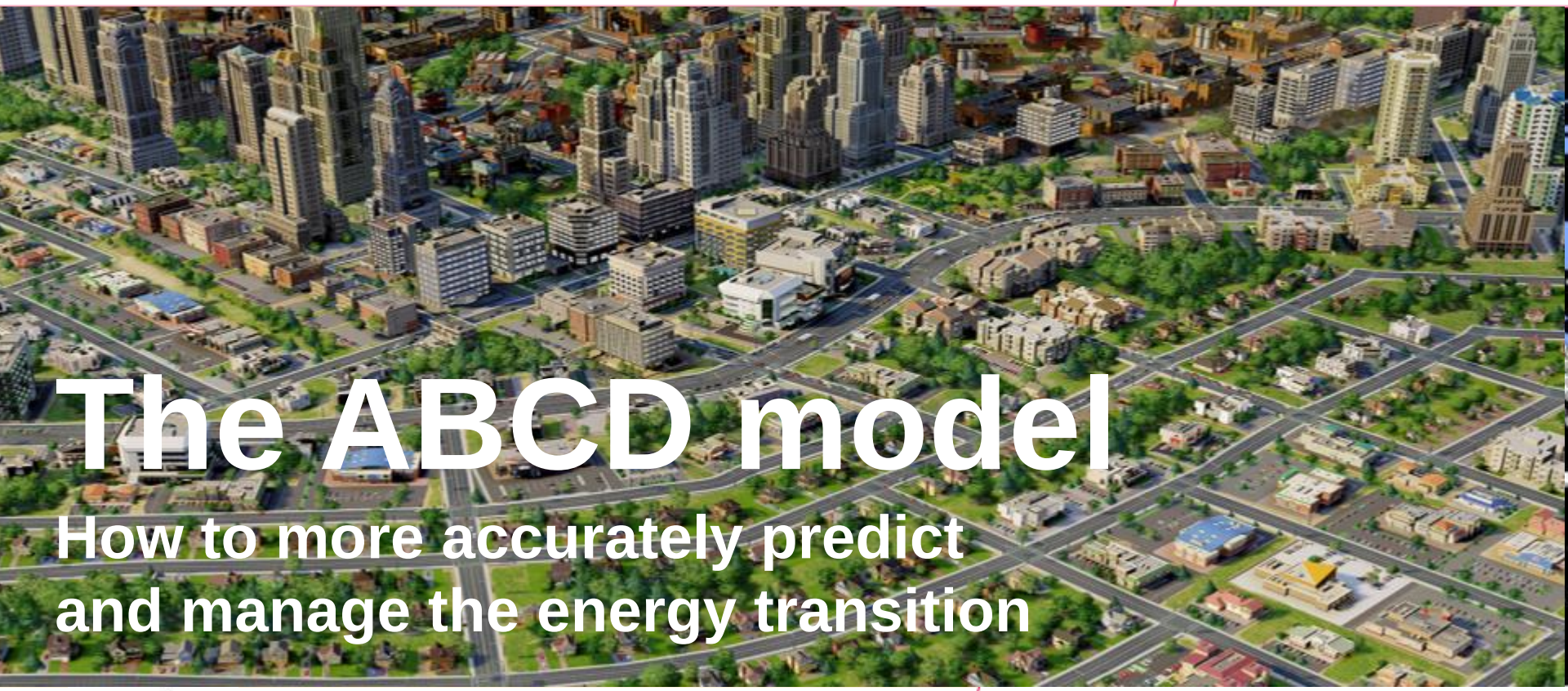
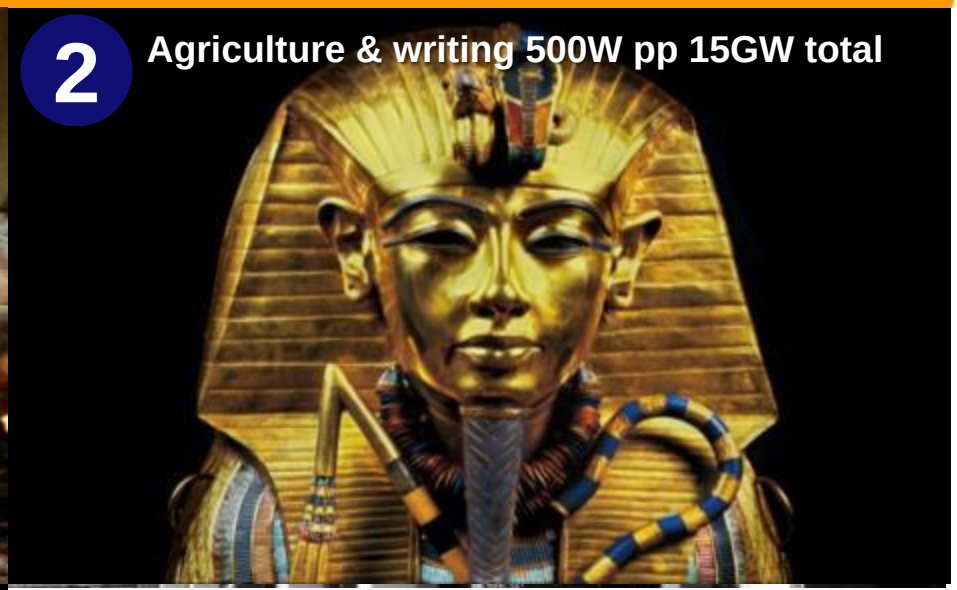


The ABCD model

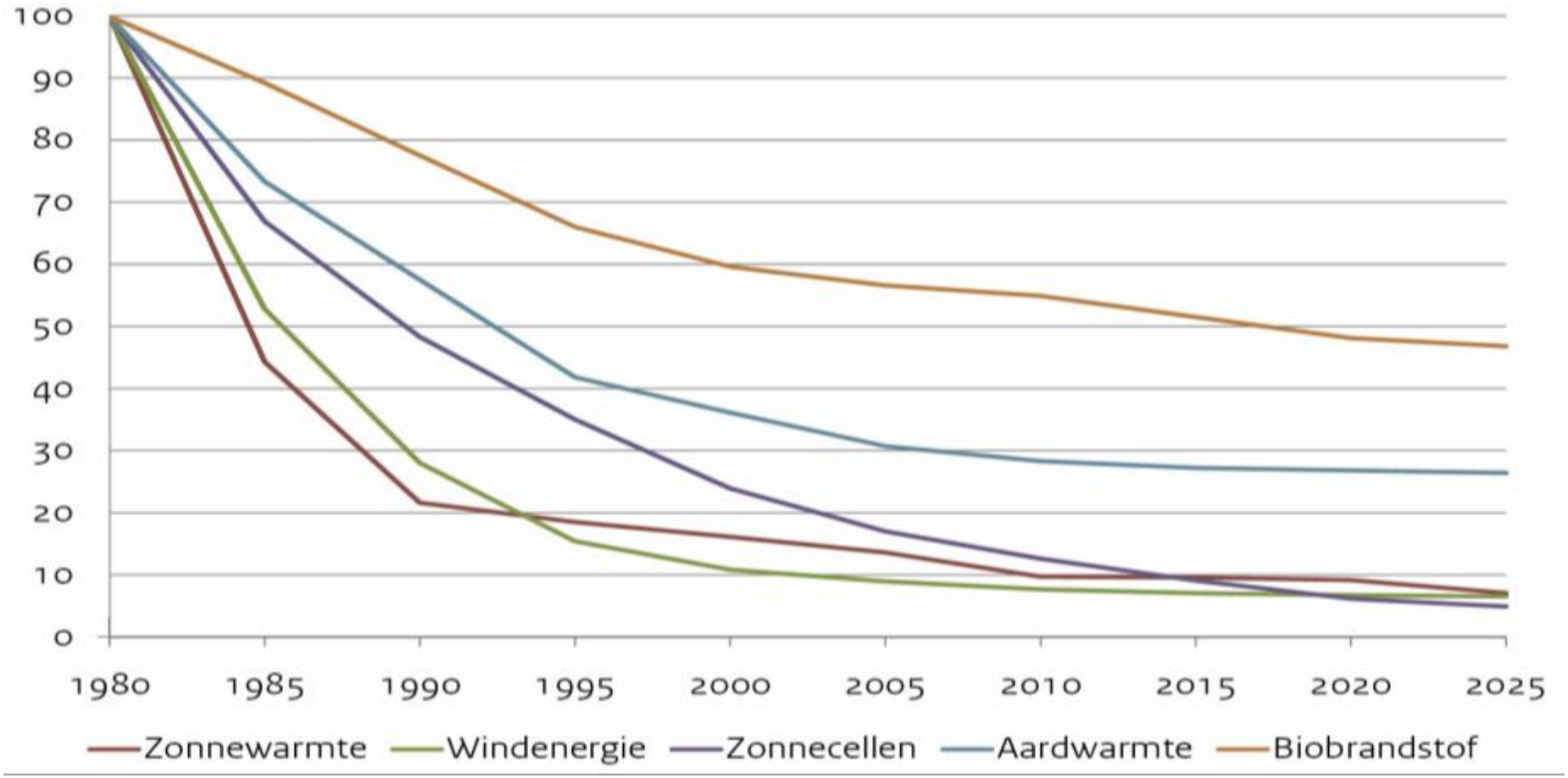
How to more accurately predict and manage the energy transition

Where innovation starts

Digging and burning is sooo 2nd milennium
We are in the middle of the 5th energy revolution



Renewables trade raw materials for knowledge
Good for the environment but also cheaper



Wind is becoming cheaper
Offshore already 5.5 cents/kWh

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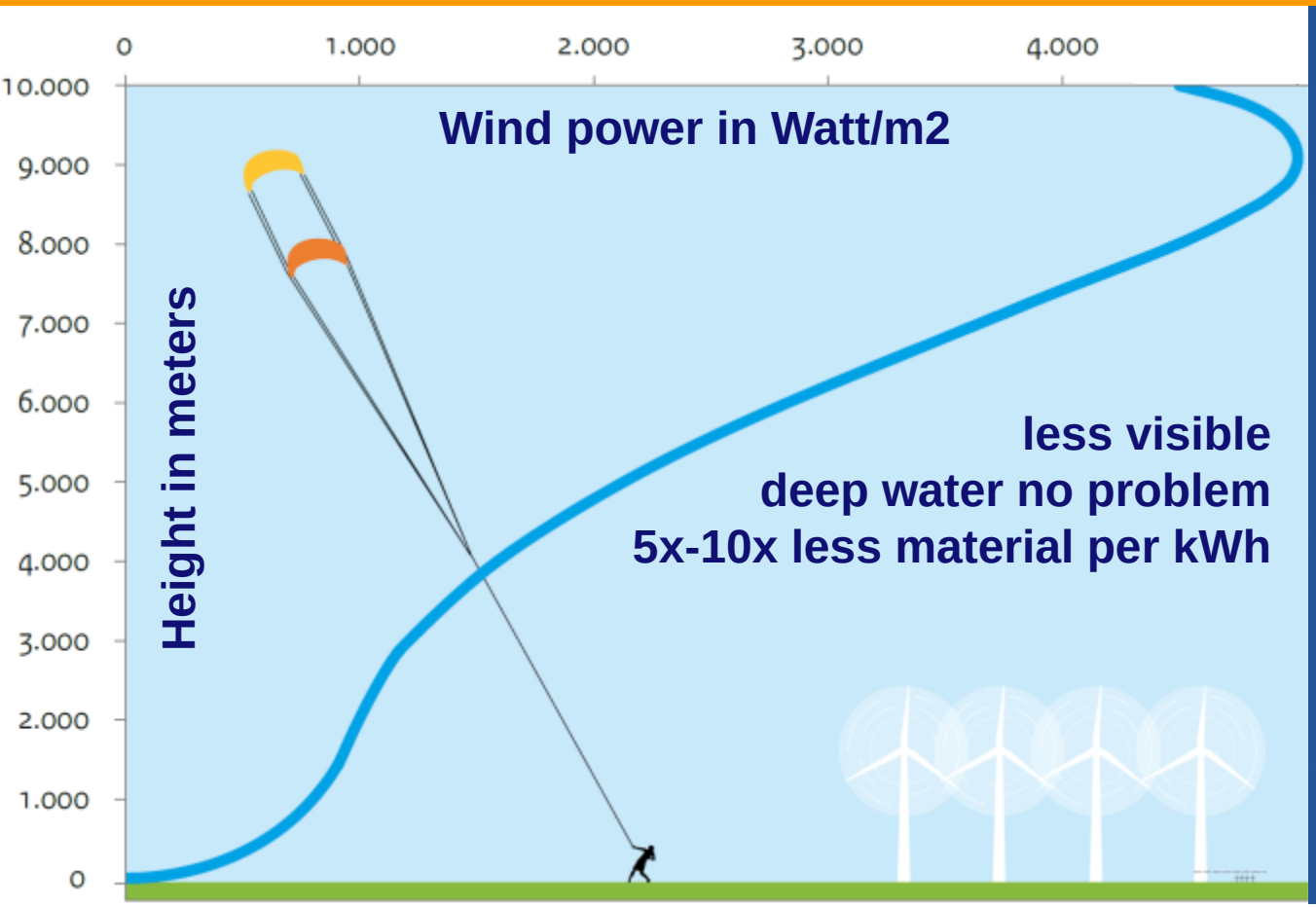
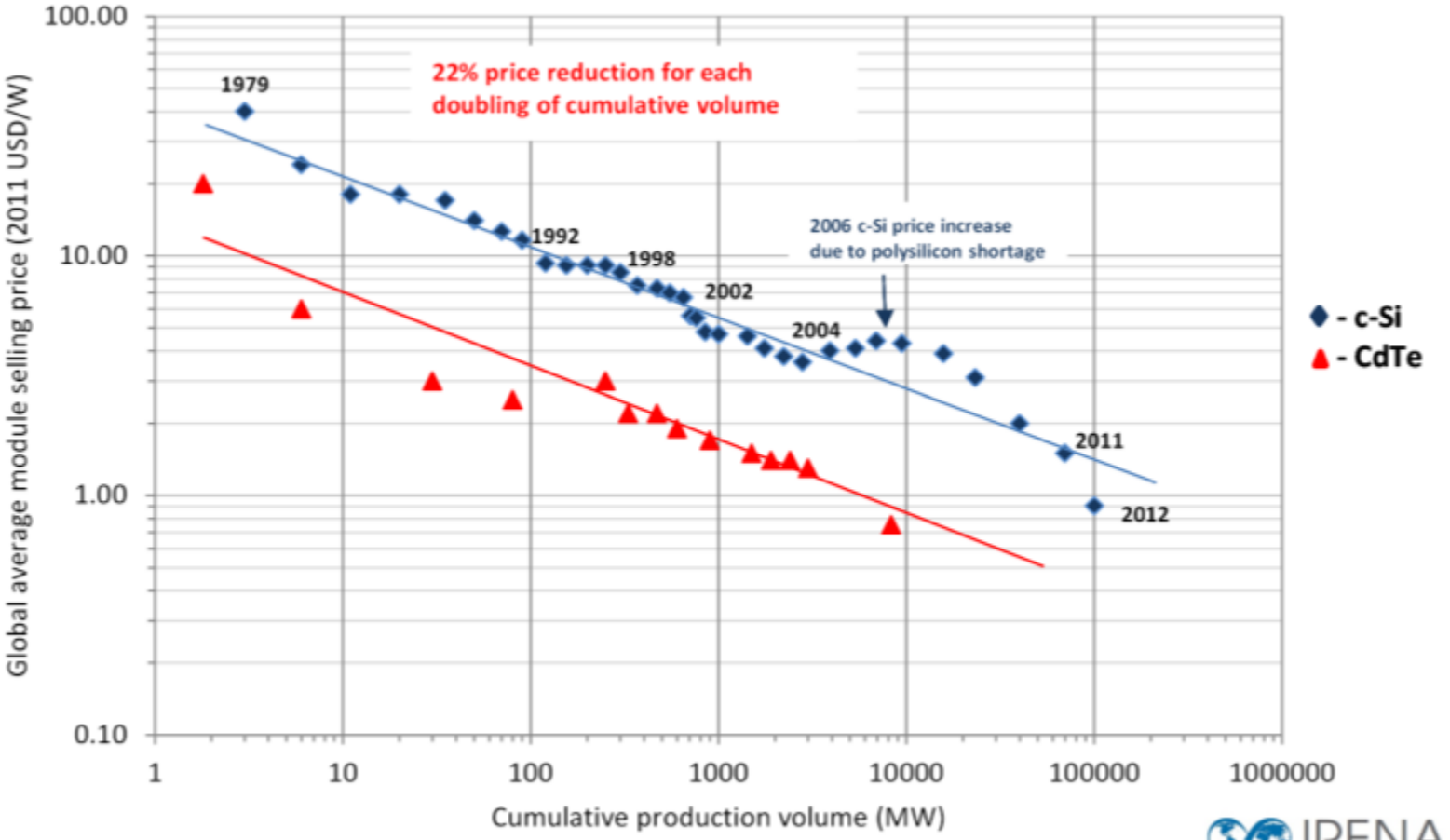
It will become much cheaper still
Especially with airborne wind energy (AWE)



Room enough on the North Sea
Red is windmills, blue is floatovoltaics

Solar is becoming cheaper
100x cheaper since 1980s… Imagine that for oil…



IRENA
International Renewable Energy Agency

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If you look at raw material cost, solar could become 1 or 2 cents per kWh

AukeHoekstra @AukeHoekstra · Aug 27

In a desert but still: less than $0.03/kWh! Solar Delivers Cheapest Electricity ‘Ever, Anywhere, By Any Technology’

My roof is a money maker

Now let's look at EVs

Did you know the first racecar was electric?

Did you know the electric motor is…
3x more efficient, 3x lighter and 30x smaller?

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Did you know the battery weight already decreased 20x since 1900?

Did you know the fastest accellerating (0-100 in 2.3 sec) production car is an electric family car?

Did you know that for every turn of the blades of one large windmill, an EV is propelled about 10km?

Did you know there is already enough discovered lithium to make 4 *billion* cars? (with 65 kWh batteries)? 10 kg of recyclable lithium vs 40 tons of gasoline…

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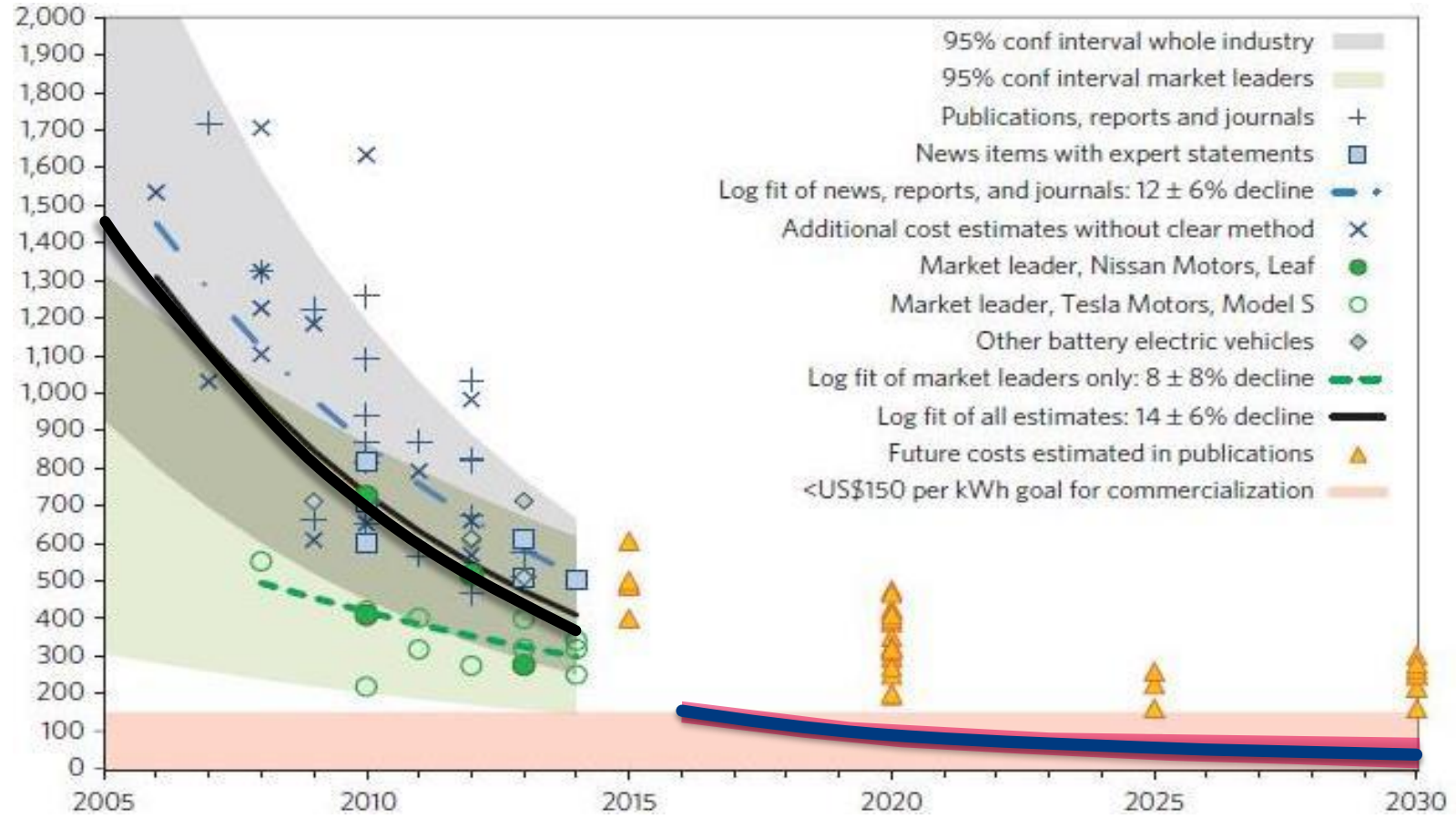
Did you know that over the cars lifetime gasoline and maintenance is already twice as expensive as the battery?

Our research indicates storage will become much cheaper still, making the ICE uncompetitive, at least in passenger cars



Source: Björn Nykvist and Mans Nilsson, Nature Climate Change, March 2015 & internship report Anand Lineshsundrani

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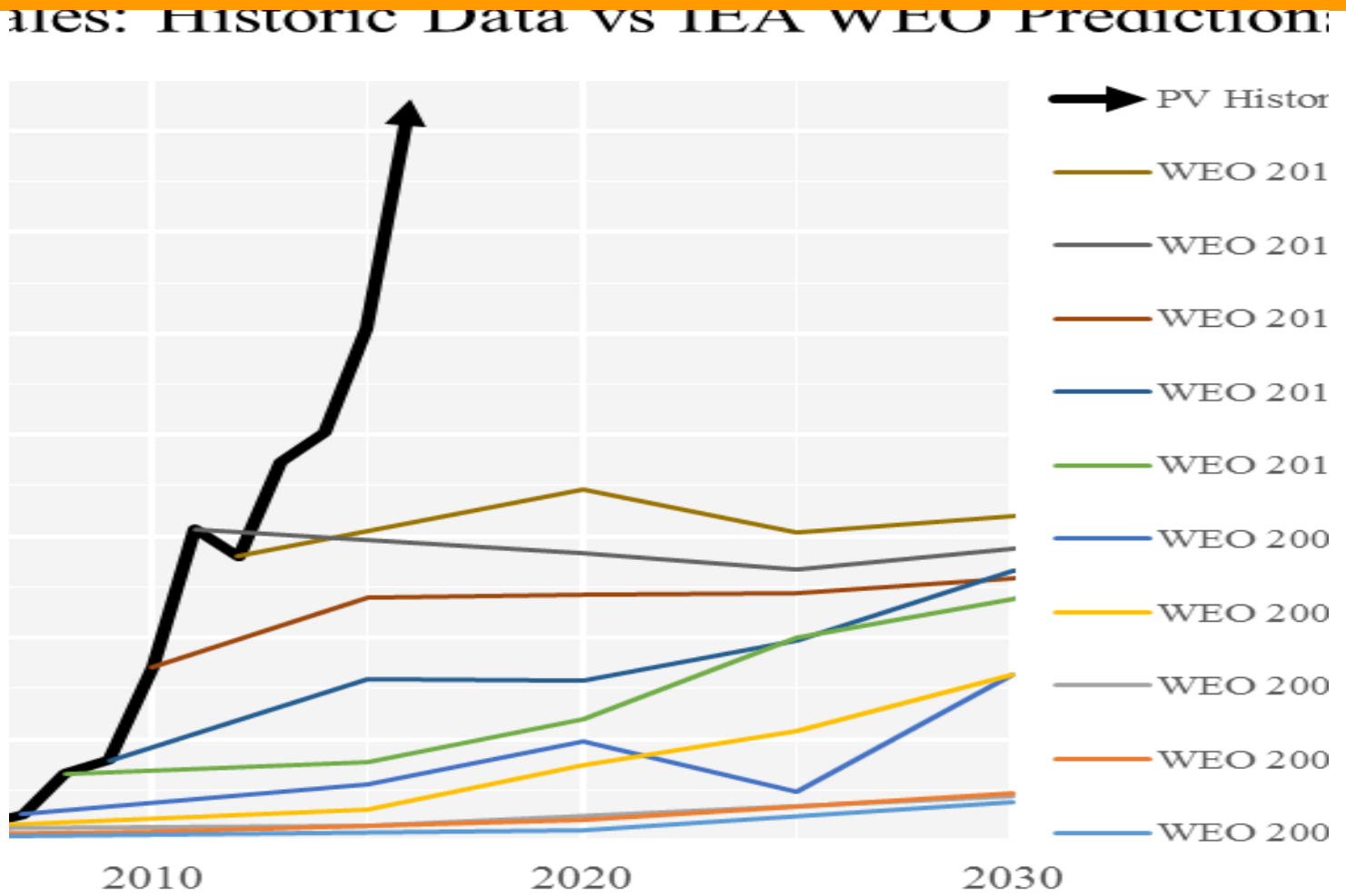
Wind, solar, EVs, storage…
This is a perfect storm!

But what does the worlds most famous model predict? (WEM of IEA)



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Reminded me of my KPN days

I made money for 25+ years by claiming Internet was going to be big

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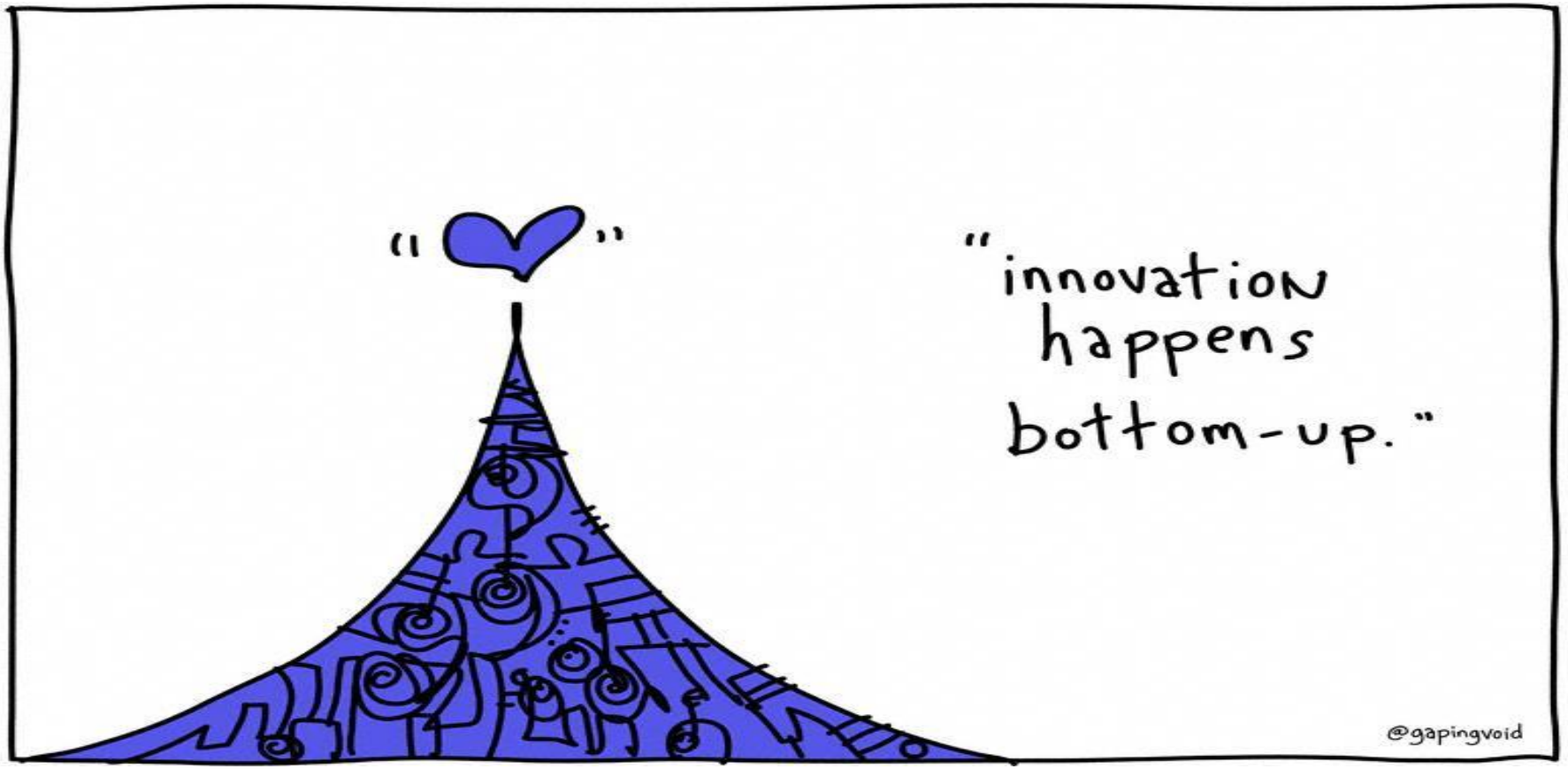
Big breakthroughs are not directed top-down: we need a bottom-up model



The questions are interrelated so we need an integral model

- **Battery and drive-train prices determine the succes of EVs and the success of EVs determines battery and drive train prices**
- **The succes of EVs is determined by available models and available models are determined by the succes of EVs**
- **Driving behavior determines how interesting an EV is, where you need charge points and what room you have for smart charging.**
- **The availability of charge points co-determines the desirability of EVS which co-determines the need for charge points (chicken-egg problem).**

The developments play on different levels so we need a multi-level model

- **(Inter)national to model climate problems and technological advances (batteries, drivetrains, renewable energy generation)**
- **Regional to model driving to and from destination and the required charge points**
- **Individual to simulate buying/charging decisions and model the load on the grid**

We must be able to tell quantified narratives: combining numbers with stories is the only way to make sense of so much complexity

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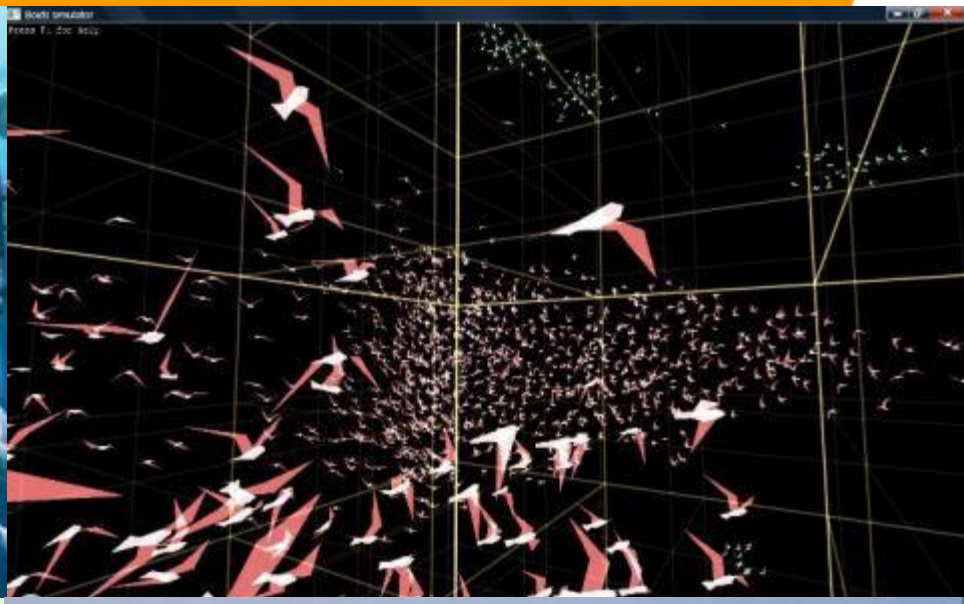
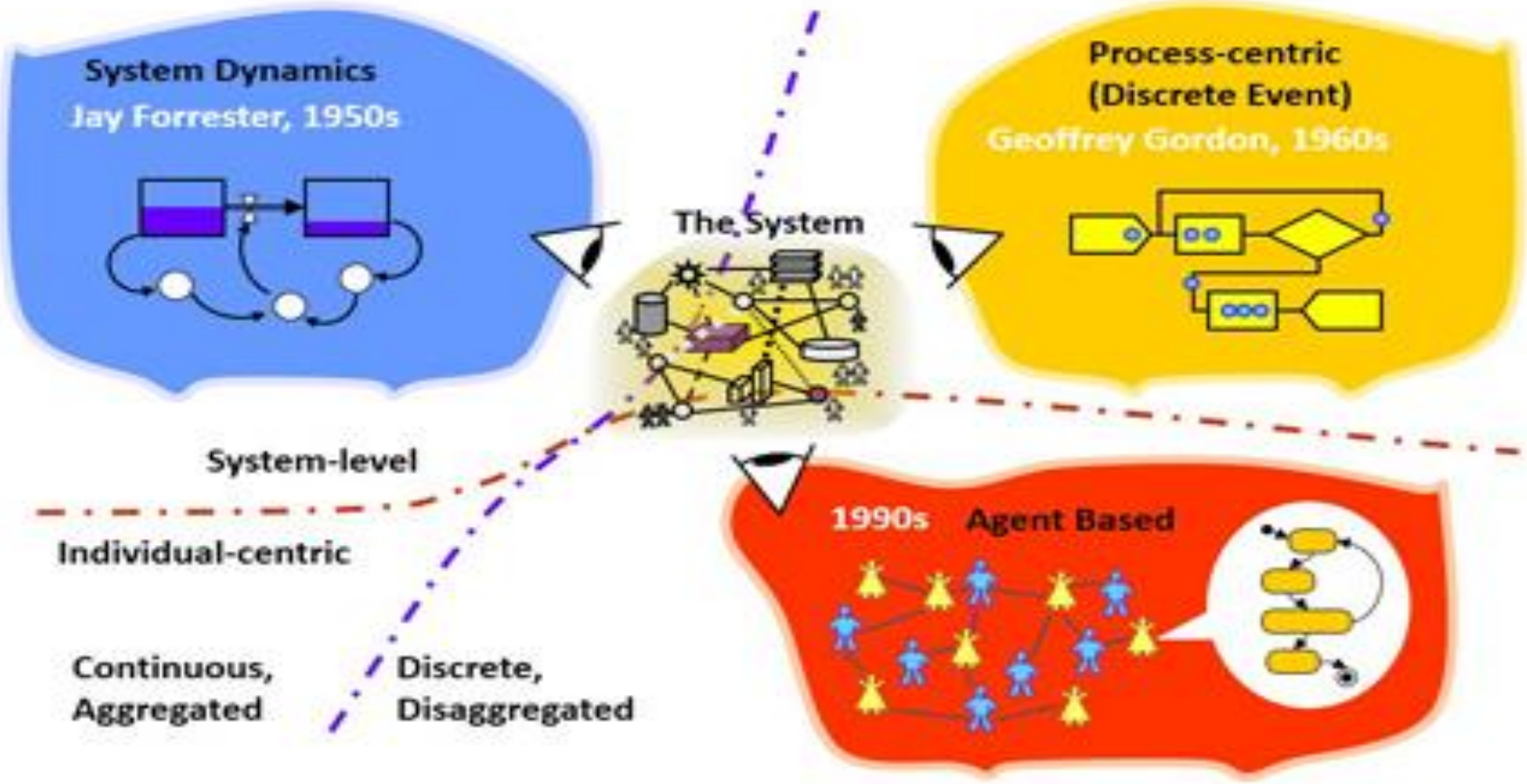
Agent-based modeling



Why agent-based modeling?

- **Bottom-up without imposing the structure of the system in advance (no pre-determined feedback loops)**
- **Ability to divide the complexity into self contained "agents" makes it manageable (linear instead of exponential growth of compexity when you add variables)**
- **Using recognizable agents and a bottom-up approach means we can enlist the help of domain experts**

Bottom up and actor based



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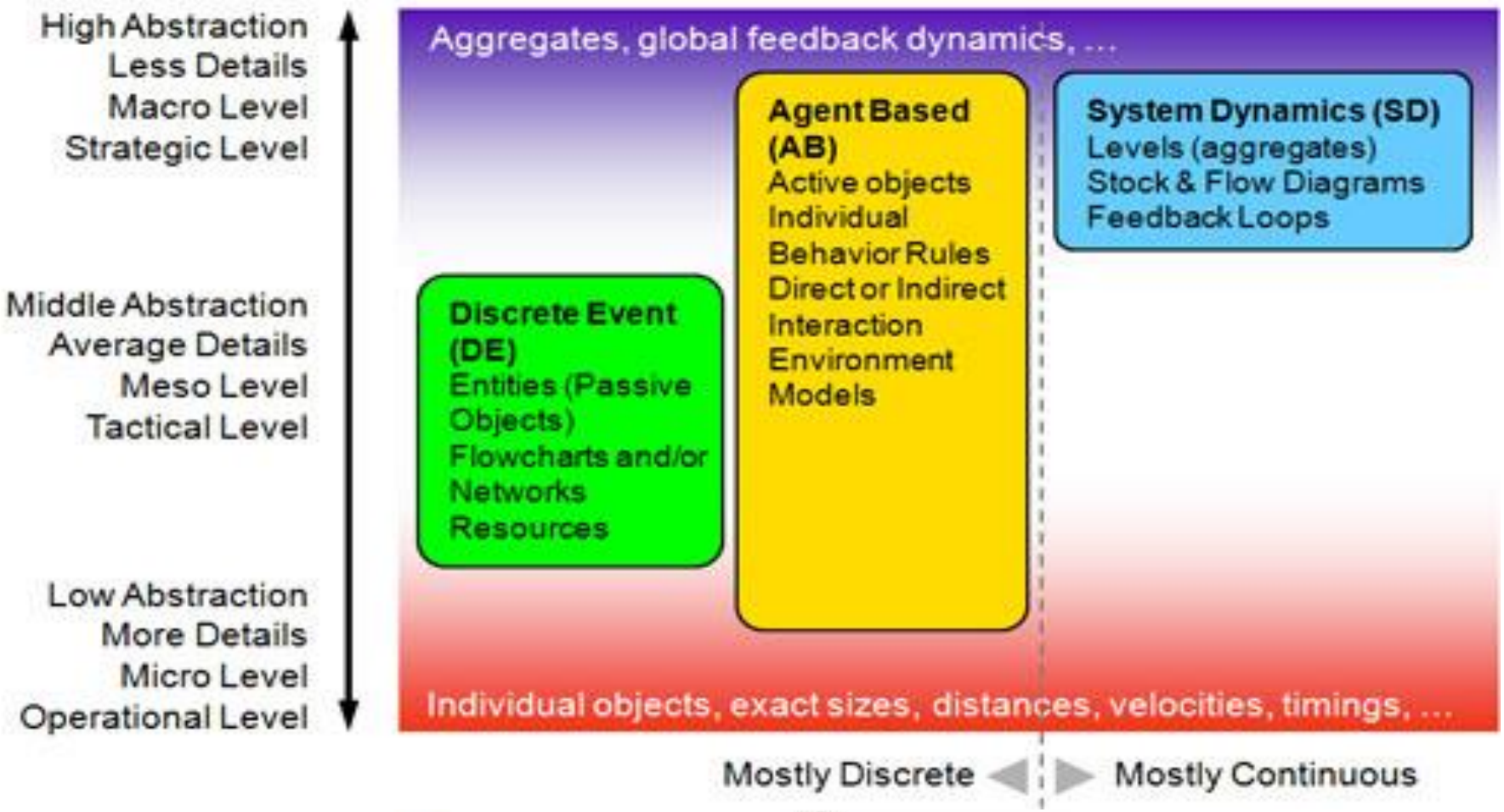
From low to high abstraction level



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What ABM tool to use?

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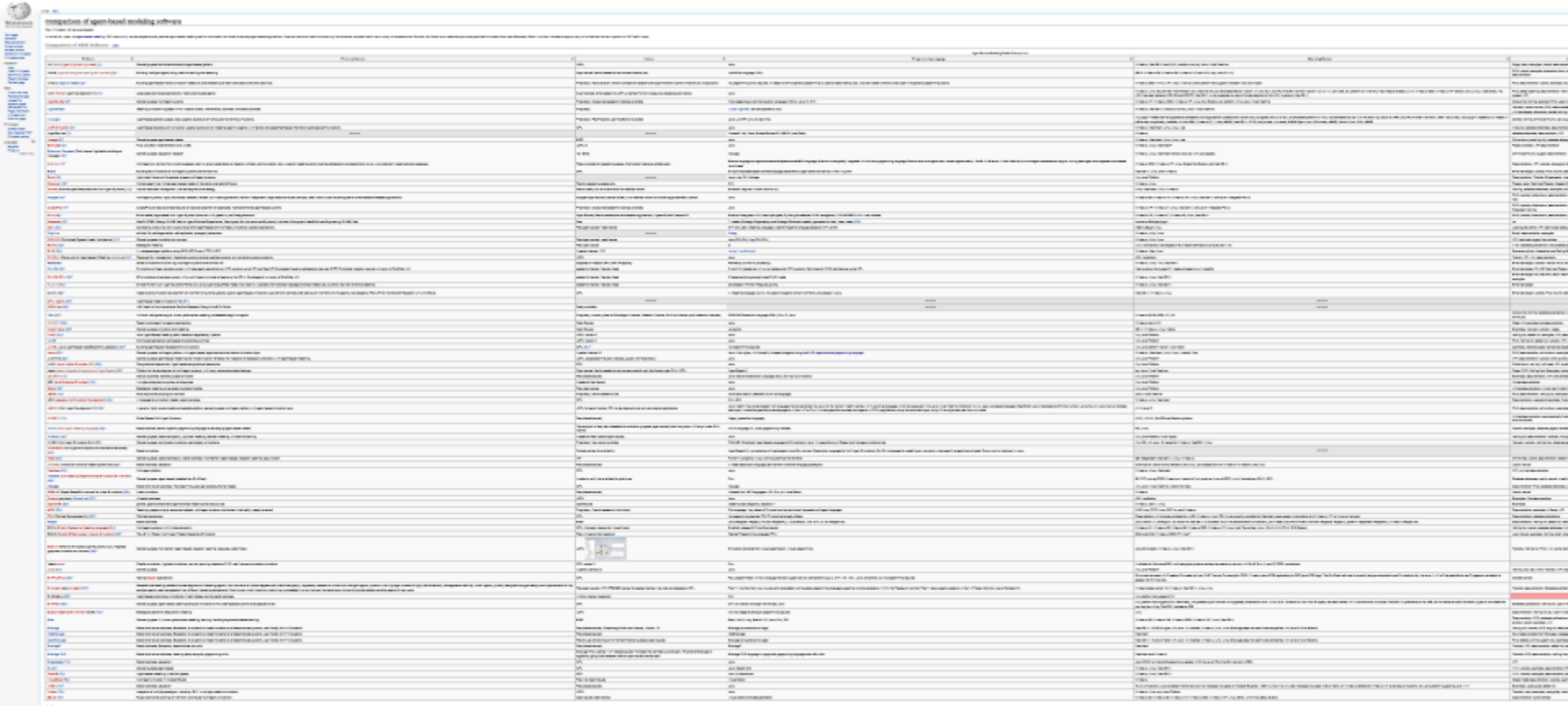
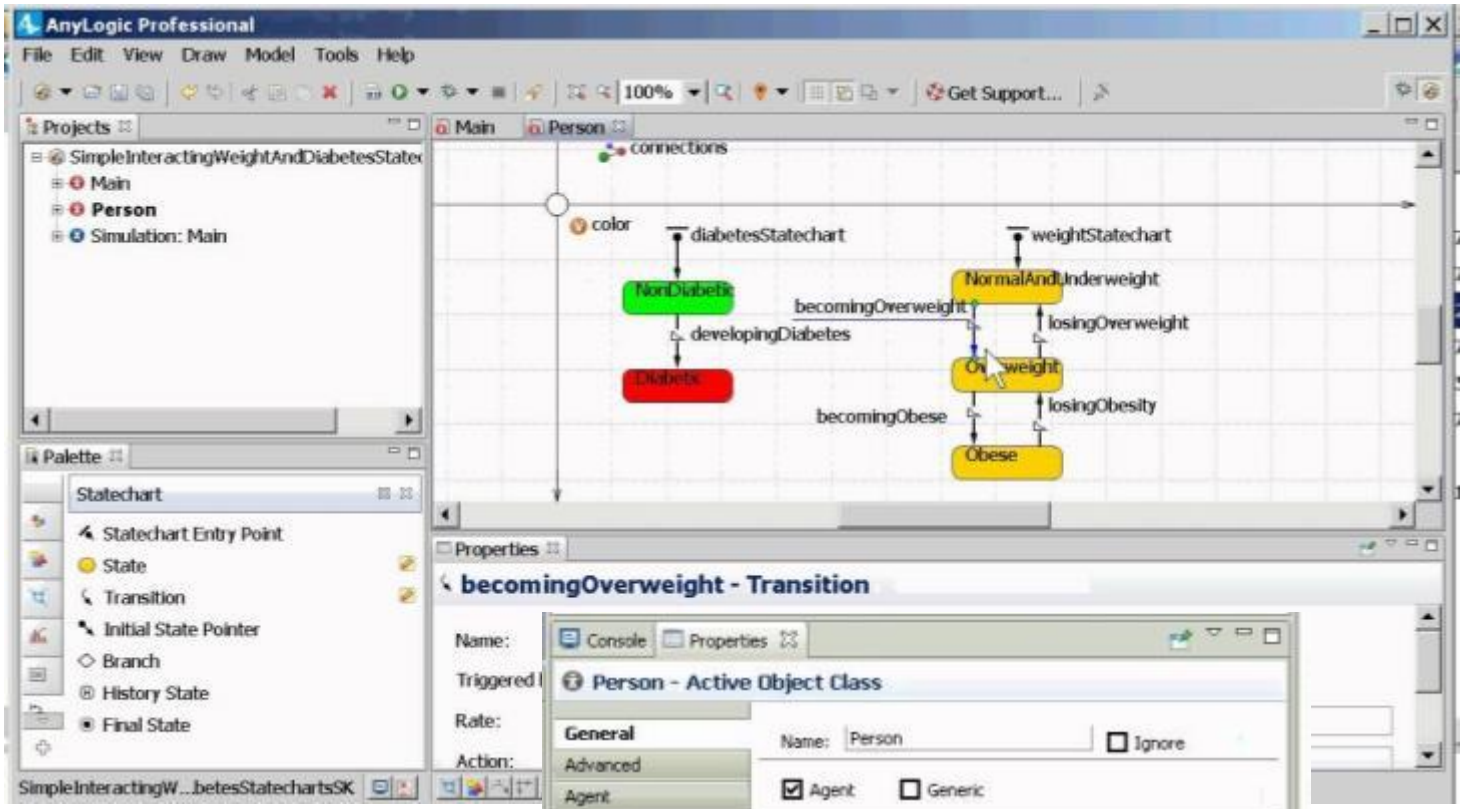
Many Java based frameworks

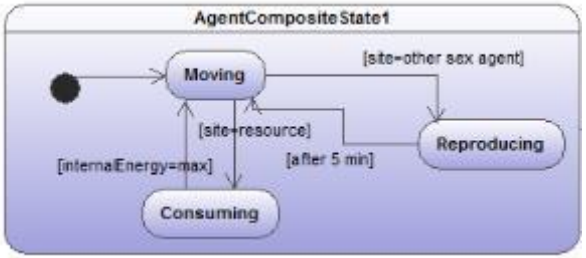
- Possible but only programmers and productivity modeler is low
- Less useful for domain experts and social scientists
- Python is in-between-solution (but execution speed)

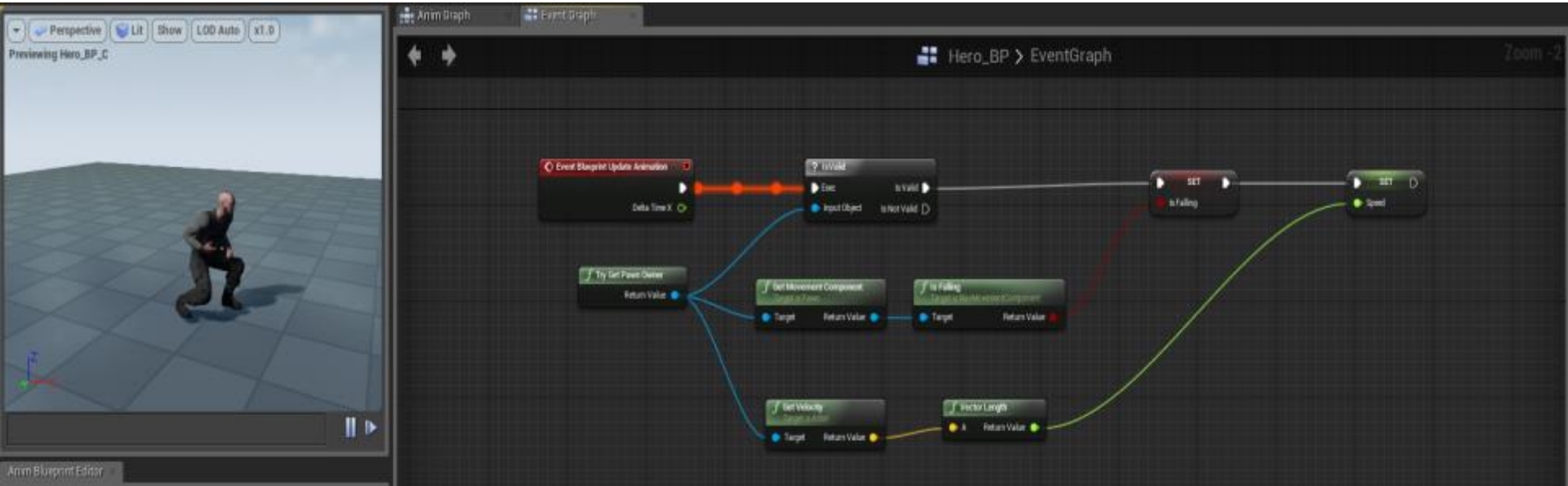


Anylogic is expensive (or limited) and you end up programming in Java

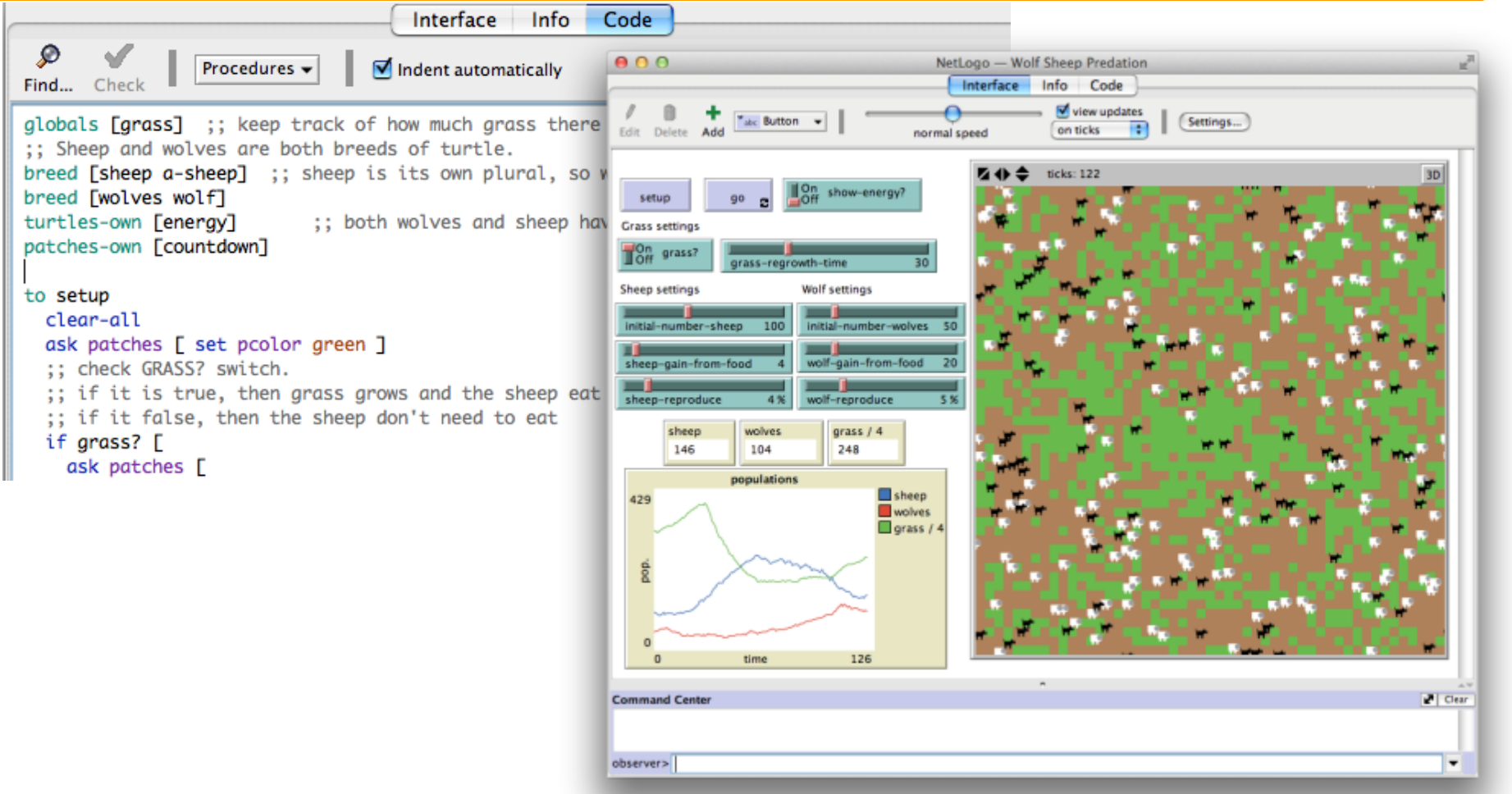


Game engines like unreal are all about how it looks

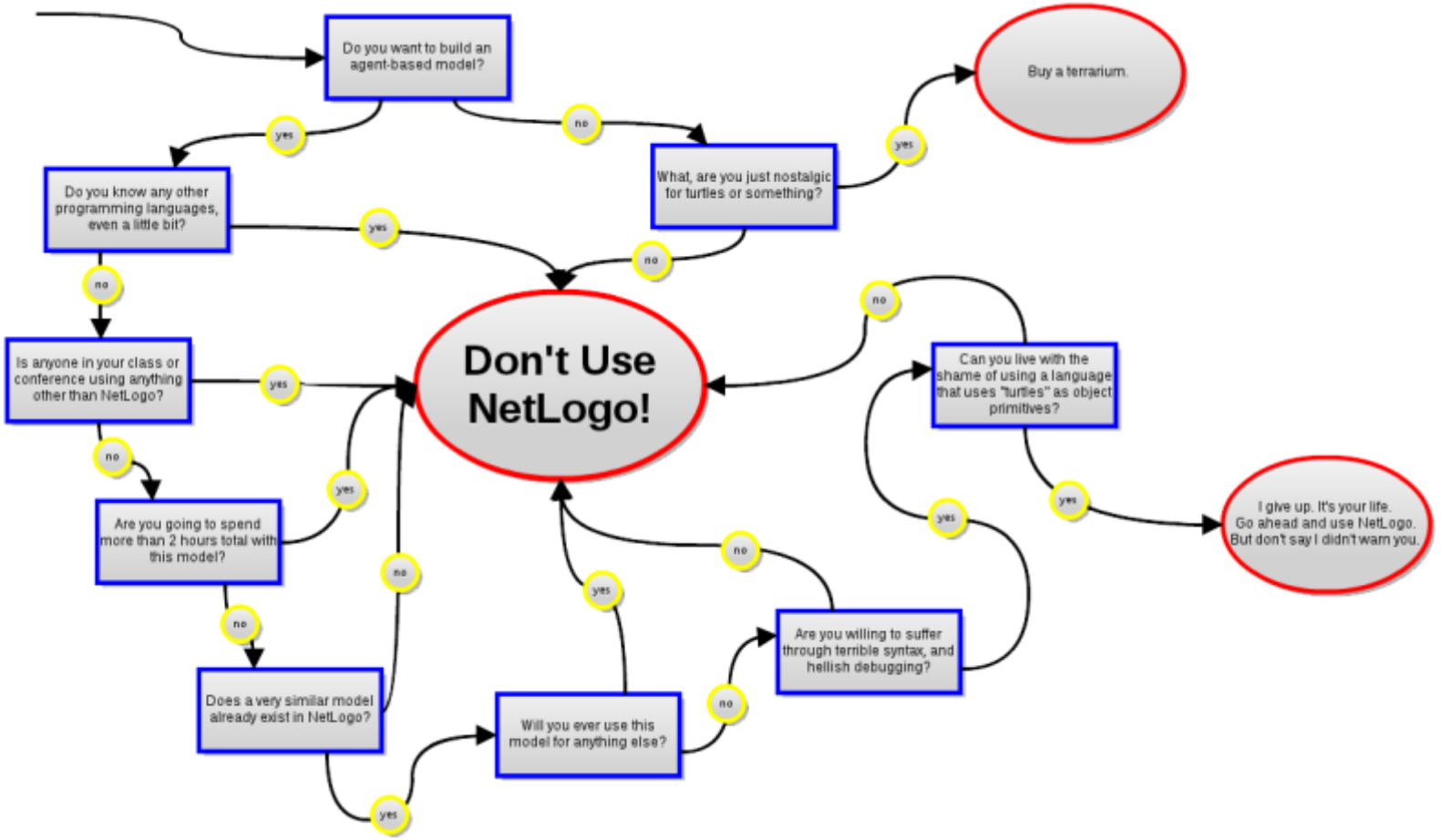




Netlogo: most popular ABM around and clever use of DSL (like Matlab and R)



Attitude of ICT people towards Netlogo



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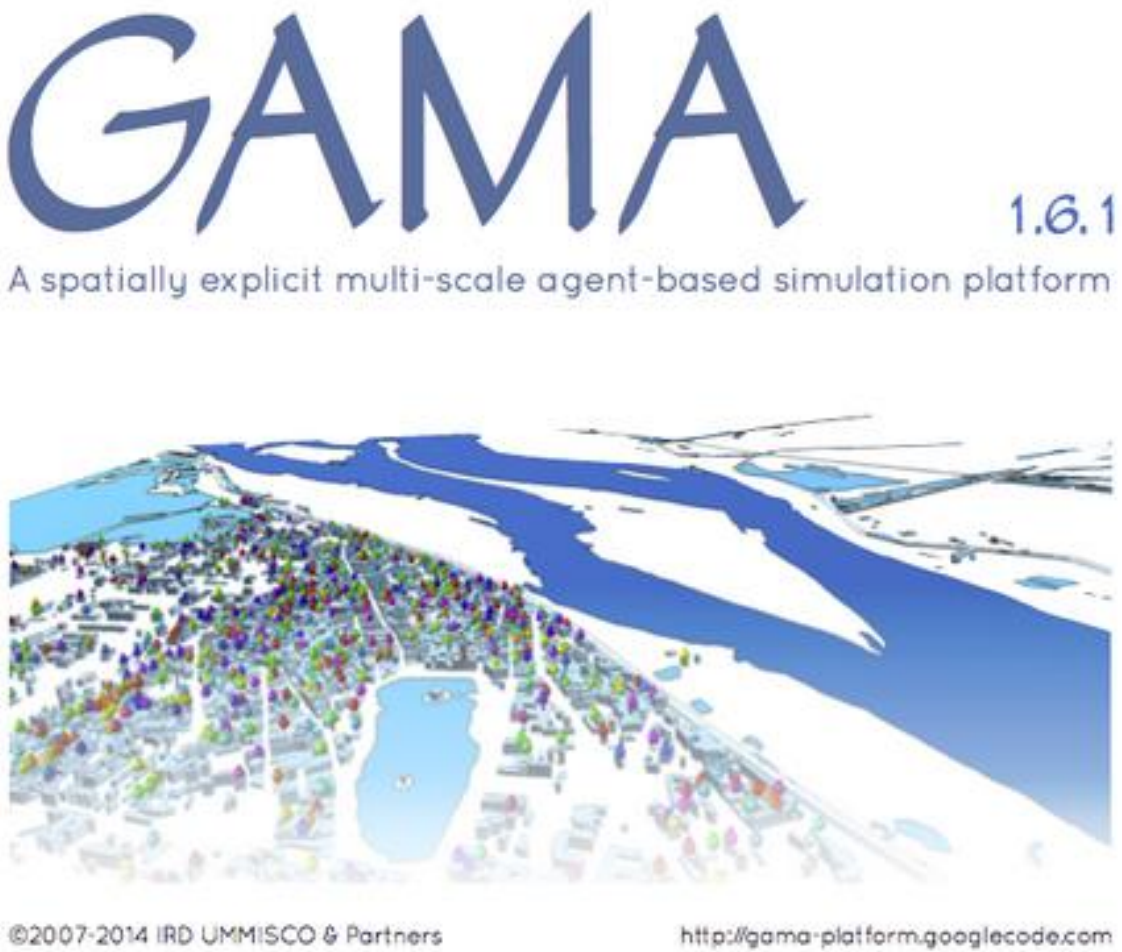
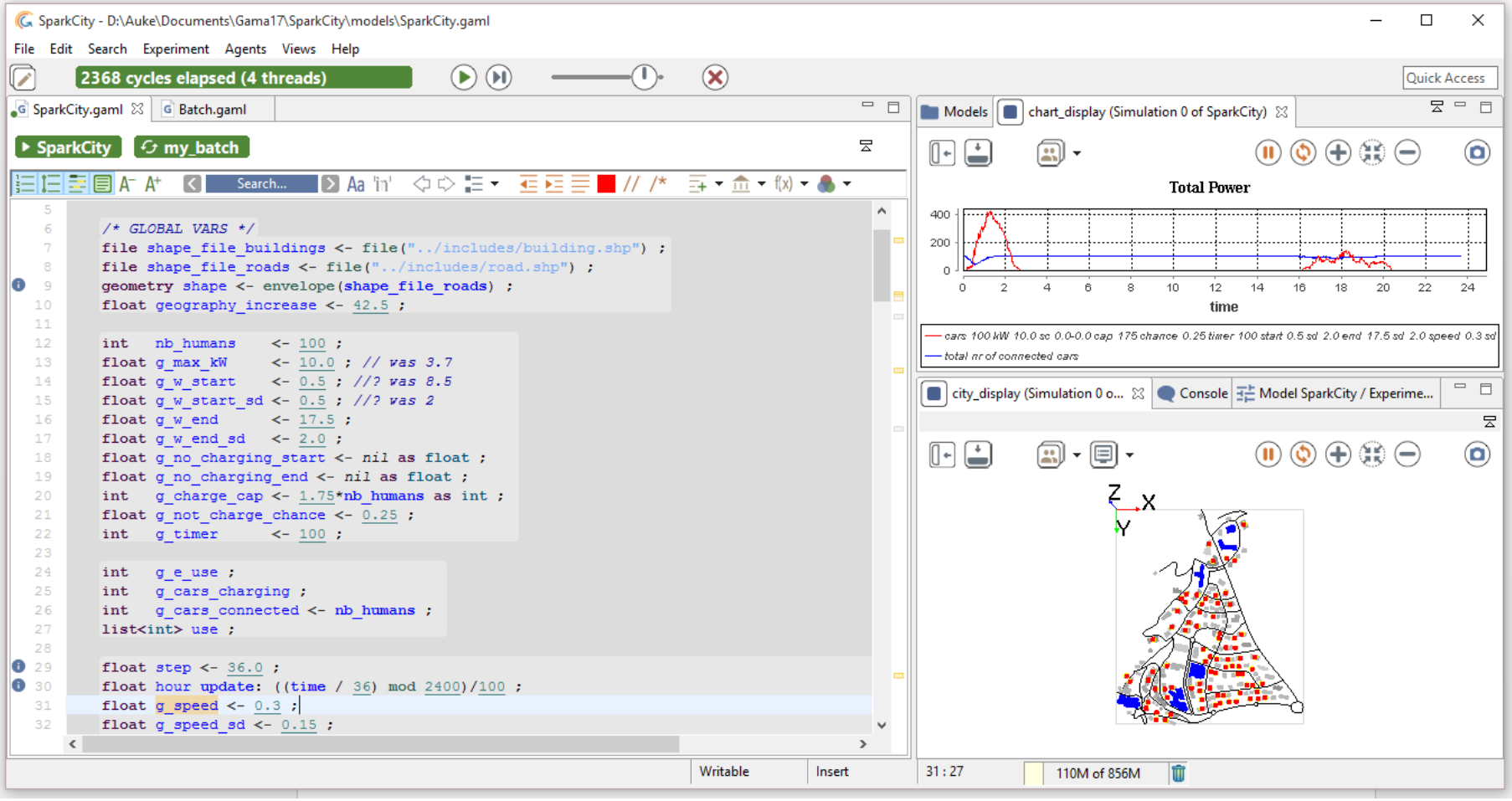
ABCD model uses GAMA



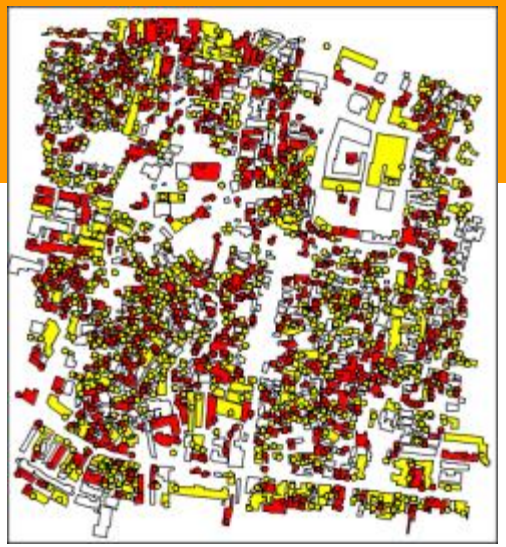
GAMA interface

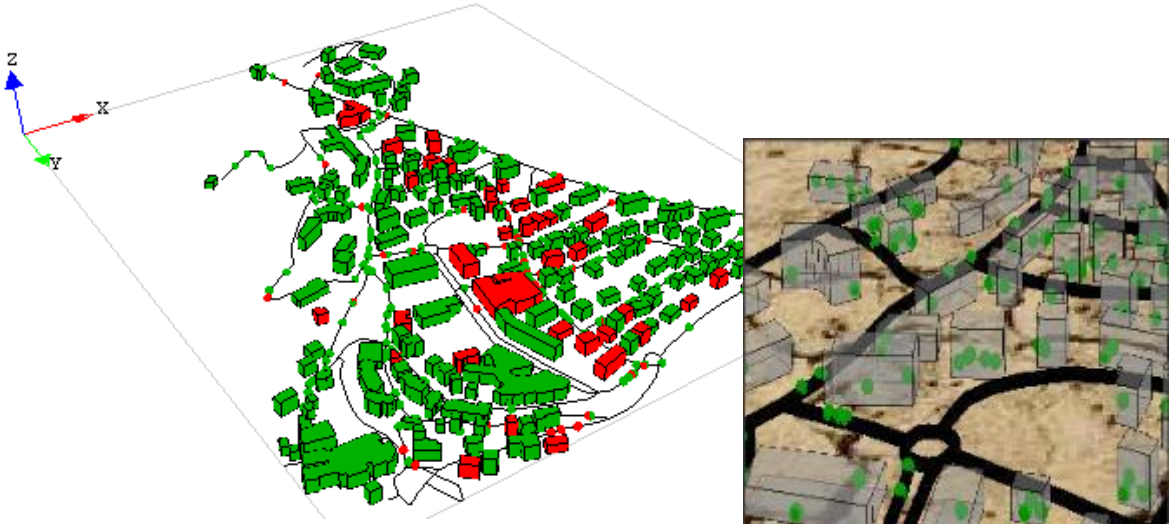
Language comparable to Netlogo but more OO (Java based)
Uses Eclipse IDE (very powerful debugging / collaboration)

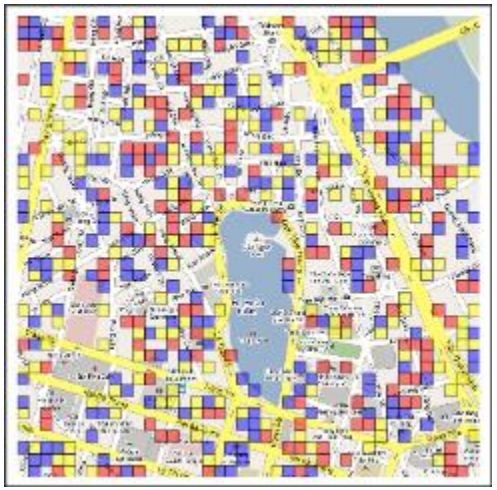


GAMA and GIS

Agentifying shape files is a breeze

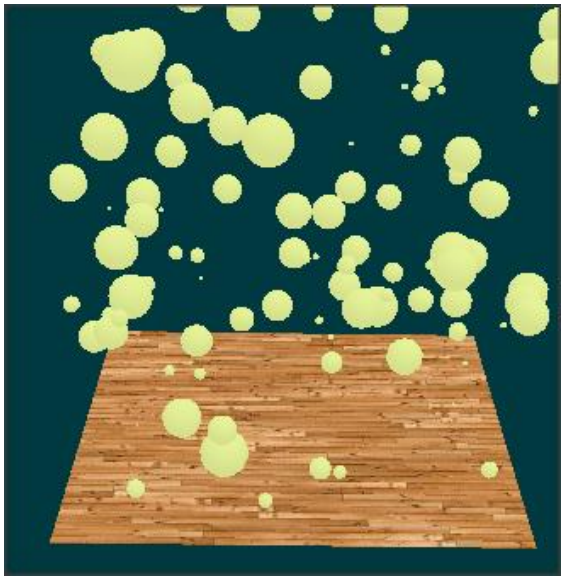


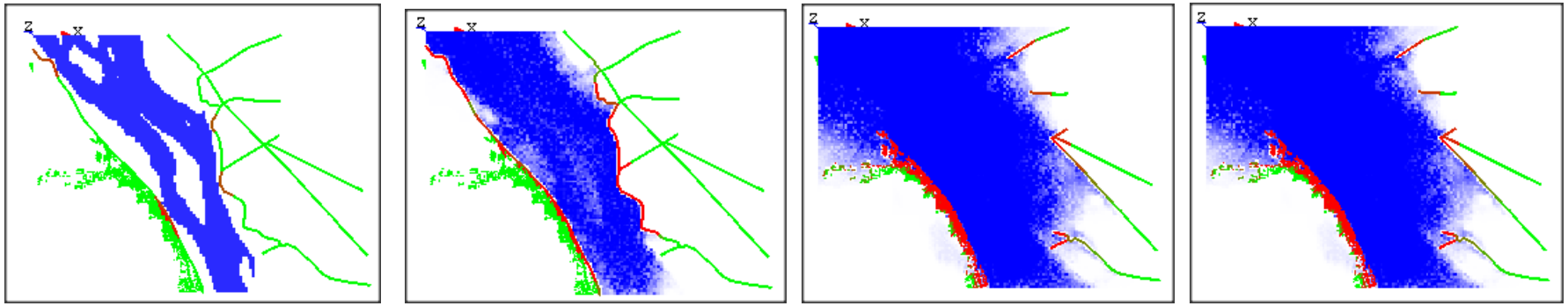




GAMA facilitates multi-level interaction

- Advanced grouping
- Interaction based on graph, distance, fysical properties, etc.
- Detailed driving modules





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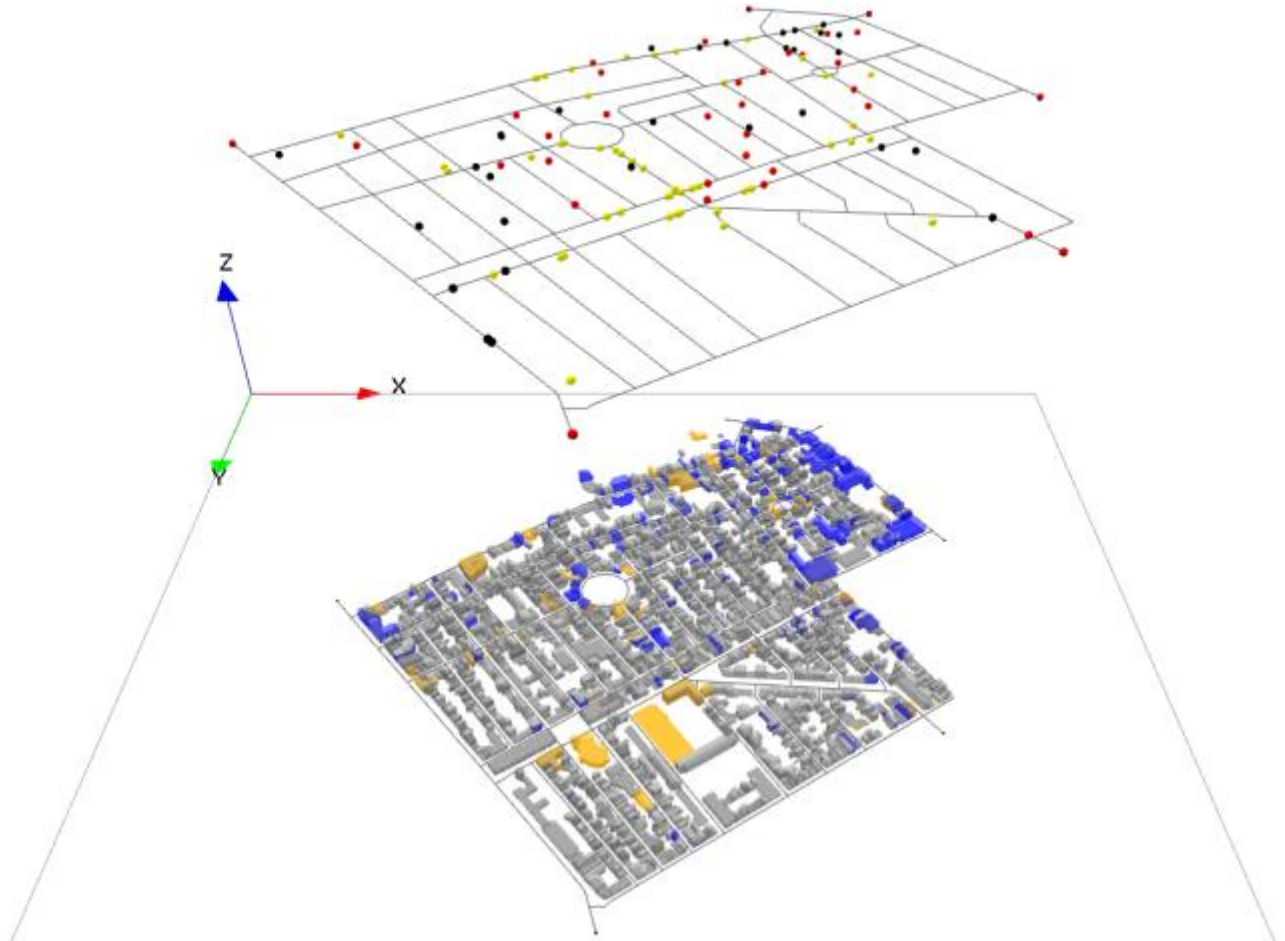
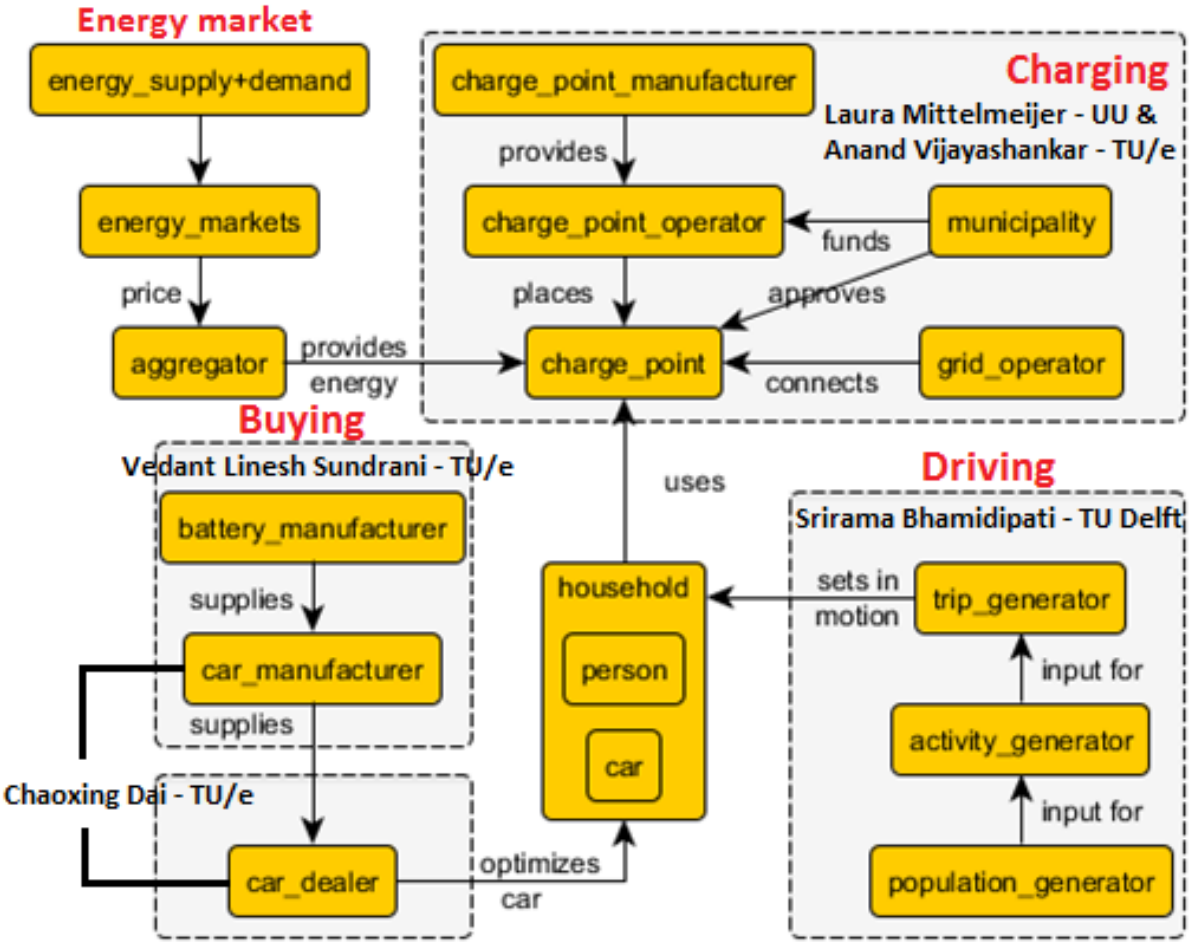
Where we are now: modeling real neighborhoods

Add layers with households, EV buying, charging, electricity grid.



Overall model



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Conclusions

- **Solar, wind, EVs and storage are poised to take over from fossil fuels in a perfect storm**
- **We need actor based, bottom-up, integral, multi-level models to manage and direct this transition**
- **ABM is the perfect modelling paradigm for the energy transition and GAMA is the perfect tool**
- **Our ABCD model is an attempt to create quantified narratives for the energy transition**
- **Starting september we need new students who want to do their master thesis with us (500 euro / month)**