The ABCD model
How to more accurately predict and manage the energy transition
Digging and burning is sooo 2\textsuperscript{nd} millennium
We are in the middle of the 5\textsuperscript{th} energy revolution

1. Fire & language  150W pp  0,15GW total
2. Agriculture & writing  500W pp  15GW total
3. Coal & printing  4000W pp  500GW total
4. Oil & telecom  11000W pp  15 TW total
Renewables trade raw materials for knowledge
Good for the environment but also cheaper
Wind is becoming cheaper
Offshore already 5.5 cents/kWh
It will become much cheaper still
Especially with airborne wind energy (AWE)

- Less visible
- Deep water no problem
- 5x-10x less material per kWh
Room enough on the North Sea
Red is windmills, blue is floatovoltaics
Solar is becoming cheaper 100x cheaper since 1980s… Imagine that for oil…
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?
Did you know the battery weight already decreased 20x since 1900?
Did you know the fastest accelerating (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...
Did you know that over the car's 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.

Wind, solar, EVs, storage…
This is a perfect storm!
But what does the world’s most famous model predict? (WEM of IEA)
Reminded me of my KPN days
I made money for 25+ years by claiming Internet was going to be big

If systemic resistance aka regime resistance aka institutional barriers are now the biggest impediments to change: what does that mean for our model?
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 success of EVs and the success of EVs determines battery and drive train prices
- The success of EVs is determined by available models and available models are determined by the success 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.
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 complexity 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
From low to high abstraction level
What ABM tool to use?
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

- Do you want to build an agent-based model?
  - yes: What, are you just nostalgic for turtles or something?
  - no: Is anyone in your class or conference using anything other than NetLogo?
    - yes: Don't Use NetLogo!
    - no: Are you going to spend more than 2 hours total with this model?
      - yes: Are you willing to suffer through terrible syntax, and hellish debugging?
        - yes: I give up. It's your life. Go ahead and use NetLogo. But don't say I didn't warn you
        - no: Will you ever use this model for anything else?
          - yes: Don't Use NetLogo!
          - no: Can you live with the shame of using a language that uses "turtles" as object primitives?
            - yes: I give up. It's your life. Go ahead and use NetLogo. But don't say I didn't warn you
            - no: Does a very similar model already exist in NetLogo?
              - yes: Don't Use NetLogo!
              - no: Will you ever use this model for anything else?
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, physical properties, etc.
- Detailed driving modules
Where we are now: modeling real neighborhoods
Add layers with households, EV buying, charging, electricity grid.
Overall model
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)