# Integrated energy system models

iiESI 102, August 2015, Iris van Beuzekom

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Where innovation starts

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- Recap on why ESI & what to look for?
- How does that apply to modeling?
- Comparing EnergyPLAN, HOMER & LEAP
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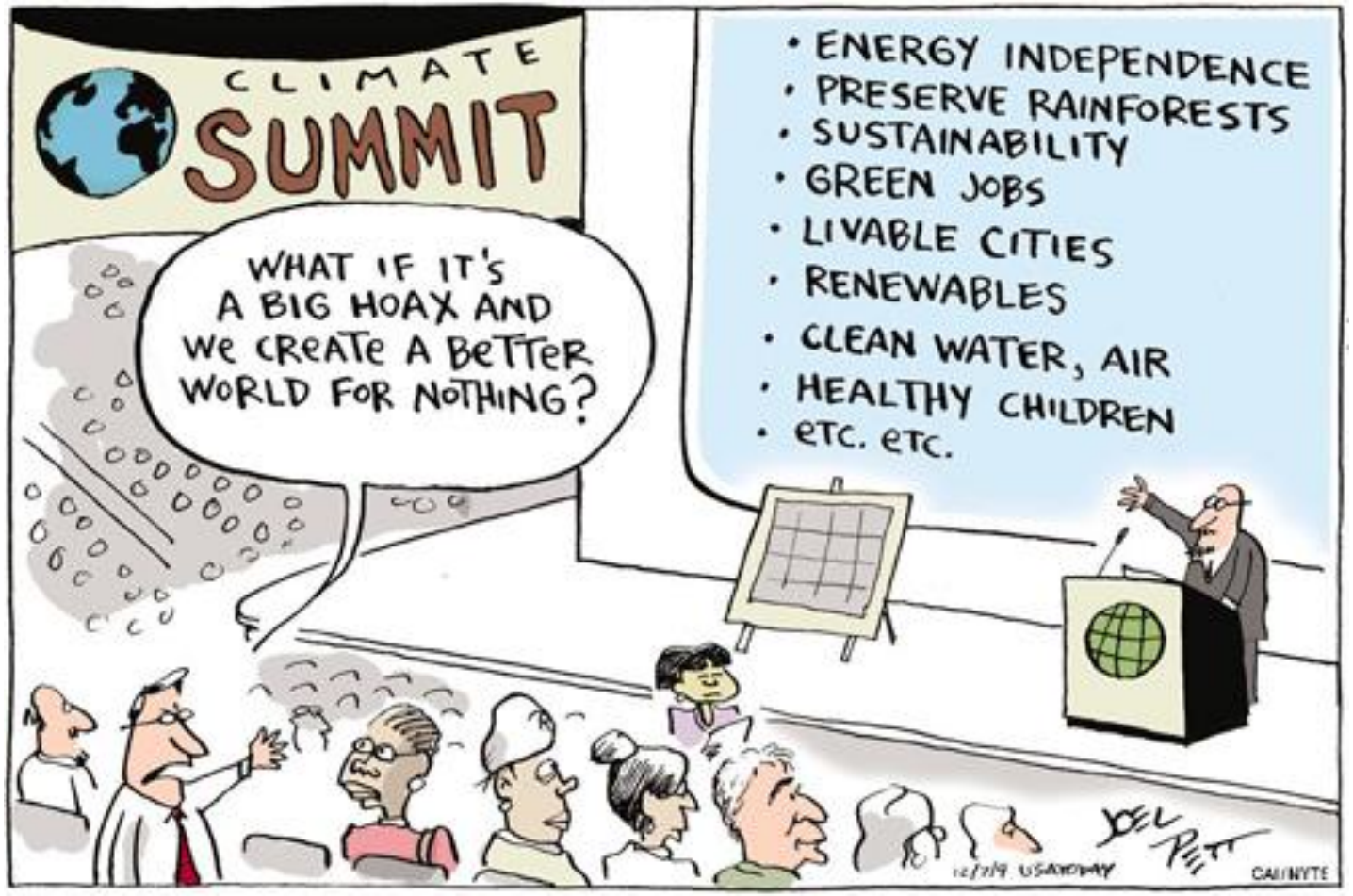
# My motivation



# Mini resume

- **BSc Sustainable Molecular Science & Technology, 2008**
  @ Delft University of Technology & University of Leiden
- **MSc Atmosphere & Energy (Civil & Env. Eng.), 2010**
  @ Stanford University, USA
- **Worked @ Dutch engineering firms until 2014**

- **Since Sept 2014: PhD-candidate 3 days / week**
- **Self-employed 2 days / week, working for:**
  - **ORTEC (www.ortec-consulting.com, operations research)**
    - **Big Data Alliance (Smart Energy research)**
  - **Capacity Energy (energy flexibility start-up)**

# As PhD candidate

- @ Eindhoven University of Technology
- Electrical Energy Systems group
- Electrical Engineering department
- Promotor: Han Slootweg
- Daily advisor: Madeleine Gibescu
- Researching the optimization of integrated energy systems for sustainable urban development (or ‘smart cities’)

# Development in ESI

- 1/3rd electricity → need broader perspective
- Fortunately, people have been working on this before
  - Many different energy models/concepts already there
  - Their difference shows the complexity of integrated energy systems: there is no universal ESI tool yet (e.g. not like standard power models)
- Some frontrunners:
  - ETH Zurich – Energy Hub
  - Aalborg – Quad-generation
  - Manchester – multi-energy modeling
  - UC Dublin – Enernet model
  - NREL – many different models, among which HOMER

# What is important regarding integrated energy systems?

- **Research scale (building scale up to global scale)**
  - **Cities & IES → Climate goals → how to reach those using integrated energy systems?**
- **Generation, conversion, storage options**
- **Supply & demand (in)flexibility**
- **Different network characteristics**
- **Cost limitations & opportunities**
- **Time (planning vs operational scope)**

# Let’s not reinvent the wheel

- **72 tools → filtered on 3 things:**
  - ***Applicable to city scale***
  - **Integrated energy character**
  - **Open source / freely available**

- **13 tools left → analyzed on**
  - **General characteristics**
    - **Modelling approach, optimization objective, time step, etc.**
  - **Energy characteristics**
    - **Resources, generation/conversion/storage types, etc.**

# Reviewed energy tools


HOMER ENERGY

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
ANALYTICS | PLANNING | OPERATIONS

TRNSYS
Transient System Simulation Tool


COMPOSE
Compare Options for Sustainable Energy

Energy PLAN
Advanced energy system analysis computer model

LEAP *Tools for Sustainable Energy Analysis*

Balmorel
*Energy system model*


ENERGINET.DK

SIVAEL

iea Energy Technology Network ETSAP TIMES

RETScreen® International
Empowering Cleaner Energy Decisions

# A few examples to compare

- **EnergyPLAN, Aalborg University, 1999**


- **HOMER, NREL, 1992 (will be highlighted Tue)**


- **LEAP, Stockholm Environment Institute, 1980**

# EnergyPLAN vs HOMER vs LEAP

- **General characteristics**
  - **Physical scale**
  - **Time step & scale**
  - **Objective**
  - **Availability**
  - **Modeling approach**
  - **User friendliness**
- **Energy characteristics**
  - **Energy services**
  - **Demand sectors**
  - **Generation types**
  - **Conversion/storage types**
  - **Economic parameters**
  - **Green/brownfield**

# Integrated energy model comparison

| | EnergyPLAN | vs | HOMER | vs | LEAP |
|---|---|---|---|---|---|
|  physical scale | local<br>regional<br>national | | local<br>island operation | | regional<br>national<br>international<br>global |
|  time step & scale | 1 hour<br>1 year | | 1 hour<br>1 year | | 1 year<br>20-50 years |
|  objective | optimize technology<br>or economics | | minimize NPC | | accounting<br>minimize cost |

# Integrated energy model comparison

| | EnergyPLAN | vs HOMER | vs LEAP |
|---|---|---|---|
|  availability | free<br>not open source | 14-day free trial<br>not open source | free for academics<br>not open source |
|  modeling approach | operational<br>*planning* | *scenario*<br>operational | scenario<br>planning |
|  user friendliness | high<br>dedicated GUI<br>few days training | high<br>dedicated GUI<br>1 day training | high<br>dedicated GUI<br>3-4 days training |

# Integrated energy model comparison

| | EnergyPLAN | vs | HOMER | vs | LEAP |
|---|---|---|---|---|---|
|  **energy services** | electricity<br>heating<br>cooling<br>e & non-e transport<br>chemicals | | electricity<br>heating<br>cooling | | electricity<br>heating<br>cooling<br>non-e transport<br>chemicals |
|  **demand sectors** | *residential*<br>transportation<br>industry<br>import & export | | N/A, only load types specified (primary, deferrable, thermal) | | all sectors<br>import<br>export |
|  **generation types** | all non-renewable & renewable generation | | CHP, microturbines<br>biomass, small hydro<br>wind, solar thermal<br>photovoltaic | | all non-renewable & renewable generation |

# Integrated energy model comparison

| | EnergyPLAN | vs HOMER | vs LEAP |
|---|---|---|---|
|  conversion/storage | batteries, pumped hydro heat storage, heat pump $H_2$ storage, carbon capture and storage | batteries, $H_2$ production & storage, fuel cells AC/DC converter | All conversion and storage types |
|  economic parameters | fuel price capital costs operation & maintenance costs carbon tax subsidies/quotas | fuel price capital costs operation & maintenance costs | fuel price capital costs operation & maintenance costs carbon tax subsidies/quotas |
|  green/brownfield | both | brownfield | brownfield |

# Research challenges for me

- **How can an integrated energy system help a city reach its energy goals?**
- **Figure out the potential & limitations of these models & how to work around that**
- **Combine electricity, heating, cooling & gas demand (Dutch perspective) in residential, commercial & industrial demand of cities; see how/where integration is possible**
  - **Time dependency (unit dispatch across energy vectors)**
  - **Location dependency (network combinations & costs)**

# Research challenges

- **Maturity of integrated energy systems research**
- **Energy systems are very location specific**
- **Integration possibilities very dependent on scale**
- **Combining short (operational) & long-term (planning)**
- **Integrated energy system models can be high-dimensional → computation & data challenges**