International Institute for Applied Systems Analysis
IIASA

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Energy modeling with a bit more reality

A deepened structural framework

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My talk echoes a fundamental controversy in econometric modeling

- Christopher Sims: Macroeconomics and reality
  - Overcoming the simplistic structural specifications by non-structural time-series based approaches

- Stephen Hall: Macroeconomics and a bit more reality
  - Only deepened structural specifications might get us further

Controversies about energy modeling
Questioning the model outcomes

- **David Victor, UC San Diego, 2015**
  - "IPCC is becoming irrelevant to climate policy"

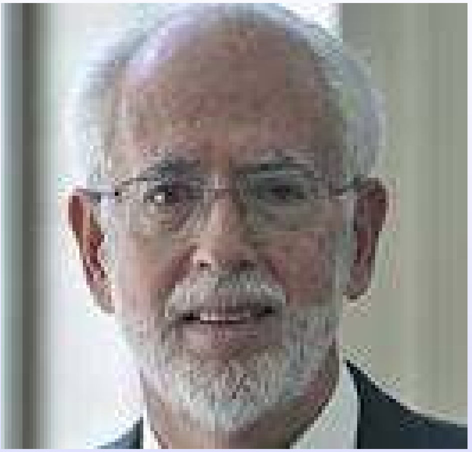
- **A damaging statement of Working Group III is undermining the reputation of IPCC (2014)**
  - "Annual economic growth might decrease by just 0.06 (!) percentage points by 2050 if governments were to adopt policies that cut emissions in line with the widely discussed goal of 2°C above pre-industrial levels".

Who is on drugs (1)

Who is on drugs (2)

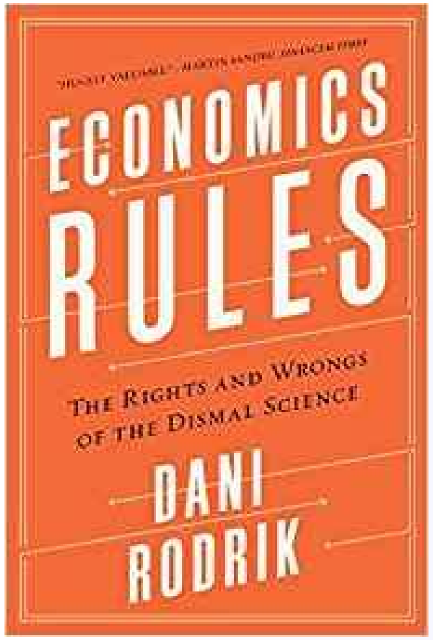
Controversies about energy modeling
Questioning the model specifications

The use and misuse of models for climate policy
Robert S. Pindyck, MIT, 2015



"Calling Integrated Assessment Models (IAMs) 'Close to useless' is generous."

- **The arbitrariness about crucial parameters**
  - **Discounting welfare of future generations**
  - **Dynamics of technologies**
- **Uncertainty about climate sensitivity**
  - **Feedbacks between emissions, temperatures, economic impacts**



Dani Rodrik (2016)

The Rights and Wrongs of the Dismal Science

Ten Commandments for Economists

Commandment 2:

It's a model, not *the* model.

but

Economists tend to fall in love with their models.

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Fathoming the transition to low-carbon structures

Learning from the Swiss project NEST at EMPA
Exploring the future of buildings

The basic structure

A platform for innovative construction technologies

The NEST design

Adding modular components by plug-and-play

Solar Wellness & Fitness Module

Reducing energy by factor 6

Urban mining & recycling unit

A residential module fully constructed from reusable, recyclable, and compostable materials.

Explores to advance the construction industry's transition to a recycling economy.

Light-weight floor elements

for self-supporting concrete floors for skyscrapers

need no steel reinforcement

70% lighter than conventional floors

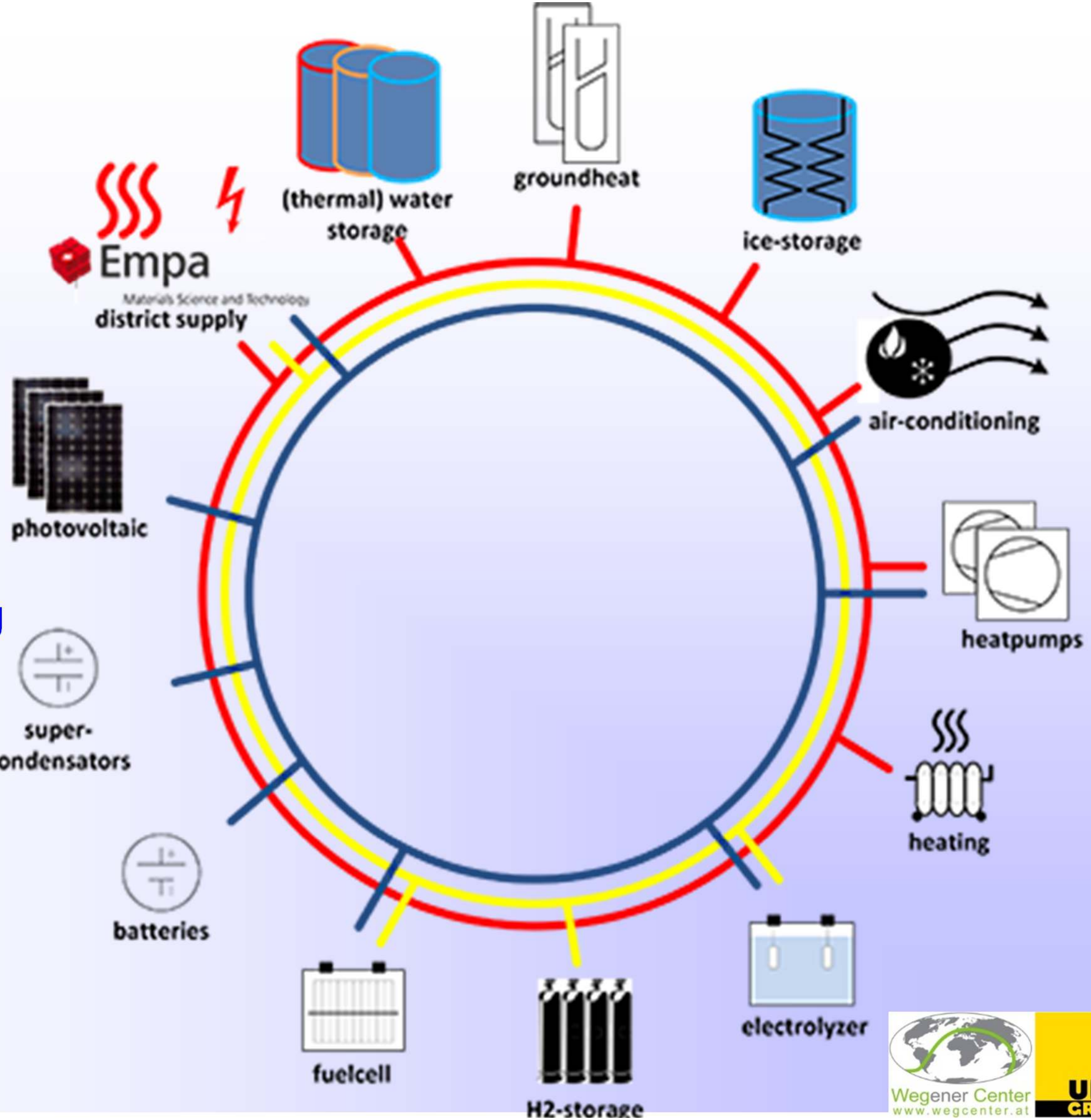
prefabricated

integration of infrastructure for heating and cooling

serve as a thermal storage

Energy Hub

- Four grids connect all components of the energy system
  - Electricity
  - Heating/Cooling
  - Gas
  - IT
  - Interdependent
  - bi-directional



A lesson from the ongoing H2FUTURE project

Exploring steel making with hydrogen

- Potential need for carbon-free electricity
  - up to half of total current electricity consumption in Austria
  - We obtain similar insights from other energy intensive industries

- It is inconceivable to replace current volumes of fossils in energy intensive industries with renewables

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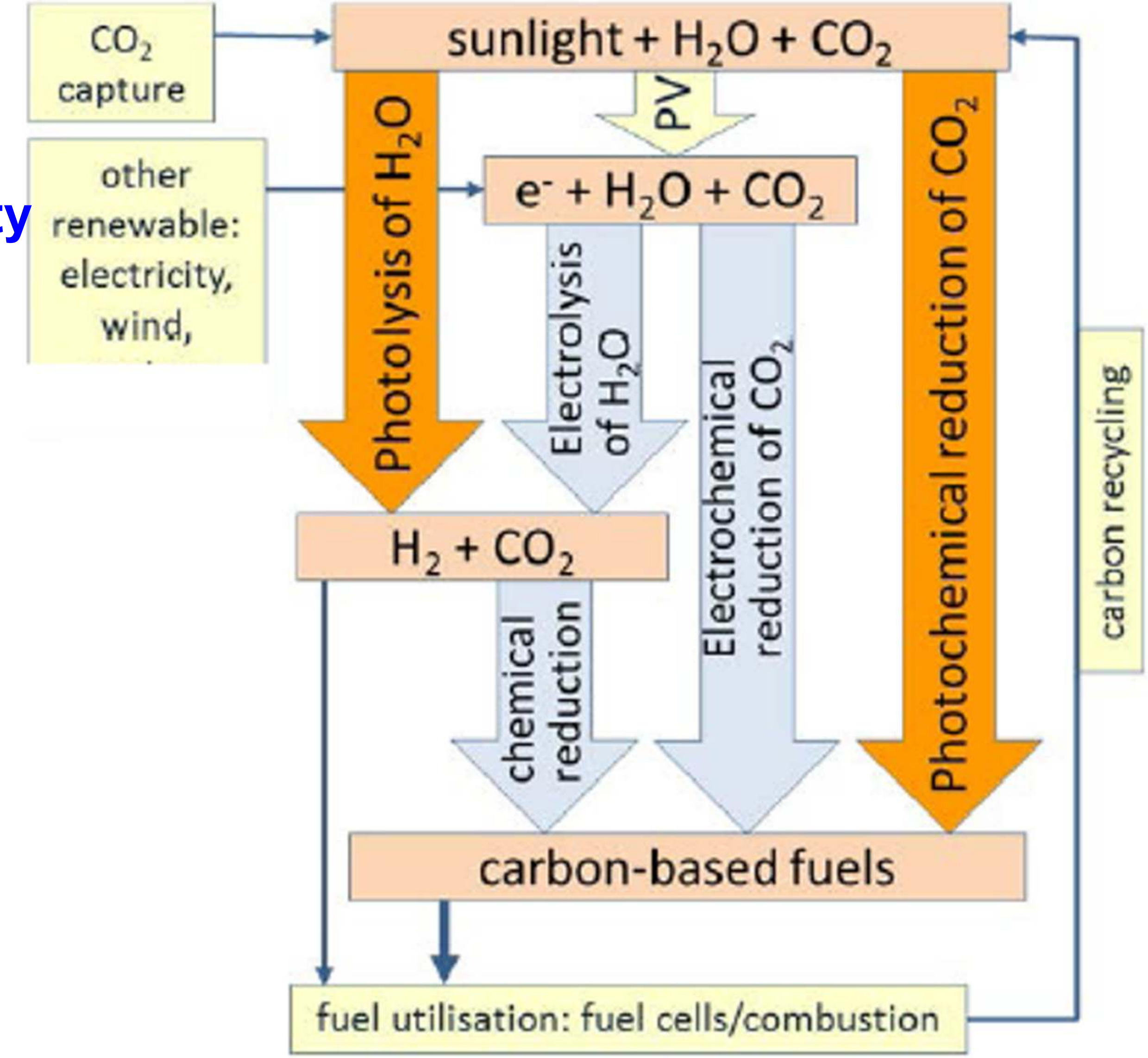
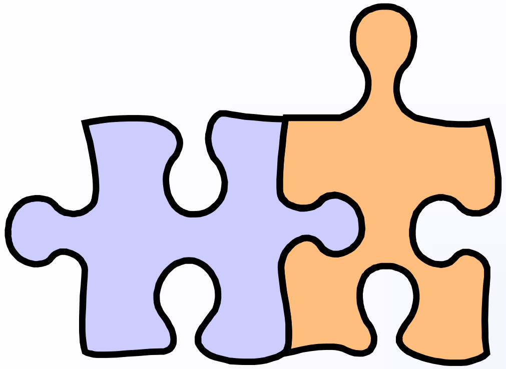
A Solar Driven Chemistry

White Paper
by the European Chemical Society





In a nutshell:
The building blocks for
a deepened structural energy modeling approach

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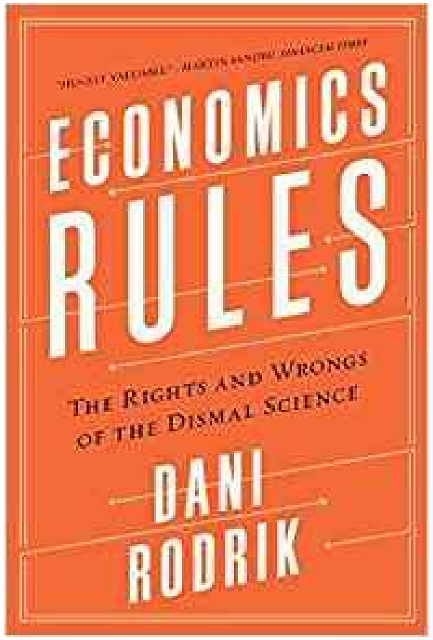
The new challenges for energy modeling

- The emerging and disruptive energy technologies
  - Buildings, transport, renewables, business models

- Current mainstream models are not able to cope adequately with these challenges
  - Deepened structural modeling approaches are a way forward



Commandment 3:

**Make your model simple enough
to isolate specific causes and how they work,
but not so simple that it leaves out
key interactions among causes**

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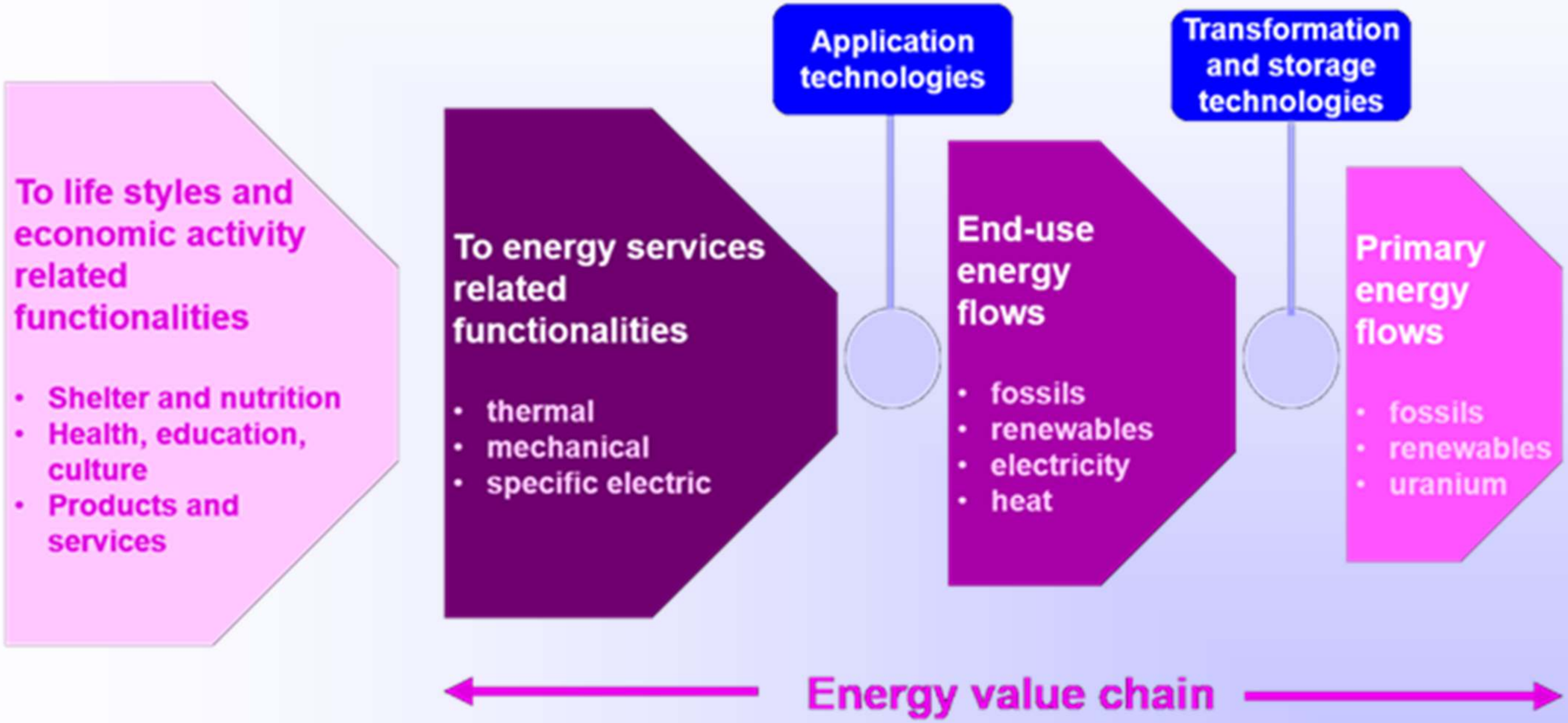
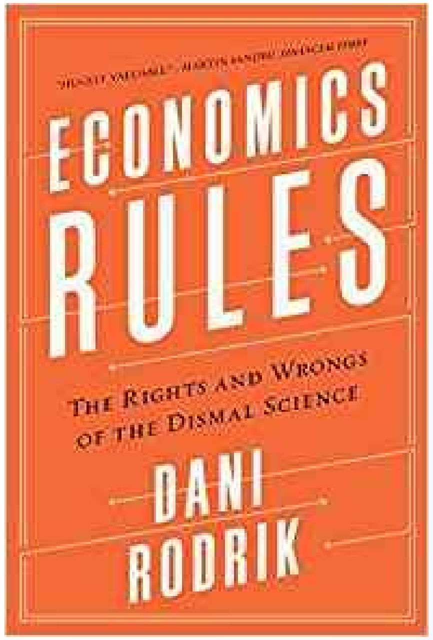
Deepened structural specifications
The basic design





Commandment 4:

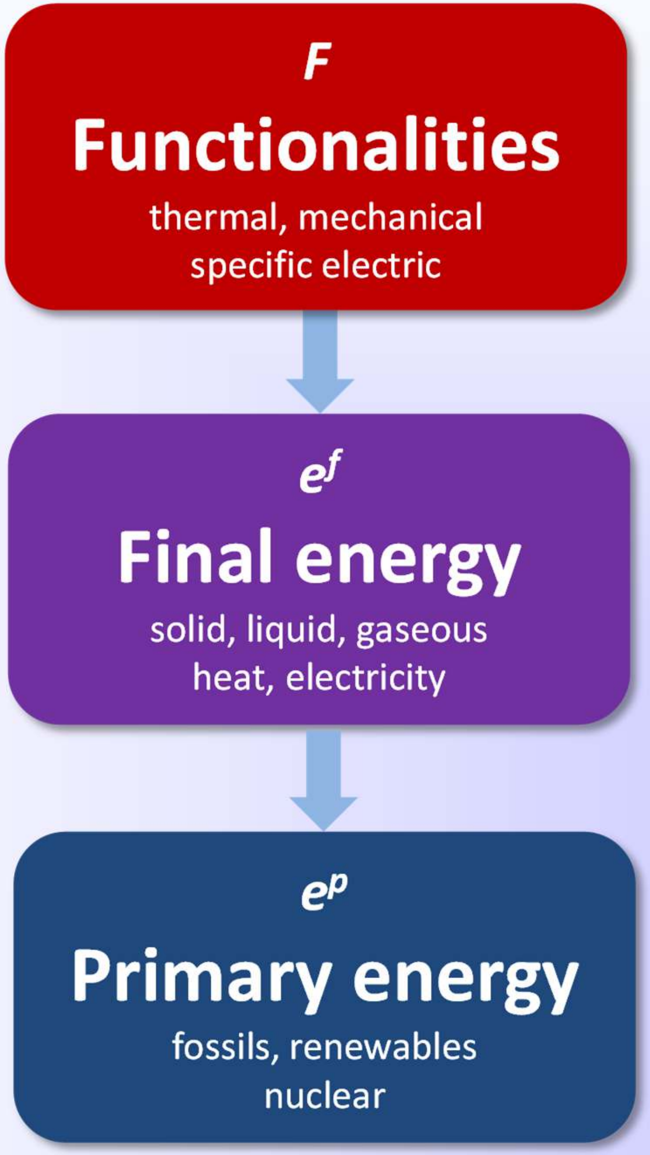
Unrealistic assumptions are OK,
unrealistic *critical* assumptions are not OK.

Tier 1:
The physical layer

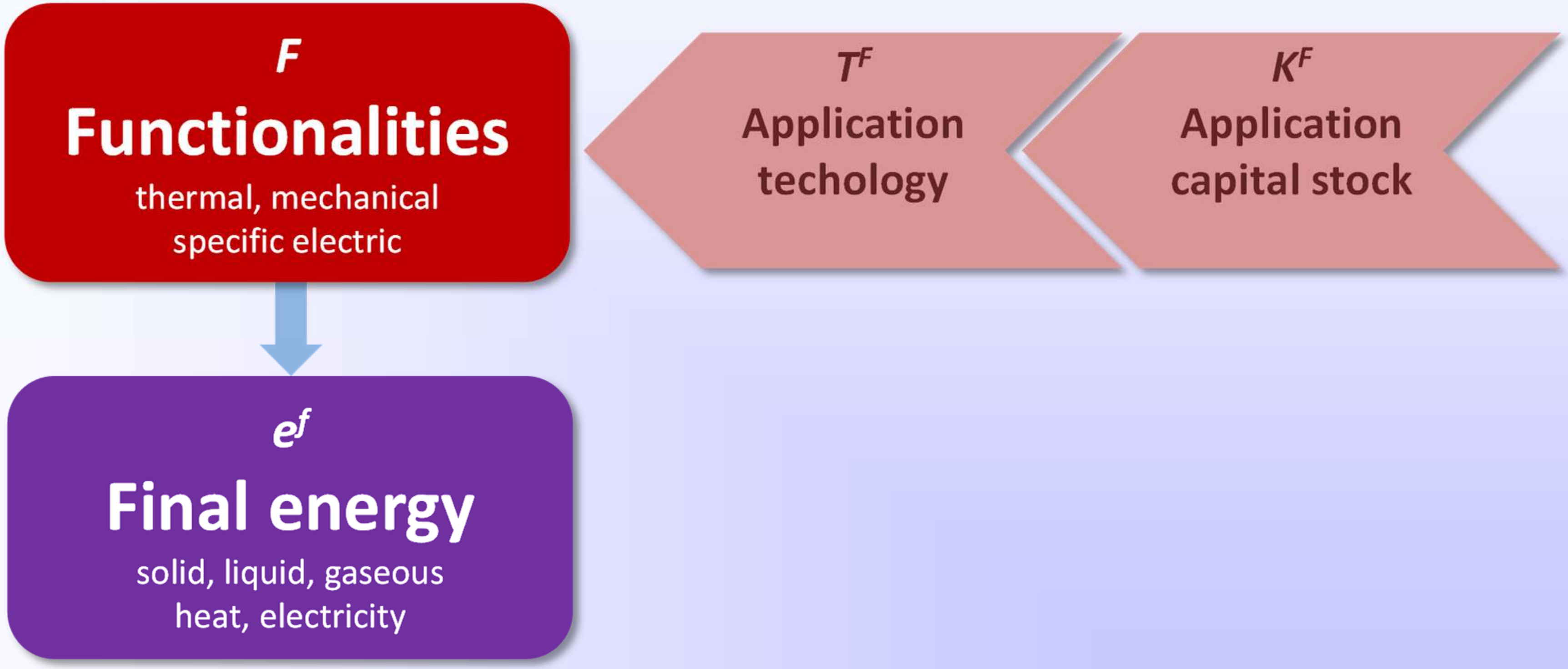
Step 1:
Identify energy services
The functionalities of an energy system

- Thermal functionalities
  - low temperature (buildings)
  - high temperature (industry)
- Mechanical functionalities
  - stationary (engines)
  - mobile (transport)
- Specific electric functionalities
  - lighting
  - electronics

Step 2:
Consider the full energy value chain



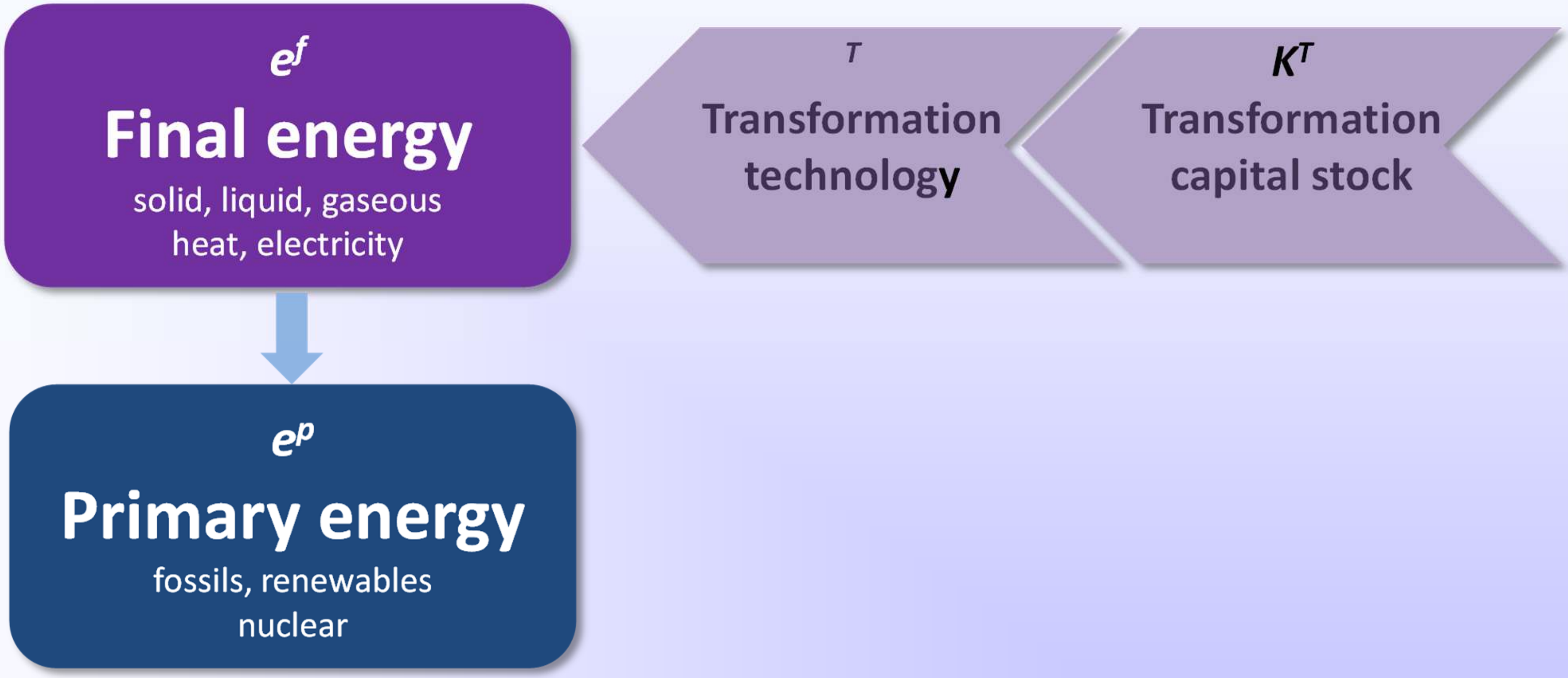
Step 3:
Identify physical interactions with capital stocks
Functionalities and final energy – application technologies



$$F = T^F(e^f, K^F)$$

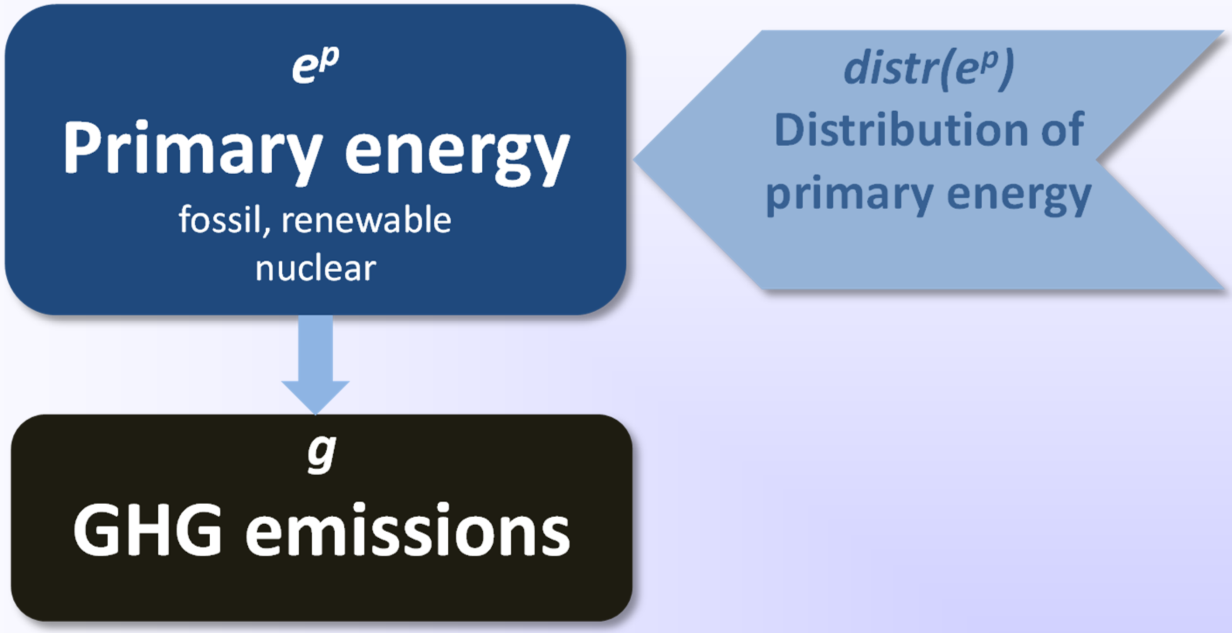
$$e^f = t^F(K^F)^{-1} \cdot F$$

Step 3:
Identify physical interactions with capital stocks
Final and primary energy – transformation technologies



$$e^f = t^T(K^T)\cdot e^p$$
$$e^p = t^T(K^T)^{-1}\cdot e^f$$

Step 4:
Link emissions to primary energy
Emissions intensities depend on fuel mix



$$g = g^{fos}(distr(e^{p,fos}))\cdot(1 - s^{p,fos} - s^{p,res} - s^{p,nuc})\cdot e^{p}$$

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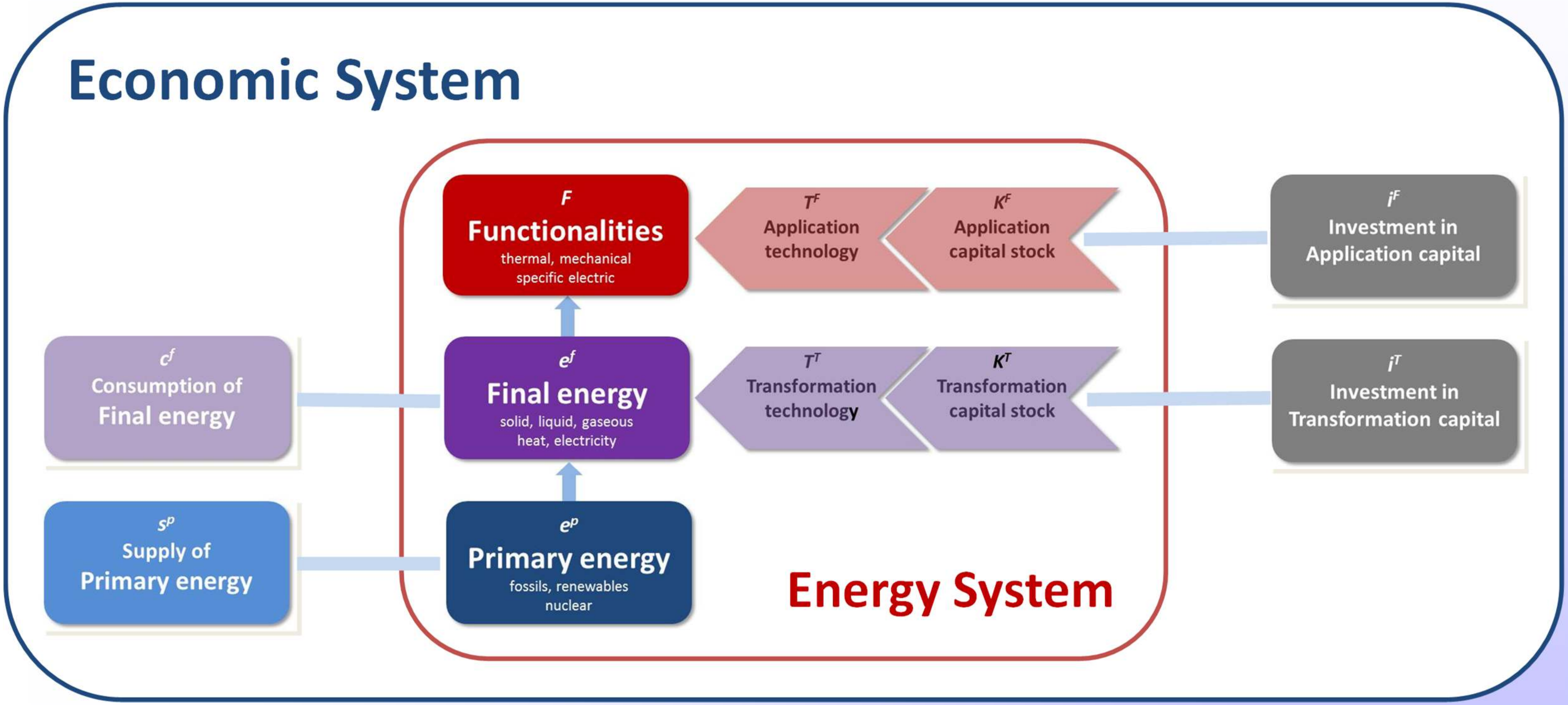
Tier 2:
The economic layer

Step 5:
Identify interactions with the economic system



The energy system interacts with the economic system vial the consumption of energy and investments into application and transformation technologies

Economic impacts
Improving the thermal structure of buildings

Investment costs per m^2	600 €
Annual capital costs	15 €/year
Saved energy per m^2	150 kWh/year
Abatement costs	10 Cent/kWh
Energy prices for consumers	
Oil	9 Cent/kWh
Gas	7 Cent/kWh
Electricity	20 Cent/kWh

2 percent / year of building stock	
Direct investments	6.4 bill €/year
Induced investments	1,8 bill €/year

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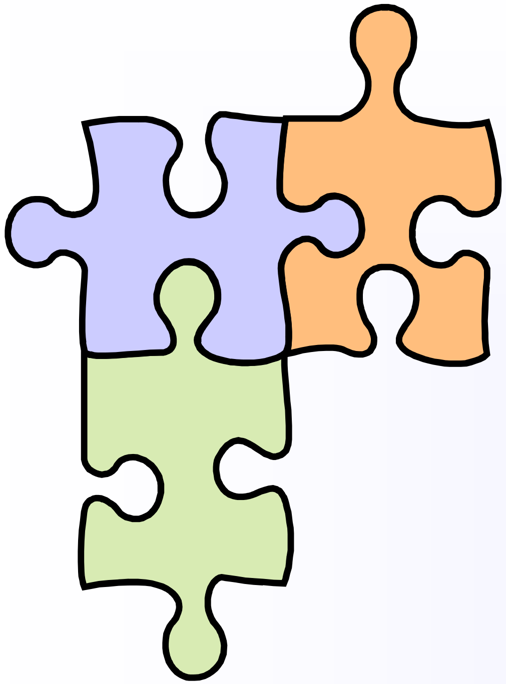
Tier 3:
Markets and institutions

Step 6:
Add mechanisms for coordination and incentives

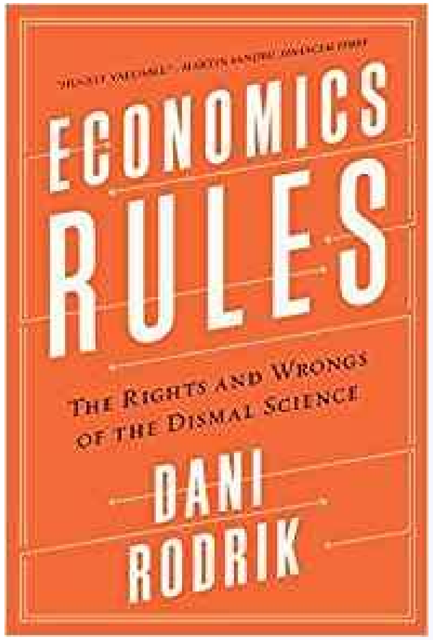
- This modeling design deliberately separates the analysis of structures from mechanisms that generate these structures

- Price-determined mechanisms
  - if prices are relevant

- Non-price determined mechanisms
  - standards and other regulations



Implementing this deepened structural modeling approach



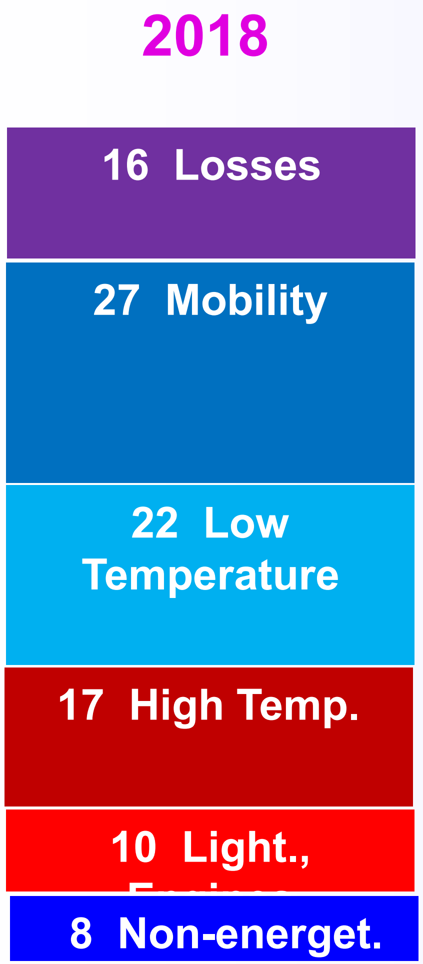
Commandment 6:

To map a model to the real world you need explicit empirical diagnostics, which is more craft than science.

Switching to a different mindset

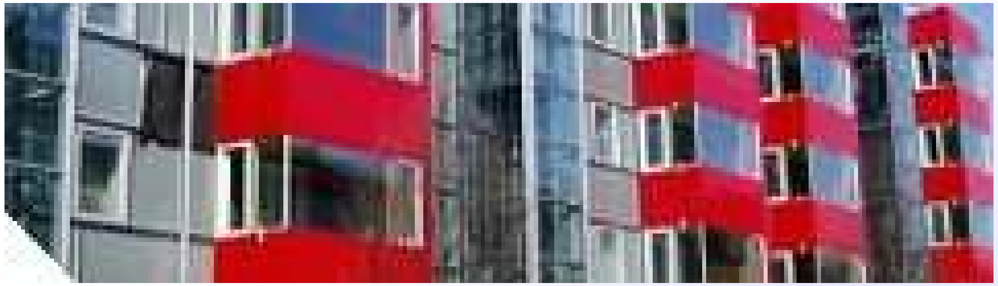
So far: Where from
can we get plenty and cheap energy

Now: What for
do we need energy



A new view on the energy system

The new buildings
Zero or even plus-energy standards



2018

22 Low Temp.

2050

6 Low Temp.

baumschlager eberle
2226 Haus, Lustenau

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The new mobility
Access to persons and goods

- Integrating all modes of mobility
- Business models based on sharing

2018

27 Mobility

2050

7 Mobility

The new energy generation technologies

Highly efficient transformation and distributions

Volkswagen

- Combined generation of electricity and heat
- Distributed generation
- Micro and smart grids

Vaillant fuel cell

2018

2050

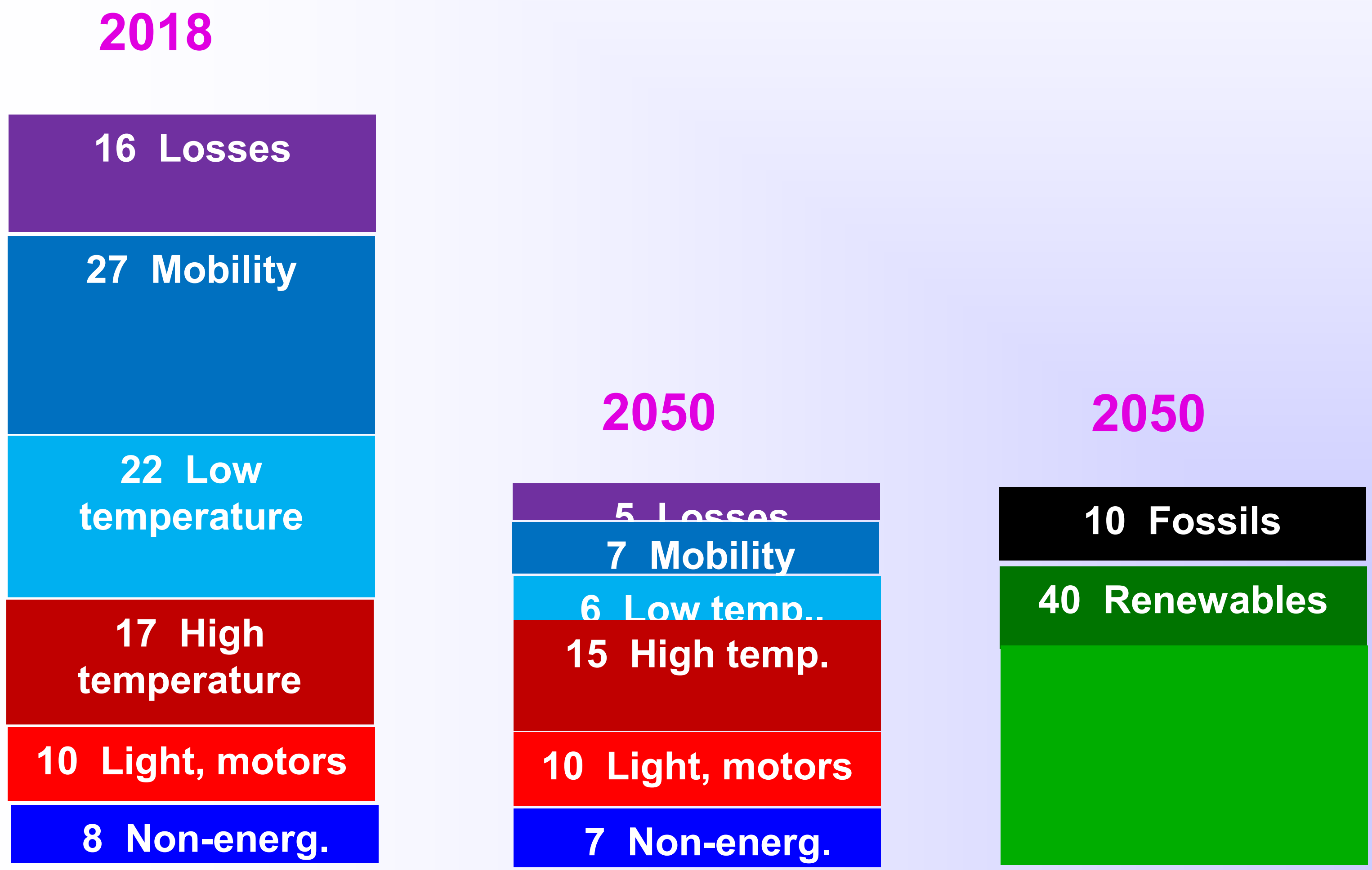
16 Losses

5

The transition to low-energy structures

A low-carbon energy system for 2050 or earlier

energyfutures.net



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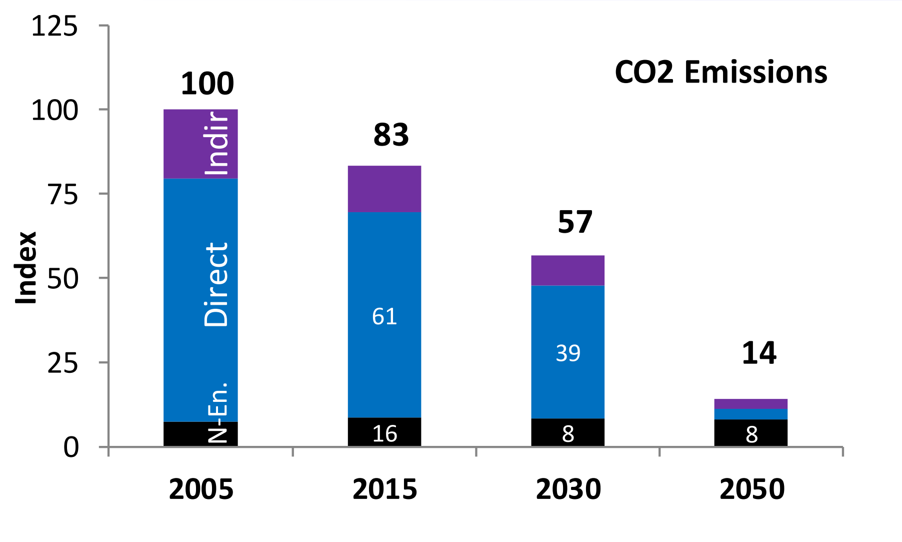
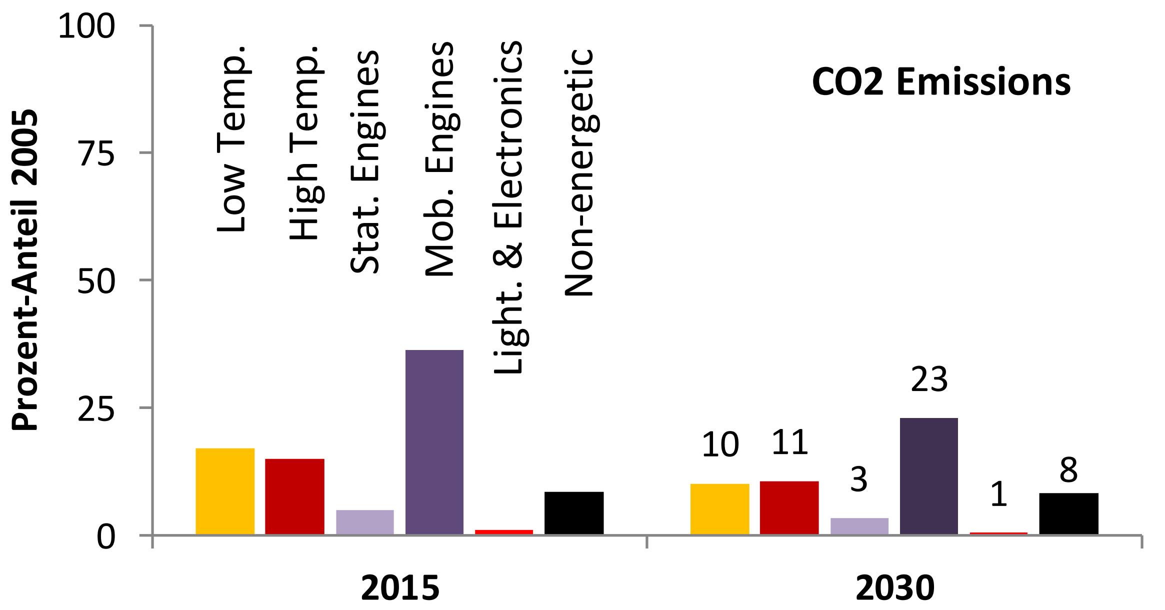
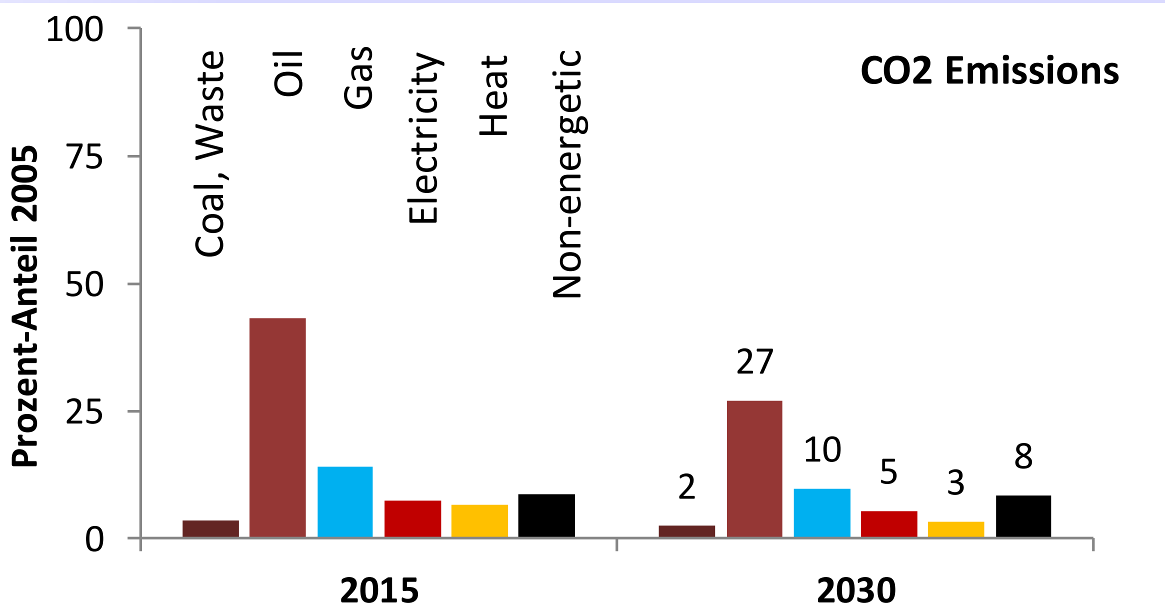
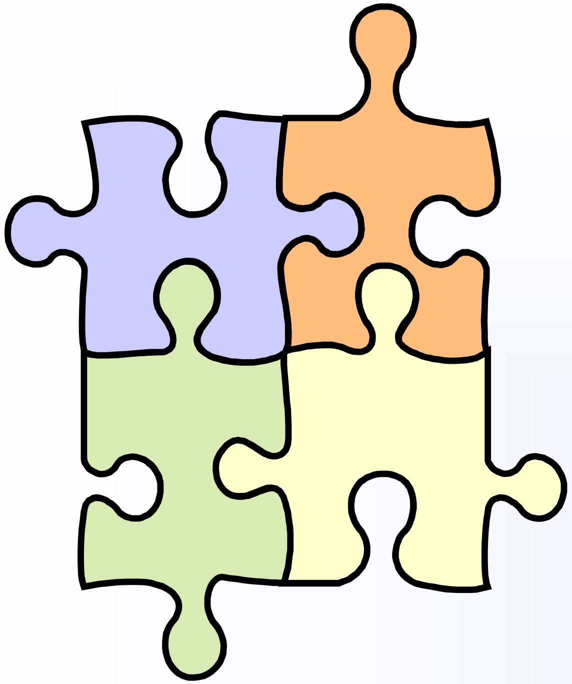
A functionality based view of CO_2 emissions





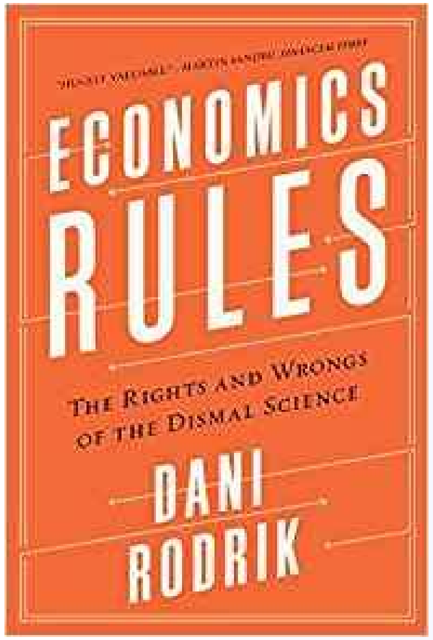




Some conclusions

Why deepened structural approaches could become the new mainstream

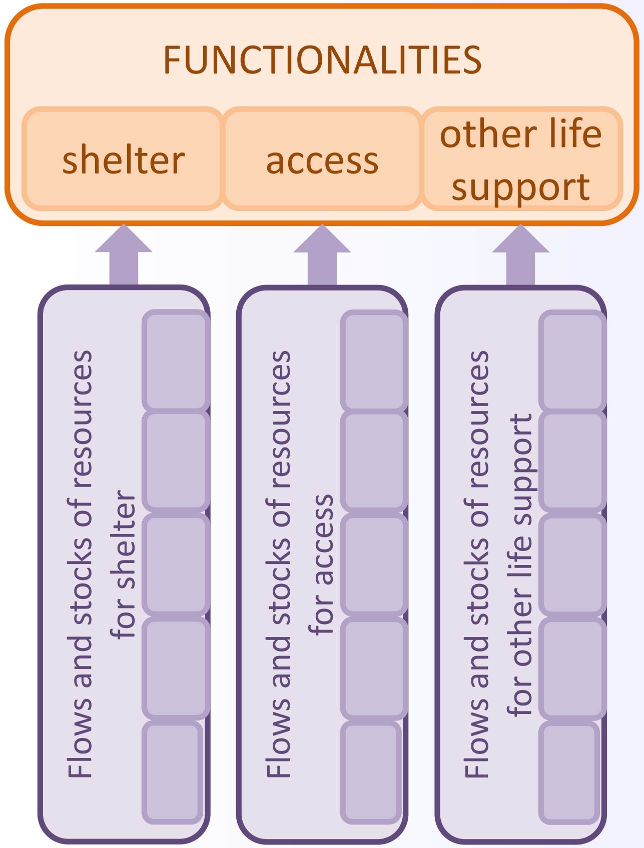
- Encompassing other approaches
  Enables including all conventional approaches
  - IO based
  - General equilibrium based
- Reproducible parameterization
  Key parameters can be cross-checked with reality
  - Energy productivity
  - Energy mix
- Scalable for all system sizes
  Applicable from micro to global system scopes



Commandment 8:

It’s OK to say “I don’t know” when asked about the economy or policy.

EconTrans
Extending this deepened structural framework to a comprehensive macro model



The basic modelling framework explains the total use of resources from three components:

- **indirect use of resources** (resources needed for producing resources, *Ar*)
- **direct use of resources** (for providing functionalities, *YF*)
- **exports of resources** (*x*)

This is the corresponding analytical model:

$$Ar + YF + x = r$$

The dependence of the resource flows (*r*) on the resource stocks (*R*) enables choosing targeted transition paths:

$$A(R)r + Y(R)F + x = r$$

Thank you.

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