« Energy & Systems »

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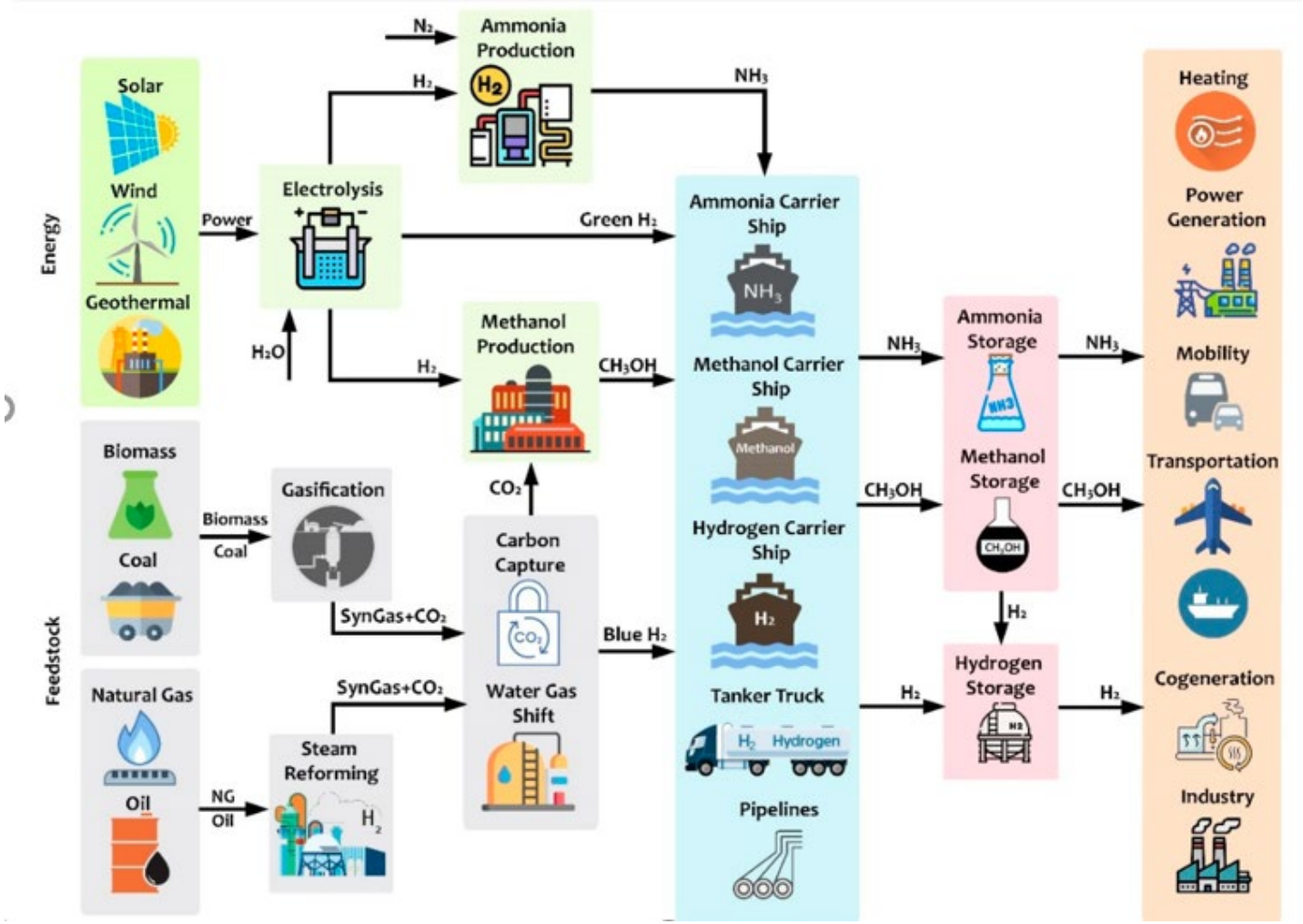
Energy conversion systems



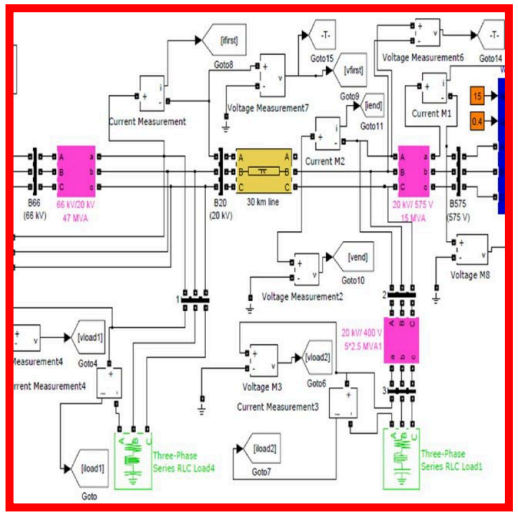
Energy transition needs
more efficient,
more reliable,
more green
"energy conversion systems"

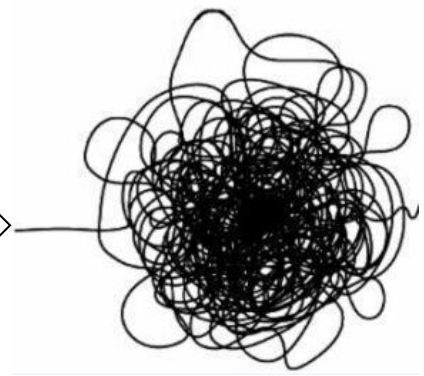
How to develop quickly these energy conversion systems?

Salimi, M., Hosseinpour, M., & N.Borhani, T. (2022). The Role of Clean Hydrogen Value Chain in a Successful Energy Transition of Japan. *Energies*, *15*(16), 6064. https://doi.org/10.3390/en15166064

simulation

Future system





results

Fast development
with "copy & paste"

Nightmare
for finding errors

confidence?
accuracy?

- Outline -

1 **Model, Representation, Simulation**

2 **Systems & Interaction**

3 **Energy & Causality**

4 **Graphical descriptions**

Model, Representation, Simulation

What different steps before simulation?

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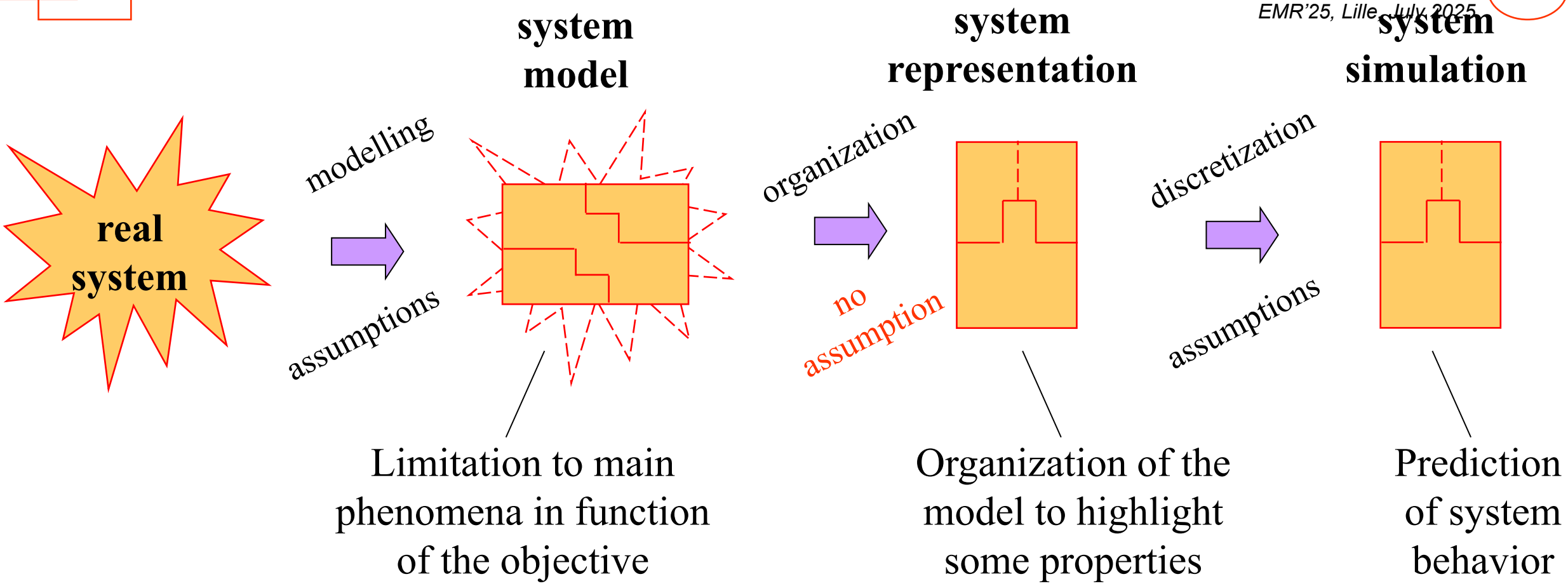
From the real system to simulation



Intermediary steps are required for complex systems

Basic example

real system

modelling

assumptions

system model

organization

no assumption

system representation

discretization

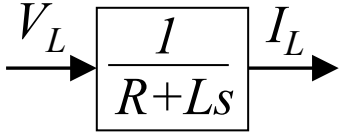
assumptions

system simulation

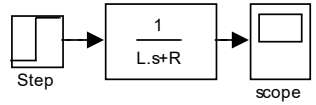
smoothing inductor

$$v_l = L\frac{d}{dt}i_L + Ri_L$$

(low frequency dynamical model)



(bloc diagram +Laplace)



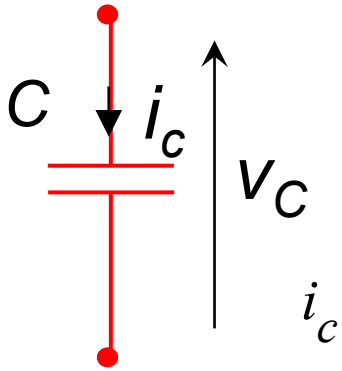
(Simulink © +Range Kutta)

Model vs. Representation

Model = description based on physical laws
(validity range function of assumptions)

Representation = organisation of a model
in order to highlight some properties

Example: capacitor



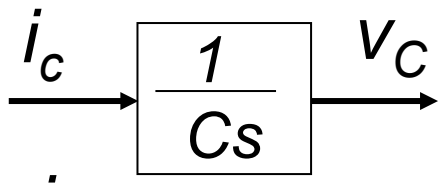
$$i_c = C\frac{d}{dt}v_c$$

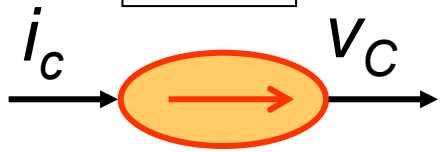
mathematical model

state space representation $\frac{d}{dt}v_c = \frac{1}{C}i_c$

transfer function $\frac{V_c(s)}{I_c(s)} = \frac{1}{Cs}$

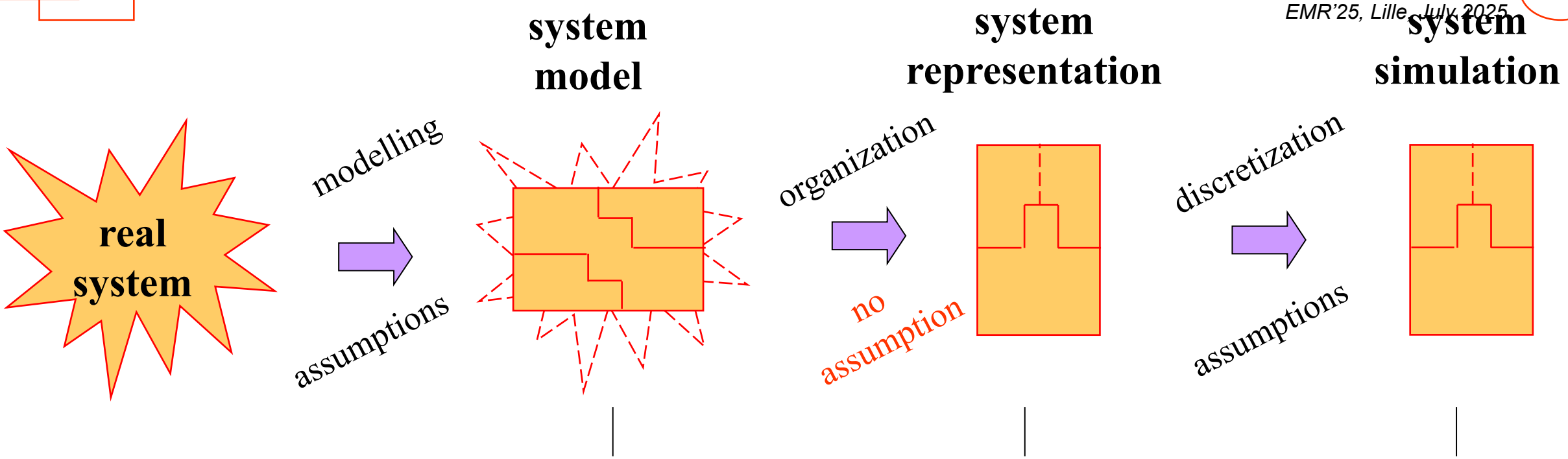
bloc diagram





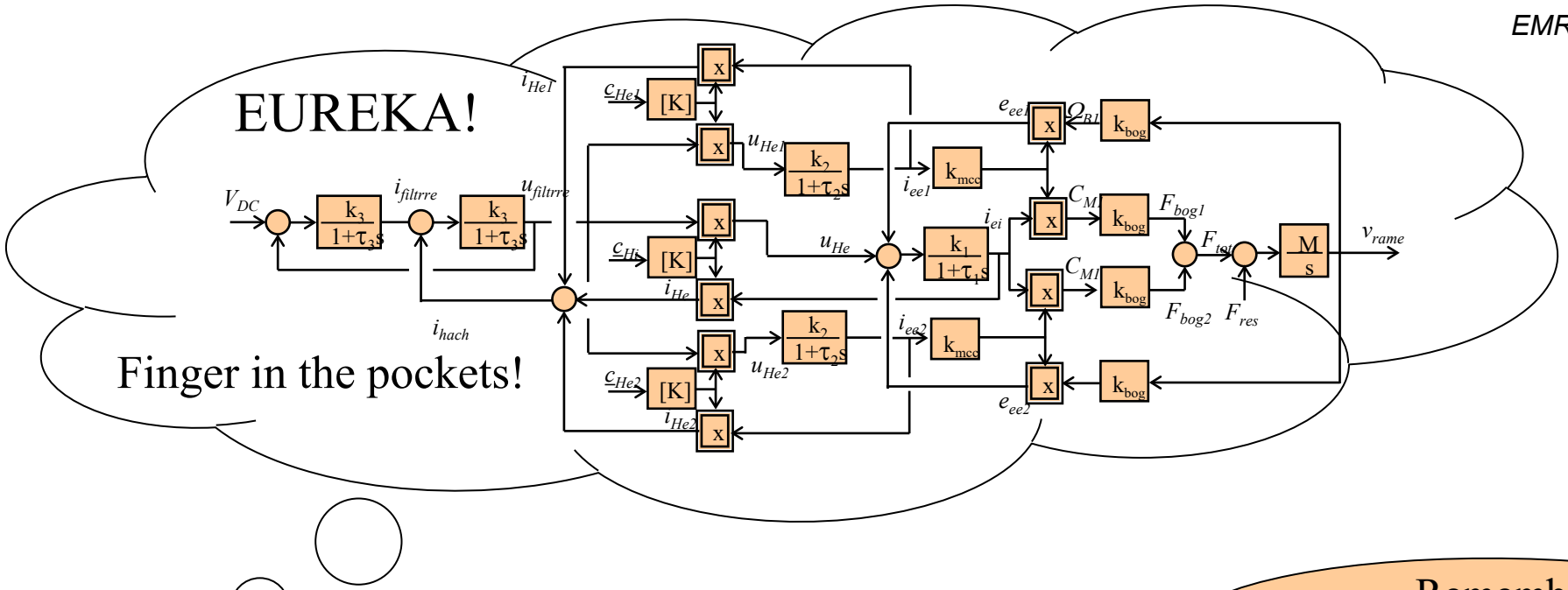
COG

Different choice at every steps



Different possibilities at each step in function of the objective

Limitation of classical block diagrams



But block diagrams:

- can be confusing for complex systems
- are limited to continuous and linear systems
- do not highlight energy properties
- do not highlight interaction between subsystems

Remember,
See the wood before the trees!

Prof. C.C. Chan

Systems & Interaction

How to connect multi-domain subsystems?

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System = interconnected subsystems
organized for a common objective,
in interaction with its environment

Systemic = science of study of systems and their interactions

Cartesian approach = the study of subsystems is sufficient to know the system behavior (without considering their interactions)

Interactions is the keyword

Systemics approach

System = interconnected subsystems

Systemic approach
Study of subsystems and their interactions
Holistic property: associations of subsystem induce new global properties.

Cartesian approach
The study of subsystems is sufficient to know the system behaviour.

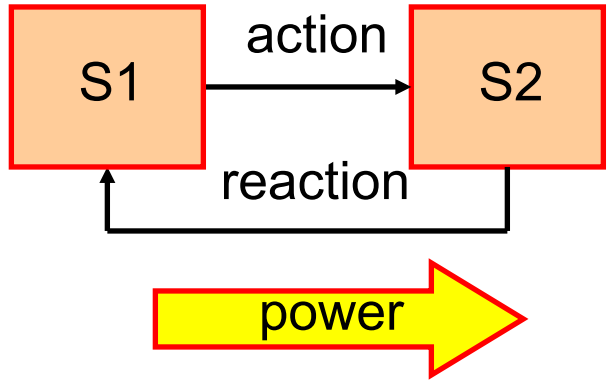
(classical but limited approach)

Cybernetic systemic
black box approach.
behaviour model

Cognitive systemic
physical laws
knowledge model

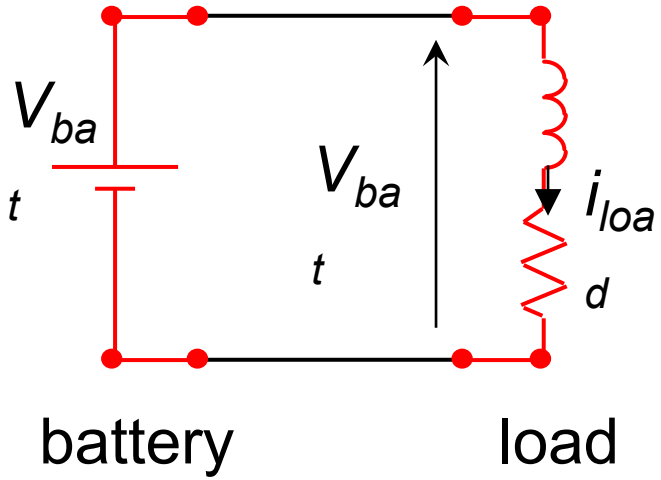
For better performances of a system
interactions and physical laws must be considered!

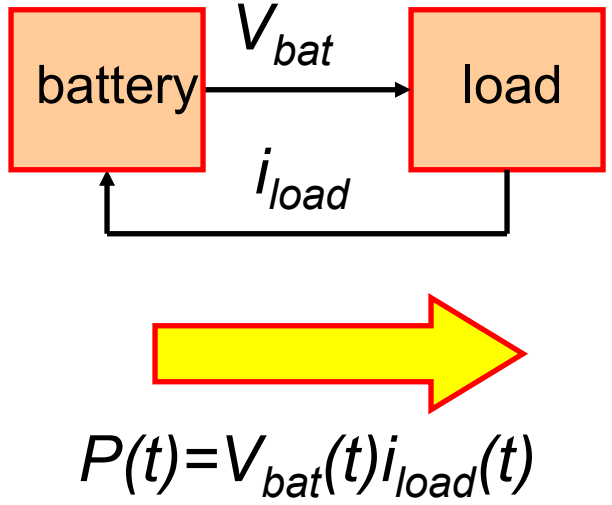
Interaction principle
Any action induces a reaction



Power exchanged by S1 and S2 = **action x reaction**

Example: battery and load

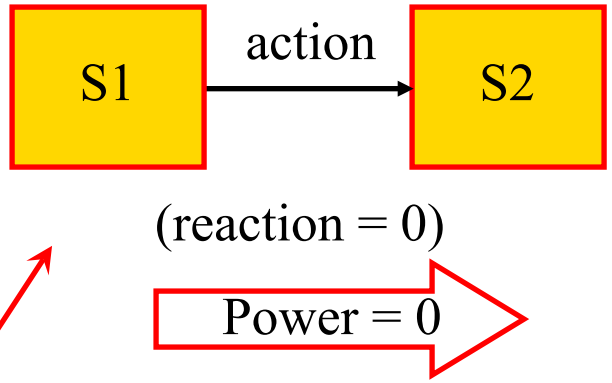


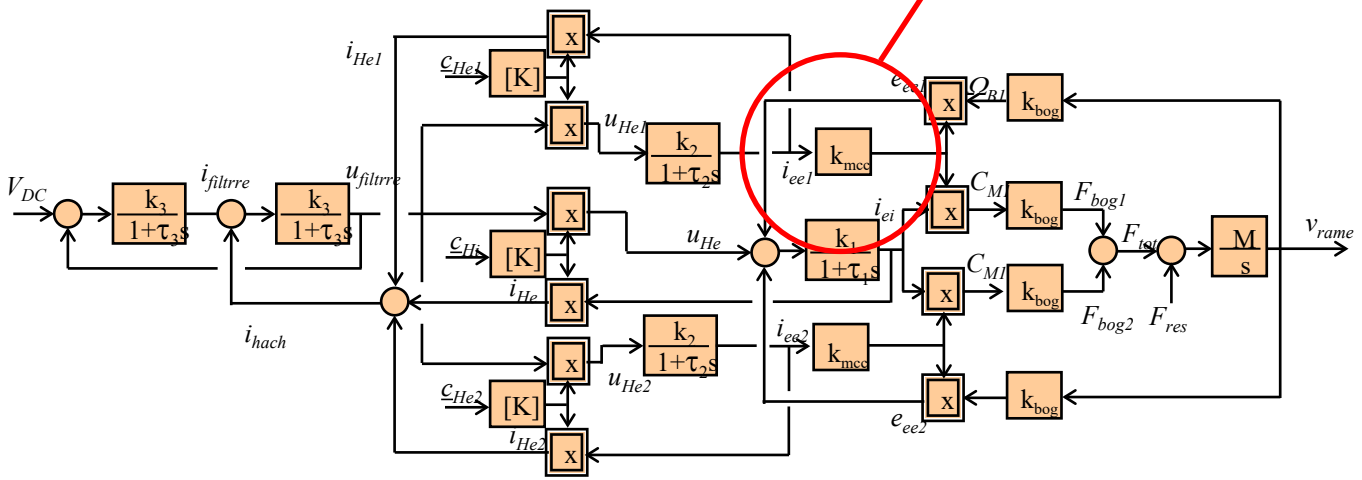


If the interaction principle is not respected for 1 subsystem

⇩

Error in the energy analysis for the whole system





Energy & Causality

How to manage energy in the best way?

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Energy [J] = amount of work that can be performed by a force, an object, a system

Power [W] = variation of energy with time

Ideal energy conversion: energy conservation (no losses)
and instantaneous transfer (no delay)

but

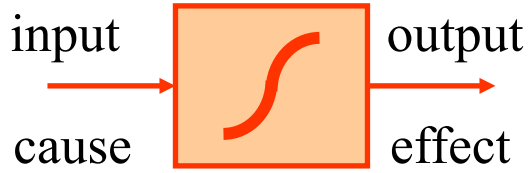
energy dissipation: losses, reduction of efficiency
energy storage: delay in energy transfer

Energy storage in subsystems
is key transformation for safety and efficiency

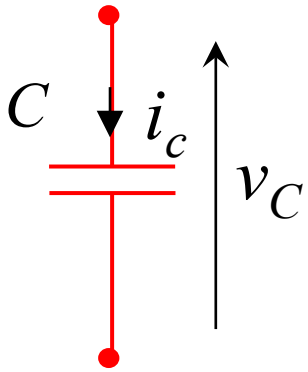
Principle of causality

Different meaning in different domains:

- Physics: output is obtained from input after a delay
- Mathematics: output is an integral function of input
- Automatic control: output is the state variable
- Energy: output is the energetic variable

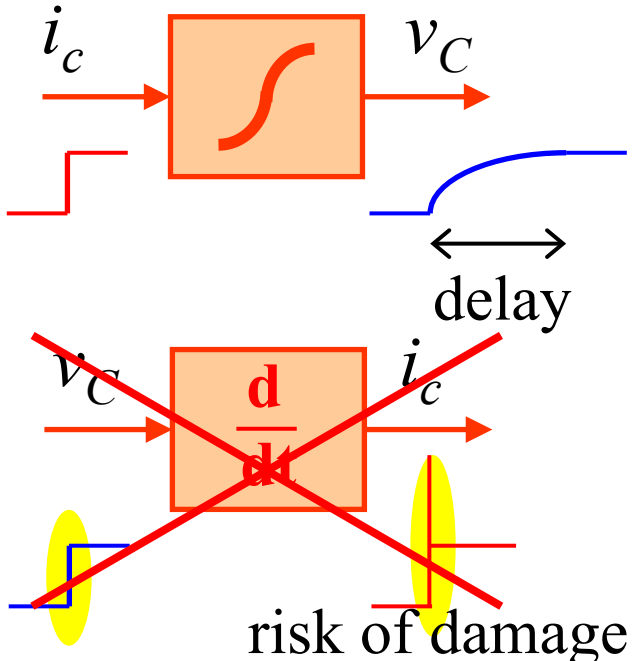


Example



$$i_c = C\frac{d}{dt}v_c + \frac{v_c}{R}$$

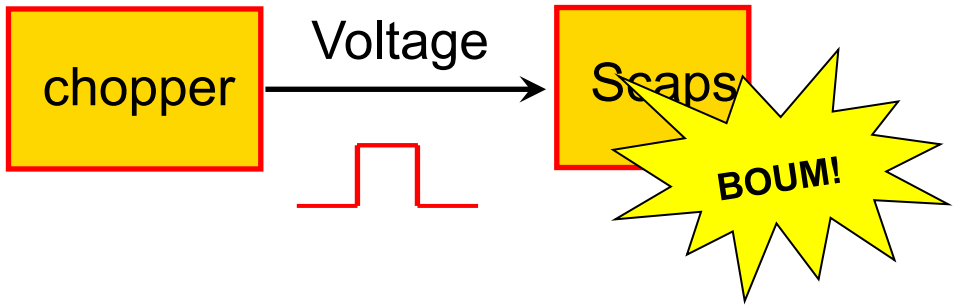
$$E_c = \frac{1}{2}v_c^{\,2}$$

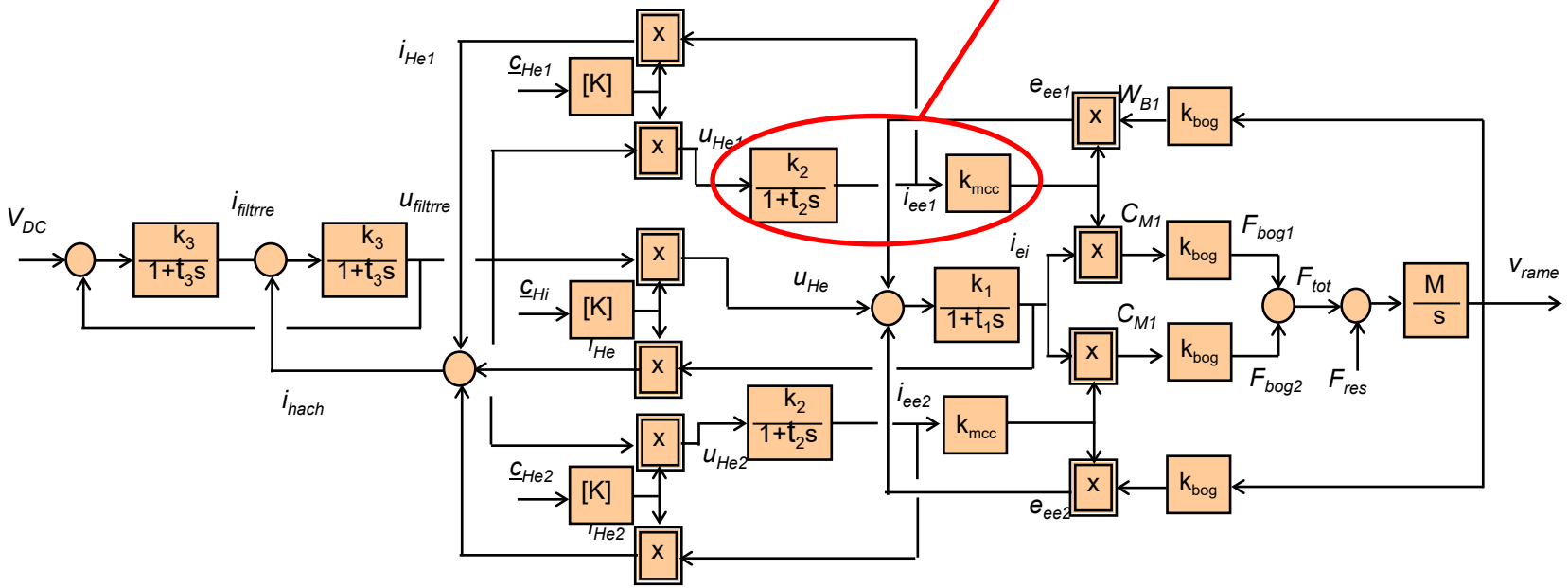


Causality mistake

If the causality principle is not respected for 1 subsystem

Risk of damage!
No real-time management





Graphical descriptions

Interest of graphical desciptions?

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Energy & System

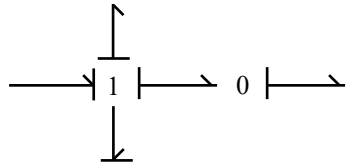
Energetic Puzzles (Laplace, France)

Bond Graph (USA, The Netherlands…)

Power Oriented Graph (Italy)

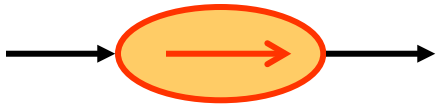
Signal Flow Diagram (Germany, Japan...)

Structural description for analysis and design ⇨ mathematical model ⇩ global controls



Block diagrams
COG (L2EP-LEEI, France)
EMR (L2EP, France)

functional descriptions for simulation and control ⇨ inversion graphs ⇩ cascaded control



Remember,
divide and conquer!

CONCLUSION

How to model and control energy conversion systems ?

- Respect the interaction principle (System) ?
- Respect of the causality principle (Energy) ?
- Common language despite multi-domain subsystems ?

EMR as a guideline !

For valuable interaction
between scientists!

International interaction!

« Biographies and references »

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Thanks for your attention !