G-L-4:

Evaluation

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Contents

Evaluation in the modelling cycle

what are you studying?

Case brief

choices

what exactly...?

System

what do you foresee?

choices

Thought simulation

choices

'touch' your thoughts

Build abstract model

what does your model foresee?

Solve/ simulate

choices

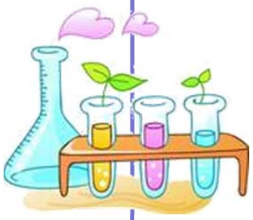
Experience

everything you did/ saw/ felt/ remember to be true...

Compare

did you both agree?

Revisit choices



Finish!

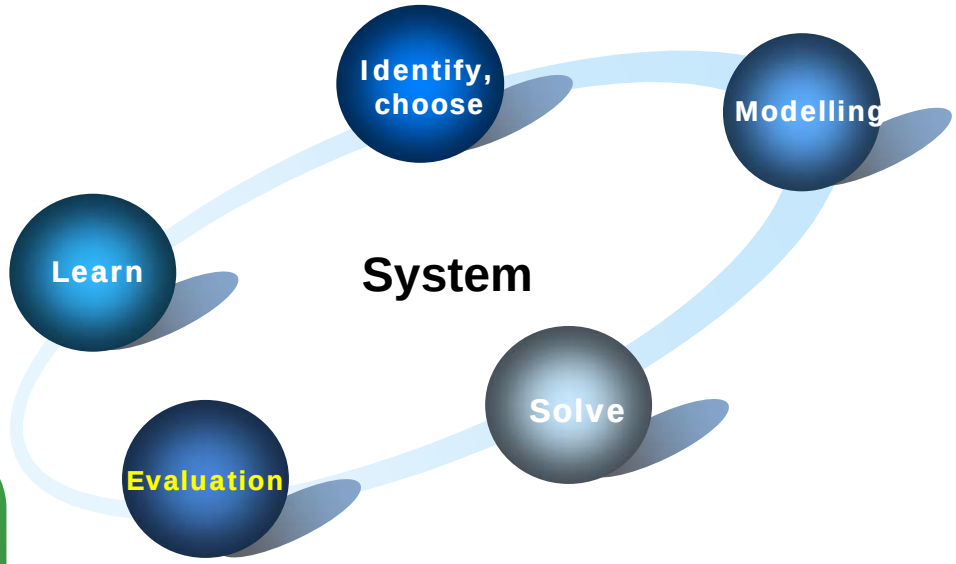
Acceptable ?

do you need more insights/ data?

Experiment

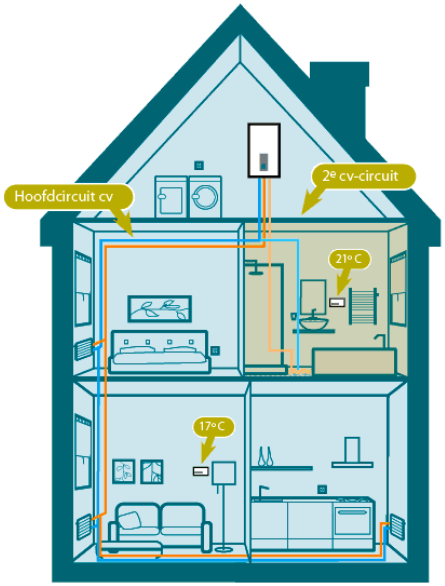
Courtesy of centech.com.pl and http://www.clipsahoy.com/webgraphics4/as5814.htm

Evaluation



Evaluation is systematic determination of merit, worth, and significance of something or someone using
metrics
against a set of
quantified expectations

A case study: Heat the house



Design brief

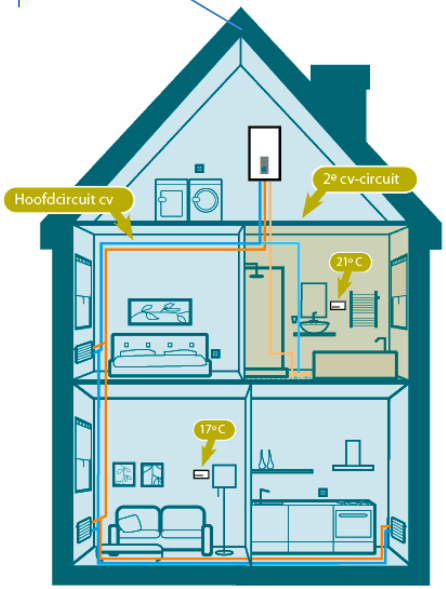
- Specify the areas of radiators and the hot water temperature for the boiler in a house in order to raise the room temperature 1 degree in 3 minutes

Courtesy of http://www.daalderop.nl/verwarming-en-koeling/twee-cv-zone-systeem/

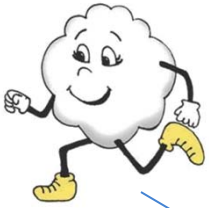
Components

Boiler

House



Water

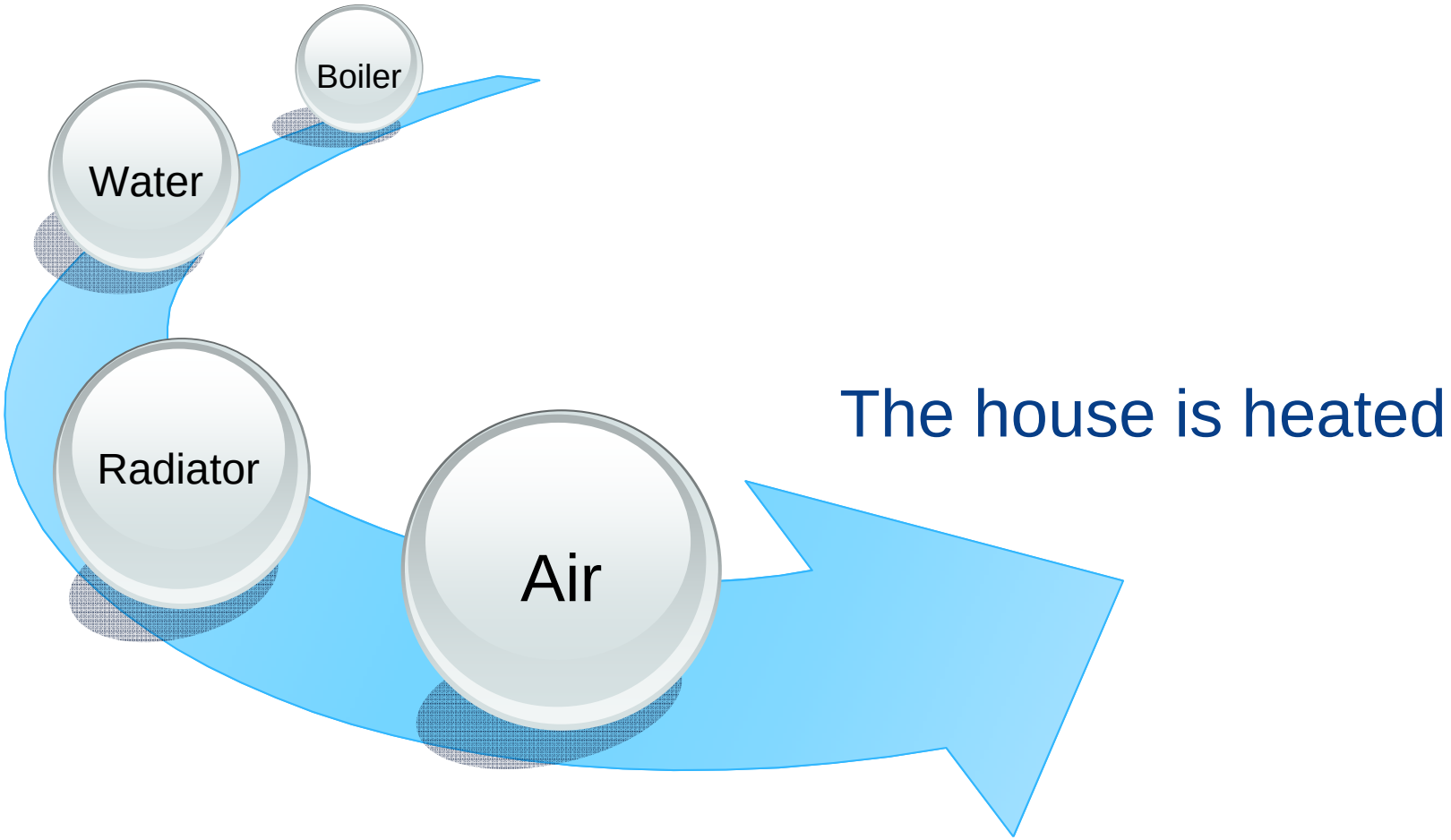


Radiator

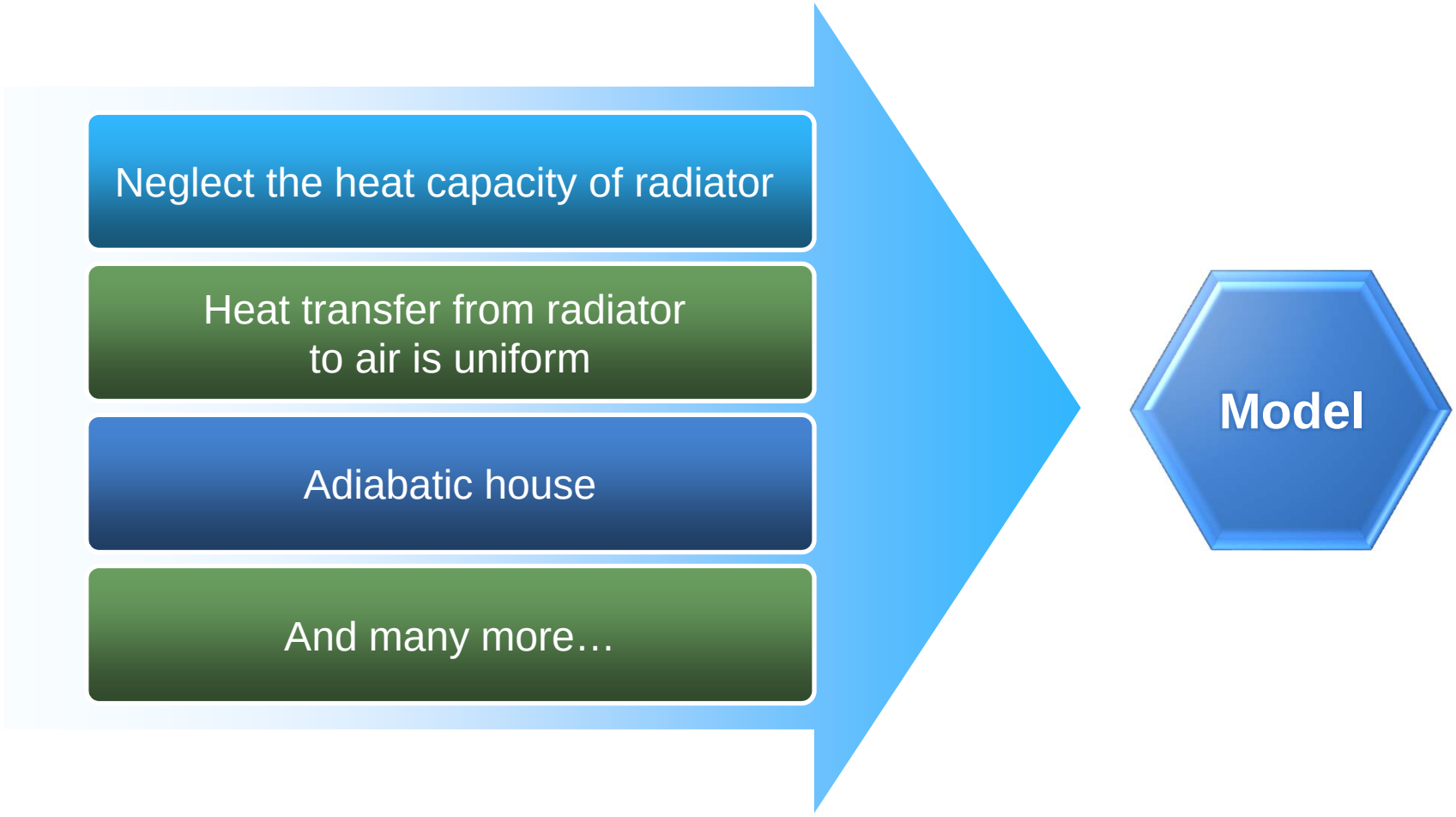
Air

Courtesy of http://www.daalderop.nl/verwarming-en-koeling/twee-cv-zone-systeem/

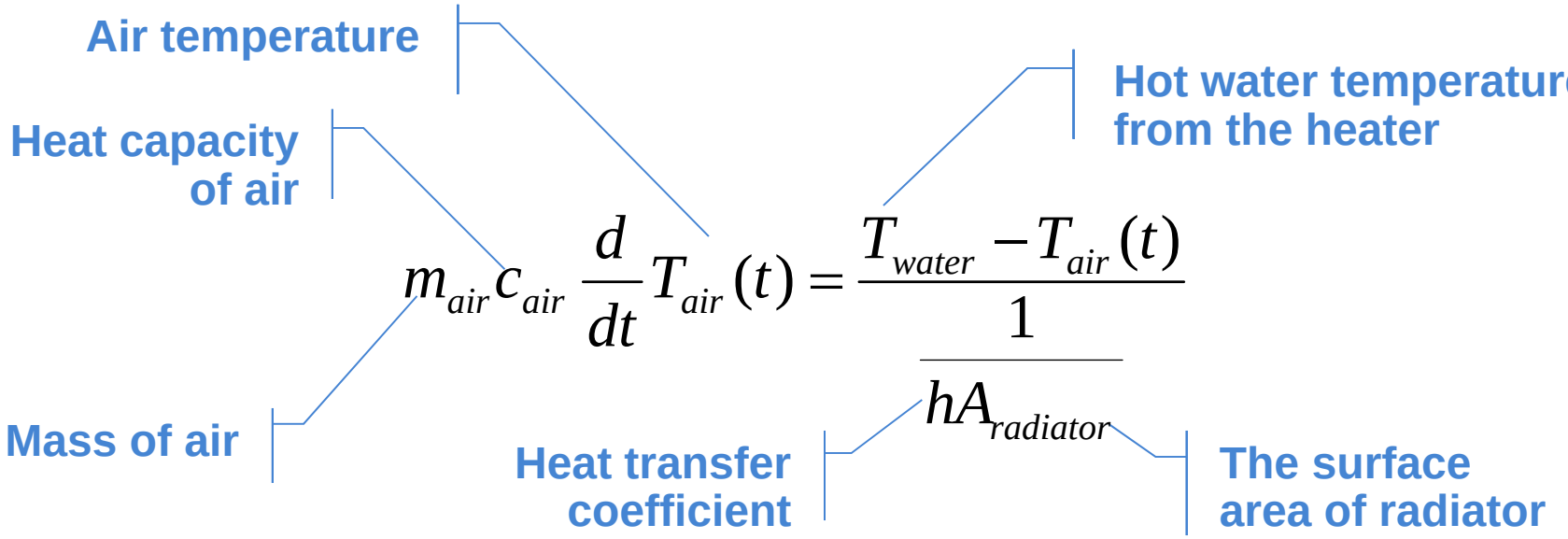
Cause - effect



Choice


Neglect the heat capacity of radiator
Heat transfer from radiator to air is uniform
Adiabatic house
And many more…
Model

Modelling

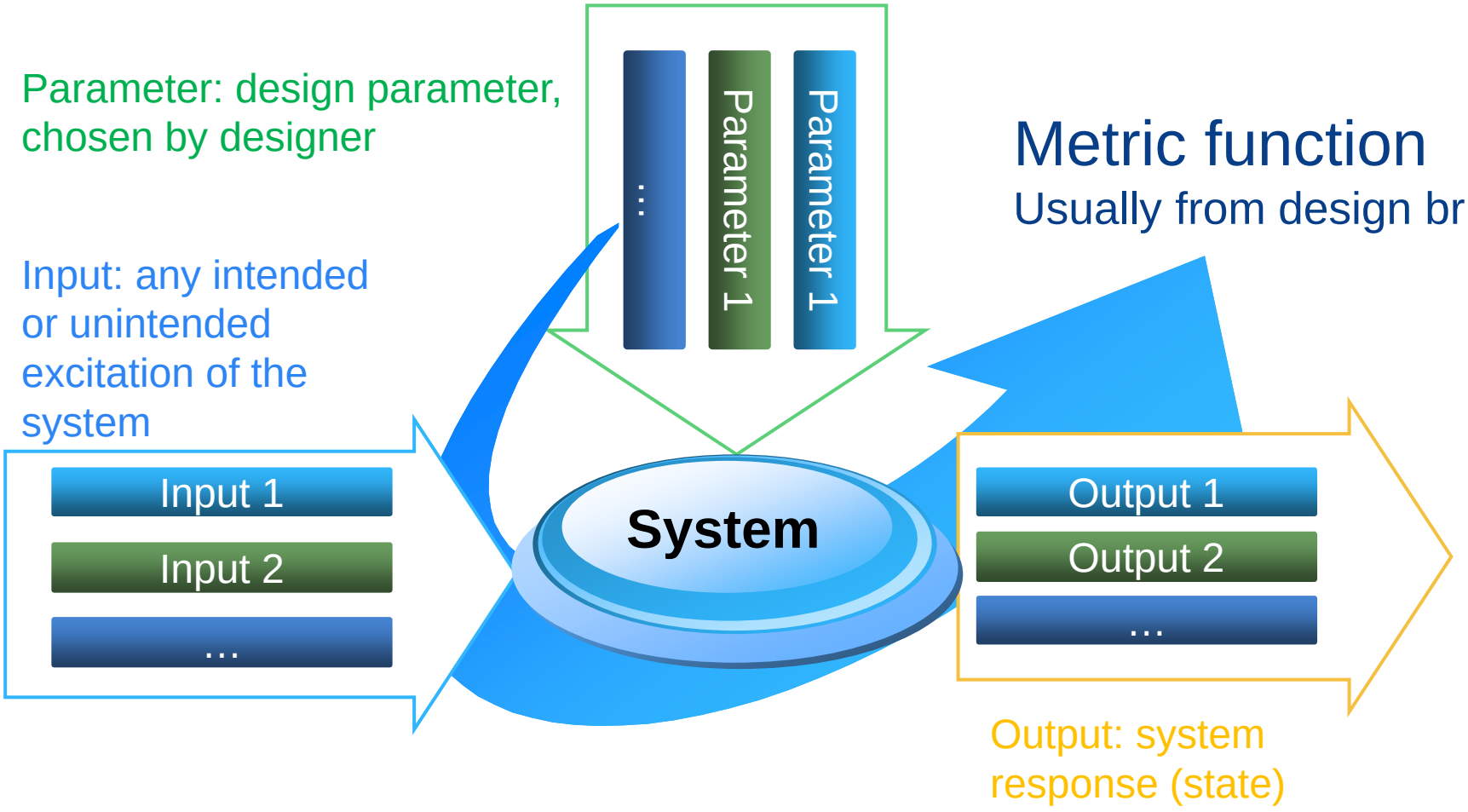


We choose

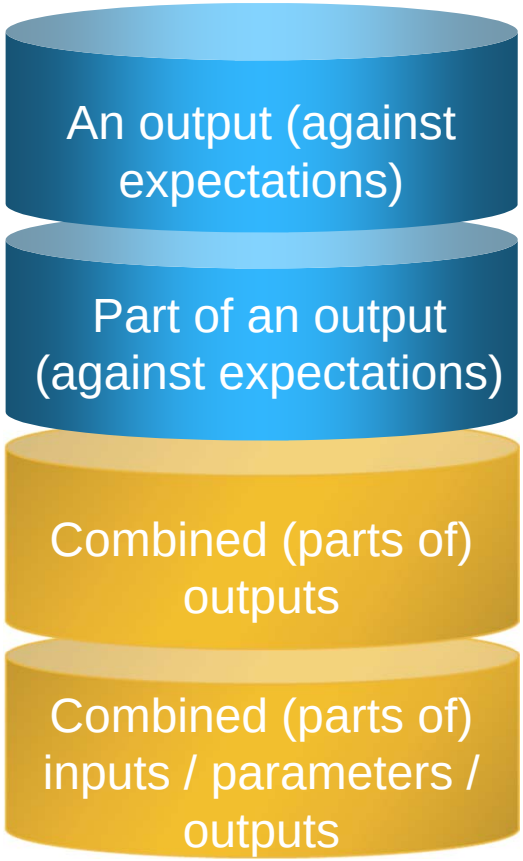
- The initial temperature of room is 10°C
- The specific heat capacity of air is 1012 J/(kg*K)
- The volume of the house is 350 m^3
- The density of air 1.024 kg/m^3
- The heat transfer coefficient is 10 W/m^2

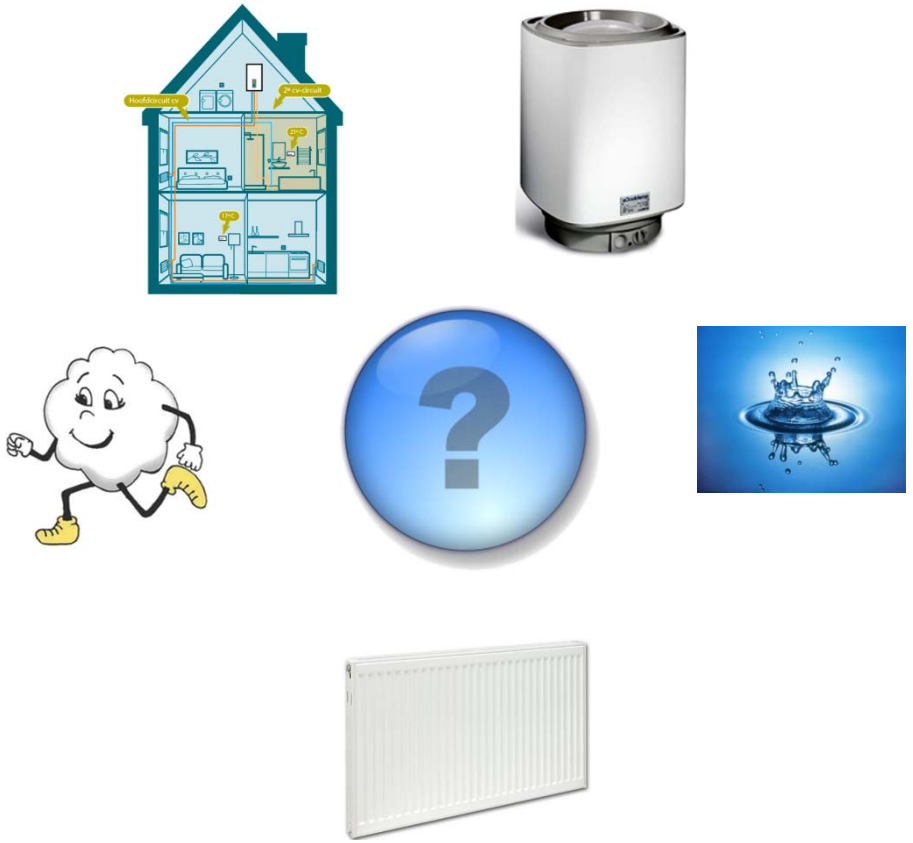
Define the evaluation criteria

Define the evaluation criteria – The metric



What is the metric in this system?

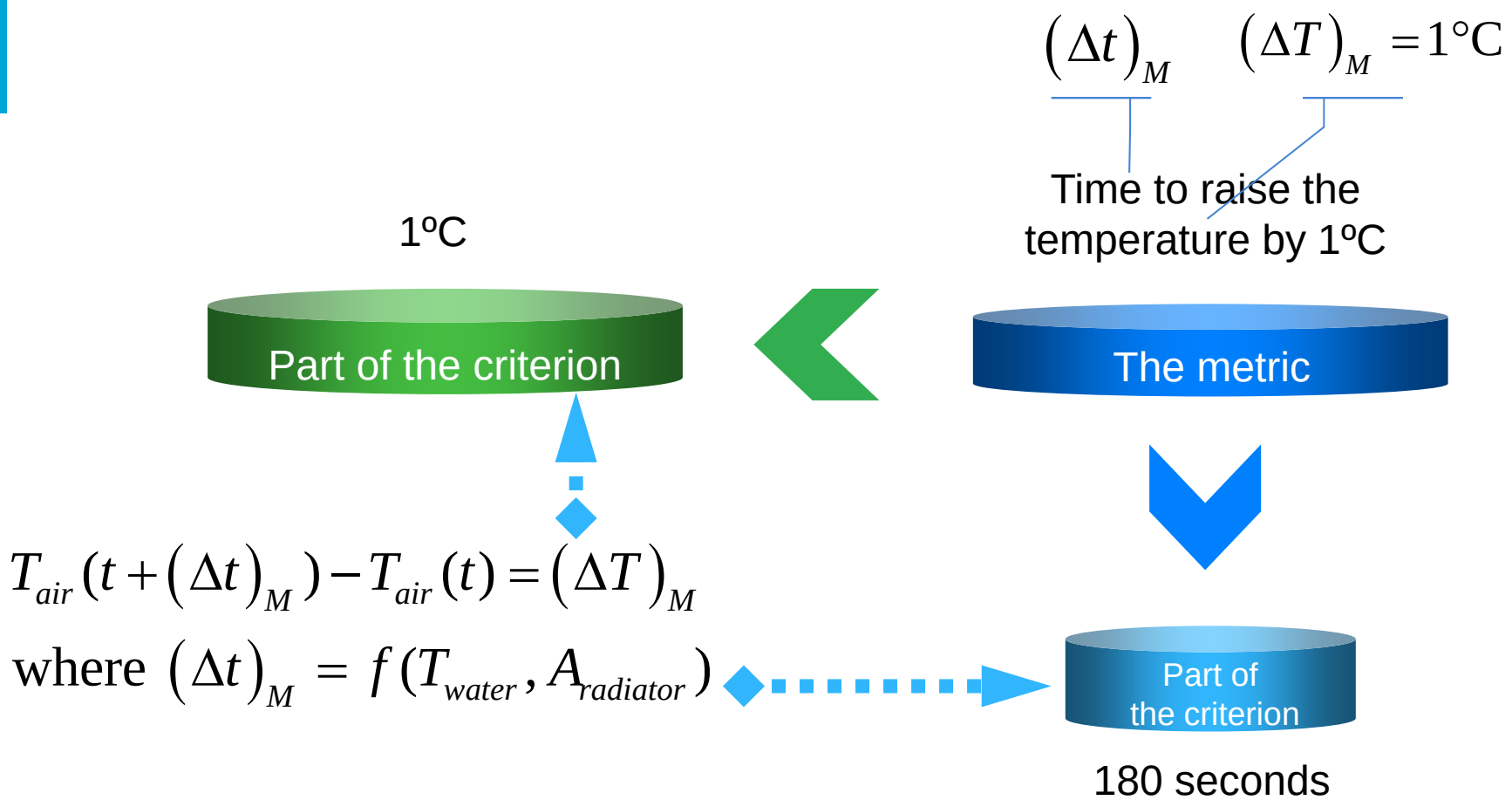




Courtesy of http://www.daalderop.nl/verwarming-en-koeling/twee-cv-zone-systeem/

The metric and the criteria

Criterion is the metric for judging (satisfaction)



Sensitivity analysis

We cannot always explore every possible solution

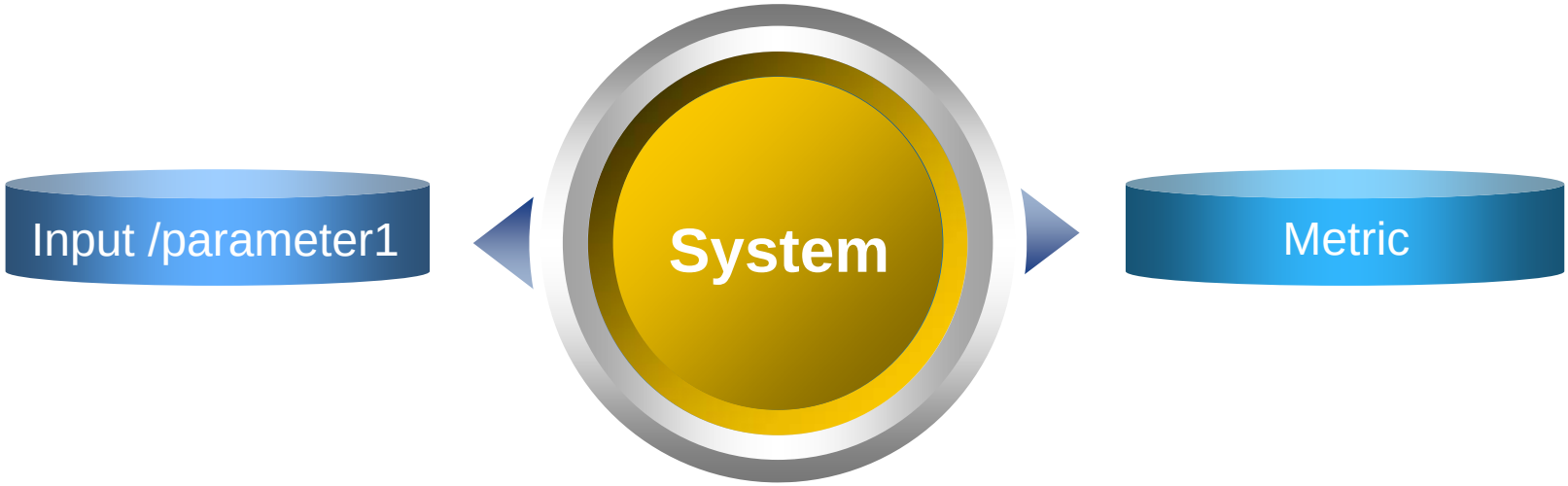
An example - Drop an cup on the floor

Simulate from
0 to 0.00125 second
Only one step

Computation time:
48 hours on
Pentium 4 3.6 GHZ CPU

Sensitivity analysis

one parameter vs one metric

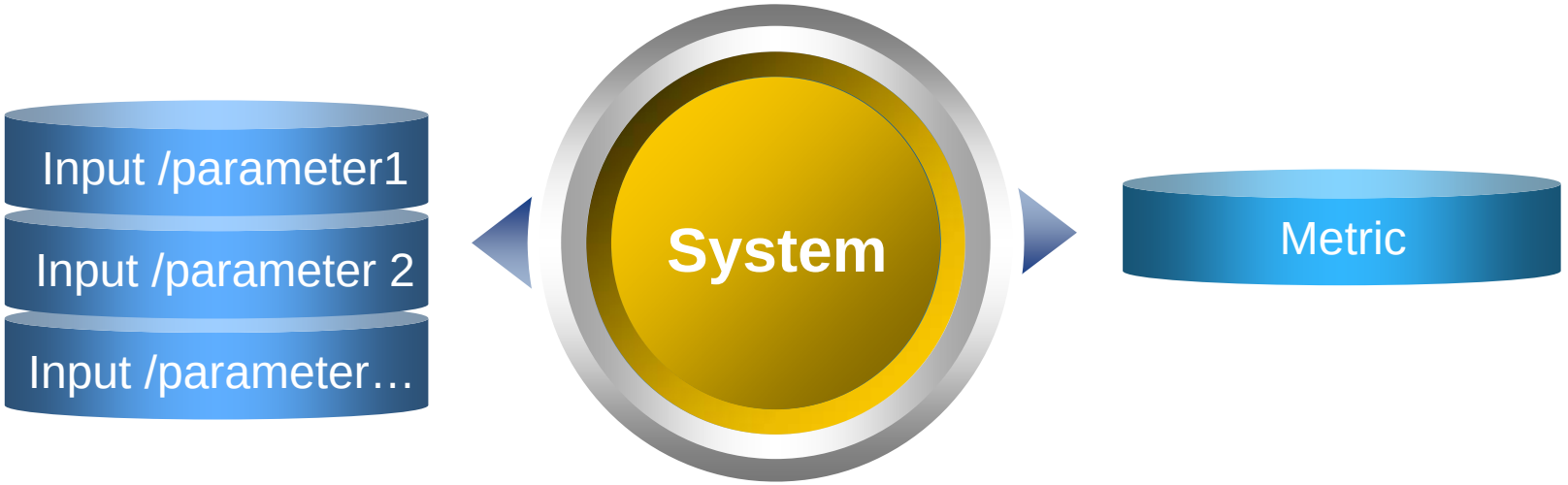


Derivative of the metric (f) w.r.t. input / parameter(p)

$$\frac{d}{dp} f(p)$$

Sensitivity analysis

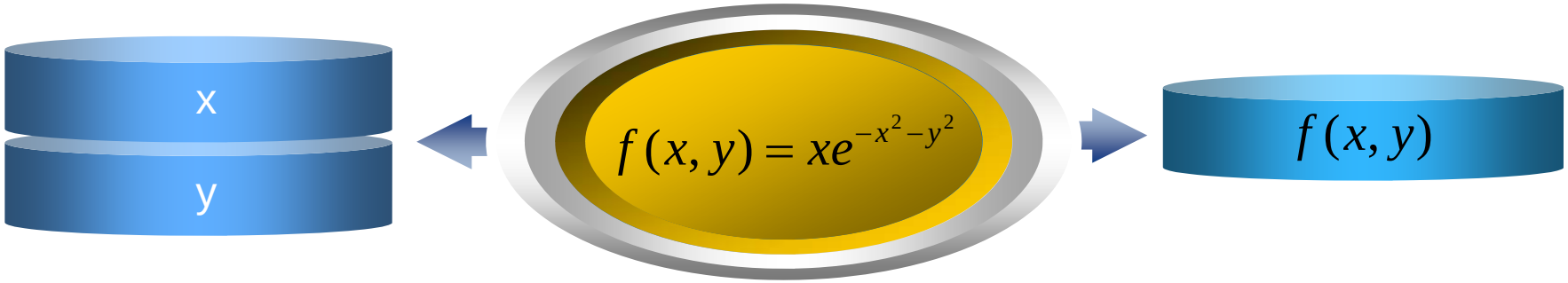
multiple parameters vs one metric

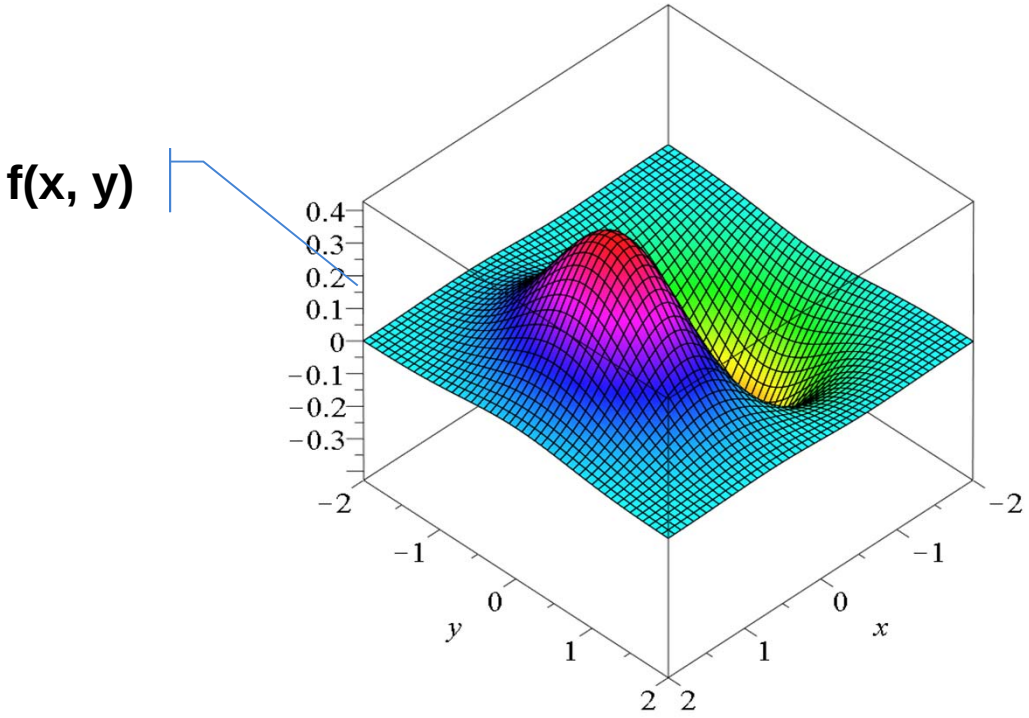


Gradient of the metric (f) w.r.t. inputs / parameters (p_1,p_2...,p_n)

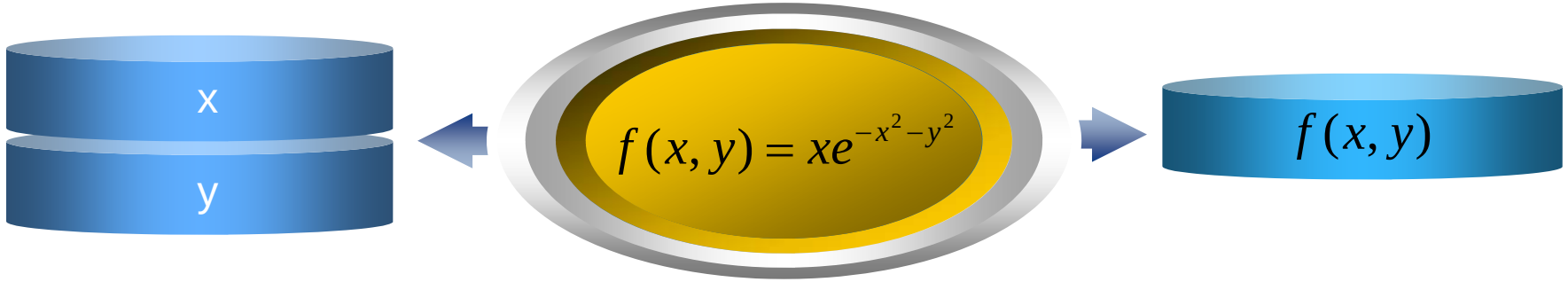
$$\nabla f = \left(\frac{\partial}{\partial p_1} f(p_1, p_2, \ldots p_n), \frac{\partial}{\partial p_2} f(p_1, p_2, \ldots p_n), \cdots, \frac{\partial}{\partial p_n} f(p_1, p_2, \ldots p_n)\right)$$

Sensitivity analysis: An Example



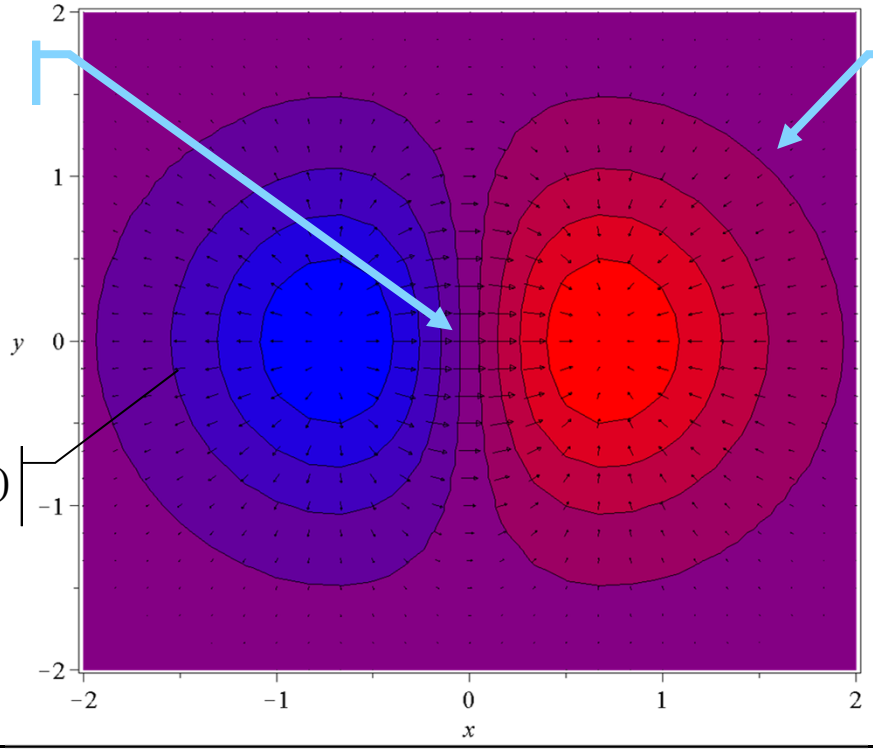


Sensitivity analysis: An Example



Sensitive

Insensitive



$$\nabla f(x,y) = \left(\frac{\partial(f(x,y)}{\partial x}, \frac{\partial(f(x,y)}{\partial y}\right)$$

Numerical approach of partial differences

$$\frac{\partial}{\partial p_1} f(p_1, p_2, \ldots p_n) = \frac{f(p_1 + \Delta p, p_2, \ldots p_n) - f(p_1, p_2, \ldots p_n)}{\Delta p}$$

Example:

$$f(x,y) = xe^{-x^2-y^2}$$

$$\left.\frac{\partial}{\partial x} f(x,y)\right|_{x=0}$$

$$= \frac{(0+\Delta x)e^{-(0+\Delta x)^2-y^2} - 0e^{-0^2-y^2}}{\Delta x}$$

$$= e^{-\Delta x^2-y^2}$$

Sensitivity analysis of the simulation

Sensitivity analysis in simulation

Suppose the temperature of house is 10°, the water is 55° and the surface area of radiators is 5m^2, the model is

$$\frac{d}{dt}T(t) = 0.0129 - 0.000234T(t)$$

Using Euler method to solve differential equation over the interval t=0 .. 5000 seconds.

Euler method:

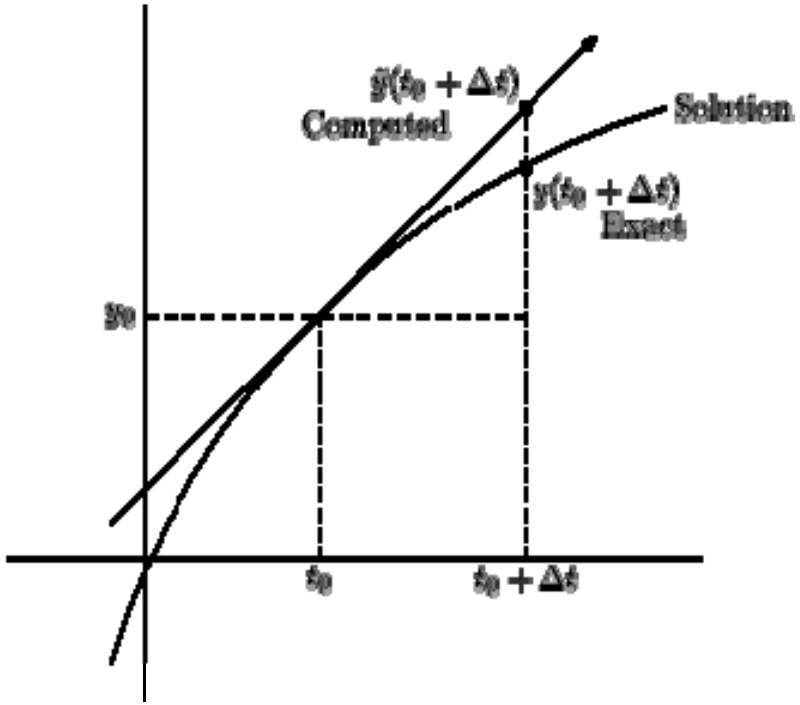
$$y(t+\Delta t) = y(t) + \frac{\mathrm{d}\, y(t)}{\mathrm{d}\, t}\Delta t$$

$$\frac{\mathrm{d}\, y(t)}{\mathrm{d}\, t} = \lim_{\Delta t \to 0} \frac{y(t+\Delta t) - y(t)}{\Delta t}$$

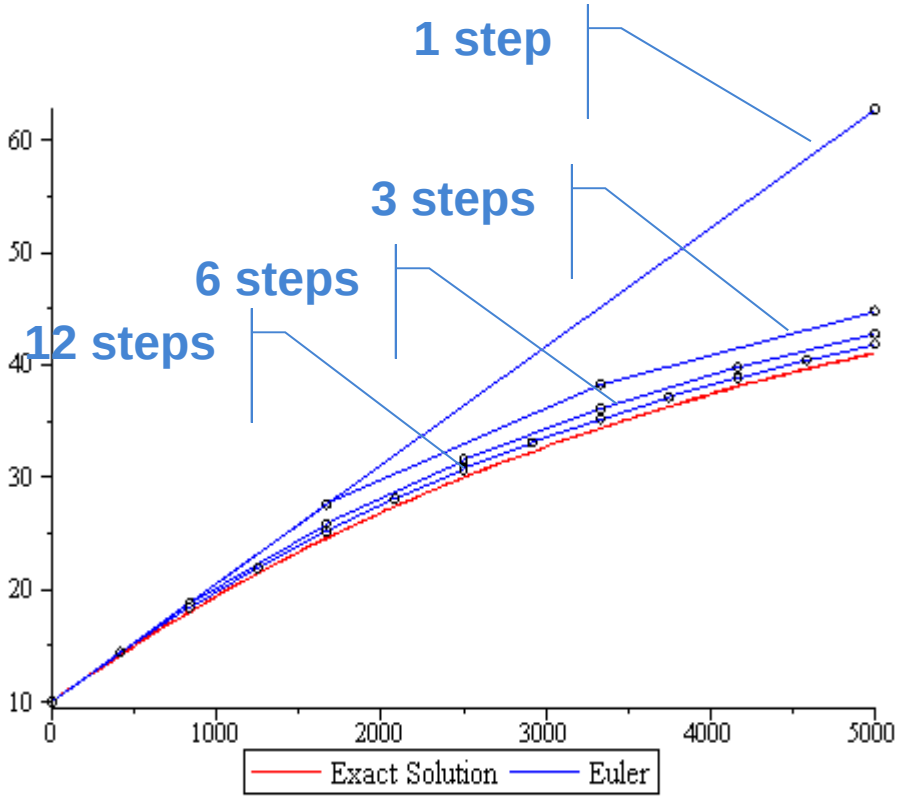
Euler method in detail

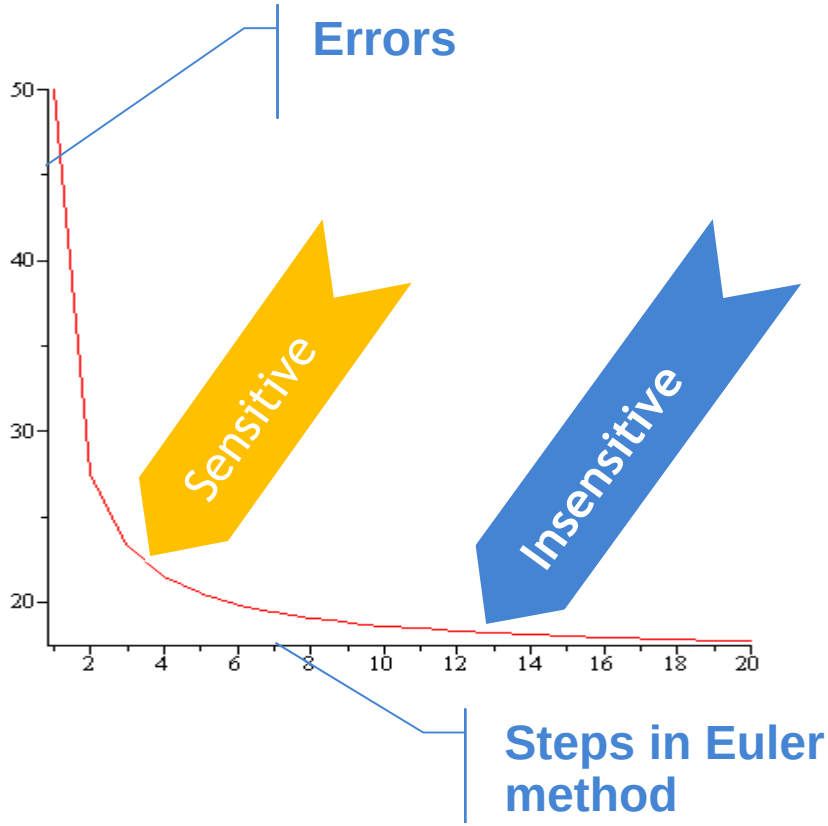
Euler method:

$$y(t+\Delta t) = y(t) + \frac{\mathrm{d}\, y(t)}{\mathrm{d}\, t}\Delta t$$



Sensitivity analysis in simulation



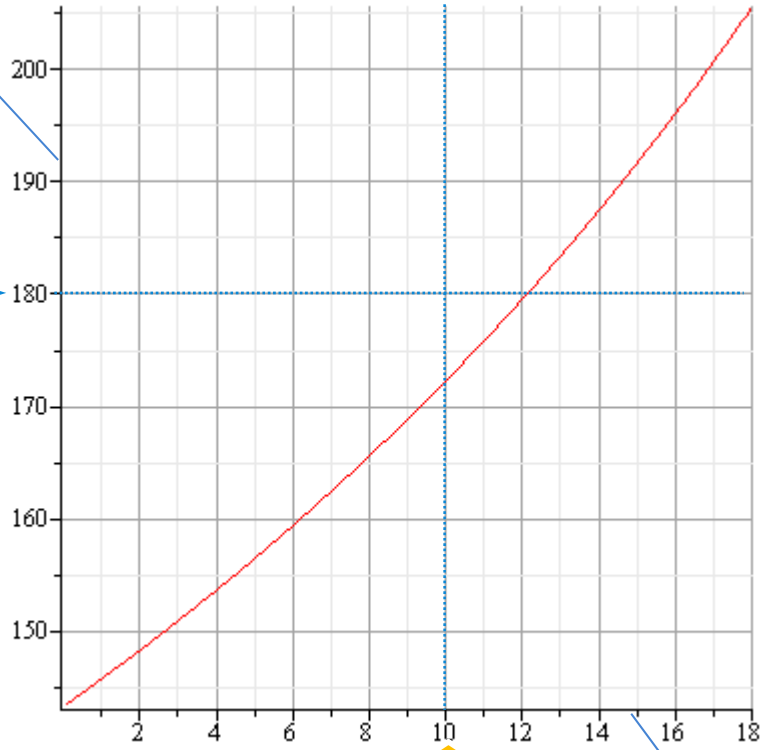


Sensitivity analysis of the system

Evaluations – the metric w.r.t initial temperature

Time to raise the temperature by 1°C

180 seconds

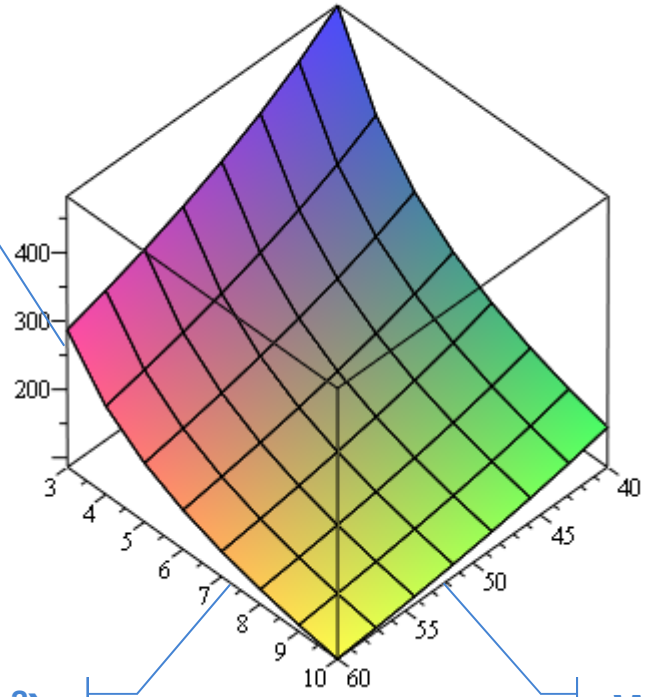


Initial room temperature

Evaluations – the metric w.r.t. surface area & water temperature

$$m_{air} c_{air} \frac{d}{dt} T_{air}(t) = \frac{T_{water} - T_{air}(t)}{\frac{1}{hA_{radiator}}}$$

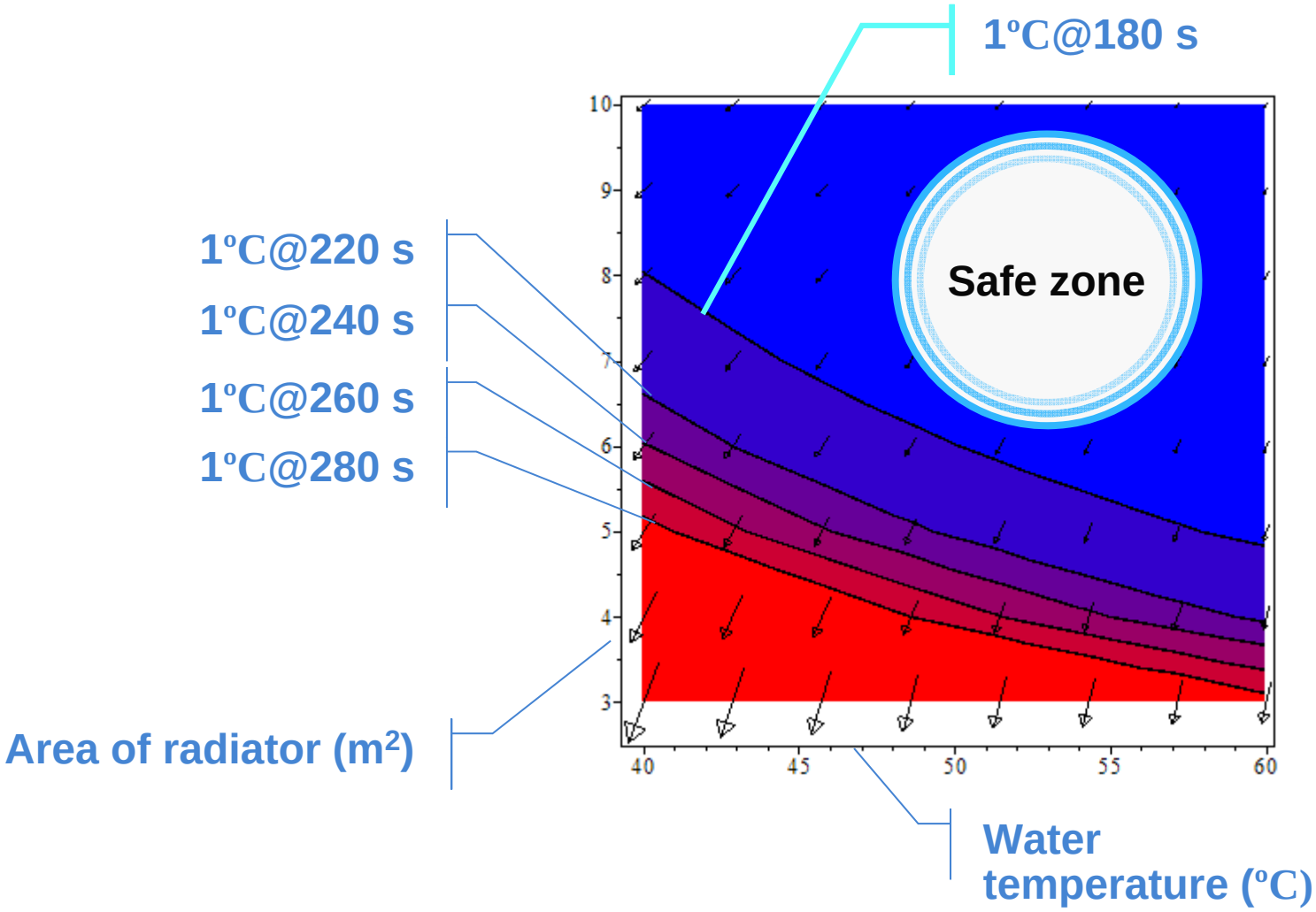
Time needed to raise the temperature by 1°C



Area of radiator (m^2)

Water temperature (°C)

Evaluations



Recall: A more complicate case

Simulate from
0 to 0.00125 second
Only one step

Computation time:
48 hours on
Pentium 4 3.6 GHZ CPU

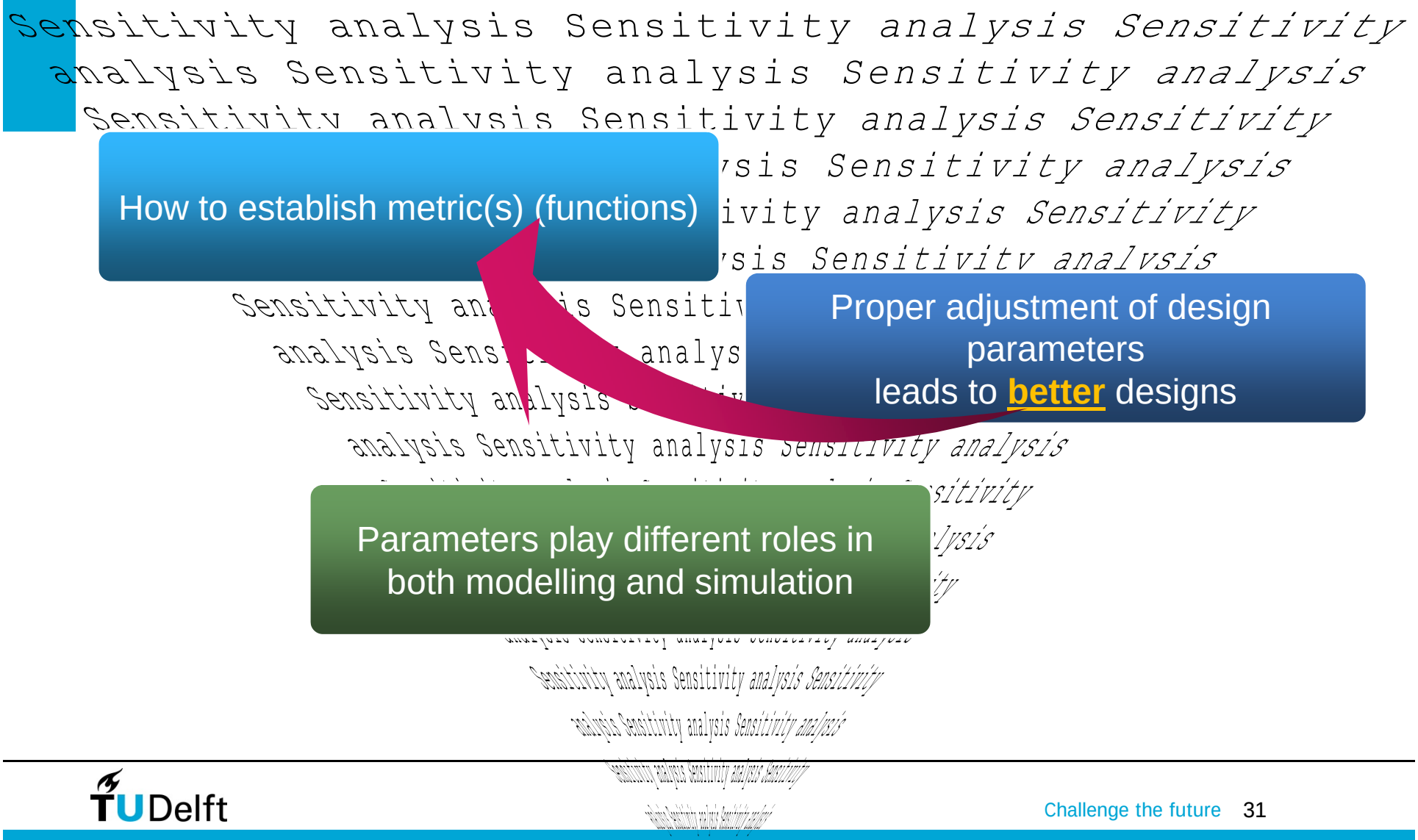
Evaluation of the results: Sensitivity analysis

1. How much do we trust our model? (sensitivity to solution parameters)

2. Think smart, not hard: Substitutes calculation-intensive ‘blind’ searches of the solutions space

3. Design for ‘insensitivity’/ tolerance-insensitive, wide tolerances

What did we learn today?



Success!

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