COMPONENT AND SYSTEM MODELING AND SIMULATION IN SOLAR THERMAL

Specialization - Cooperation

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Mini-Workshop on Optimal Control of Thermal Systems in Buildings using Modelica

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AGENDA

- A common customer interaction
- What is complexity? It’s not complicated.
- Avoid Complications
- Example of software interfaces
- Requirements
- Example in Modelica

Customer interaction:

- Customer: ‚Which of my options is the best?‘
- Answer: ‚It‘s complicated‘. Customer hears: ‚I have no idea!‘
- You: ‚Which system do you want me to look at?‘
- Customer: ‚Do you have something generic?‘
- You: ‚No, we will have to get to the root of this, and build a system from scratch.‘
- Customer hears: ‚It won‘t be quick and it won‘t be cheap!
  But pay me to find out for you...and me ☺’

To achieve something great you have to stand on shoulders of...

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To achieve something great you have to stand on shoulders of...

...giants?

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What is Complexity?

- Complexity (intrinsic): used to characterize something with many interacting parts, possibly interacting in multiple ways:
  - Complex (non-linear) interactions, e.g. convective, conductive, radiative heat transfer in a network of components
  - intrinsic: ‚comes with…', translated: …it cannot be removed, but must be managed!
- Complicated (extrinsic): ‚it is difficult to comprehend',
  - comprehend: understand, learn.
  - extrinsic: ‚coming from outside', translated: …it can be avoided!
- Complications are made: by failing to code properly, document clearly or an inability to get an overview on various levels (no GUI, no zoom)

Complexity is your enemy. Any fool can make something complicated.
It is hard to make something simple.
- Richard Branson

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Avoid Complications

The Zen of Python (20)

- ...
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- ...
- Readability counts.
- ...
- Now is better than never. Although never is often better than *right* now.
- If the implementation is hard to explain, it's a bad idea.

(https://www.python.org/dev/peps/pep-0020/)

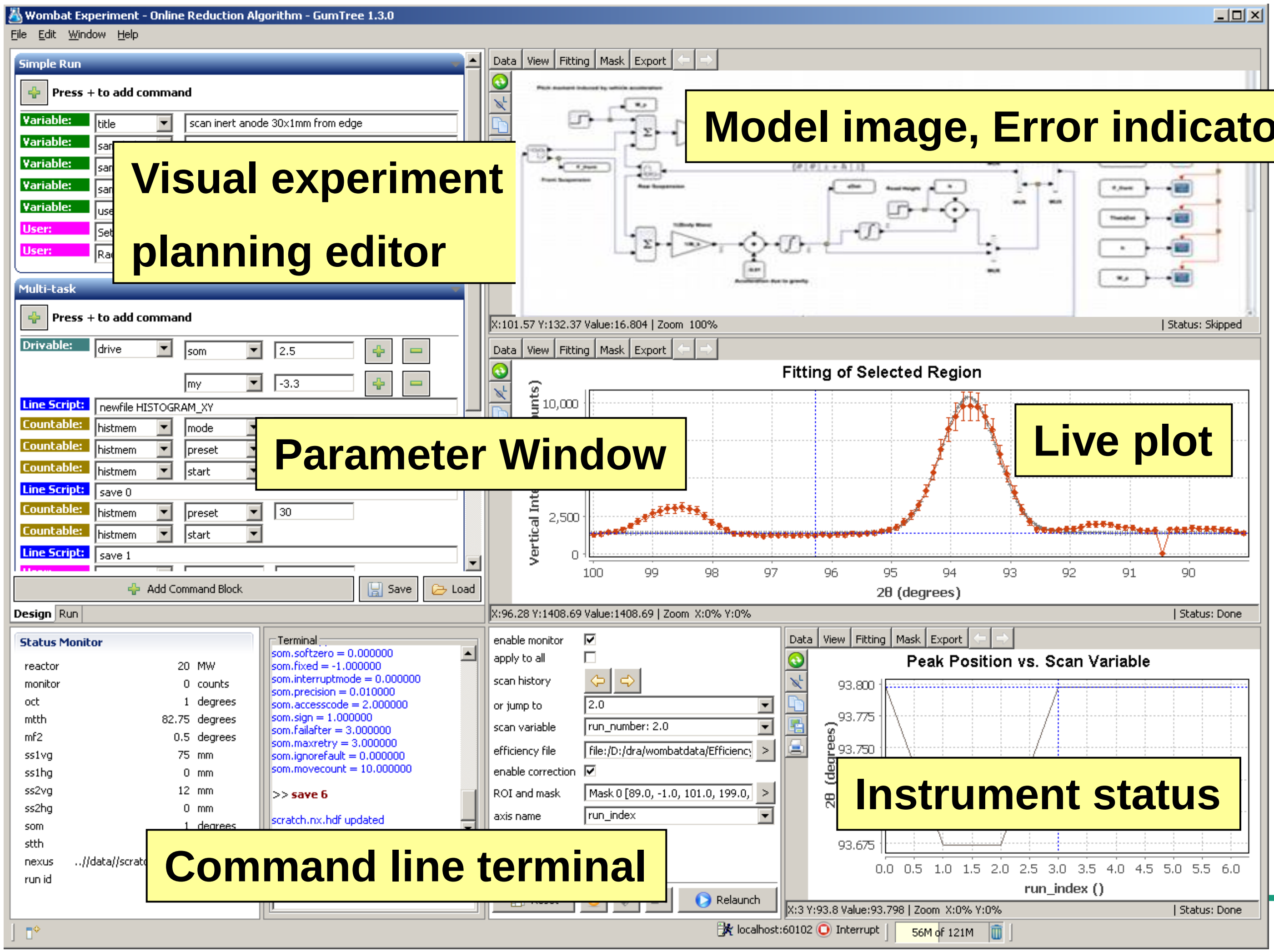
- 'complexity science': the study of the phenomena which **emerge** from a collection of interacting objects
  - emerging phenomenon: e.g. F-save (un-complicated!)
- How to produce un-complicated answers (clear, quick & cheap)?
  - Use a library of re-usable components and systems, which is:
    - reliable (verified and validated)
    - well coded
    - clearly documented
    - hierarchical
    - zoomable (GUI)

Practical Situation:

- Average employee retention time < 1 year? Knowledge management:
  - Cumulative, but how?
- Focus:
  - Accumulation of solar thermal knowledge, not code
- Goal:
  - Intuitive, fast understanding (of code, components and systems)
  - Reliable and fast results
- Needs:
  - The right software: Visual model & data presentation
  - Focus on handover of new and accumulated solar thermal knowledge
  - Do not forget Pre-/Post-processing
- Standing on shoulders of predecessors
  - Good code, components, systems, documentation ➔ giants!
  - Bad code... ➔ start over

Example: Gumtree

Opensource scientific application framework (Eclipse RCP)



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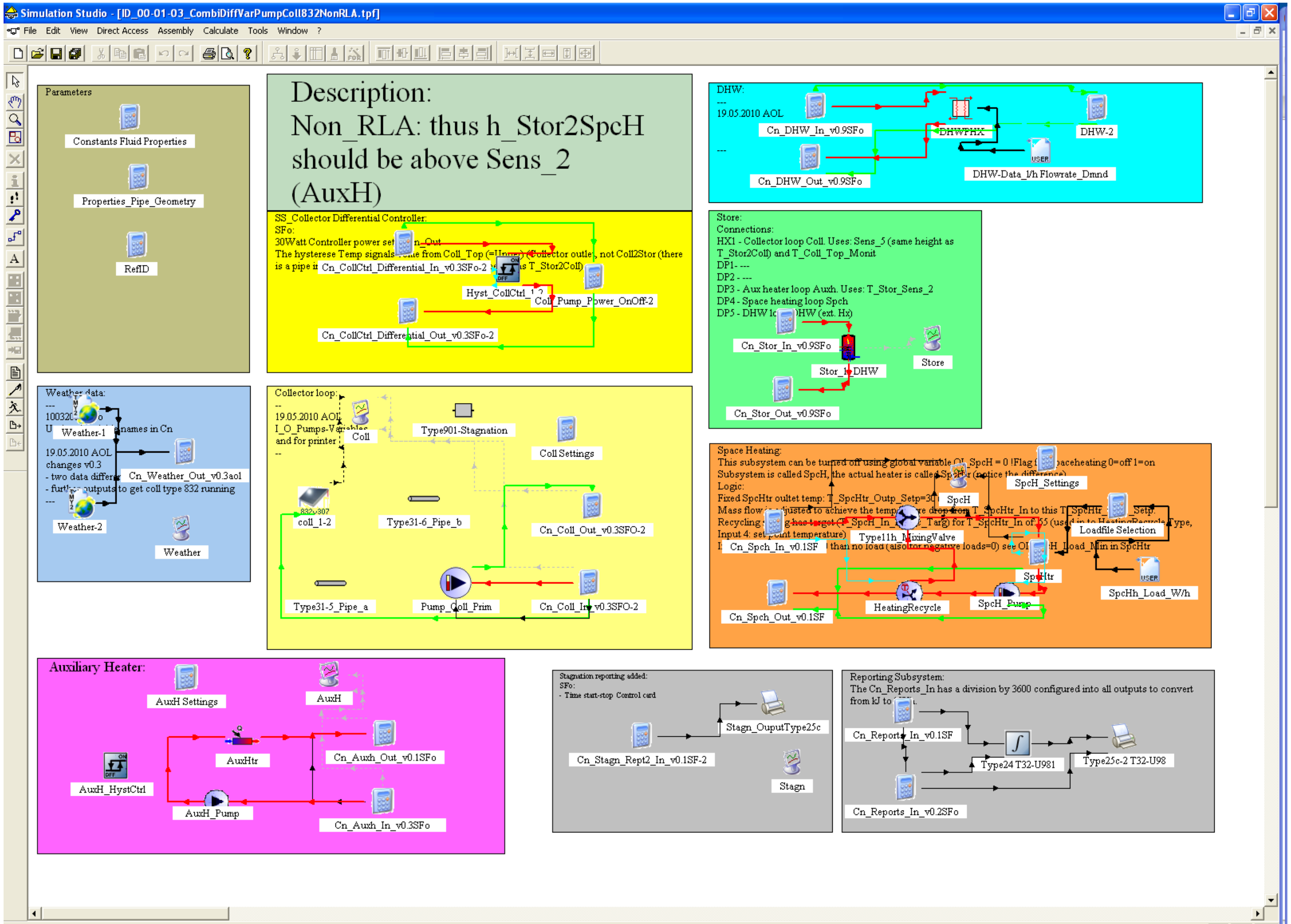
Example of Standard Systems

Modular TRNSYS Deck



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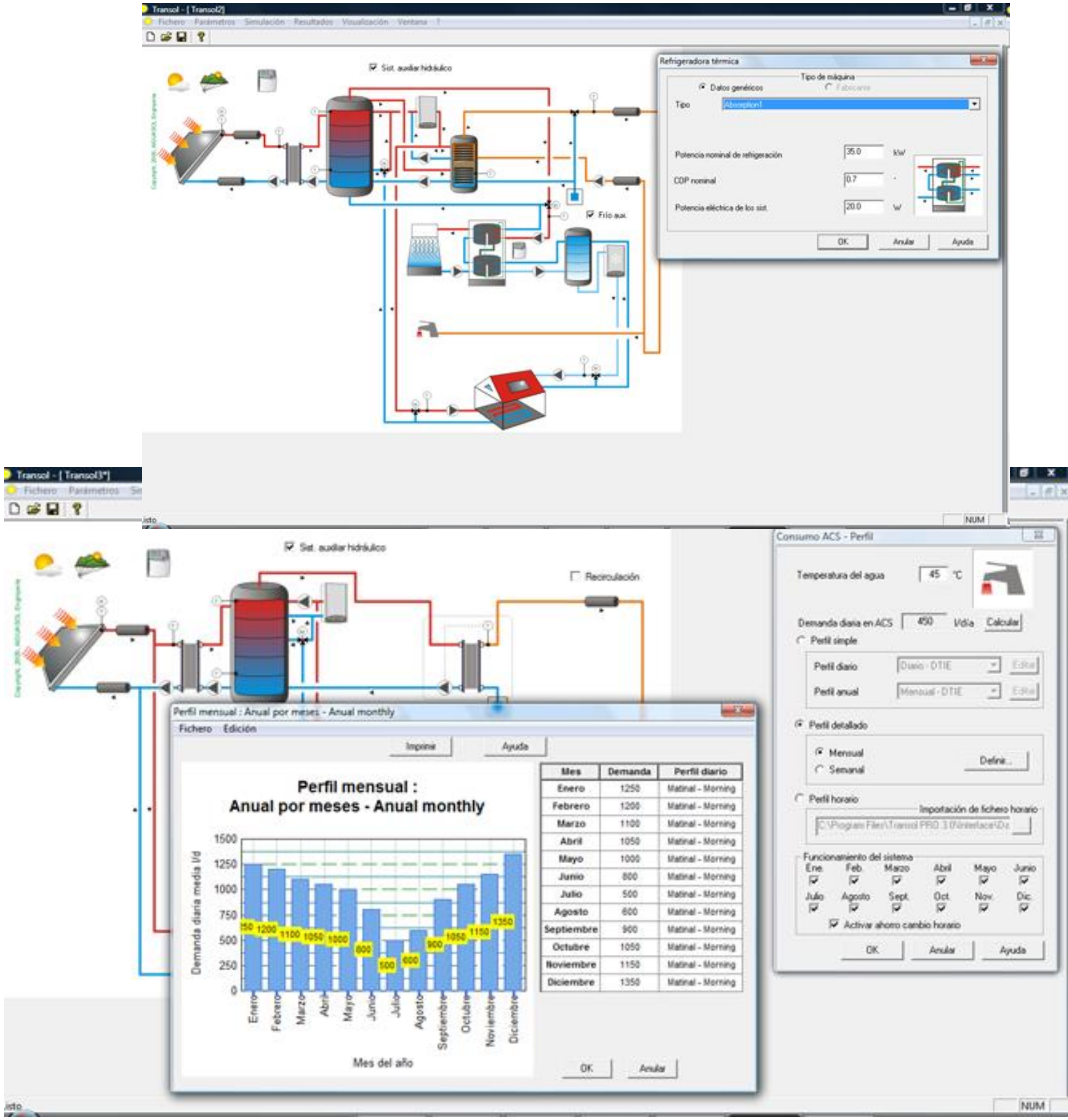
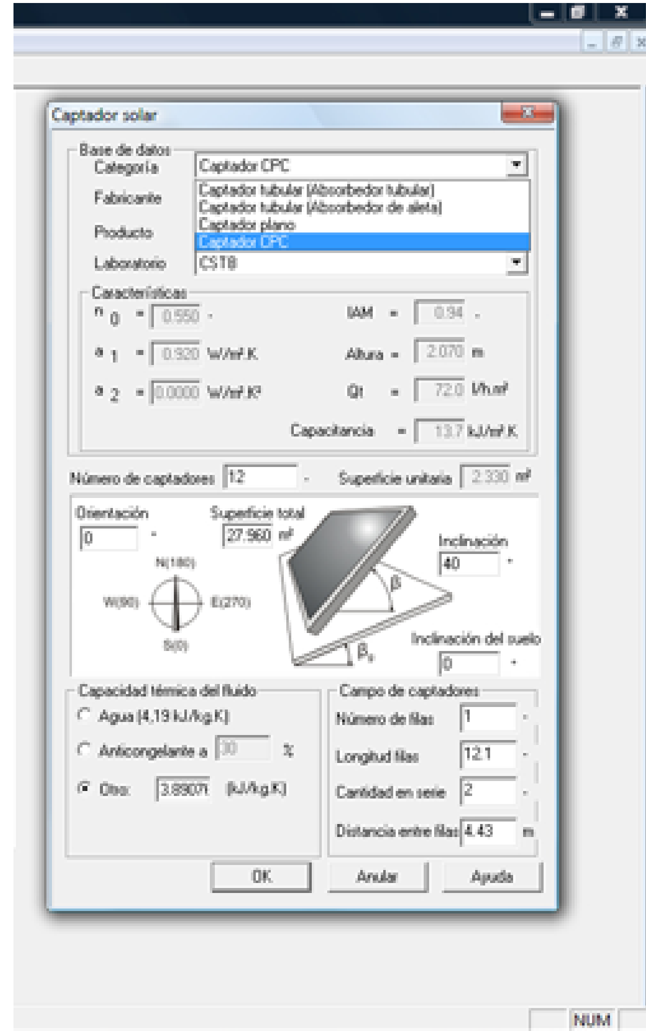
Example of Standard Systems

TRANSOL 3.1 Pro (or Polysun)





Example of Modelica code (quick)

s.WindowSolar (Read-Only) - [Modelica Text]

ion Commands Window Help

```
model WindowSolar "window model for solar gains"
  //Parameters
  parameter Modelica.SIunits.Area A "gross area";
  parameter Real g_g = 0.75 "total solar energy transmittance";
  parameter Real F_C = 0.25 "shading provisions factor";
  parameter Real F_F = 0.7 "frame area factor";
  parameter Real F_W = 0.85 "incident radiation factor";
  parameter Real F_S = 1 "shading coefficient";
  //Variables
  Modelica.SIunits.Power Q;
  Modelica.SIunits.RadiantEnergyFluenceRate I;
  Modelica.Blocks.Interfaces.RealInput u
    a;
  Modelica.Blocks.Interfaces.RealOutput y
    a;
  Modelica.SIunits.Area A_eff "effective solar collecting area";
  Real g "effective total solar energy transmittance";
  Real I_g "Grenzwert fuer Verschattung";
  Modelica.Blocks.Interfaces.RealInput u1
    a;
equation
  u = I;
  u1 = I_g;
  y = Q;
  g = g_g * F_W;
  if I < I_g then
    A_eff = A * F_F * g * F_S;
  else
    A_eff = A * F_C * F_F * g * F_S;
  end if;
  Q = I*A_eff;
  a;
end WindowSolar;
```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Example of Modelica code (better)

s.WindowSolar (Read-Only) - [Modelica Text]

ion Commands Window Help

```
model WindowSolar "window model for
  //Parameters
  parameter Modelica.SIunits.Area A
  parameter Real g_g = 0.75 "total s
  parameter Real F_C = 0.25 "shadinç
  parameter Real F_F = 0.7 "frame ar
  parameter Real F_W = 0.85 "incider
  parameter Real F_S = 1 "shading co
  //Variables
  Modelica.SIunits.Power Q;
  Modelica.SIunits.RadiantEnergyFlue
  Modelica.Blocks.Interfaces.RealInp
    a;
  Modelica.Blocks.Interfaces.RealOu
    a;
  Modelica.SIunits.Area A_eff "effec
  Real g "effective total solar ener
  Real I_g "Grenzwert fuer Verschat
  Modelica.Blocks.Interfaces.RealInp
    a;
equation
  u = I;
  u1 = I_g;
  y = Q;
  g = g_g * F_W;
  if I < I_g then
    A_eff = A * F_F * g * F_S;
  else
    A_eff = A * F_C * F_F * g * F_S;
  end if;
  Q = I*A_eff;
  a;
end WindowSolar;
```


l.Facades.Constructions.Wndw_optc - [Modelica Text]

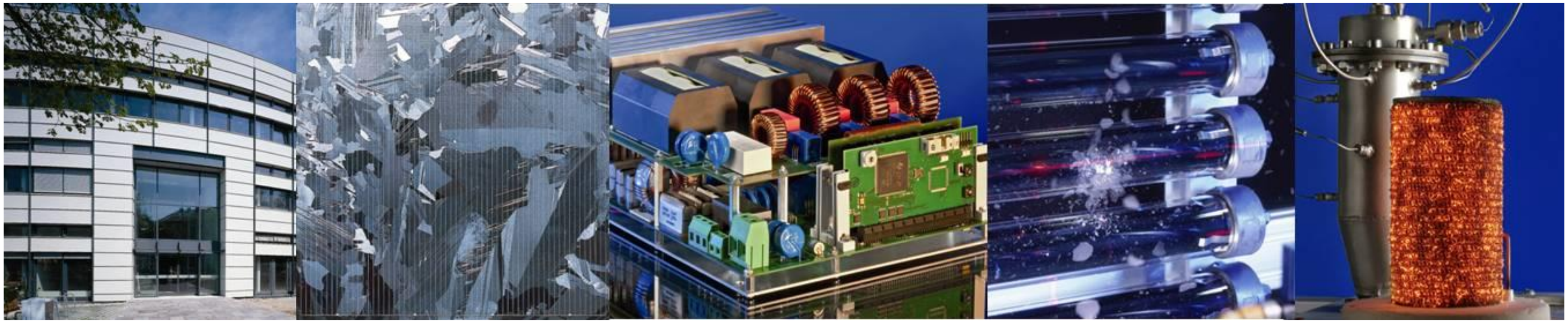
ion Commands Window Help

```
block Wndw_optc "Optical model for solar gains through a window"
  /*
   Description: Simple optical model for solar gains through a window
   Warning(s): The model is asymmetric.
   Author(s): MeE, SFo
   Date: 2015-03-15
   Checked by: MLo
   Sources: none (literature, standards etc.)
  */
  // UNITS
  import SI = Modelica.SIunits;
  //Parameters
  parameter SI.Area area( min=0) = 1 "Gross window area incl.frame [m2]";
  parameter Real frame_fact(unit="1", min=0, max=1) = 0.3
    "fraction of window covered by frame [0-1]";
  parameter SI.TransmissionCoefficient tau( min=0, max=1) = 0.75
    "Total solar transmittance at normal incidence [-]";
  parameter Real IAM_avg( unit="1", min=0, max=1) = 0.85
    "[-] Incident Angle Modifier (constant average)";
  parameter SI.HeatFlux H_max = 600
    "Max. incident power for shading switch (< no shade, > shaded) [W/m2]";
  parameter Real shade_fact(unit="1", min=0, max=1) = 0.75
    "transmission reduction factor when shading is on [-]";
  Modelica.Blocks.Interfaces.RealInput H_in "Incident power [W/m2]"
    a;
  Modelica.Blocks.Interfaces.RealOutput Q_gain
    "Transmitted energy through window [W]"
    a;
equation
  if H_in < H_max then // max. allowed incoming heat flux
    Q_gain = H_in * area*(1-frame_fact) * tau * IAM_avg; // no shading
  else
    Q_gain = H_in * area*(1-frame_fact) * tau * IAM_avg * (1-shade_fact); // shaded
  end if;
  a;
end Wndw_optc;
```

Requirements

- Quality Graphical User Interface (GUI) for each of the development stages:
    - Component development (code, hierarchical)
    - Model development (connection editor, zoom, verification & testing of in-/output).
- Pre-, post-processing, workflow (sensitivity analysis, design space exploration and optimisation)
- Component Library (Mathematical-physical models, Thermodynamic/mechanic components)
    - Library of useful, tested (validated) and well documented modules
    - Modular & Hierarchical (the only way to manage complexity!)
- System Library: DHW, Combi, Process Heat, SFH, MFH etc. (verified /validated)
- Speed is not an issue: ‘test modular‘ & ‘run in background’

Thank-you for your attention!



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