ROYAL INSTITUTE OF TECHNOLOGY

Simulation of historic buildings

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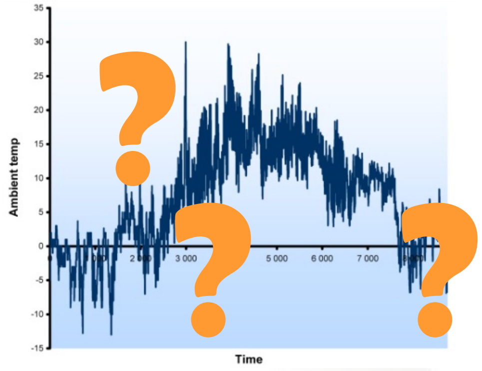
CONTEXT

SIMULATION

Reality



Math

```
if (T >= 0)
   vsat = global_a * pow(global_b + T/100,global_c) / (461.51*(T+273.15));
 else
   vsat = global_d * pow(global_e + T/100,global_f) / (461.51*(T+273.15));
```

Result

Output

CONTEXT

SIMULATION

How minimize uncertainties?

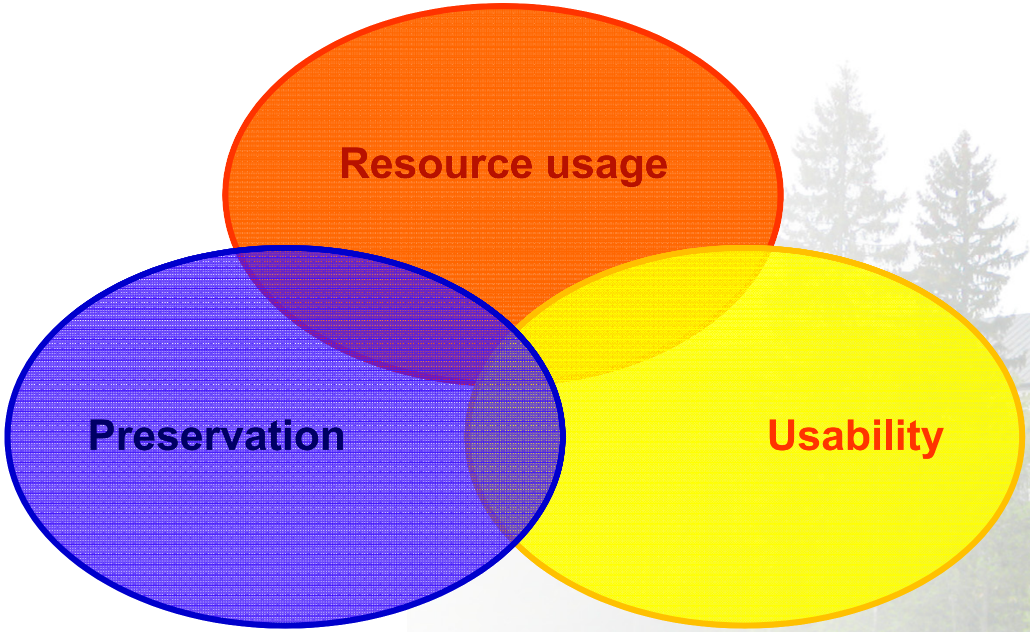
a. Measuring
   - Over long time – time consuming
   - Costs
   - Right equipment
   - Knowledge

b. Calibration according to measure series
   - Takes time – time consuming
   - Runtime creates issues
   - Costs

c. Inverse modeling
   - Creates “intelligent guesses”
   - Can save time

CONTEXT

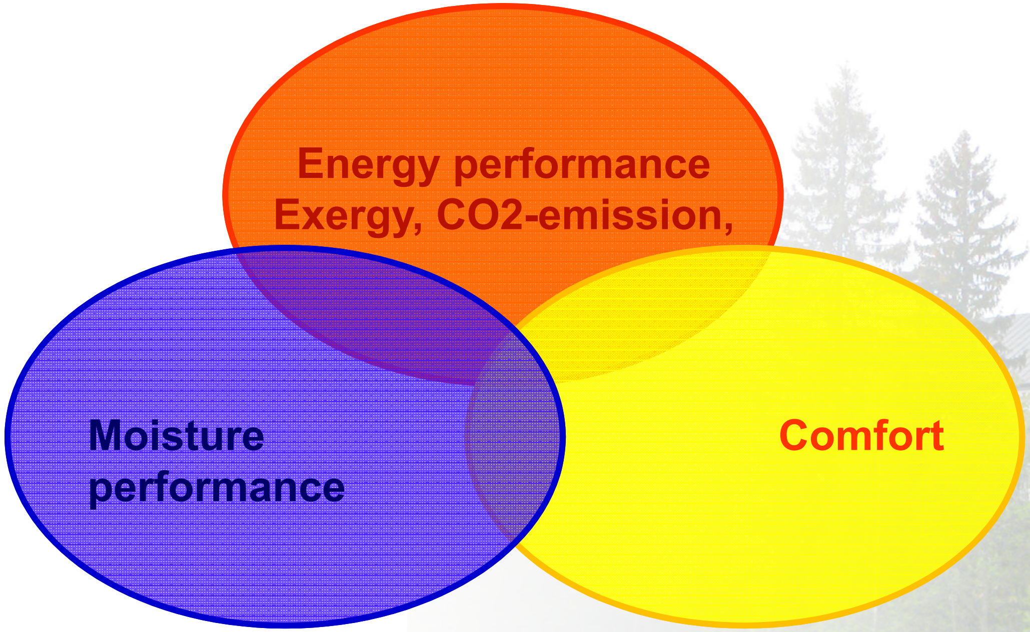
ASPECTS



Multi-criteria issue

CONTEXT

ASPECTS



Multiple functions

CONTEXT

MOISTURE

Moisture performance

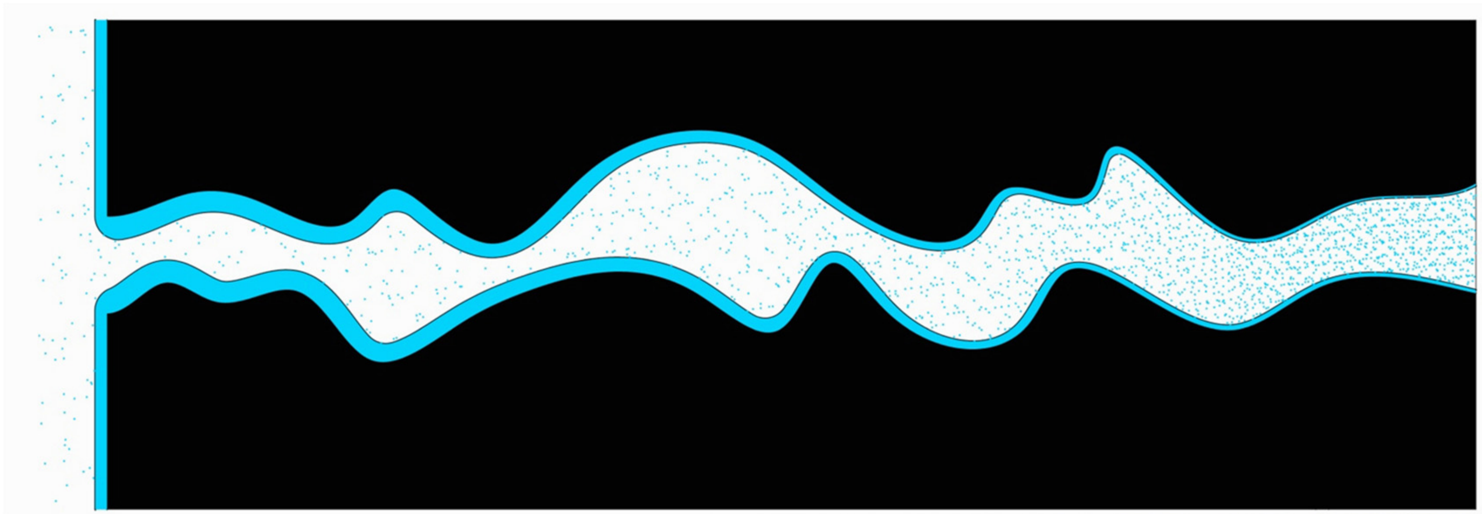
a. Damage risk
   - Mould
   - Algea
   - Freezing
   - Deformation/ cracking
   - Salt activity
   - Soiling

b. Multiple processes
   - Increased complexity
   - High inter-dependency

CONTEXT

MOISTURE

T	0 °C		T	+10 °C
RH	95 %	Liquid flow →	RH	50 %
w	120 kg/m³		w	20 kg/m³



v_{sat}	0,0049 kg/m³	←	v_{sat}	0,0094 kg/m³
v	0,0046 kg/m³	Vapor flow	v	0,0047 kg/m³
p	580 Pa		p	615 Pa

CONTEXT

DIFFERENCES

How do historic buildings deviate from modern ones?

a. **Indoor conditions**

- The buildings may be made for less climatic difference over the **building envelope,** which may render them **less suited to modern use** and/or demands from present day users
- Often more or less sensitive **items of historical value** kept inside, that may pose special demands on the indoor conditions

b. **Existing materials and building components**

- Might be **inaccessible, poorly known or documented, exchanged** in parts
- Might display **larger deviations in quality** than modern materials
- May be influenced by **deterioration, moisture and/or chemical exposure**
- May be made for conditions where labor intensive maintenance was rule more than exception

CONTEXT

DIFFERENCES

How do historic buildings deviate from modern ones?

c. **Existing systems**

- May be **insufficiently known**
- May cause **unexpected effects** when combined with modern ones
- **Natural ventilation** important

d. **Values at stake**

- Damages may cause the **loss of irreplaceable values** in the destruction of historically significant artifacts, buildings details and/or decorations
- Lack of usability may cause lack of financial will to maintain the building, which in a longer term perspective **endanger the entire building structure**, putting part our history at risk

We thus have special demands combined with high values at stake, making long term predictions of the consequences of our actions necessary = a need for reliable simulation

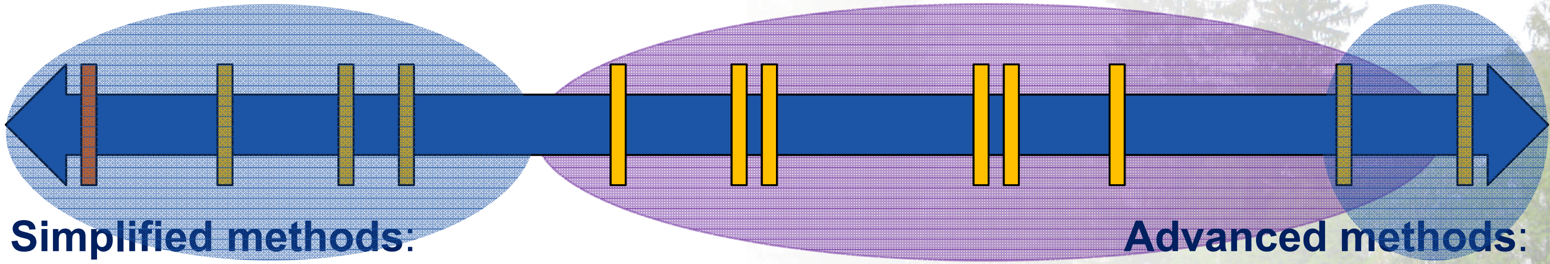
CONTEXT

DIFFERENCES

Historic buildings are different

General recommendations

Individual assessment



Simplified methods:
Faster, simpler, cheaper for the building owner/manager

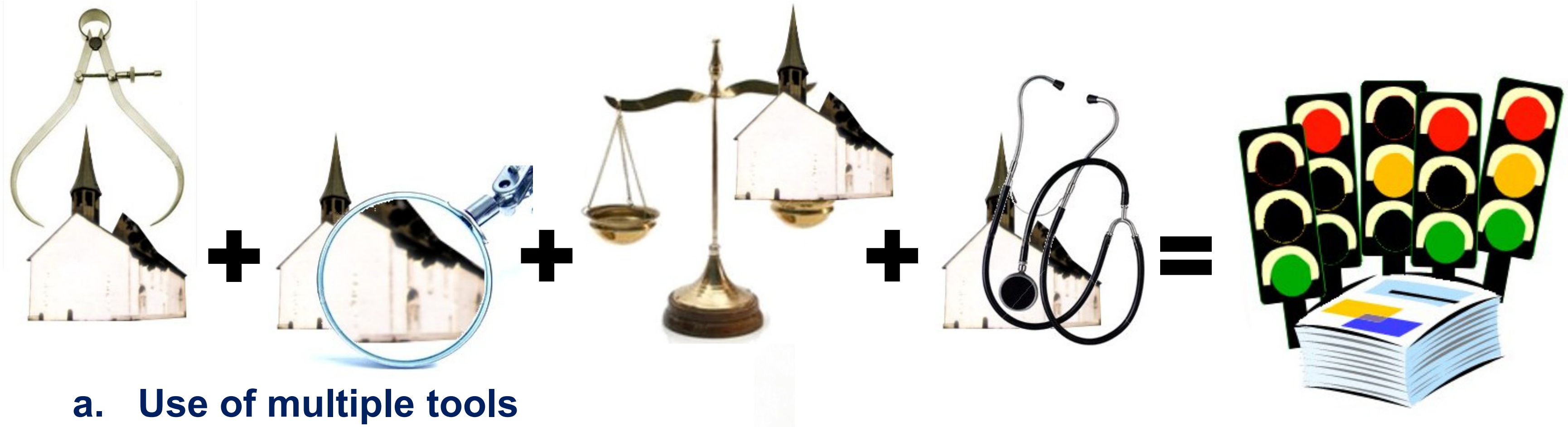
Advanced methods:
More reliable, more time and resource demanding process

different tools and methods are appropriate in different cases

and these need to **be accessible to practitioners on the field**

ISSUES

METHODS



a. Use of multiple tools

b. Use of a multi-functional tool

ISSUES

METHODS

Complexity vs simplicity

a. Stability of software
b. Run time
c. Risk of user errors

ISSUES

WHOLE & PART

Whole building

Specific points

WISH LIST

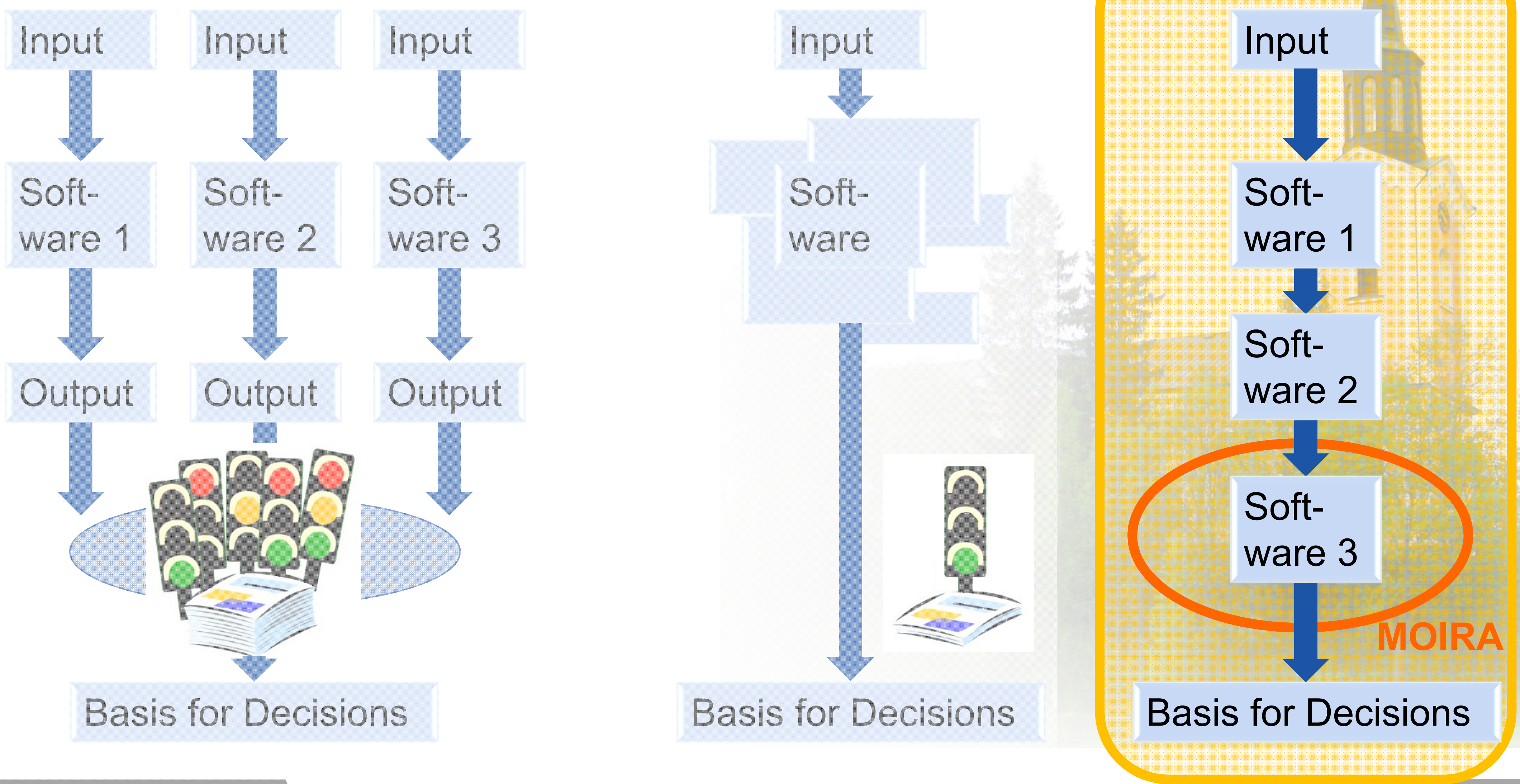
a. Domain-related
- Energy
- Exergy
- Costs
  - *Use of resources*
  - *Investments and maintenance*
  - *Cultural values*
- Environmental impact
- Comfort and IAQ
- Moisture
- Damage risks:
  - *Fluctuations*
  - *Mould*
  - *Salt*
  - *Pollution*
  - *Light*

b. Scope-related
- Dynamic and allowing long simulation periods
- Multi-zonal
- Deliver overview and inter-dependence – whole building system
- Deliver predictions for critical points too, not just averages

c. User-related
- Accessible
- Fast
- Reliable
- Flexible
- Simple to calibrate

d. Decision-related
- Clear and unambiguous
- Gathering, balancing
- Quantifying - MCDA

PROCESS

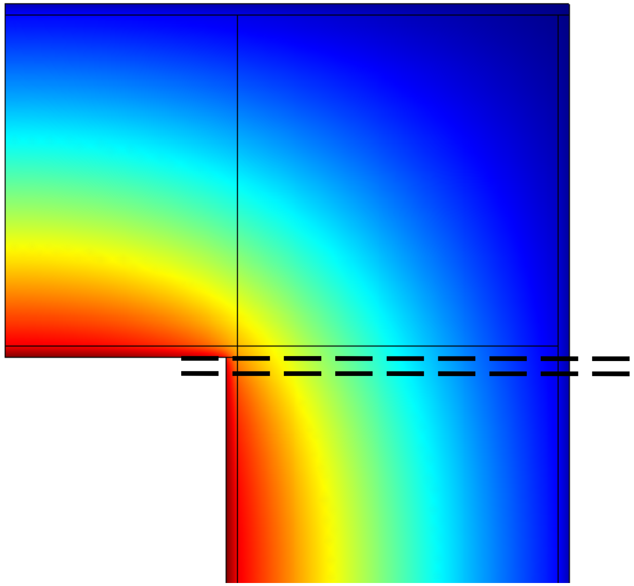


Input
Input
Input
Soft-ware 1
Soft-ware 2
Soft-ware 3
Output
Output
Output
Basis for Decisions
Input
Soft-ware
Basis for Decisions
Input
Soft-ware 1
Soft-ware 2
Soft-ware 3
MOIRA
Basis for Decisions

PROCESS

WHOLE & PART

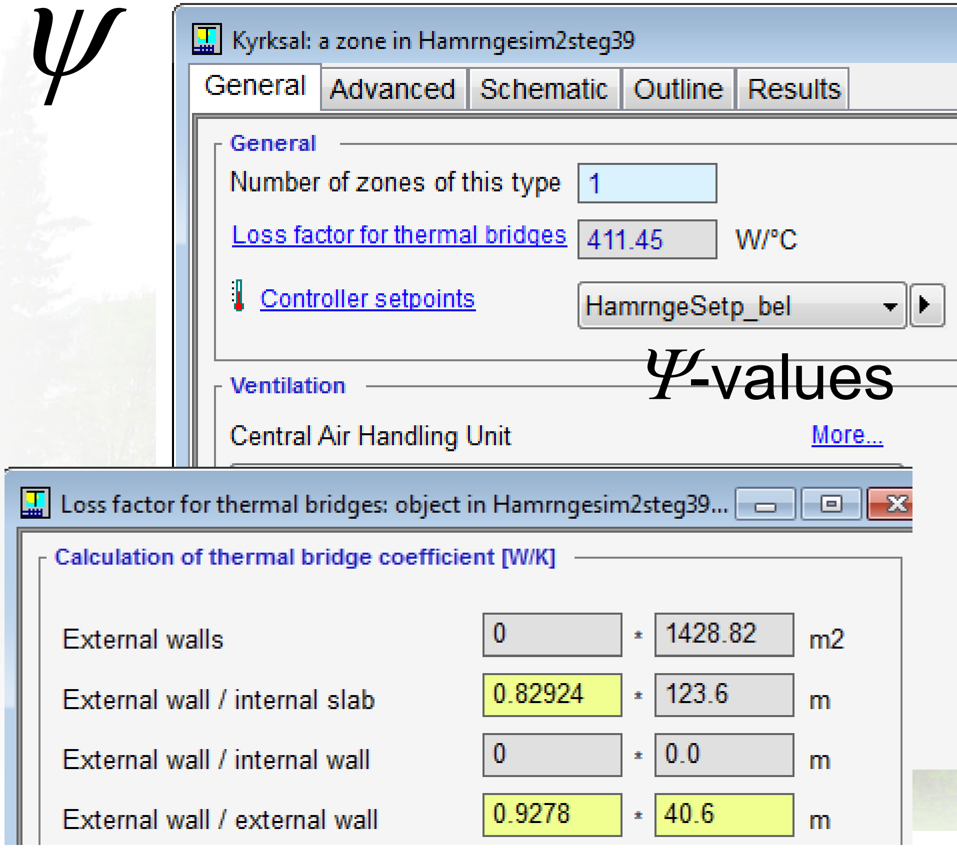
Sub-method: Very small wall part method



Very small wall part

+

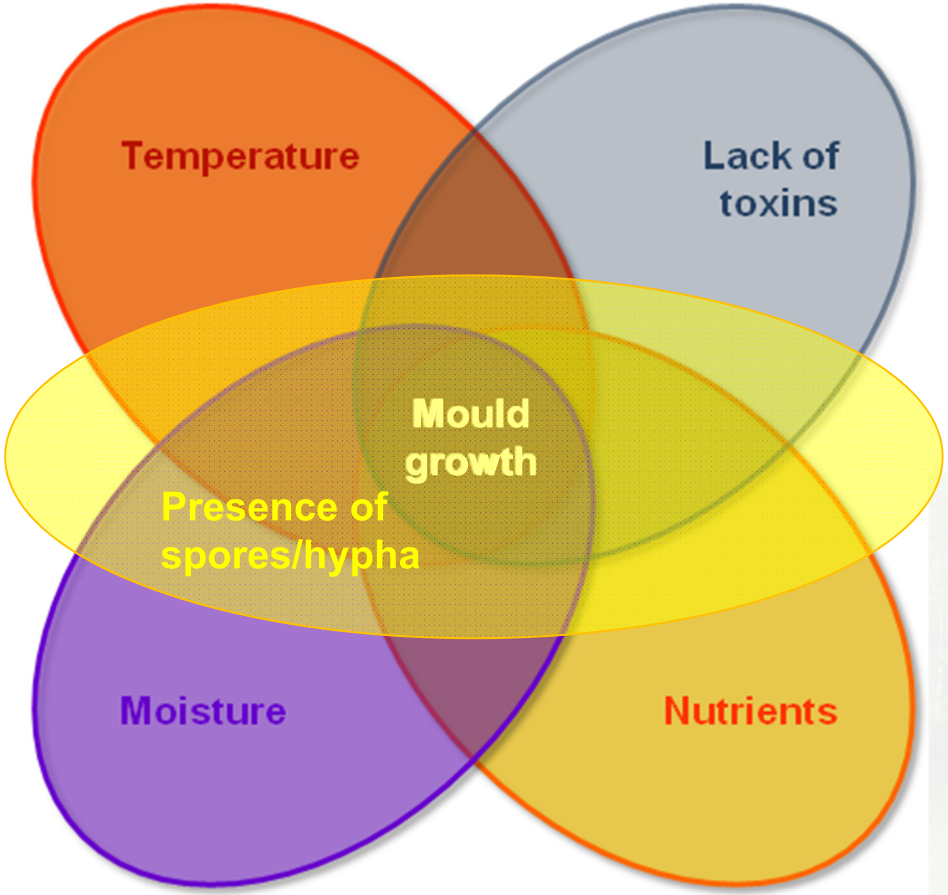
ψ



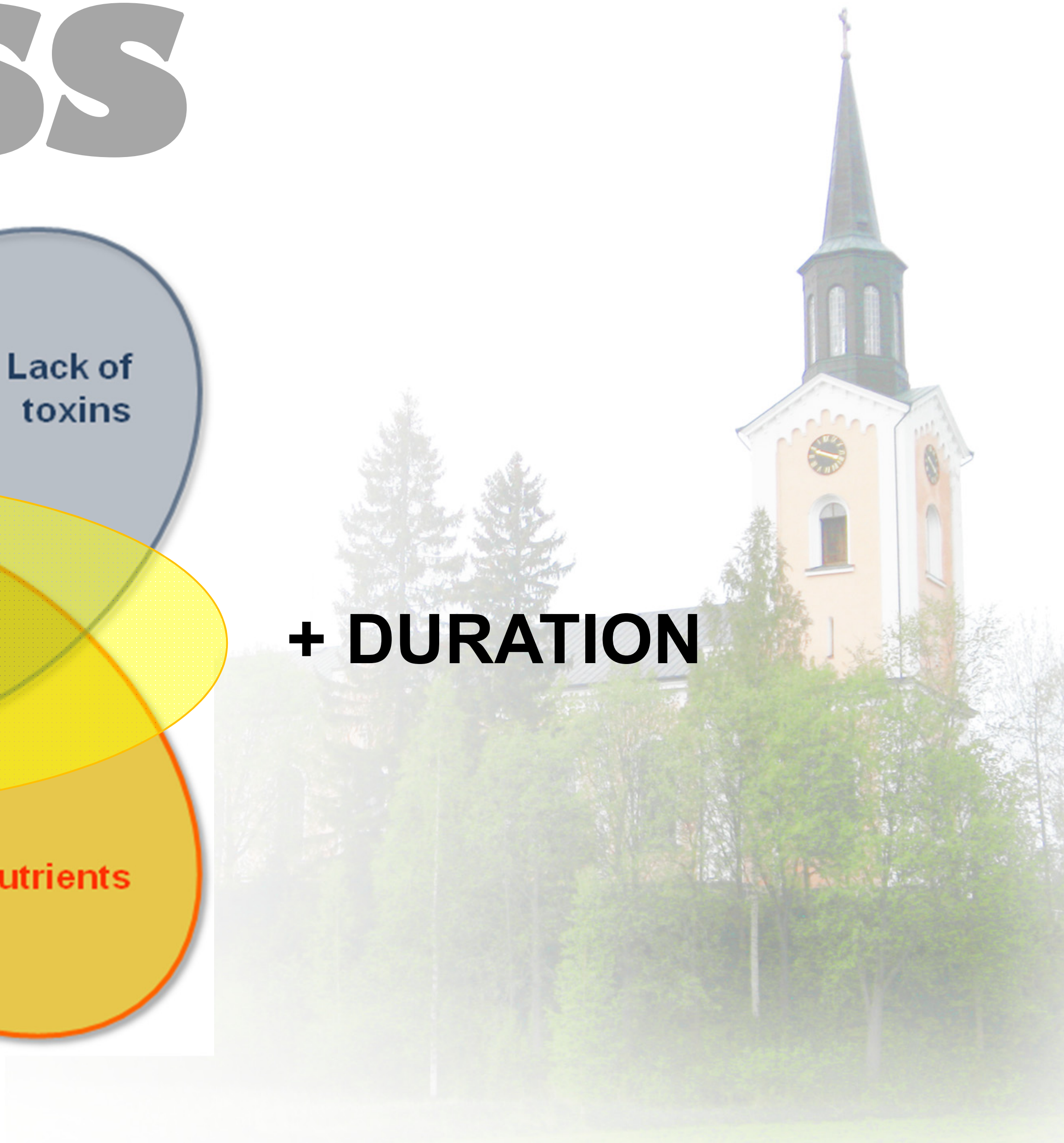
Ψ-values

PROCESS

MOULD RISK

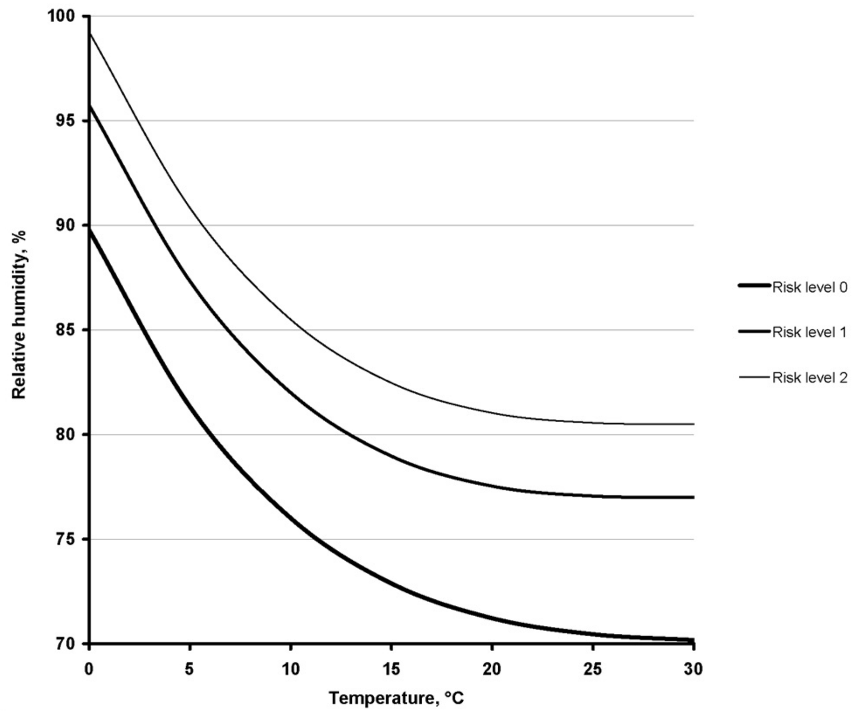


+ DURATION



PROCESS

MOULD RISK



$$mrc = \frac{RH_t}{RH_{mr1}} \quad for \quad RH_t \le RH_{mr1}$$

$$mrc = 1 + \frac{RH_t - RH_{mr1}}{RH_{mr2} - RH_{mr1}} \quad for \quad RH_{mr1} < RH_t \le RH_{mr2}$$

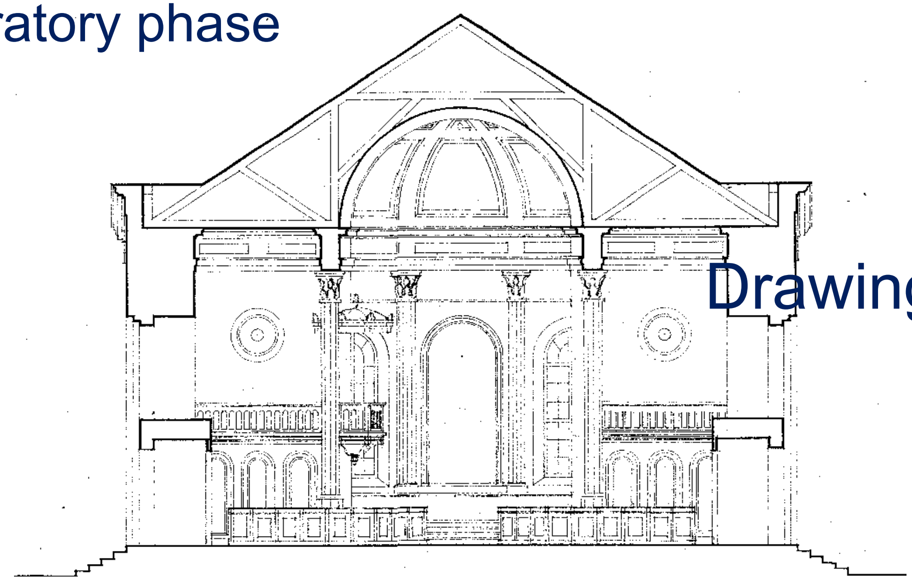
$$mrc = 2 + \frac{RH_t - RH_{mr2}}{RH_{mr3} - RH_{mr2}} \quad for \quad RH_{mr2} < RH_t \le RH_{mr3}$$

$$mrc = 3 + \frac{RH_t - RH_{mr3}}{1 - RH_{mr3}} \quad for \quad RH_{mr3} < RH_t$$

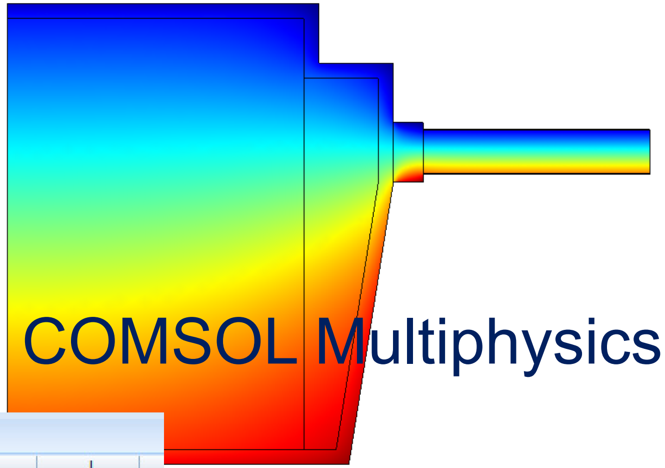
PROCESS

STEPS

a. Preparatory phase



Drawings



COMSOL Multiphysics

Measured values

Hamrange_091106-091113_Torun [Compatibility Mode]

	A	B	C	F	G	H	I	J	
1	Mätningar i Hamrånge kyrka 2009-11-06--1[illegible]res								
2			Time	Air, 0.6 m	Air, 1.1 m	Air, 1.6 m	Air, 2.2 m	Air, 3.0 m	Ai
3	2009-11-06	00:01:32	2009-11-06 00:01	11,812	12,057	12,192	12,198	12,286	
4	2009-11-06	00:03:32	2009-11-06 00:03	11,866	11,908	12,034	12,220	12,287	
5	2009-11-06	00:05:32	2009-11-06 00:05	11,760	11,856	12,025	12,155	12,276	
6	2009-11-06	00:07:32	2009-11-06 00:07	11,821	12,008	11,995	12,123	12,190	
7	2009-11-06	00:09:32	2009-11-06 00:09	11,899	11,937	12,114	12,141	12,195	
8	2009-11-06	00:11:32	2009-11-06 00:11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Present climatization strategies

Historical climatization strategies

PROCESS

STEPS

a. Preparatory phase: what does it deliver?

Data necessary for the building of both following whole building simulation models:

Measure series, outdoors and indoors

Existing installations and control strategies

Use, routines, schedules

Material data, component measures and build-up

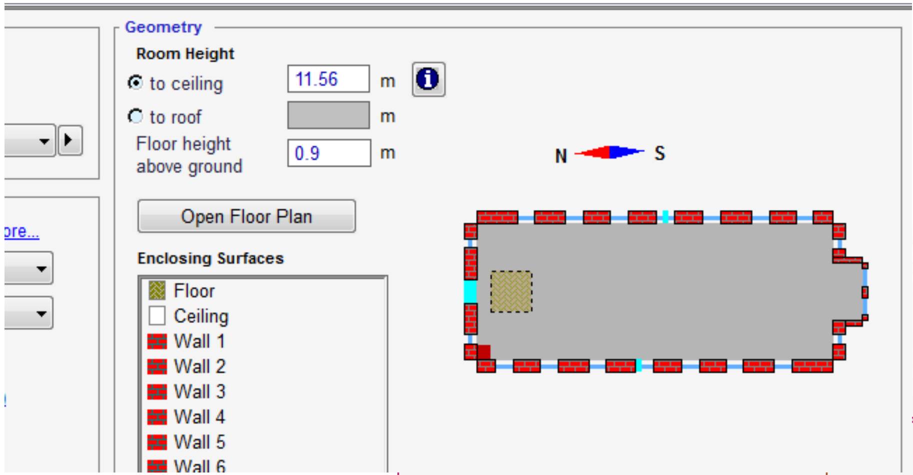
Geometry

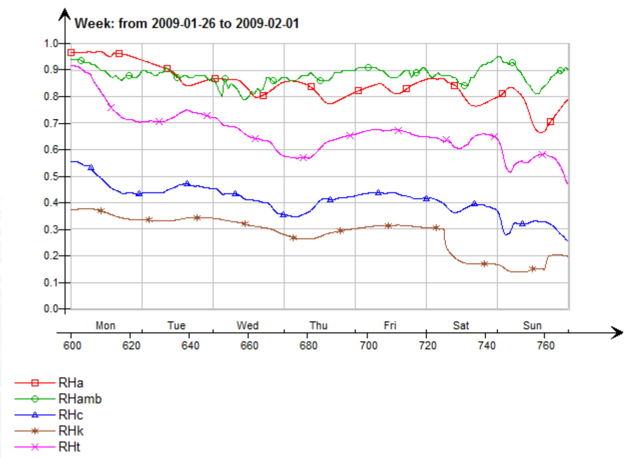
Behavior of thermal bridges

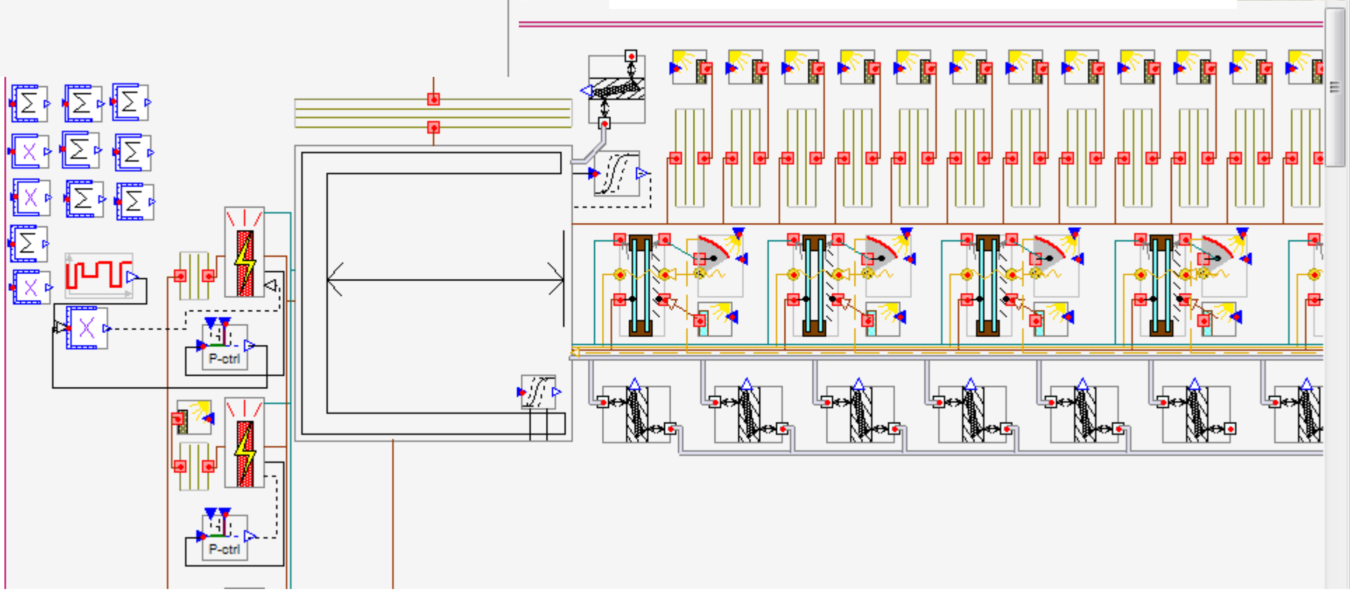
Inventory of problem and/or especially sensitive areas

PROCESS

b. Primary simulation







STEPS

IDA-ICE

PROCESS

b. Primary simulation – what does it deliver?

Results on:

Energy and exergy usage

Temperatures

Air flows

IAQ, Fanger’s comfort indexes

Indata for the following secondary step:

Temperatures

Heat flows

Air flows

STEPS

PROCESS

c. Recalculating simulation

```
File   Edit   Format   View   Help
// Moira node configuration file
//
// Nodes having data from processes rather than nodes must be processed _after_
// all other nodes. If two nodes are circular bound together, the order of which
// they appear here in this file, will be in the order they will be processed.
// This particulary happens to Zone nodes.

//Component nodes

//KW1

[node]
//0
nodename = KW1exts
processtype = p2
a = AMB
c = KW1n1
IDA1 = KW1exts

[node]
//1
nodename = KW1n1
processtype = p3
a = KW1exts
c = KW1n2

[node]
//2
nodename = KW1n2
processtype = p4
a = KW1n1
c = KW1n3
```

```
Start (time): 1297040039
Initializing IDA-data structures...Done.
Counting timesteps...done.
90313 timesteps found.
Read 203 nodes.
Linking nodes...done.
Checking nodes...Done.
Loading nodes...Initializing NODE-data time step 0...done.
Processing timestep...100%. Done.
Processed 90313 timesteps. Done.

Start (time): 1297040039
Stop (time):  1297040061
```

MOIRA

MOIsture Recalculation Application

STEPS

PROCESS

c. Recalculating simulation – what does it do?

Recalculates the previous whole building simulation with addition of moisture performance while keeping the useful results from it and making use of its structure and solving of flexibility related issues

Analyses the outcome in the form of risk assessment curves

Allows for the addition of moisture sources and dehumidifying devices

Contains several simplifications, for instance are temperature effects of condensation and evaporation not taken into consideration

Includes diffusive and capillary flows as well as suction of ground moisture

STEPS

CASE STUDY

Hamrånge Church

Church hall 8750 m^3, crawl space 600 m^3

Electric radiators in nave, set points:

2009 – weekdays 12 ºC, weekend 20 ºC

2010 – weekdays 11 ºC, weekend 19 ºC

CASE

CASE STUDY

Hamrånge Church

CASE

4 scenarios:

Sc 1	Status quo, crawl space vents open
Sc 2	Crawl space vents closed
Sc 3	Crawl space vents closed first half of the year, open second half
Sc 4	Crawl space vents closed, plus dehumidifier

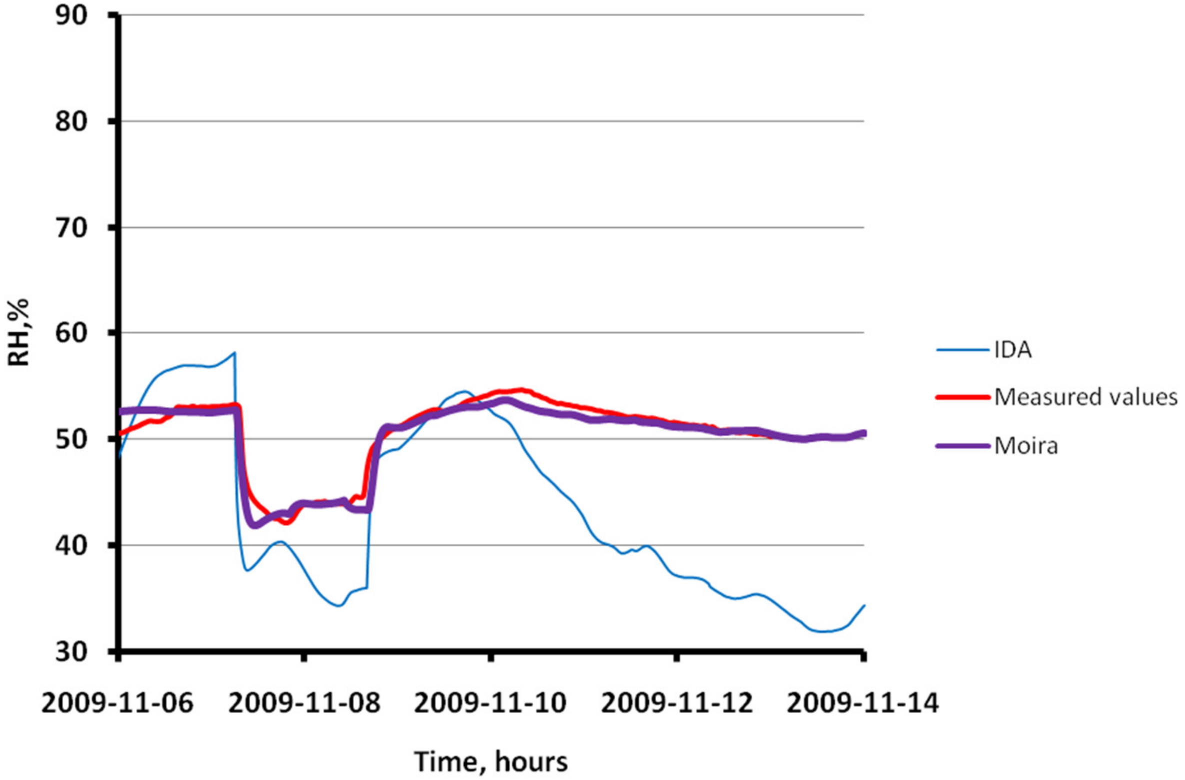
Results, energy usage:

Sc 1	132 MWh	± 0 %
Sc 2	129 MWh	- 2,3 %
Sc 3	130 MWh	- 1,5 %
Sc 4	141 MWh	+ 6,8 %

CASE STUDY

CHURCH HALL

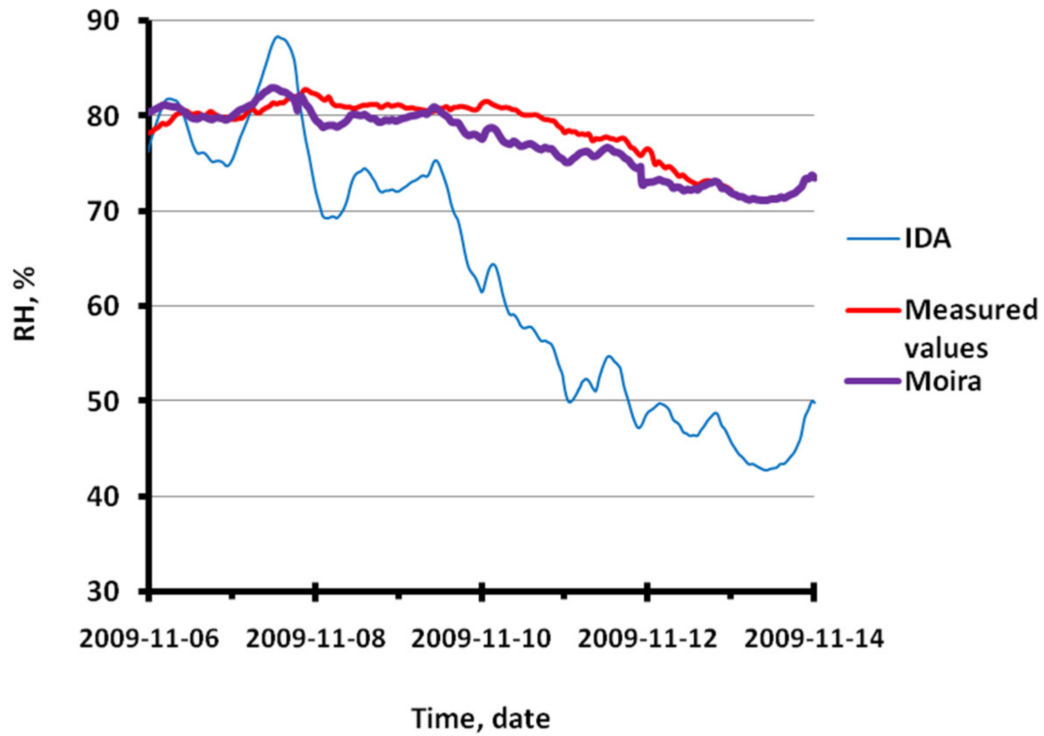
Hamrånge Church

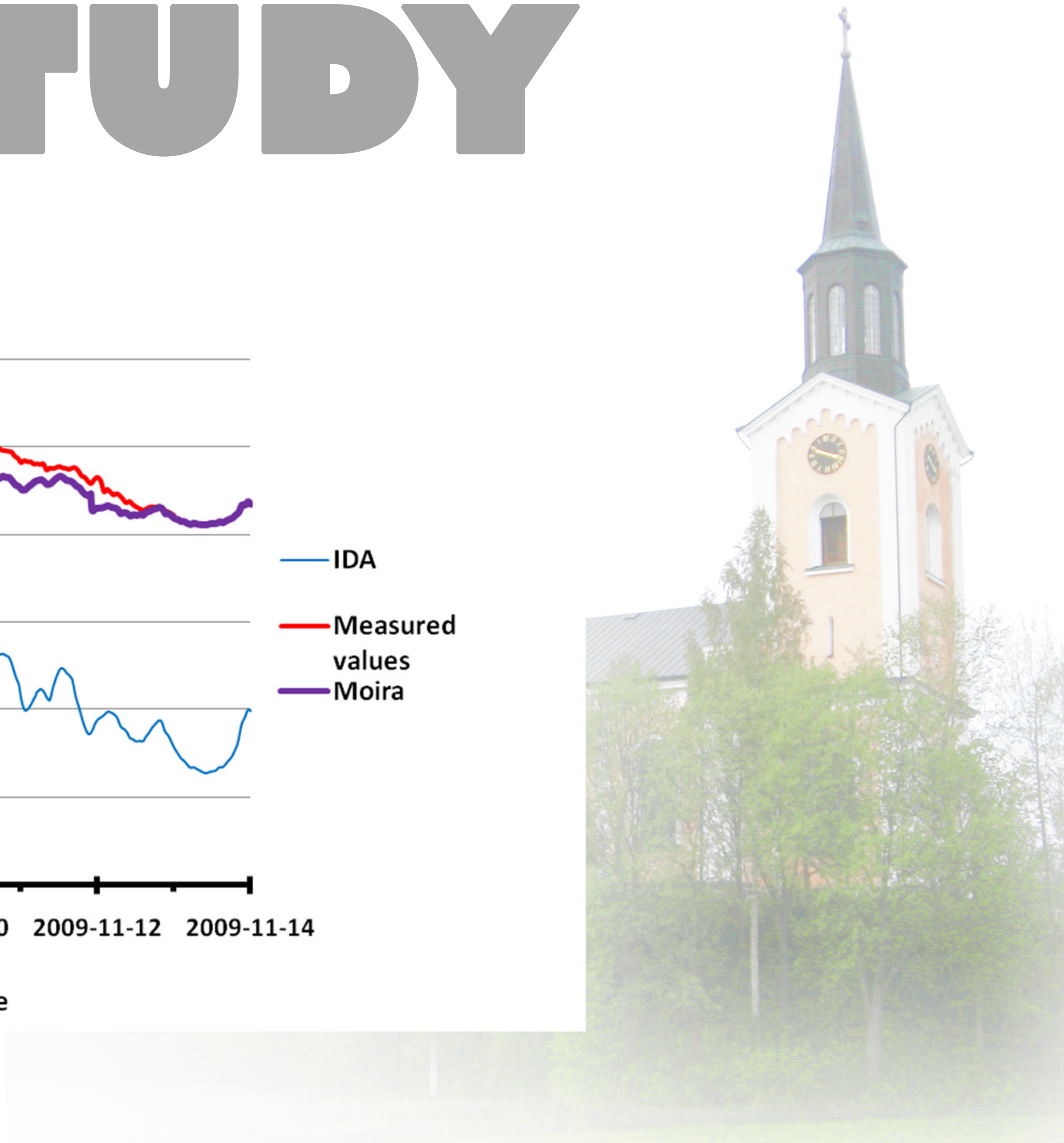


CASE STUDY

CRAWL SPACE

Hamrånge Church

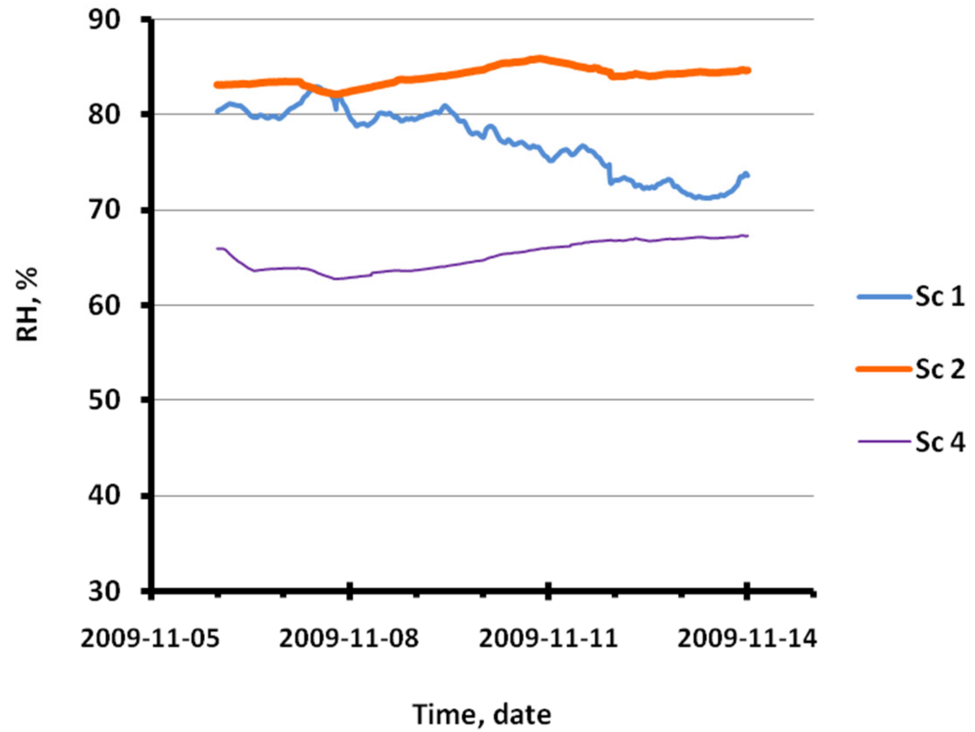




CASE STUDY

CRAWL SPACE

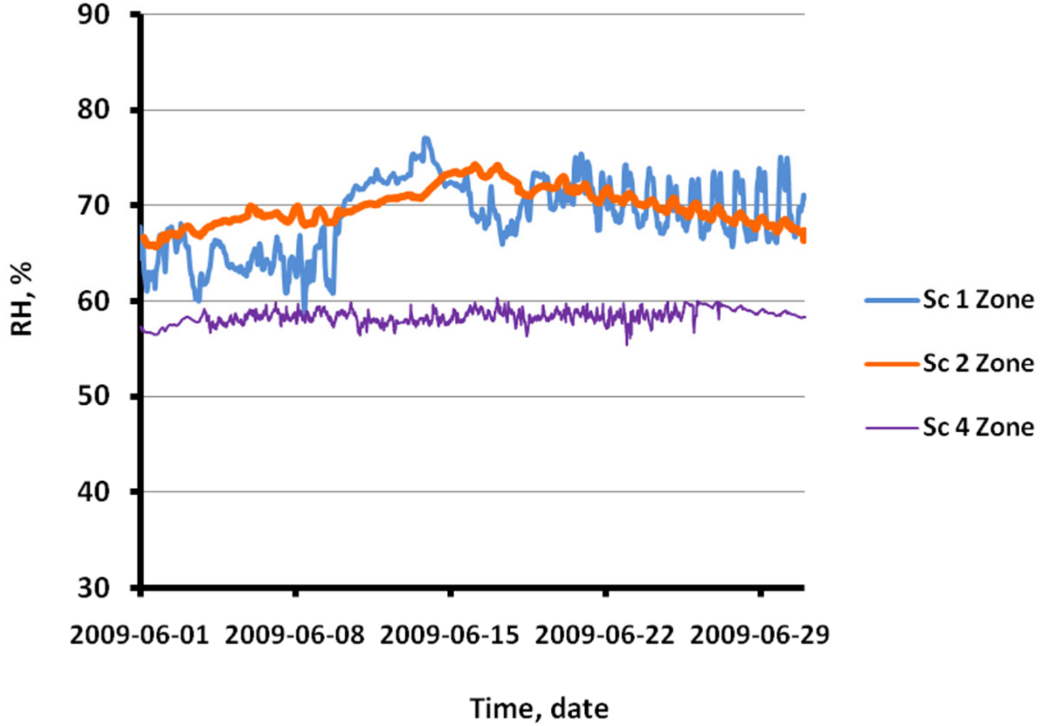
Hamrånge Church

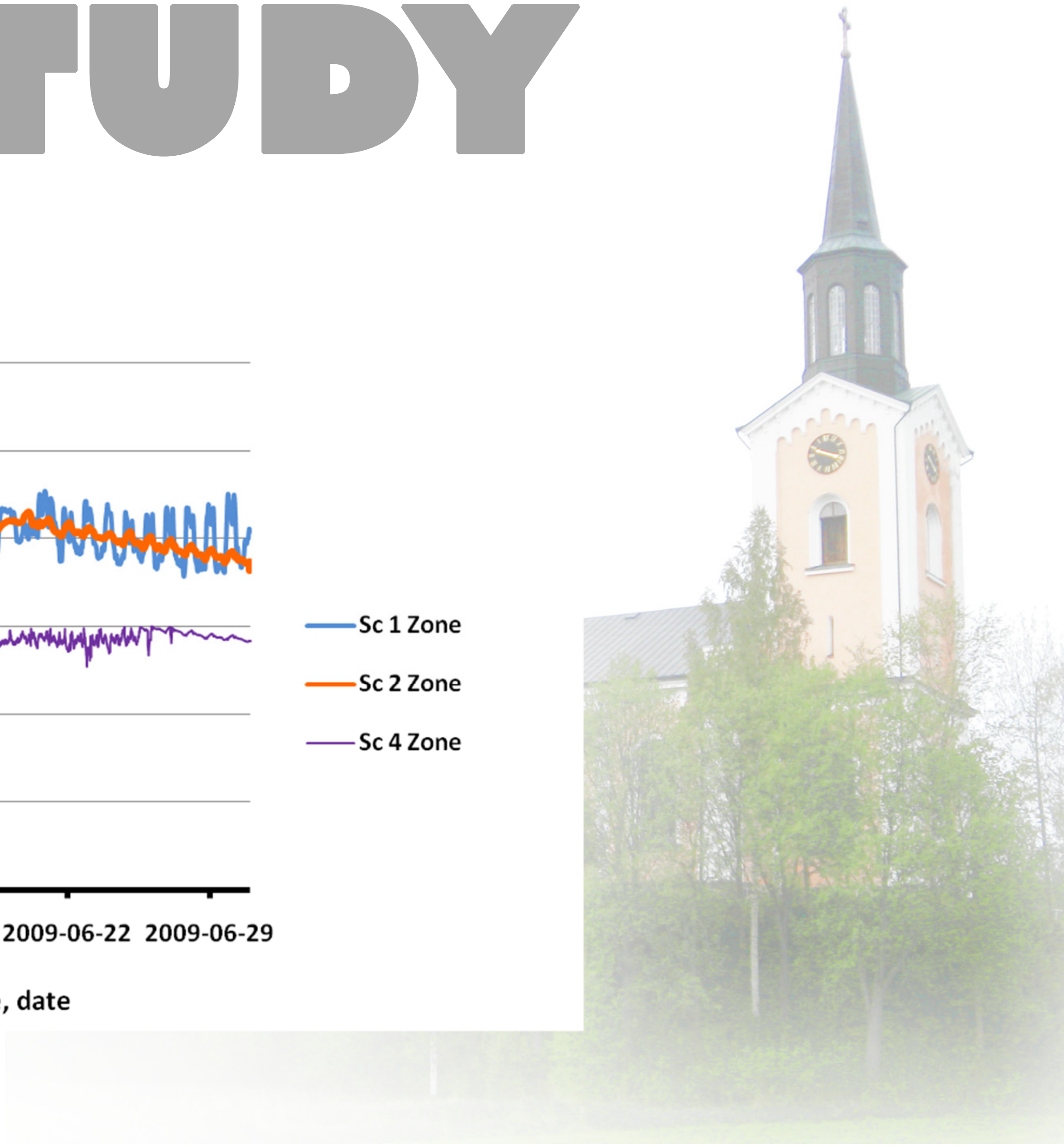


CASE STUDY

Hamrånge Church

CRAWL SPACE

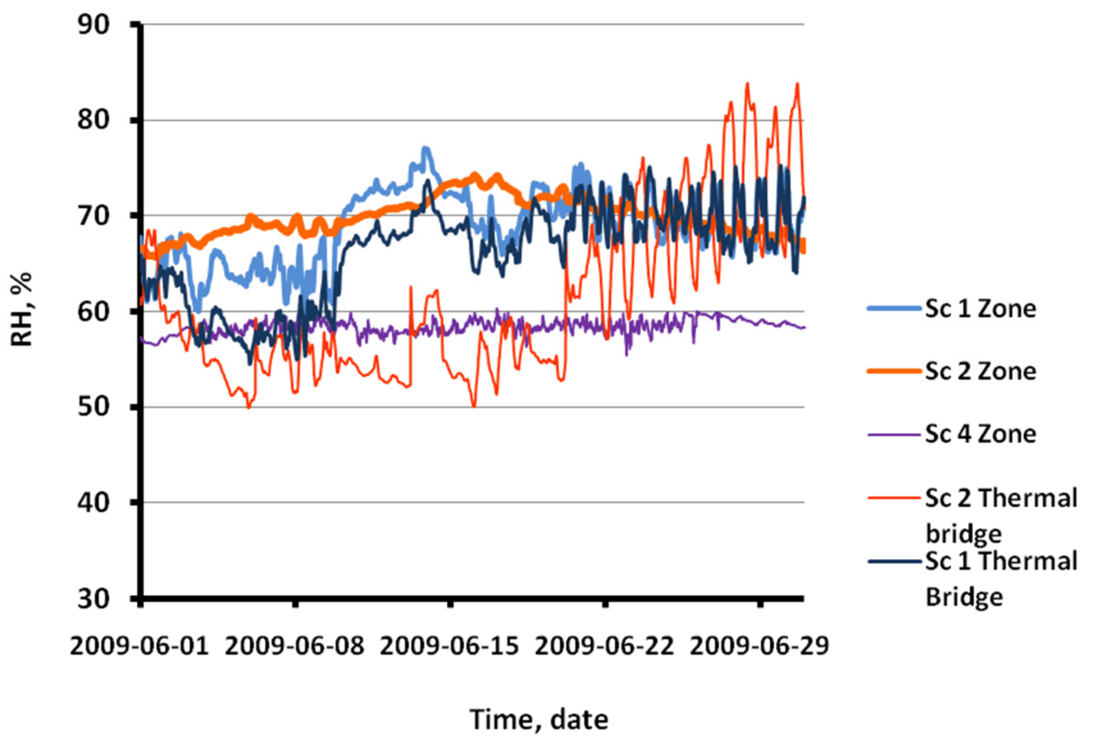




CASE STUDY

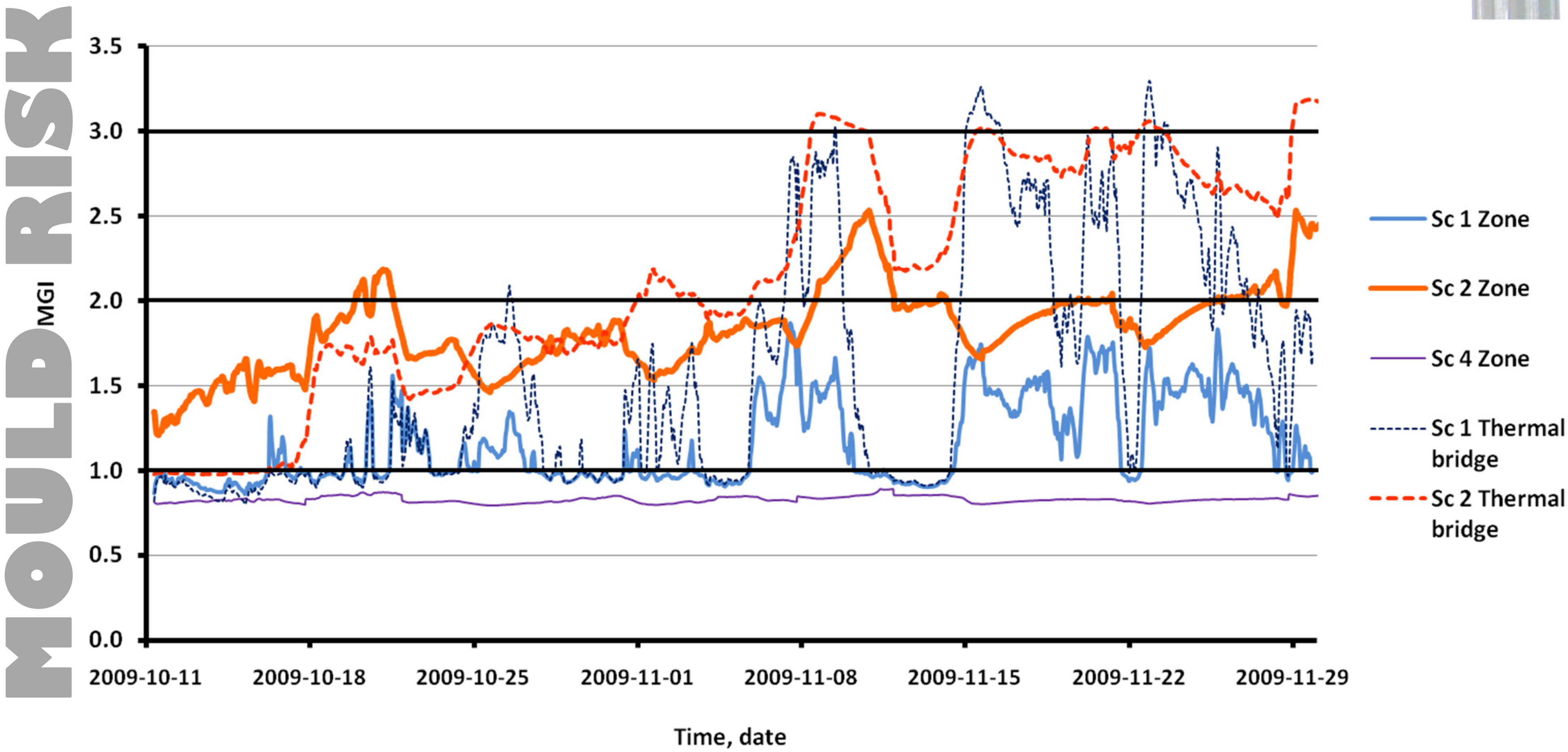
Hamrånge Church

CRAWL SPACE



CASE STUDY

Hamrånge Church



CONCLUSIONS

Conclusions

Different kinds of historic buildings need different kinds of tools and methods to be properly assessed

Simulations need to be whole-building and take risk prone points into account

The simulation method must be able to include potential strategies

Measuring is necessary to calibrate the simulation model and make the results reliable

Damage risk assessment should be included

Moisture, being one of the most important factors in damaging processes, needs to be taken into consideration

Thank you for your attention

We also thank the Swedish Energy Agency for the funding of the project