Hygrothermal Analysis for Retrofit Design

Presented by:

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How to address Energy Efficiency using Building Science

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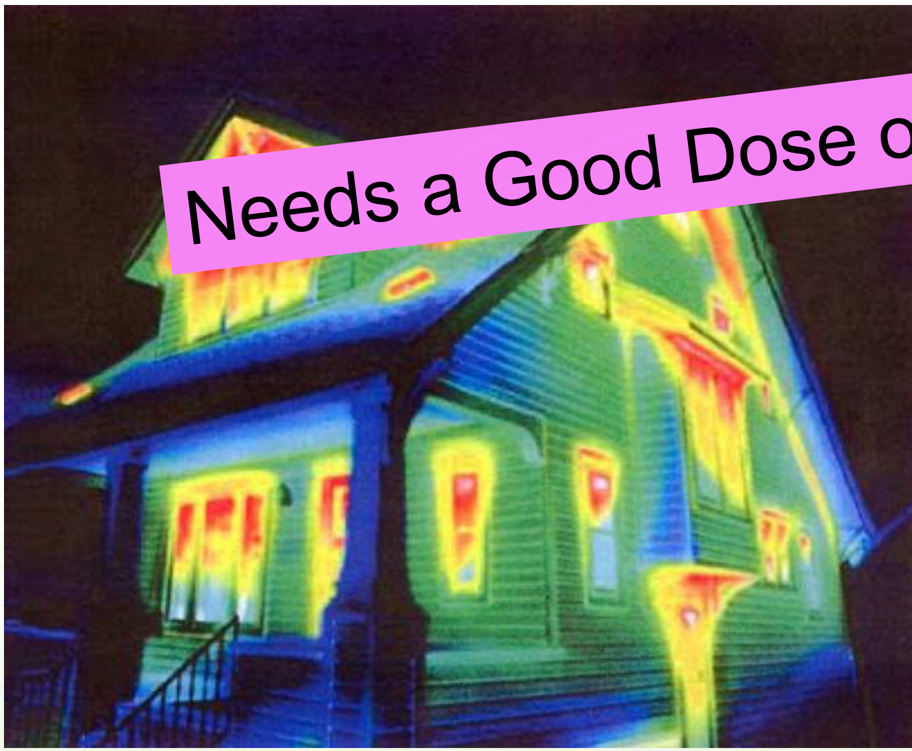
Why is Retrofit Different ?

- Retrofit Challenges
- Diversity of Retrofit Issues
- Tools and Current Information
- Methodology and Solutions (2-examples)
- IEA Annex 55
- Conclusions

Retrofit here ? What do you think ?

Needs a Good Dose of Building Science



Infrared Thermography

Past Approach

Trial and Error

Attention to Detail
but
Little Building Science

Worked until:

- Enhanced Comfort Requirements
- Energy Conservation
- Material started to Change

What is different with RETROFIT?

- Limited past knowledge
- One solution does not fits all (Envelope + Climate)
- Client is different not Builder but owner/contractor
- Level of Building Science Understanding (lower)
- Workmanship/crew is different
- Environmental loading will change
- Easy and difficult retrofits, wide range of challenges
- More unknowns …. Larger risk for failures
- More Economics based

European Prospective

Sweden, Finland, and Norway started major retrofit activities 1986 to now

- Moisture problems
- Indoor air quality (health implications)
- Durability

Germany, Belgium

- Same IAQ, Moisture Issues
- Not achieving retrofit performance

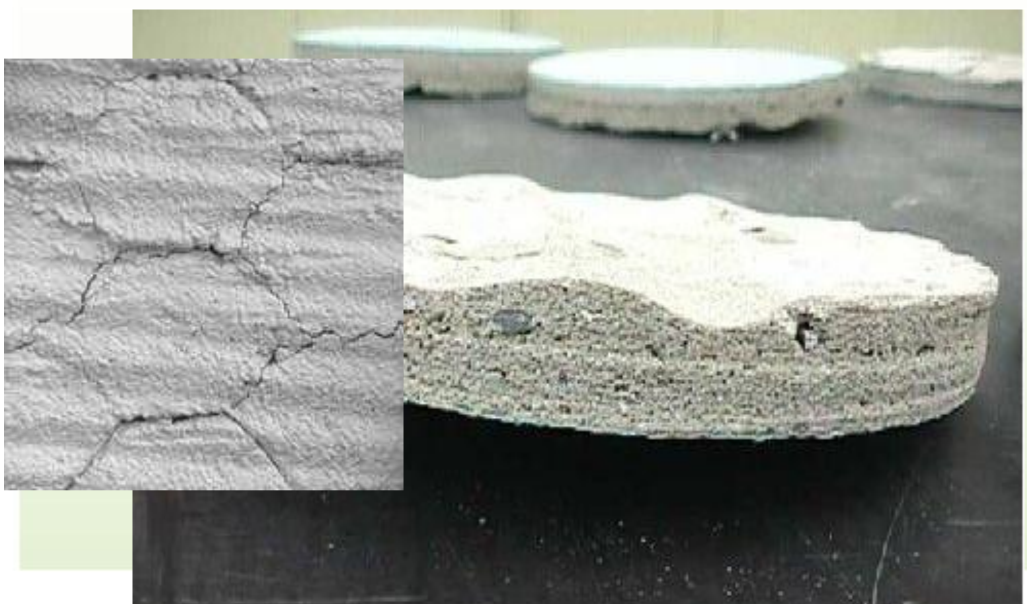
Unknowns in RETROFIT

- Envelope Assembly unknown (NO MANUAL yet)
- Prime properties (Trouble with new, near impossible with old data)
- Aging of materials (Mortars, WRB, paints, plasters..)
- Initial Conditions
- Sub-systems ?

Wood has Changed

What used to be ?

Stucco has changed



Building Papers have changed

Additional Unknowns

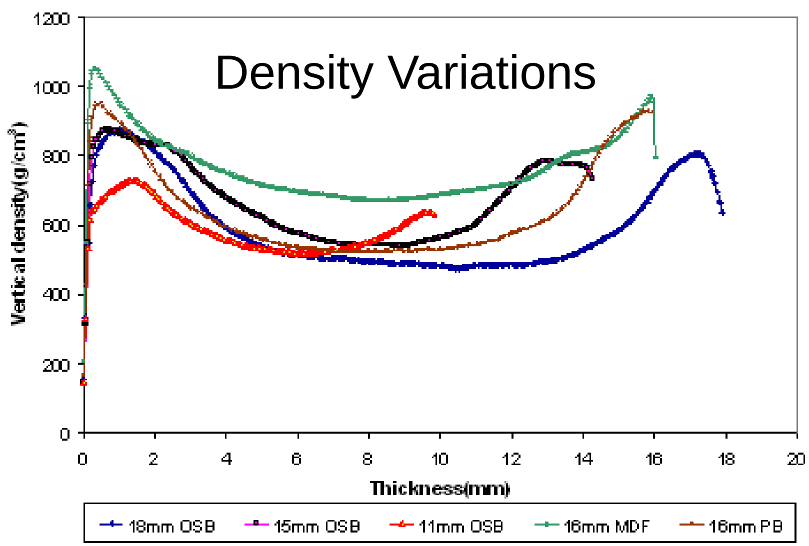
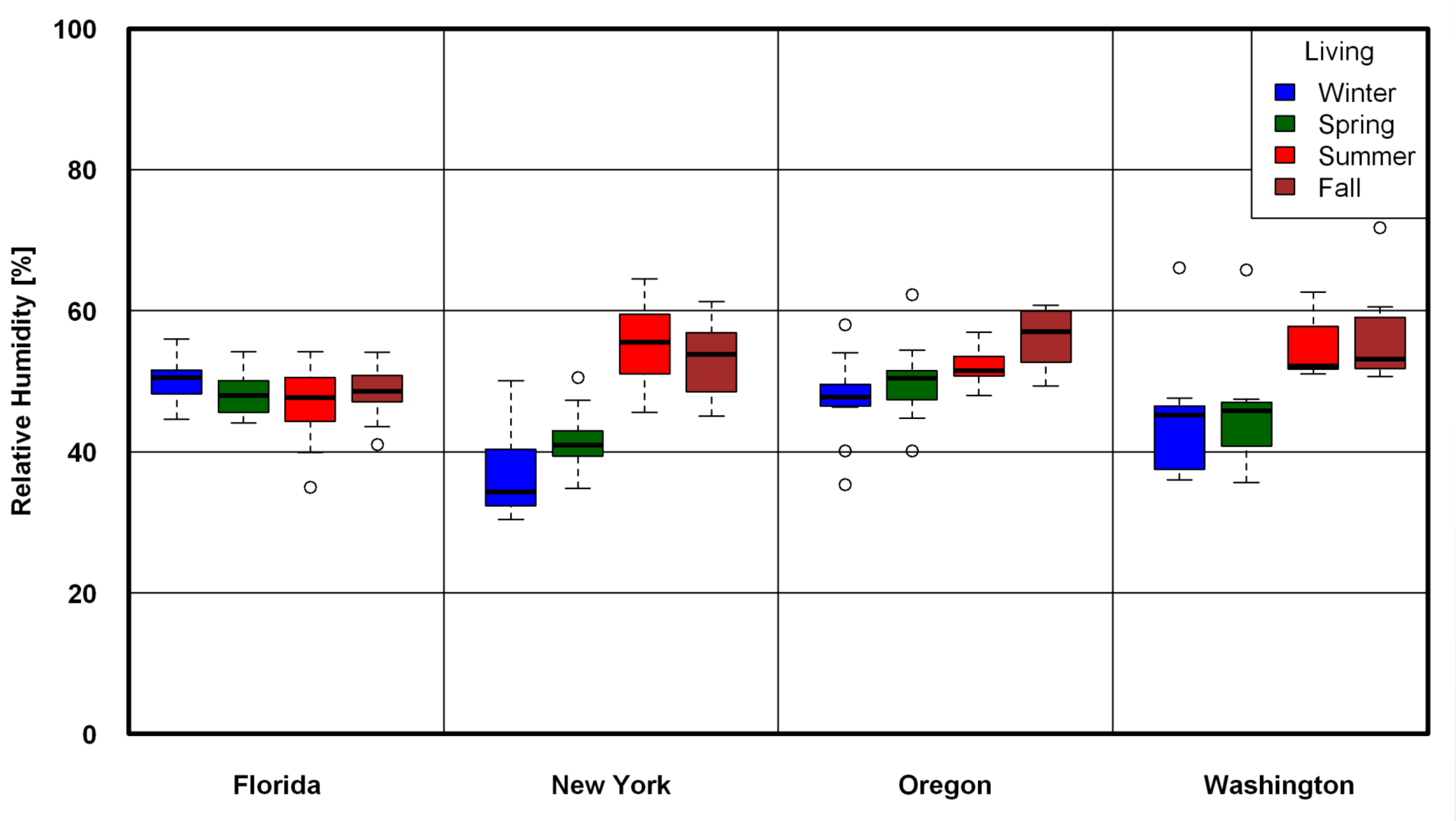


Figure 4. Vertical density profiles of specimens scanned by X-ray QMS Density Profiler.

Interior Loads based on Climate

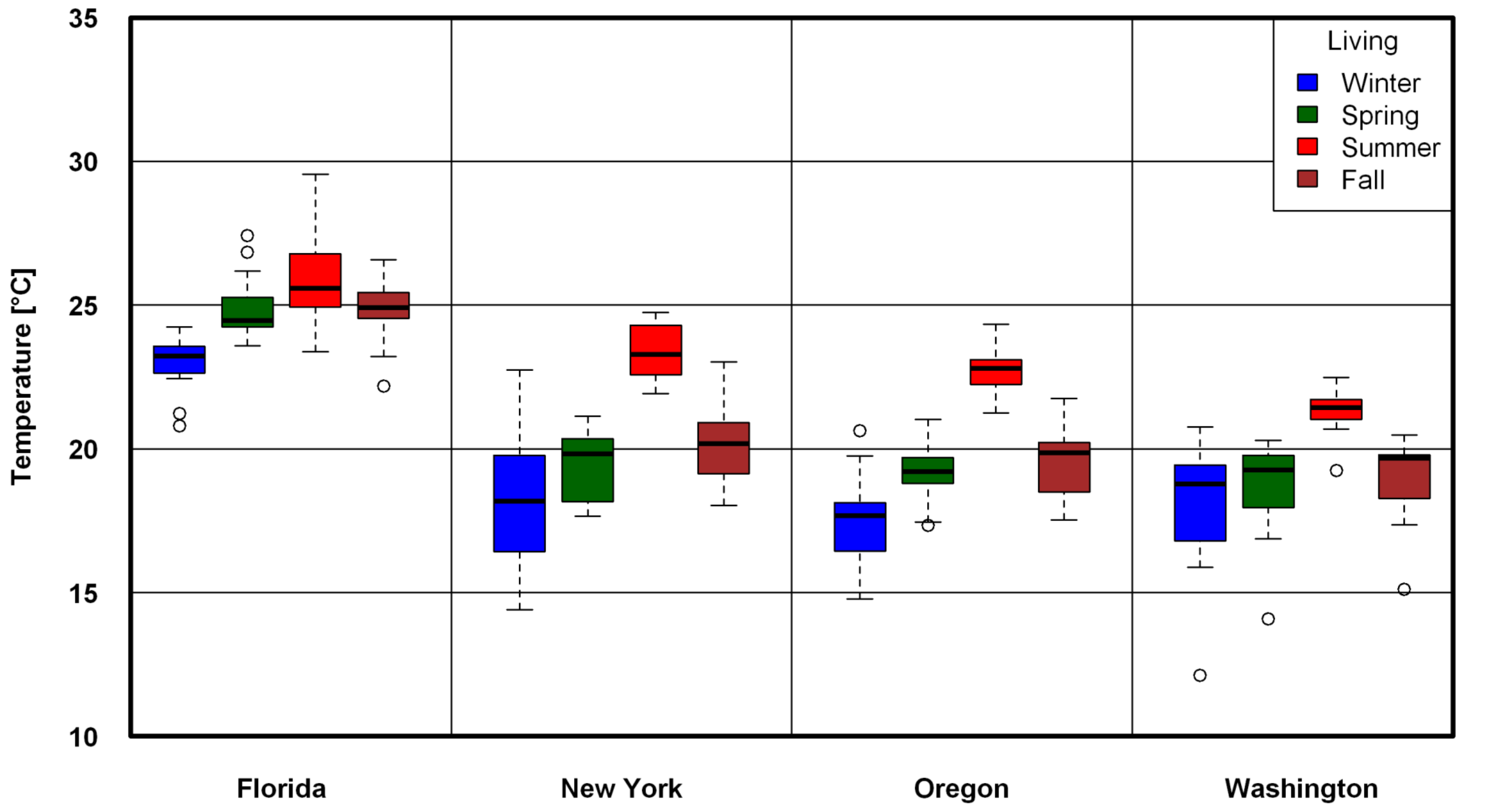
Variations in time and location



HUD/Steven Winters/ORNL

Interior Loads based on Climate

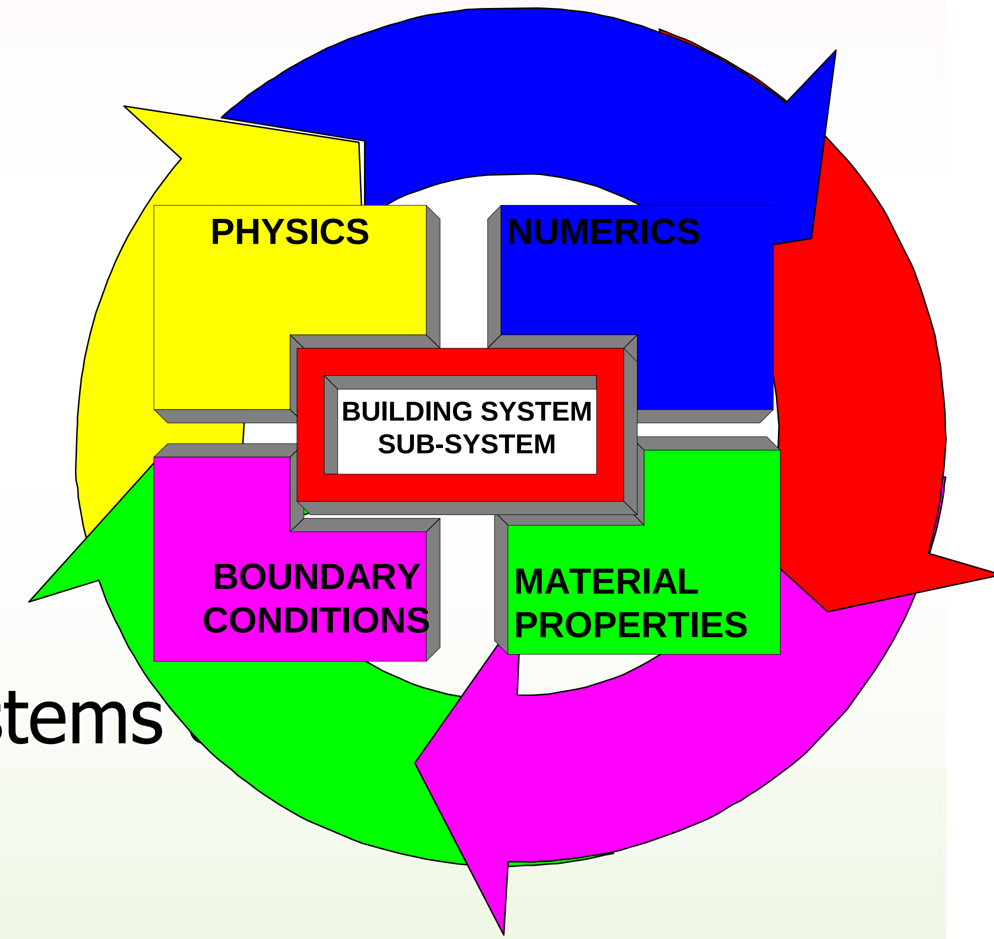
Variations in time and location



HUD/Steven Winters/ORNL

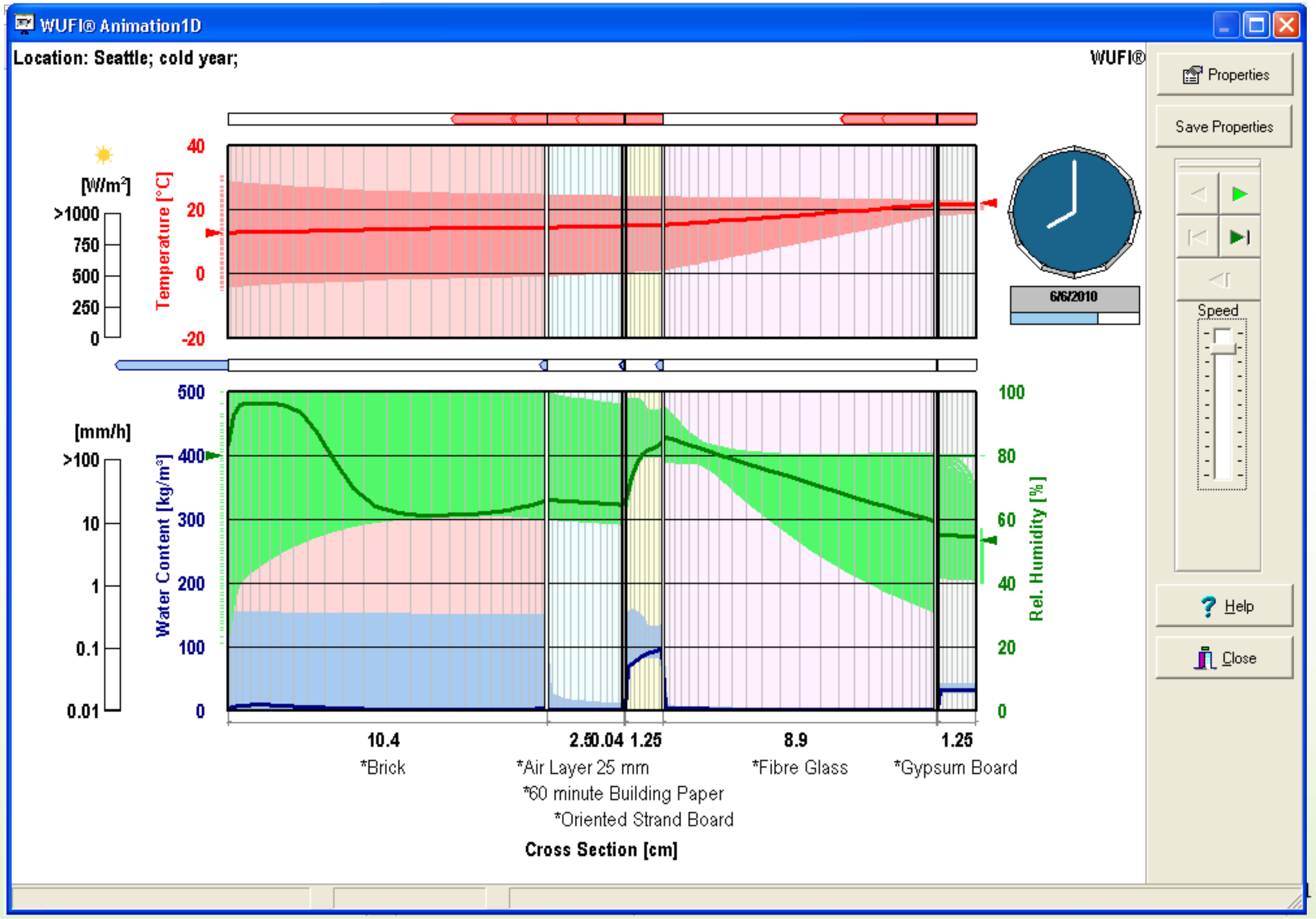
Building Science Approach

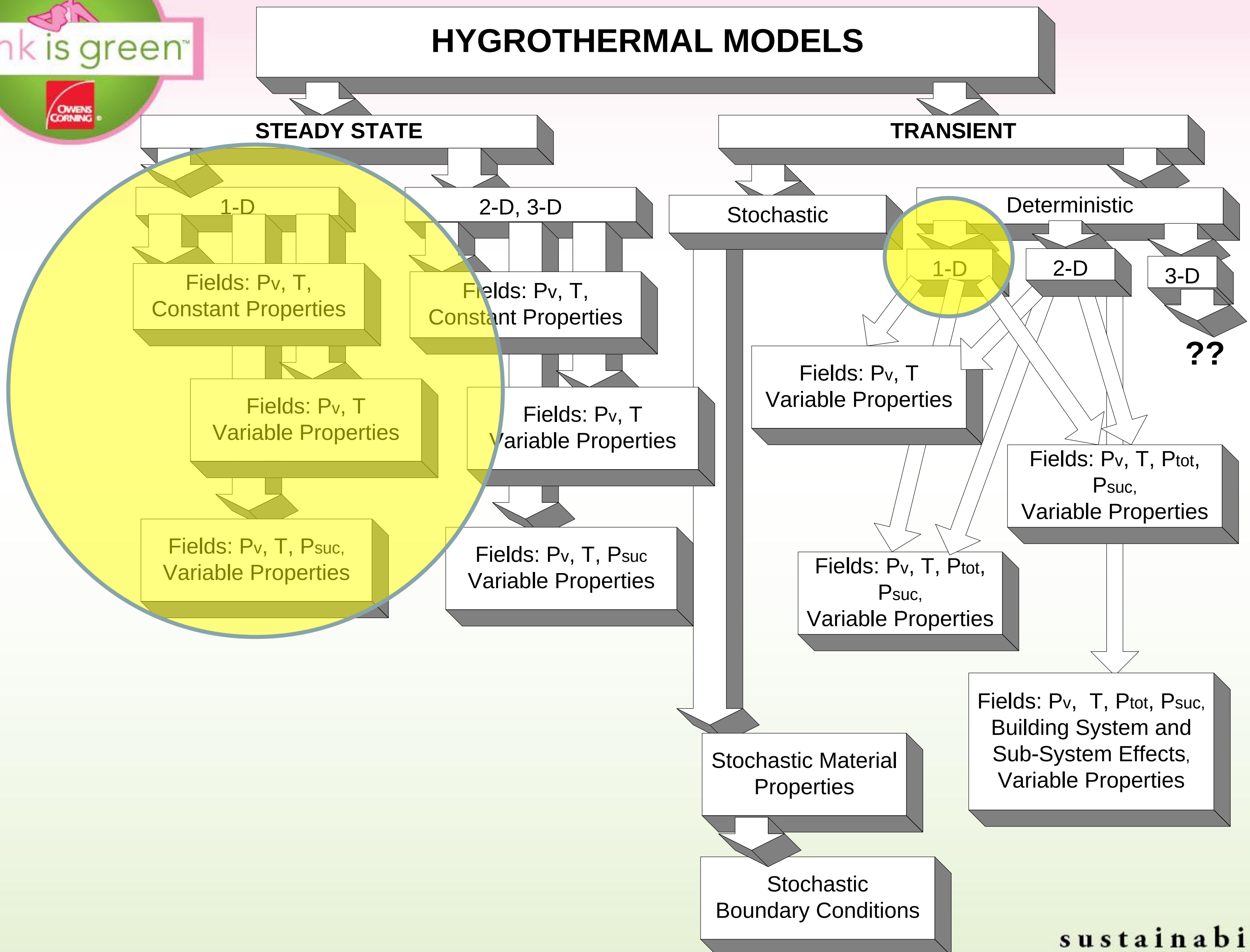
- Define Physics
- Define Load Inputs
- Define Material
- Define Construction Systems
  Sub-Systems



Moisture Design- Deterministic Tool

Use Standard ASHRAE 160 *(Criteria for Moisture-Control Design Analysis in Buildings)*

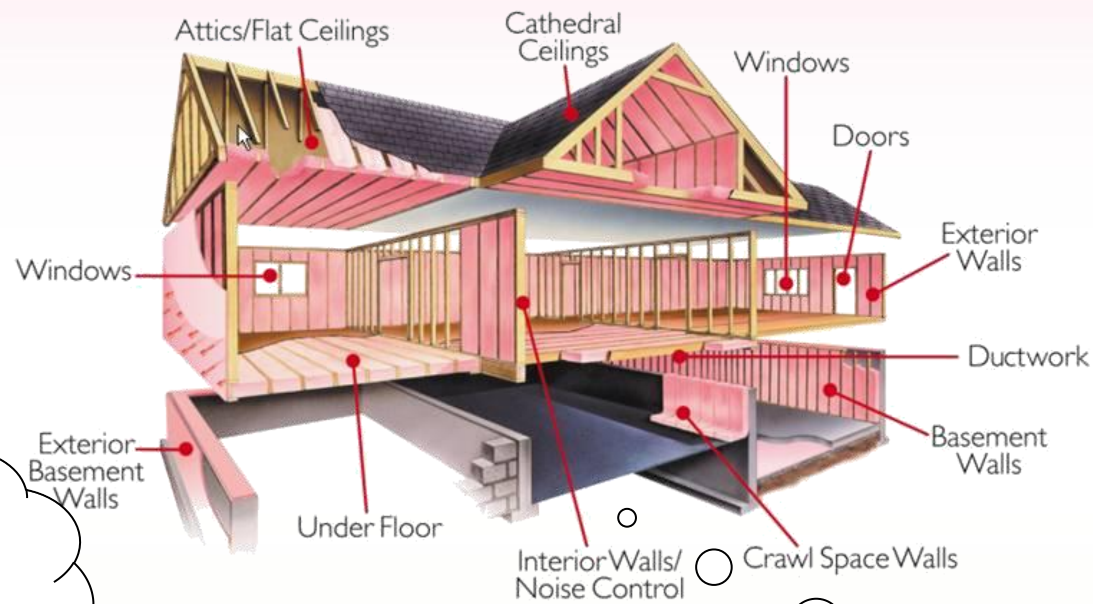



HYGROTHERMAL MODELS
STEADY STATE
TRANSIENT
1-D
2-D, 3-D
Stochastic
Deterministic
1-D
2-D
3-D
??
Fields: P_v, T, Constant Properties
Fields: P_v, T, Constant Properties
Fields: P_v, T Variable Properties
Fields: P_v, T Variable Properties
Fields: P_{v}, T, P_{suc}, Variable Properties
Fields: P_v, T, P_{suc} Variable Properties
Fields: P_v, T Variable Properties
Fields: P_v, T, P_{tot}, P_{suc}, Variable Properties
Fields: P_v, T, P_{tot}, P_{suc}, Variable Properties
Fields: P_v, T, P_{tot}, P_{suc}, Building System and Sub-System Effects, Variable Properties
Stochastic Material Properties
Stochastic Boundary Conditions

Inquiring Minds Want to Know…

What is **MOST** Economical?

What is more important to improve my home first?



How does our home compare to an energy-efficient home?

Will my house be healthy and durable ??

How long will it take to re-coup my investment?

Risks

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Two recent examples: replaced FG with other insulation systems

- Use of spray foam to seal and insulate wall with higher R-value in Northwest Pacific

- Use of wet spray cellulose in Cold Climate (Michigan)

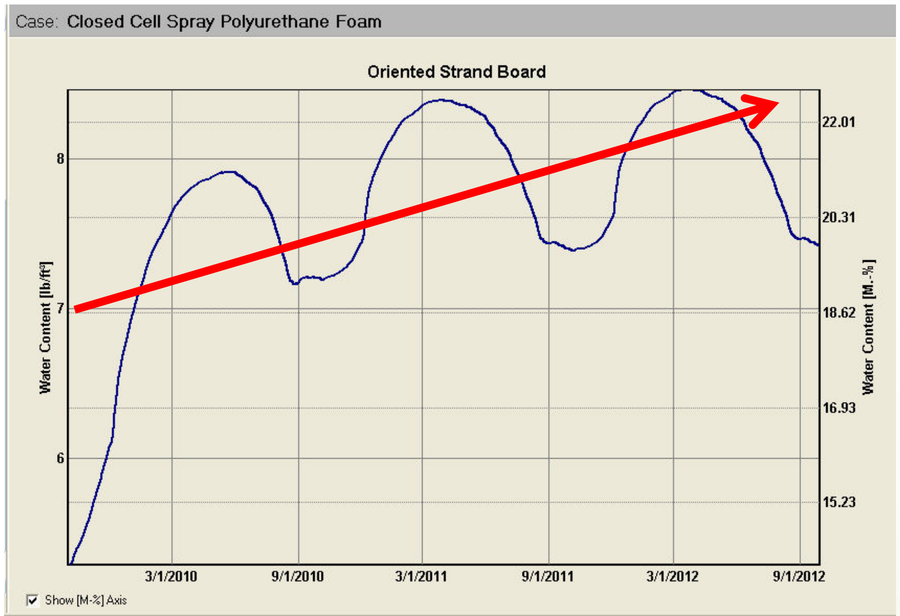
Using standard construction approach

Attend the XI Thermal Conference for more details (Both cases have experimental field Data)

Use of Closed Cell Spray Foam (Northwest)

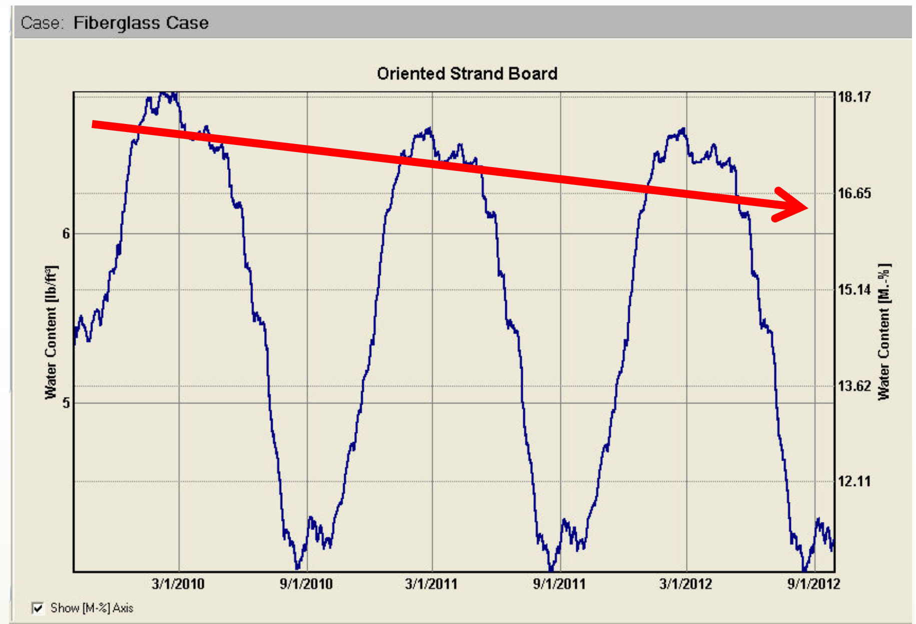
Stucco Cladding, 2 Bldg Paper 60 min, OSB, Closed Cell, GYP, 10 Perm Paint

Net Accumulation with time



3 Years of Analysis

Net Drying with time



3 Years of Analysis

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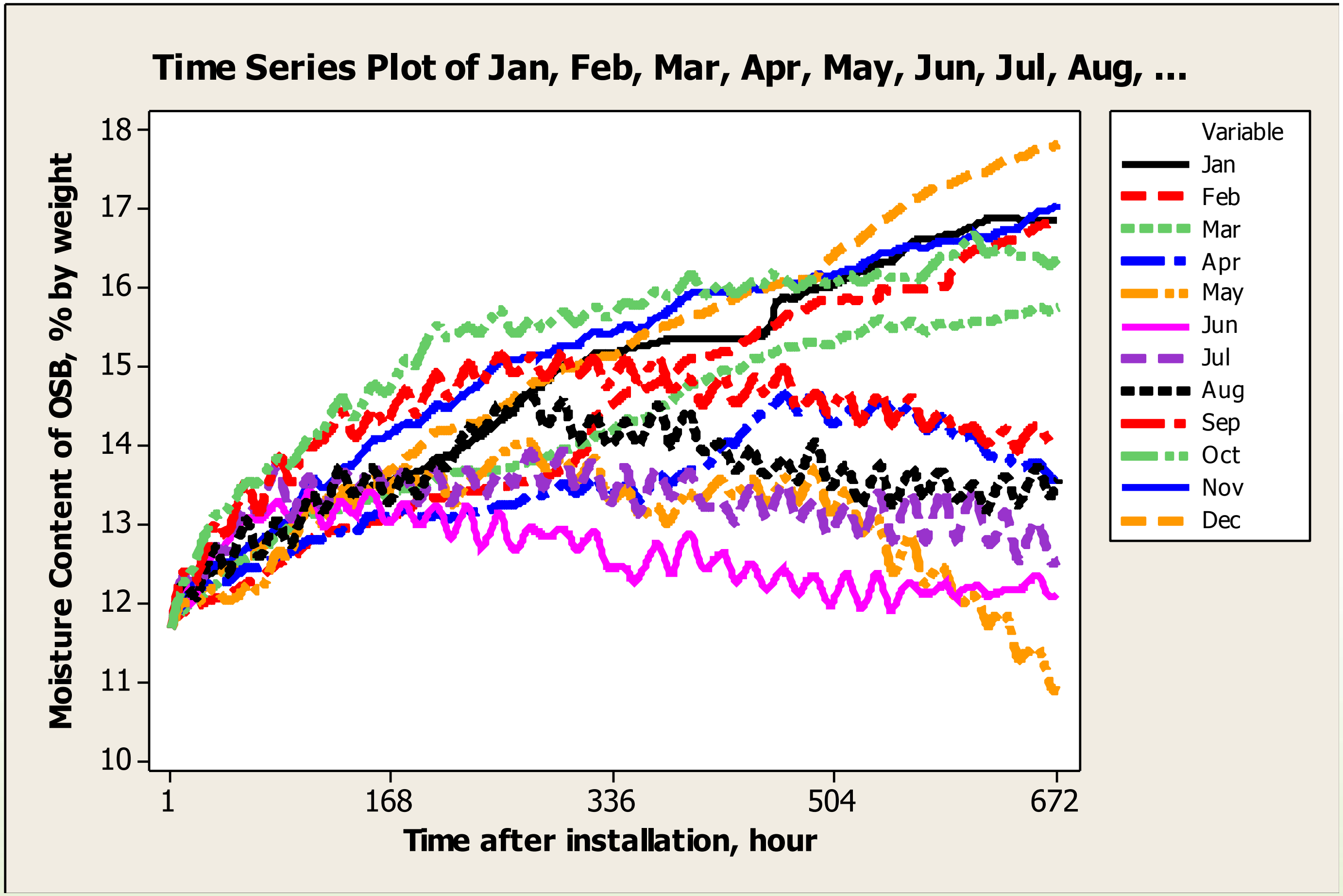
- **Use of Blown Cellulose (Cold-Climate) 40 % by mass (2.5 lb/ft3)**

Hygrothermal Performance

Retrofit Risk of Initial Conditions



Detroit Michigan

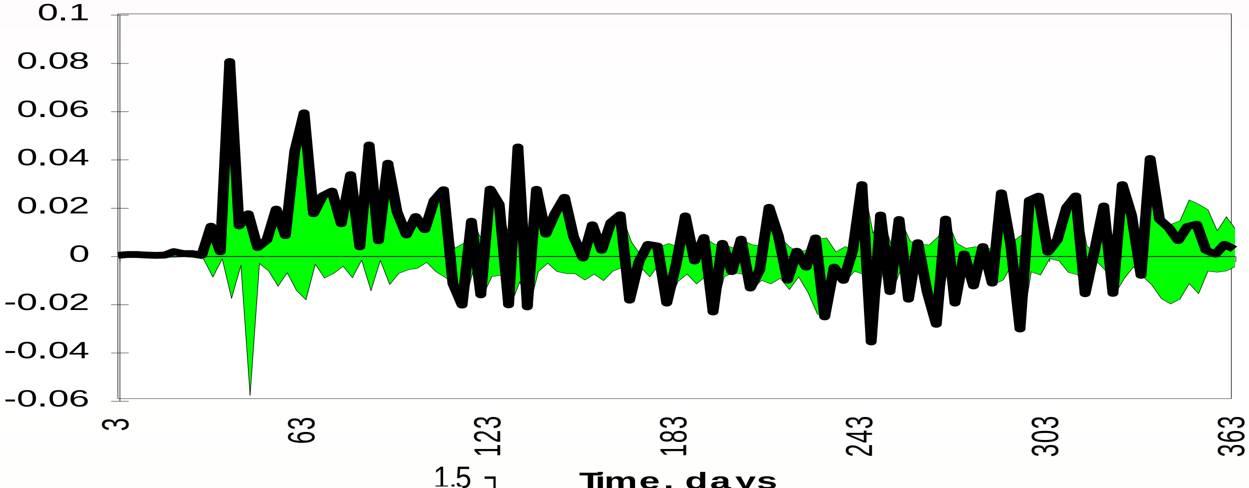
What Retrofit Analysis Needs

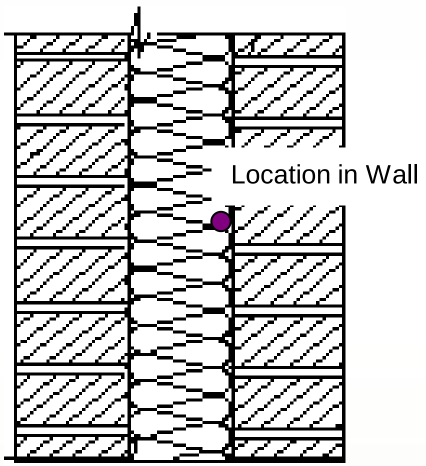
- Load based analysis
- Move from deterministic to probabilistic

NEW IEA Annex

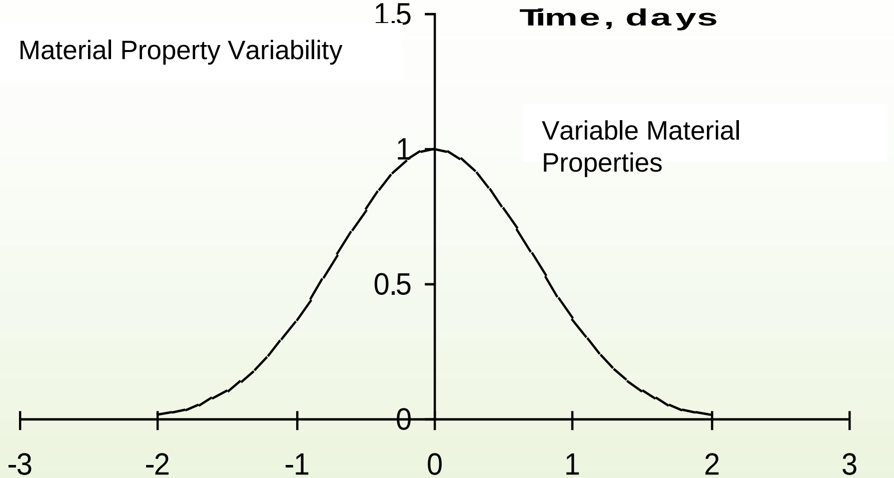
Stochastic Approach

Stochastic runs: +/- 40%





Material Property Variability



Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO)

The RAP-RETRO ***mission*** is to answer the following question:

How do we design and realize robust retrofitting with low energy demand and life cycle costs, while controlling risk levels for performance failure?

Start: Spring 2010 (4 years in total)

International Energy Agency
Energy Conservation in Buildings and Community Systems (ECBCS)

Carl-Eric Hagentoft

Improving the energy efficiency is often the main focus. (40 to 60 % space heating and cooling)

Adding insulation and improving the air and vapor tightness results in a different building envelope.

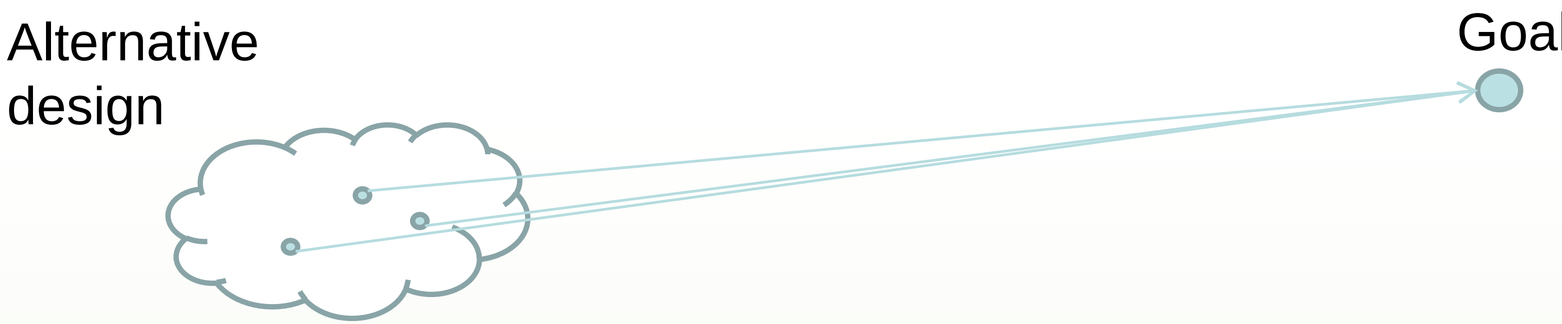
Complex interaction between building envelope, building services, external climate and the users.

As a result retrofitting measures not only often do not meet the energy targets; they also result in performance failures.

Difficult to design for 100% safety!

We can not double the thickness of the beam as in structural engineering!

Deterministic approach

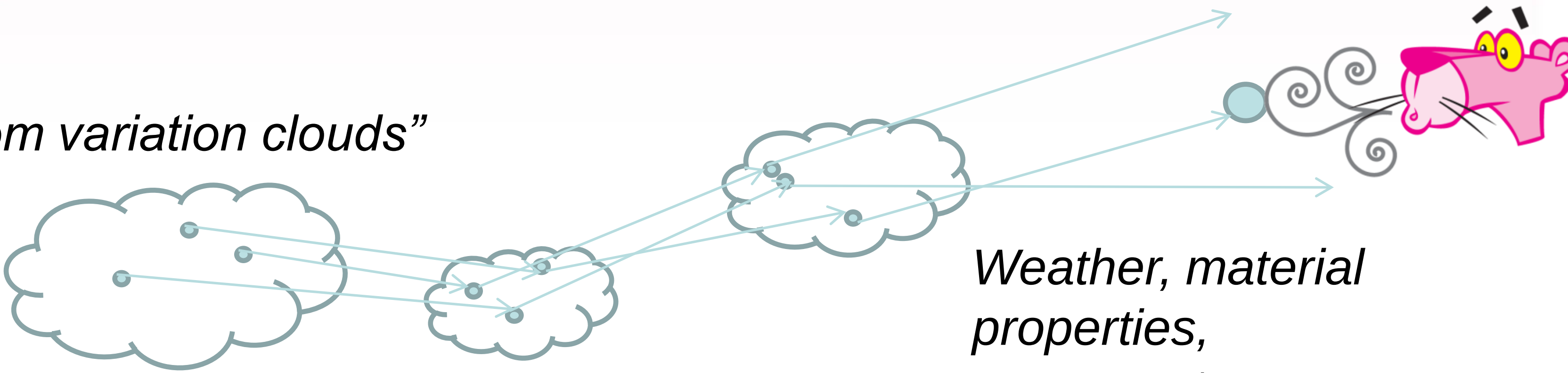


(Except if we accept poor energy efficiency!)

We must design as safe as possible – accounting for the all uncertainties and for what could happen!

Probabilistic approach

“Random variation clouds”



Construction
Retrofit

Maintenance
operation

Weather, material properties, exposure to spores, human behavior,…

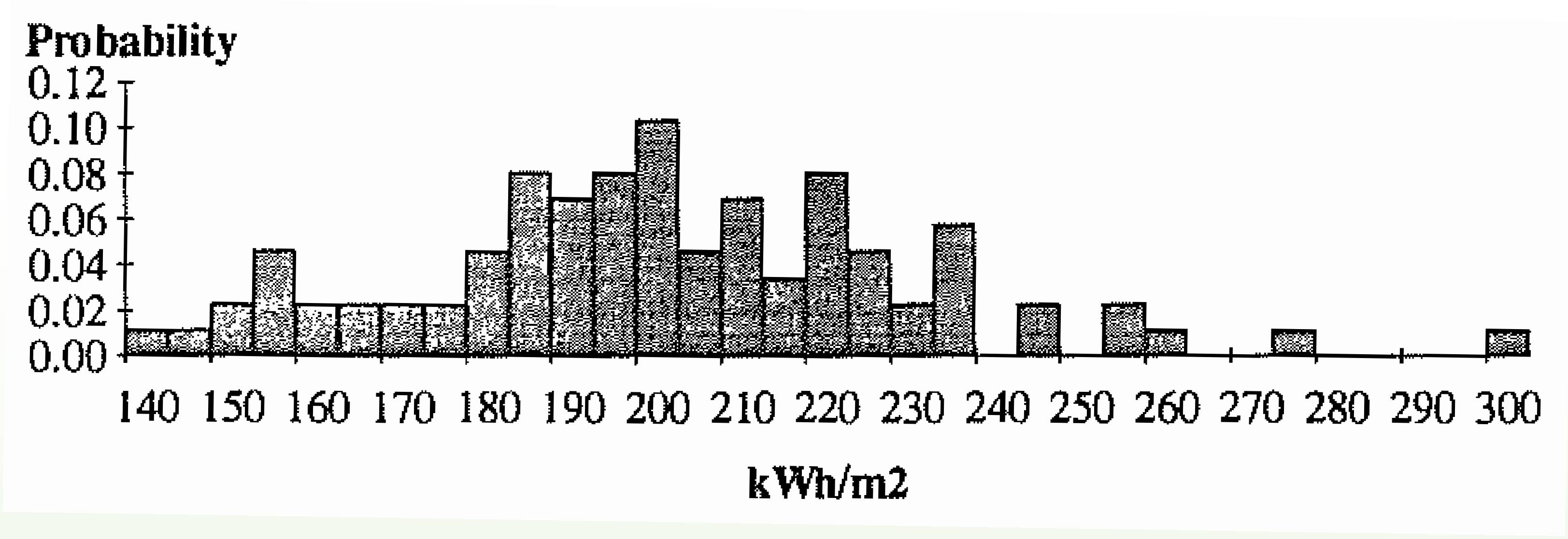
Examples of random variations in:

Indoor moisture sources, internal gains airing, aging of material, cracks in façades,…

Workmanship initial conditions of material,…

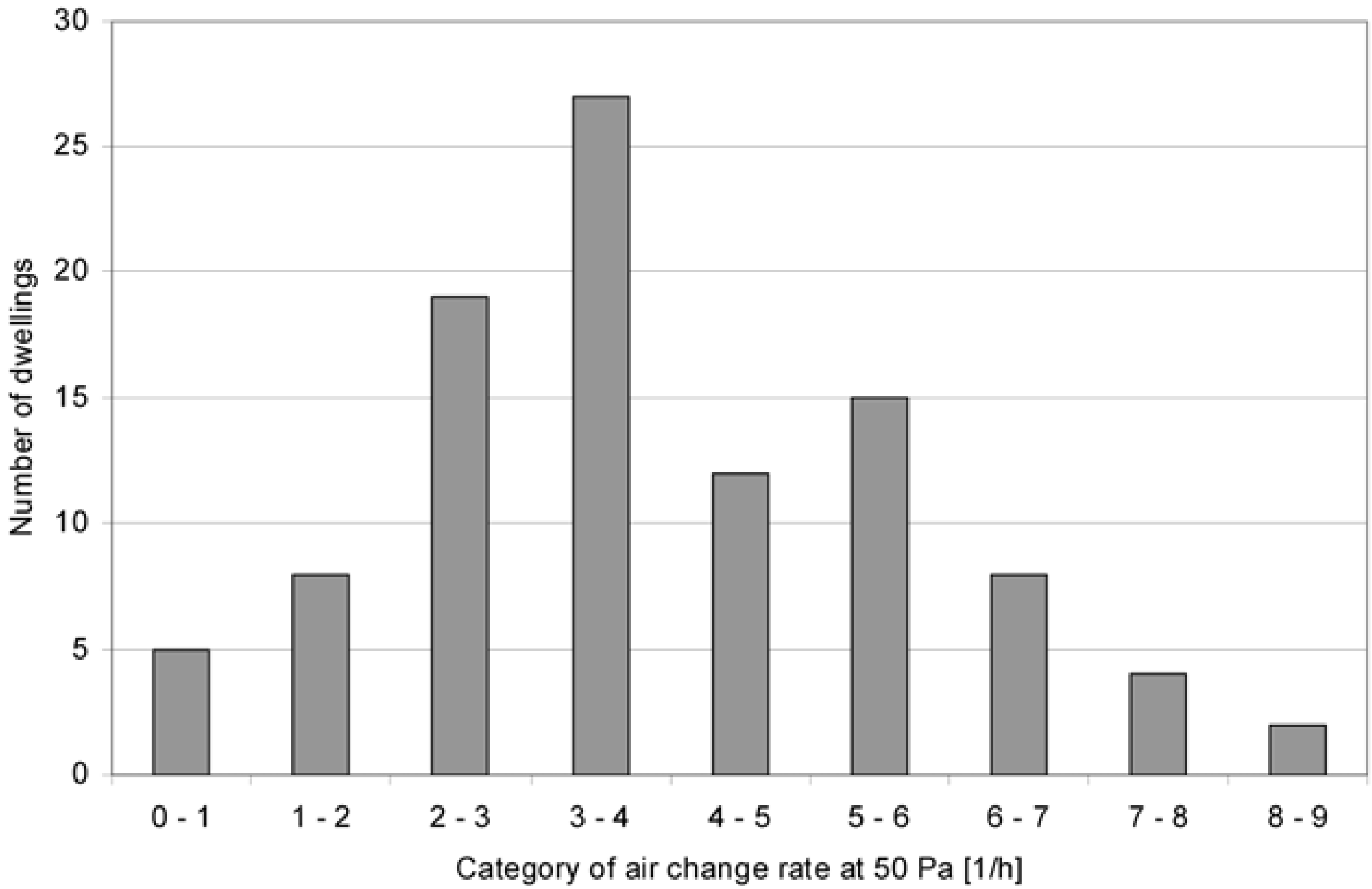
Energy Performance is Stochastic

Distribution of annual energy demand per square meter in 87 similar Swedish dwellings from the 80's



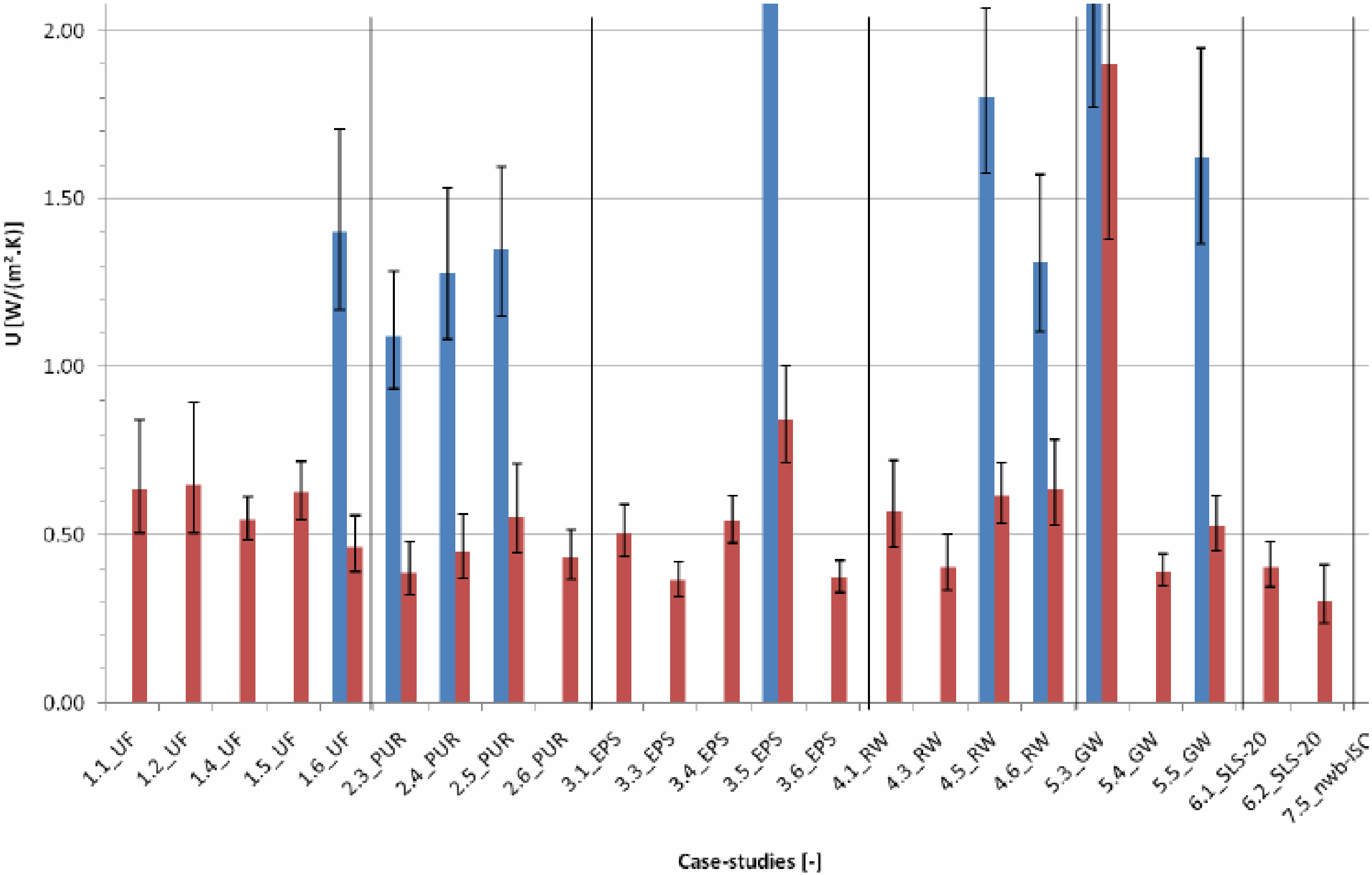
Air Tightness is Stochastic

Performance -Air tightness at 50 Pa of 100
Wood frame Finnish buildings built after year 2000



Retrofit Energy is Stochastic

Performance- Thermal protection/U-values:
Measured U-values of a number of Belgian cavity walls.
Blue before retrofitting, red: after insulation retrofitting



The *scope* of the annex is to:

To develop and provide decision support data and tools for energy retrofitting measures leading to substantial upgrading.

The tools will be based on probabilistic methodologies for prediction of energy use, life cycle cost and functional performances.

The objectives of the annex are to:

- Develop a common framework for probabilistic assessment of energy retrofitting measures

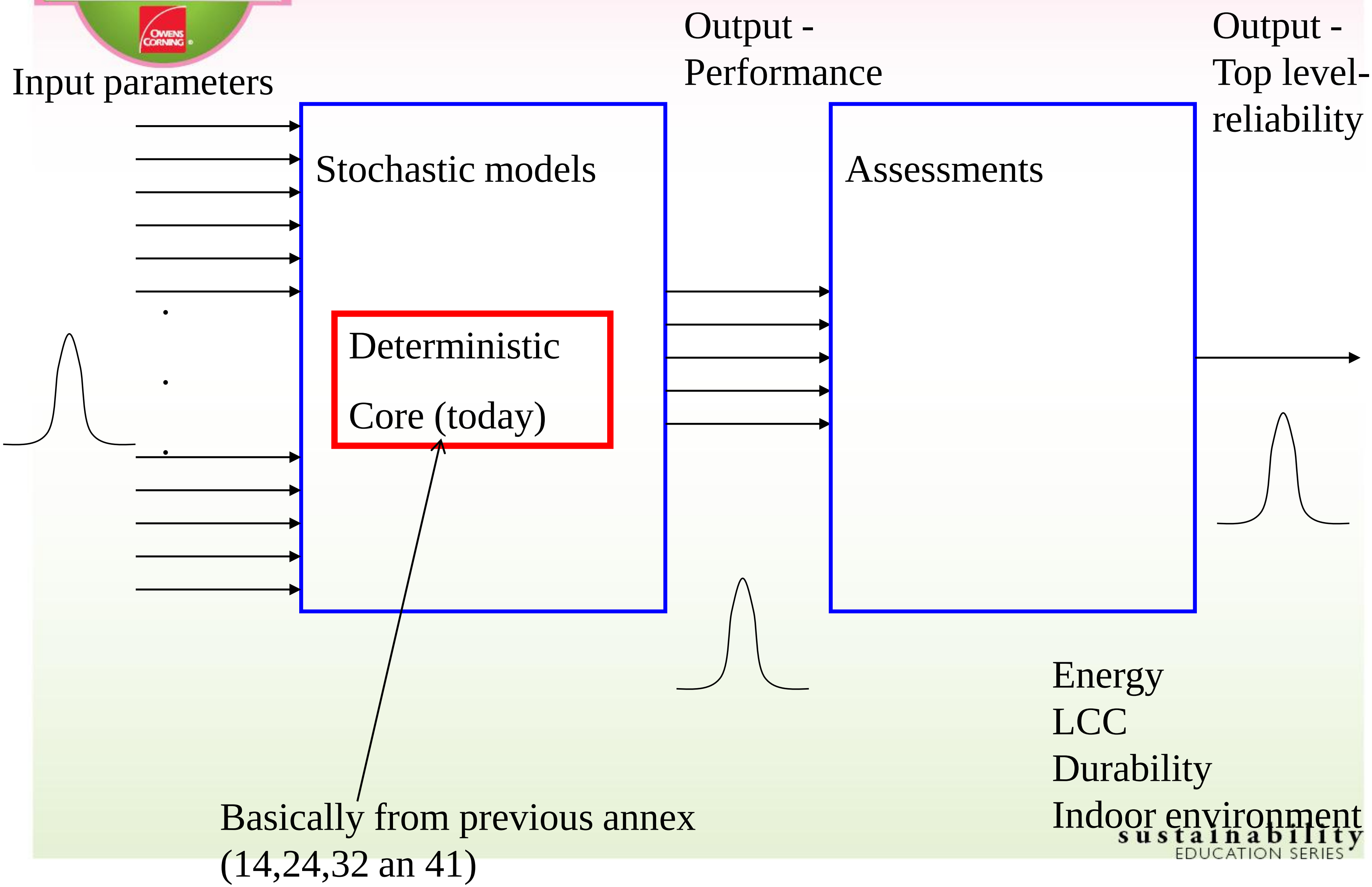
- Develop and validate probabilistic tools for energy use, life cycle cost and hygrothermal performances

- Collect and analyze data in order to create stochastic data sets

- Apply and demonstrate probabilistic methodology on (at least) five real life case studies, with a focus on residential buildings

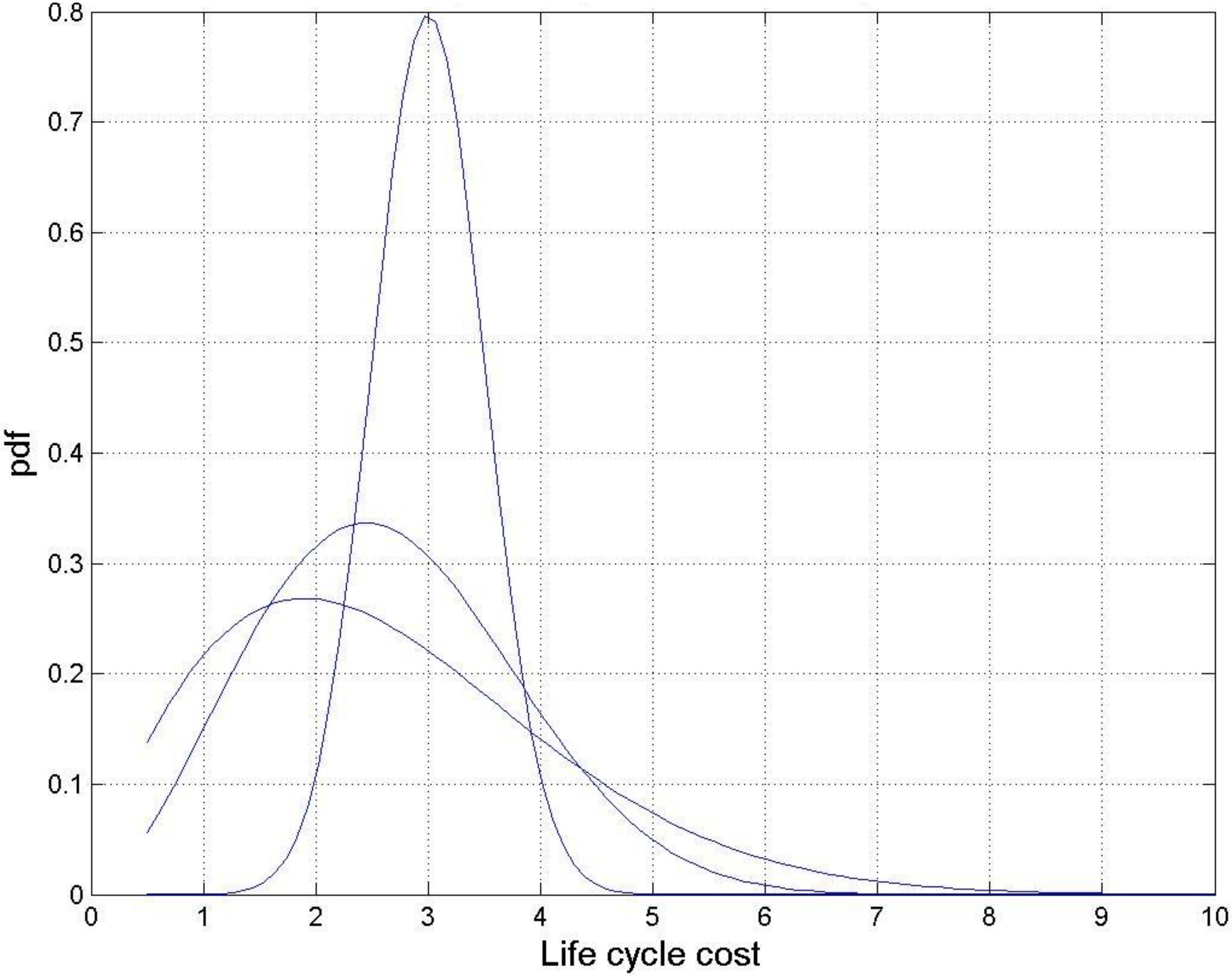
- Create guidelines for practitioners including assessment of common retrofitting techniques.

To build the work on the gained knowledge in building physics and to add risk assessment tools.



Distribution of life cycle cost for alternative design

An example of a decision support tool



Subtask for New IEA Annex

Subtask 1: *Gathering of stochastic data*
ST1.1 Energy, cost and performance
ST1.2 Boundary conditions
ST1.3 Material and building services
ST1.4 Workmanship

Subtask 2: *Probabilistic tools*
ST 2.1. Tools for probabilistic assessmen
ST 2.2. Validate probabilistic tools

Subtask 3: *Framework and Case studies*
ST 3.1 Common framework
ST 3.2 Characterization and collection of performance criteria, collected from standards and reference literature.
ST 3.3. Evaluation of framework for assessment

Subtask 4: *Practice and Guidelines*
ST 4.1 Listing of frequently used retrofitting technologies – benefits and risks
ST 4.2 Guidelines for how to use the developed framework for risk assessment in practice

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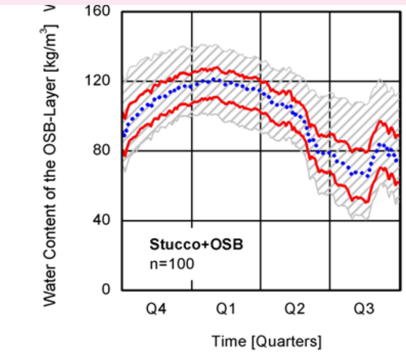
Subtask leaders :

Vasco Freitas and Nuno Ramos University of Porto, Portugal	ST1
Staf Roels, KUL, Belgium, Hans Jansen, DTU, Denmark	ST2
John Grunewald, Technische Universität Dresden, Germany	ST2
Carsten Rode , DTU, Denmark	ST3
Angela Sasic, Chalmers, Sweden	ST3
Achilles Karagiozis, Oak Ridge National Laboratory, USA	ST4
Andreas Holm, IBP Holzkirchen, Germany	ST4

Conclusions



- Retrofit Analysis needs special tools
- One solution does not fits all (Envelope + Climate)
- Risk for failure is higher
- New IEA Annex 55 will jumpstart the probabilistic approach (Whole Building Hygrothermal Analysis)
- Start with SIV (Seal, Insulate and Ventilate) but do more

Revised 7/23/2010


Paradise Cove Lua
Hawai'i 2002