Moisture Modeling

- Reasons
  - Durability
  - Mold growth
  - Vapor barriers
  - Drying out
  - Leak tolerance
  - Cupping / curling

Moisture Models

- Must understand
  - boundary conditions
  - material properties
  - transport mechanism
  - deterioration/damage mechanism
  - construction realities
- Most models are presently 1-D
- Research models are 2-D/3-D

Moisture Models

- Spreadsheet
  - Static, approximate
- EMPTIED from CMHC
  - simple, fast, approximate, air leakage potential
  - gross approximation of storage, drainage
- MATCH from TIL Denmark
  - commercial, offers most of WUFI benefits
  - clunky interface
- WUFI from IBP and ORNL
  - Very robust, good interface, powerful

Moisture Models

- Vapour diffusion easy to model
- "Hygric mass" often requires transient models
- Temperature and moisture are coupled!
- Challenges
  - Liquid transport is difficult
  - Moisture properties poorly known
  - Boundary conditions poorly known

Results

- Compare competing wall designs
- Conduct parametric studies
- How high MC? For how long?
- Interpretation is difficult, e.g.,
  - No gain year over year
  - Freeze-thaw cycles when over 90% saturation
  - Hours or days over 80% or 95% RH
  - Mold models
  - Annual plots
- Need material performance thresholds

Glaser Method

Element	R	ΔT	t ºC	M	R_v	ΔP_v	P_v	P_{sat}	RH
			21.0				990	2474	40%
Inside Film	0.120	1.8		10000	0.000	2			
			19.2				988	2212	45%
Vapour retarder	0.000	0.0		60	0.017	344			
			19.2				643	2212	29%
Batt insulation	2.500	37.6		2000	0.001	10			
			-18.4				633	143	442%
Plywood	0.012	0.2		40	0.025	517			
			-18.6				117	141	83%
Outside Film	0.029	0.4		20000	0.000	1			
			-19.0				115	136	85%

Average Winter Conditions

Element	R	ΔT	t ºC	M	Rv	ΔP	P	Psat	RH
			21.0				990	2474	40%
Inside Film	0.120	1.1		10000	0.000	3			
			19.9				987	2307	43%
Vapour retarder	0.000	0.0		60	0.017	506			
			19.9				481	2307	21%
batt	2.500	23.5		2000	0.001	15			
			-3.6				465	465	100%

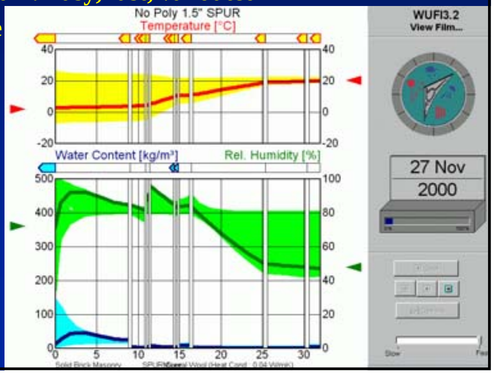
Flow To back of sheathing
Permeance: 57.9 Pressure: 524
Flow to: 30369 ng/m2 s = 0.11 g/m2/hr

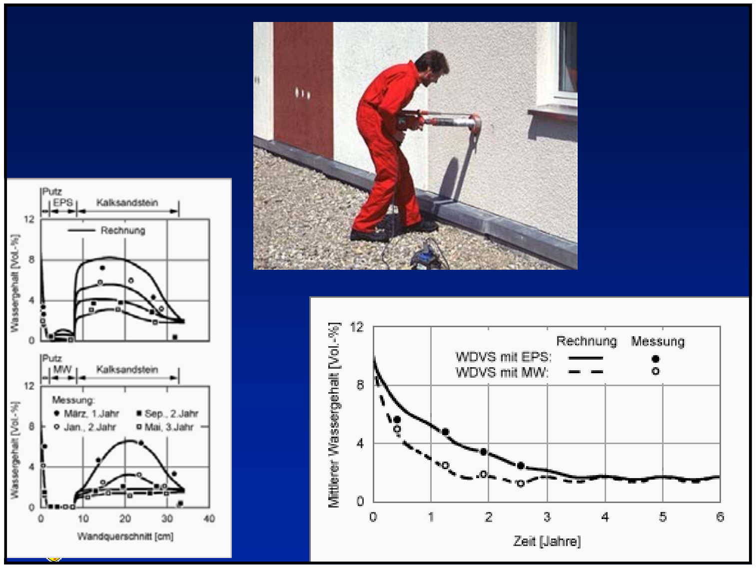
Element	R	ΔT	t ºC	M	Rv	ΔP	P	Psat	RH
plywood	0.012	0.1		40	0.025	81			
			-3.7				385	462	83%
Outside Film	0.029	0.3		20000	0.000	1			
			-4.0				384	452	85%
Total Resistance	2.66	23.9		0		603			

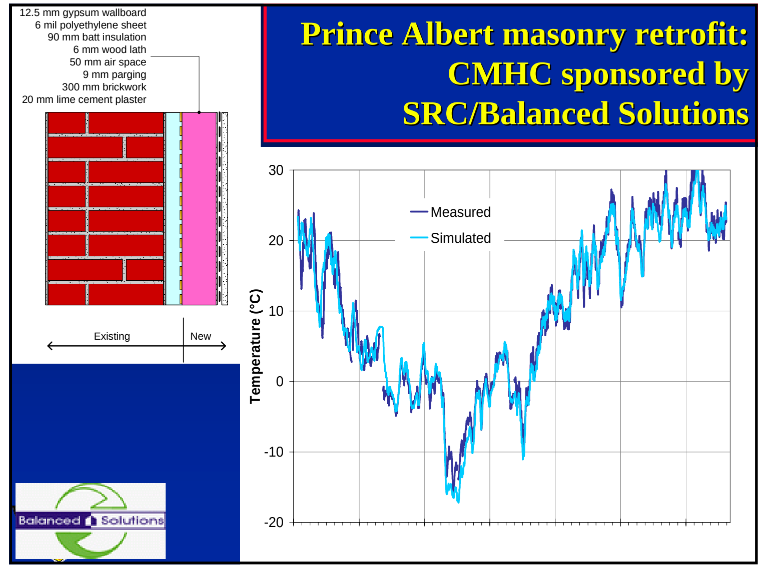
Flow Away from back of sheathing
Permeance: 40 Pressure: 81
Flow Away: 3243 ng/m2 s = 0.01 g/m2/hr
Net Accumulation 0.10 g/m2/hr

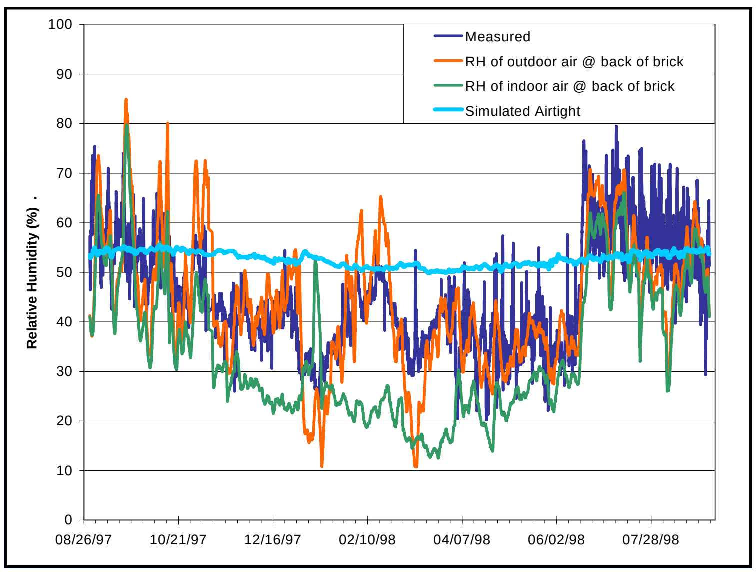
WUFI 3.3 Pro /ORNL

- Dynamic hourly, liquid, adsorbed, diffusion storage
- Handles driving rain. Easy, fast, validated
- Intuitive interface



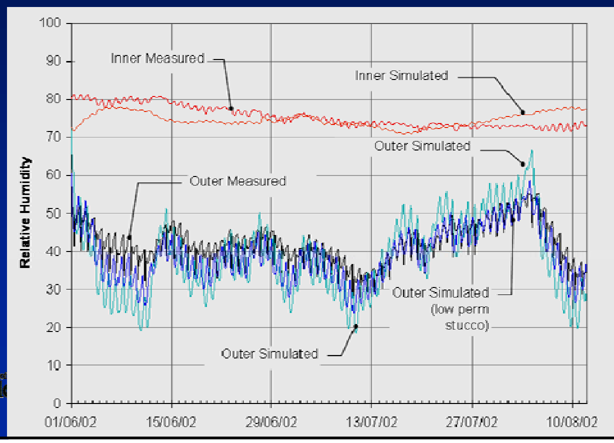

Putz
EPS
Kalksandstein
Rechnung
Wassergehalt [Vol.-%]
MW
Messung:
März, 1.Jahr
Sep., 2.Jahr
Jan., 2.Jahr
Mai, 3.Jahr
Wandquerschnitt [cm]
Mittlerer Wassergehalt [Vol.-%]
Rechnung
Messung
WDVS mit EPS:
WDVS mit MW:
Zeit [Jahre]


12.5 mm gypsum wallboard
6 mil polyethylene sheet
90 mm batt insulation
6 mm wood lath
50 mm air space
9 mm parging
300 mm brickwork
20 mm lime cement plaster
Existing
New
Prince Albert masonry retrofit:
CMHC sponsored by
SRC/Balanced Solutions
Measured
Simulated
Temperature (°C)
Balanced Solutions


Measured
RH of outdoor air @ back of brick
RH of indoor air @ back of brick
Simulated Airtight
Relative Humidity (%)
08/26/97
10/21/97
12/16/97
02/10/98
04/07/98
06/02/98
07/28/98


Case Study:
Hygrothermal Performance of a Strawbale Winery

California Strawbale

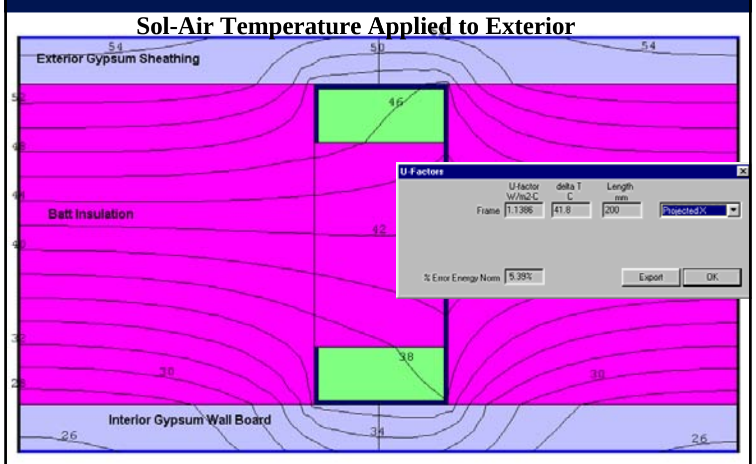


Case Study - Cuban Resort

- Canadian firm in hot humid climate

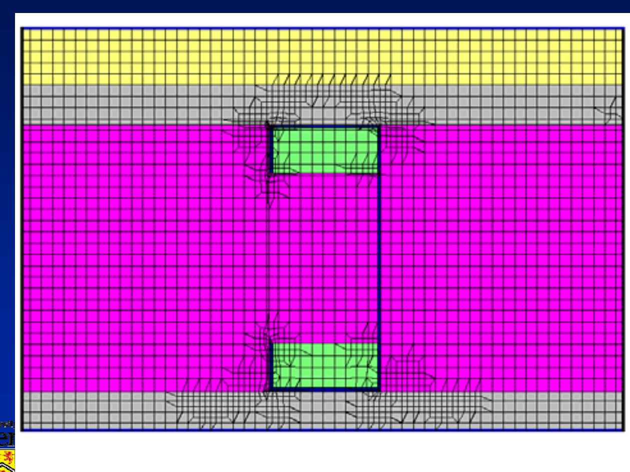
Questions:

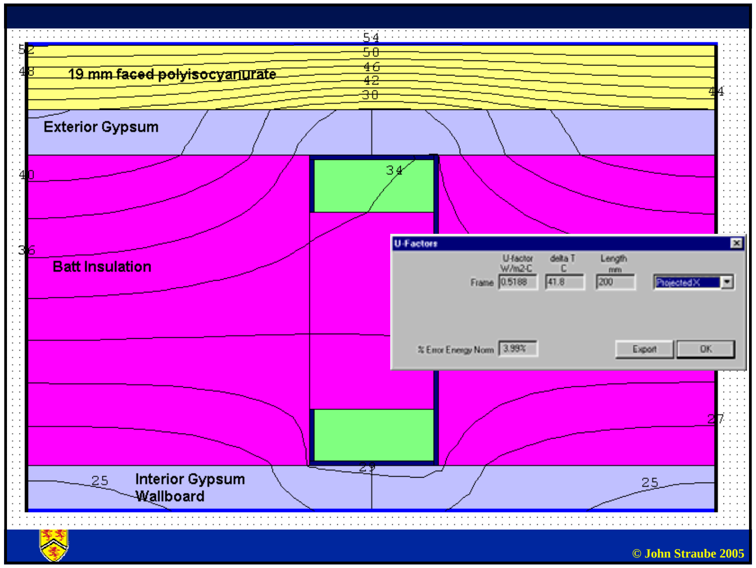
- Do we need an exterior vapor barrier?
- Does wall meet the design specs?
  - U < 1, RSI >1 (R_{imp} > 5.6)



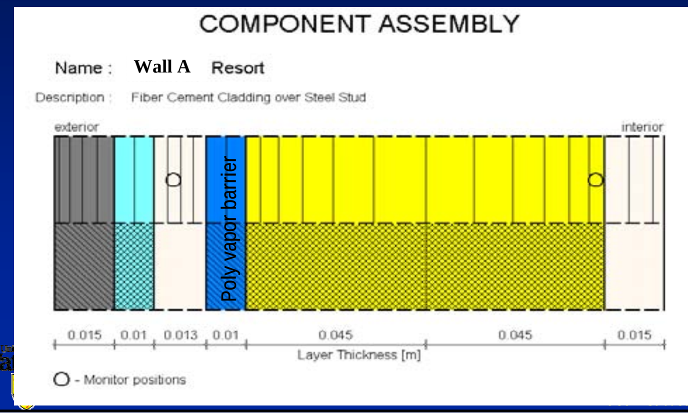
Steel Stud and Gypsum

Solution -- use 19 mm exterior Insulation

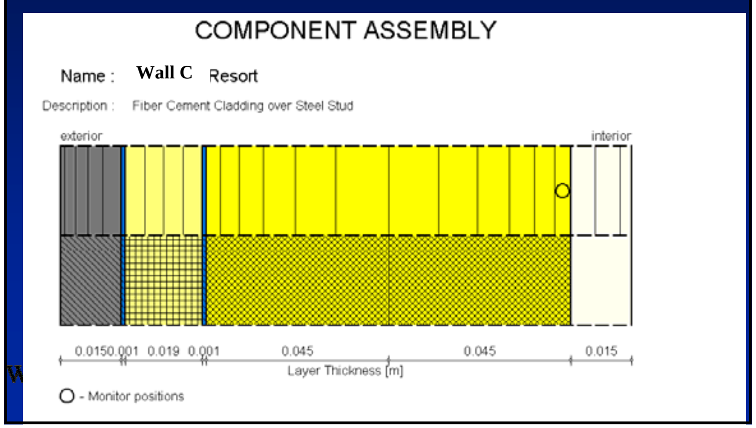


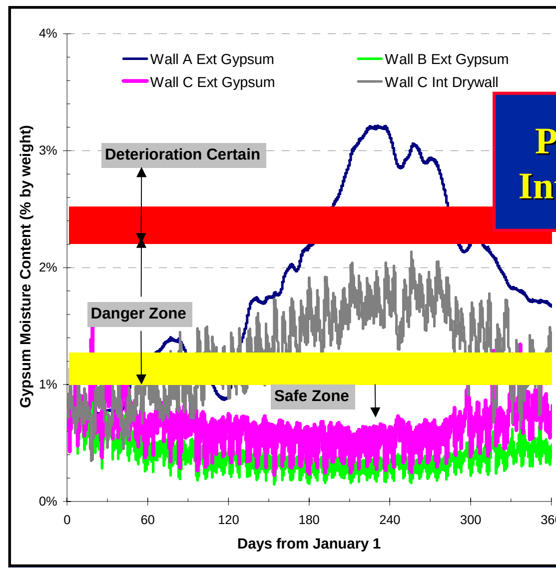


Wall Mesh



Suggested Wall





Presentation/ Interpretation

Case Study Highrise Apartment

- Portland Oregon (VA building)
- Fixed energy budget
- Longer term relation – quality matters
- Builder – Developer team
- Concrete Frame – steel stud infill
- Intent
  - Meet energy requirements
  - Enhance durability, reduce risk

Approach

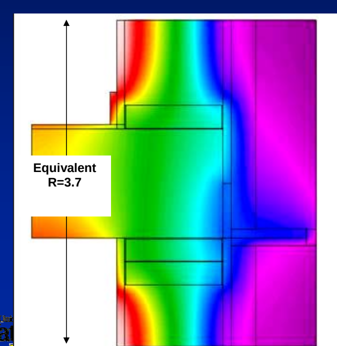
- Given – fixed range of wall designs
- Approach
- Steady-state thermal analysis of obvious thermal bridges (Therm)
  - Essentially relative analysis
- Transient hourly analysis of center of wall hygrothermal performance (WUFI)
  - Relative and absolute performance standards

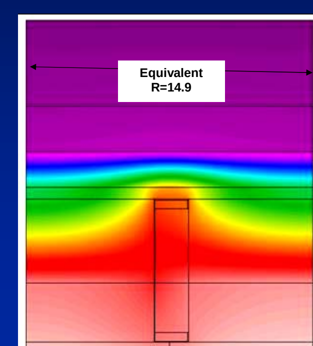
Wall Types

- All Brick Veneer with 6” steel studs, different vapour control strategies
- Wall A
  - Tyvek over sheathing
  - R20 batts
- Wall B
  - 38 mm of EXPS over Tyvek over sheathing
  - R11 batt studspace insulation
- Wall C
  - 50 mm EXPS over bitumen membrane / sheathing
  - No batt

Thermal Analysis

Two Dimensional Slice through floor





Thermal Results

- Assembled 2-D slices into 3-D estimates
- Wall A obviously performs poorly

Wall Type	@ Stud	@ Slab	Total Effective	
Wall A	1.3	0.70	1.2	R6.8
Wall B	2.6	2.2	2.5	R14.2
Wall C	2.3	2.3	2.3	R13.0

Waterloo

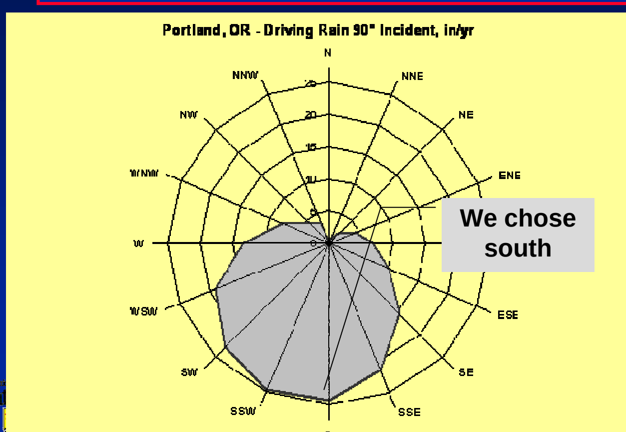
Moisture Analysis

- Durability (corrosion) and mold are key concerns
- Poly VR or not?
- Winter condensation on exterior sheathing
- Summer condensation interior

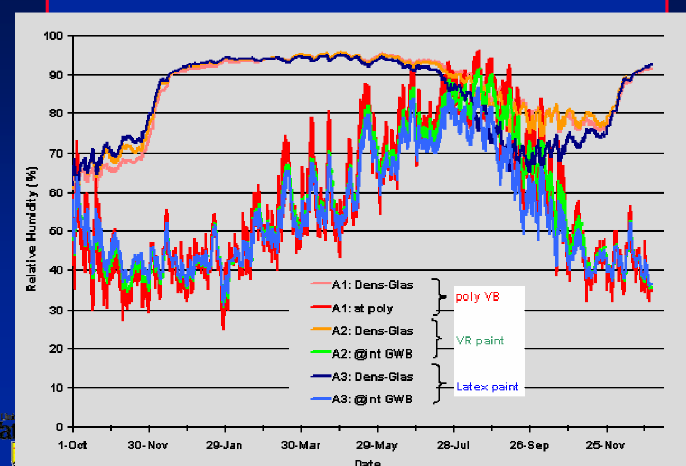
- First decide which orientation requires detailed analysis
- North has coldest temps. West has highest. Rain?

Waterloo

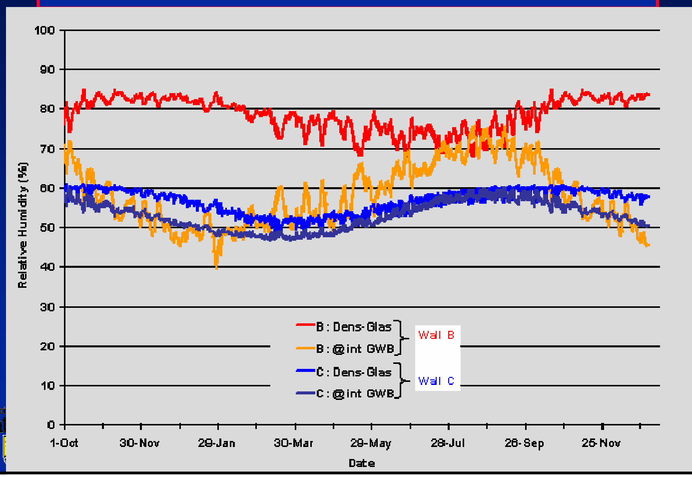
Weather Analysis



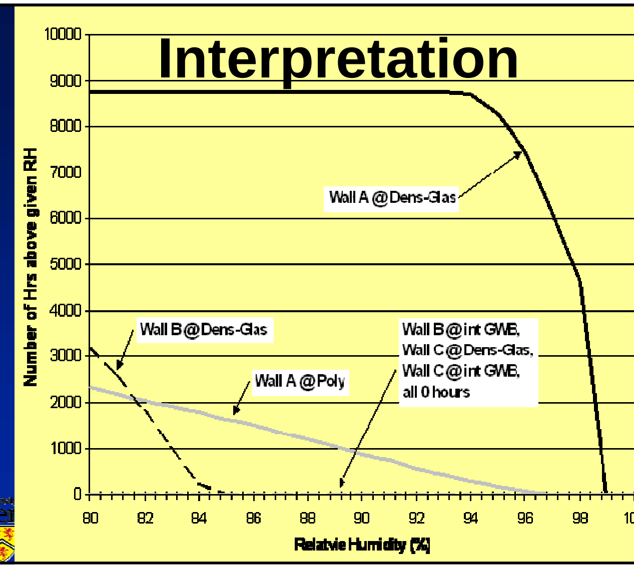
Wall A



Wall B/C

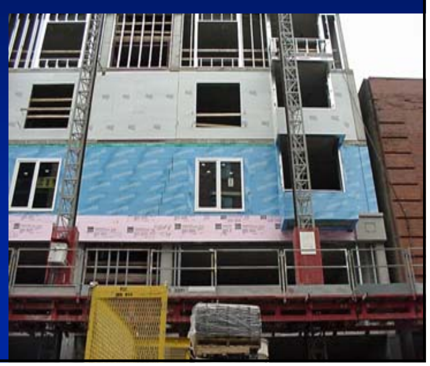


Interpretation



Outcomes

- Clients chose all insulation on the outside
- "most expensive"
- Reliable energy use
- Very durable in high risk environment



Sustainability

- Reduce the consumption of non-renewable resources
- Architects need to make different choices during all stages of design
- Simulation allows different choices to be quantitatively assessed

Energy Models

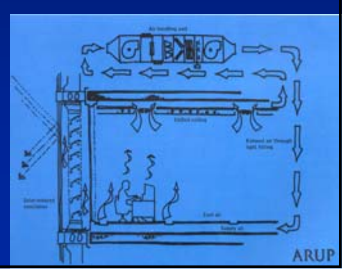
- Whole building energy analysis
  - Peak – equipment sizing
  - Hourly – system choice, annual consumption, comfort
- Use is growing but rare
- Models tend to be too complex
  - Easy to make big errors
- Simple hourly needed

Energy Consumption

- Requires time to develop sophisticated models
- Good, if cumbersome, models available
  - DOE 2.1E (soon to be replaced)
  - TRNSYS (modular component)
  - Energy-10
  - EE-4
  - Quest
  - HOTCAN (soon ESP-r)

Double Façade Design

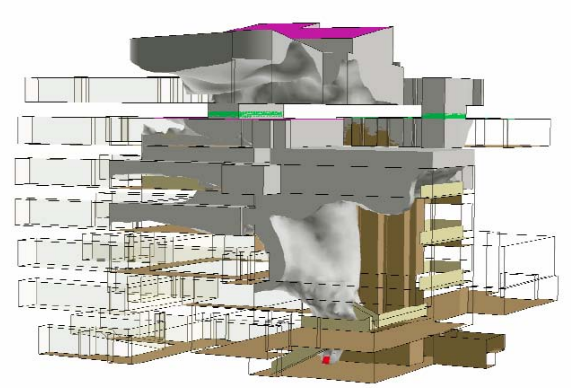
- Simulation will tell you it does not save energy



Fire

- Important enough for large buildings to model
- Atria, novel fire suppression, tunnels, subways, etc
- Advanced CFD modeling requires specialists
- Can model crowds and evacuation, in for example, stadia

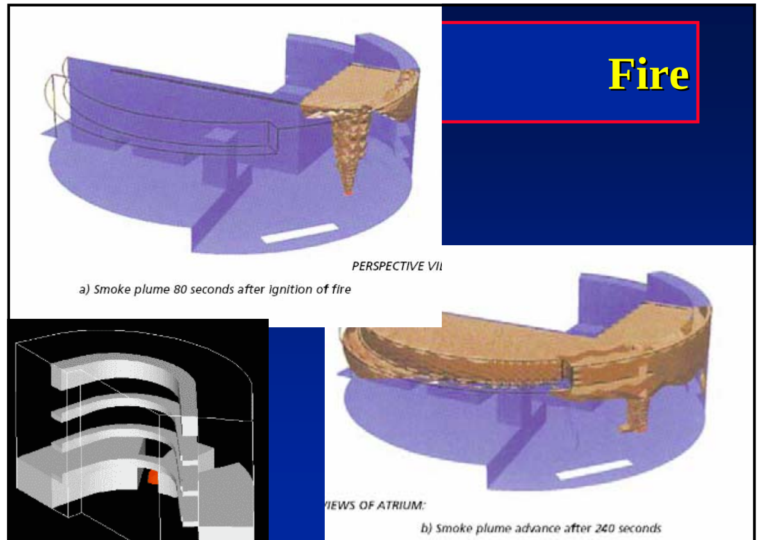
Fire



Smoke, represented by a gray iso-surface, penetrates into many occupied areas of a building with a complex atrium

Source: RWDI

Fire



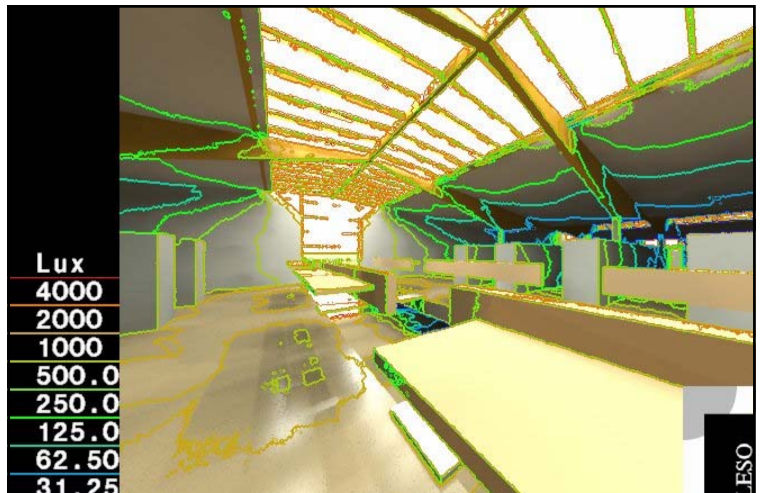
a) Smoke plume 80 seconds after ignition of fire

b) Smoke plume advance after 240 seconds

Source: RWDI

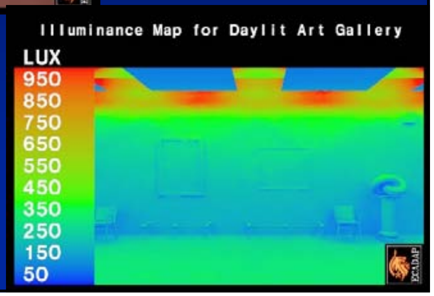
Lighting

- Influence well-being, sales, energy-consumption, etc
- Radiance, by LBNL is the product of choice
- Powerful, free(!),
- Desktop version Integrated with AutoCad
- Requires time to model 3-D
- Incredible rendering possible, but effort ...



Rendered View

Illuminance Levels



Future

- Modeling to support more decisions
- Modeling required for energy consumption
- Development of new materials
  - Esp active
- Development of new systems
  - Esp interconnected
- Web connected energy flows

Conclusions

- Simulation have/will become more powerful
- But will designers use the tools?
  - Need to have lower barriers to entry
  - Architects must work with simulators – such specialization cannot be standard architect role
- Basic tools not used by practioners – need more interest, more effort, more education
- Simpler tools at concept level “close enough”