



Paradigmeskifte mod robuste bygningssimuleringer

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Laver du "usikre" beregninger?!

- JA! (sandsynligvis)
- Privat og generelt
 - Tilbagebetalingstid < yy år
 - Huskøb: maks. yy kr.
 - Osv.
- Bygninger
 - Energiforbrug = ~~yy kWh/år~~
 - Antal h overtemp. = ~~yy h > 26 °C~~
 - Dagslysfaktor = ~~2,2 %~~



Paradigmeskifte væk fra deterministiske beregninger

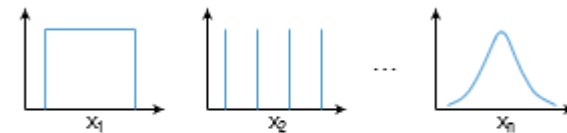
- Opgør med deterministiske beregninger!
- Medtag usikkerheder!
 - Muliggør bedre design
 - Mere robusthed
 - Reelle beregninger
 - Realistiske forventninger

Deterministic world

Fixed x_1 and x_2 $\longrightarrow$ Fixed y

Probabilistic world

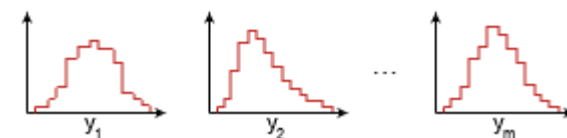
Variable inputs



Monte Carlo Building Simulations



Output distributions



Om mig

- 2004-07 Fysik, Aarhus Universitet (~Bachelor)
 - 2007-13 MSc, Architectural Engineering, Aarhus Universitet
 - 2011- Ingeniør hos MOE, Rådgivende Ingeniører
 - 2014-17 ErhvervsPhD, Aalborg Universitet & MOE
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- PhD'en: Mål at forbedre anvendelse af bygningssimuleringer i den kritiske tidlige designfase ved brug af probabilistisk modellering, usikkerheds- og følsomhedsanalyser og vidensbaserede databaser.



Usikkerheder...?

Fysiske egenskaber

- Imperfektioner, lækager, snavs, skyggende træer, ...

Brugeradfærd

- Setpunkter for opvarmning/køling, brugstid, solafskærmning, naturlig ventilation, ...

Vejret

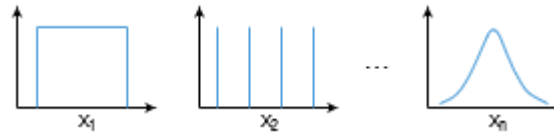
- Aldrig "standard" DRY år, sol, vindhastighed, ...

Modelrealisme og software

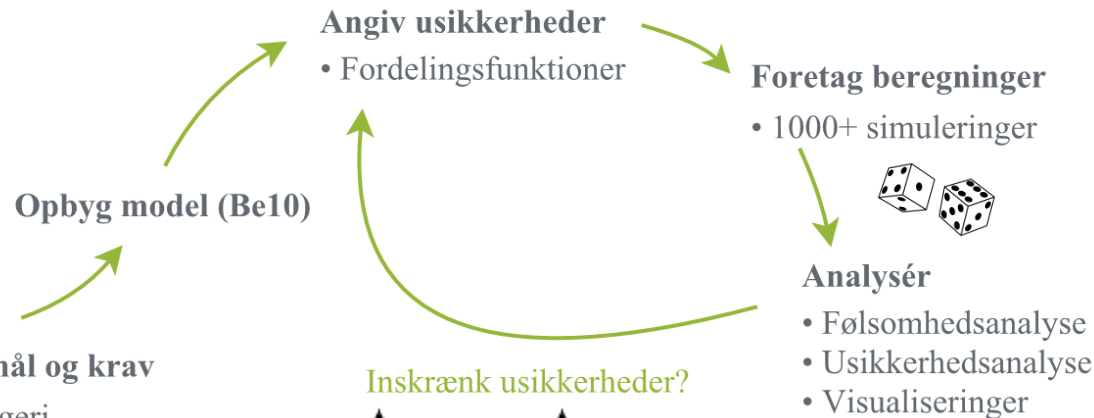
- Månedsgennemsnit, timebasis, minutbasis
- Begrænsninger i muligheder, nøjagtighed af algoritmer, ...
 - Randbetingelser og gridstørrelse i CFD
 - Skygger i Be10



Metode: overblik



1. Grove skøn fra erfaringer
2. Litteratur
3. Bygherre: erfaringer & tidligere målinger
4. Foretage nye målinger
5. Erfaringsdatabase?



Opstil mål og krav

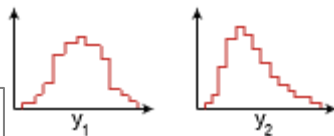
- Nybyggeri
- Renovering

Krav... hvor stor sikkerhed?

? Maks + 25%

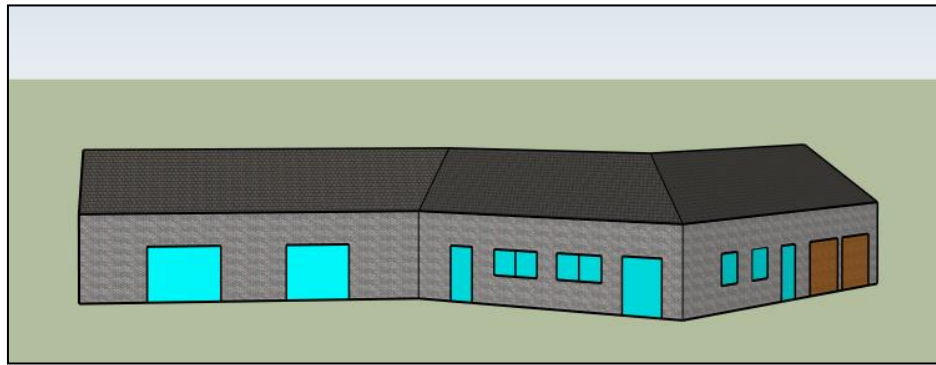
? Middelværdi / Median

Inskrænk usikkerheder?

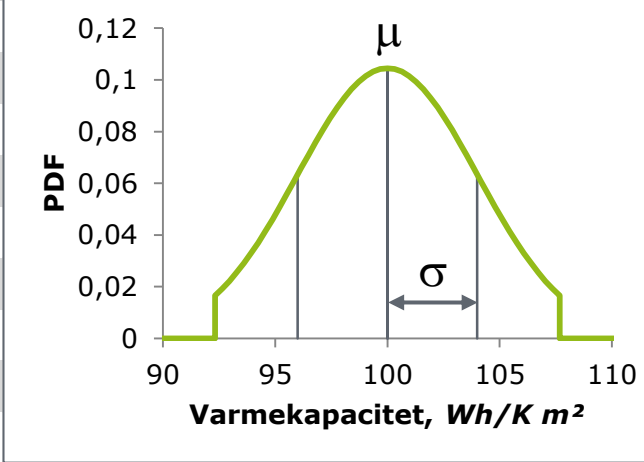
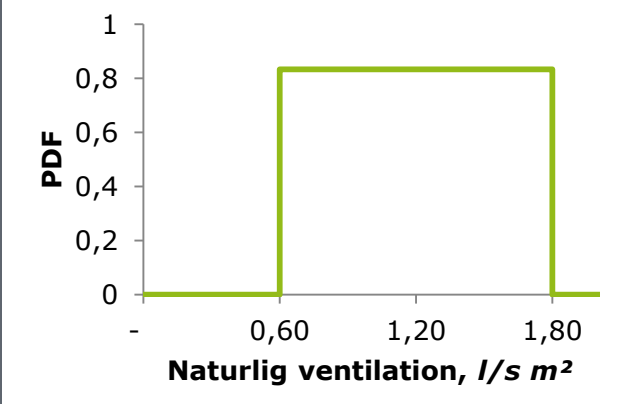


CASE: Ny bolig

- Præcis geometri og leverandørspecificationer
 - Eks. vindue:
 - 948 mm x 1188 mm
 - $U = 1,17 \text{ W/m}^2 \text{ K}$
 - $g = 0,51$
 - Eks. ventilation.
 - Varmegenvinding = 0,886
 - SEL = 0,922



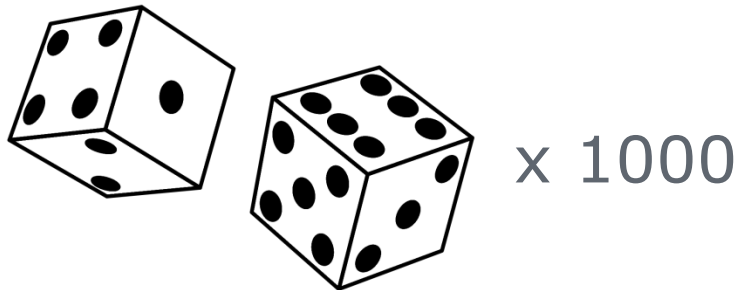
CASE: Angiv fordelingsfunktioner

Parameter	Unit	Fordeling	μ	σ	Min	Maks
Varmekap.	$Wh/K m^2$	Normal	100	4	92	108
Setpunkt, opv.	C	Normal				
Floor area	m^2	Uniform				
U loft	$W/m^2 K$	Normal				
U terræn	$W/m^2 K$	Normal				
U væg	$W/m^2 K$	Normal				
Linjetab, fund.	$W/m K$	Uniform				
Linjetab, vin.	$W/m K$	Uniform				
g-værdi	-	Normal				
Vent qm,s	$l/s m^2$	Uniform				
Nat. vent.	$l/s m^2$	Uniform	0,6	1,8		
Infiltration	$l/s m^2$	Uniform				
Vent. SEL	-	Normal				
Vent. vgv	-	Normal				
Personer	W/m^2	Normal				
Udstyr	W/m^2	Normal				
Cirk. Pumpe	W	Normal				
VBV	l/m^2	Normal				
VBV beholder	W/K	Normal				

Sampling og simulering

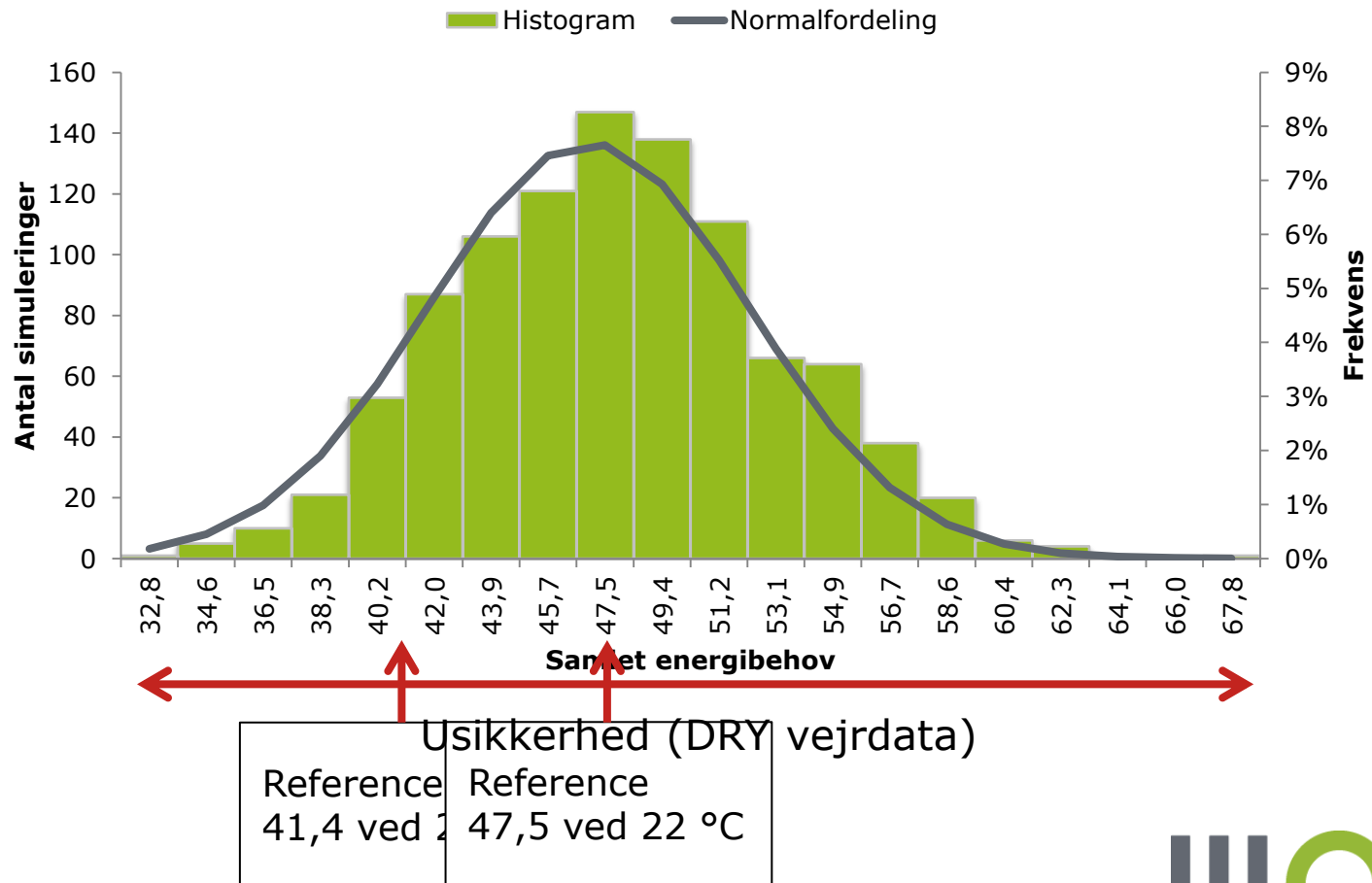
1. Vælg prøvetagningsstrategi (sampling)
2. Foretag simuleringer

Med Be10... 1000 simuleringer ~ 2-3 minutter

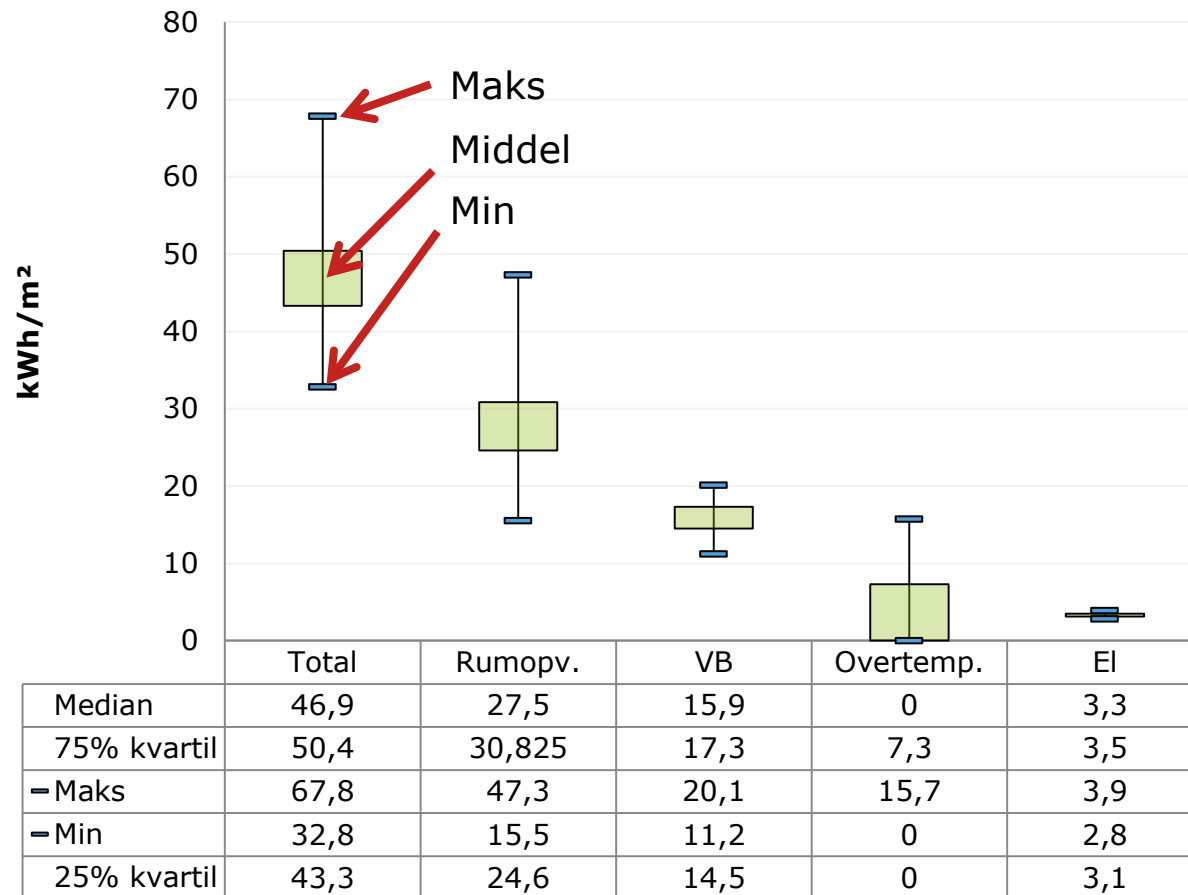


Resultater = sandsynlighedsfordelinger

- Usikkerhedsanalyse ift. brugeradfærd, materialer, m.m.
- Middel $47,0 \pm 5,0$ kWh/m²

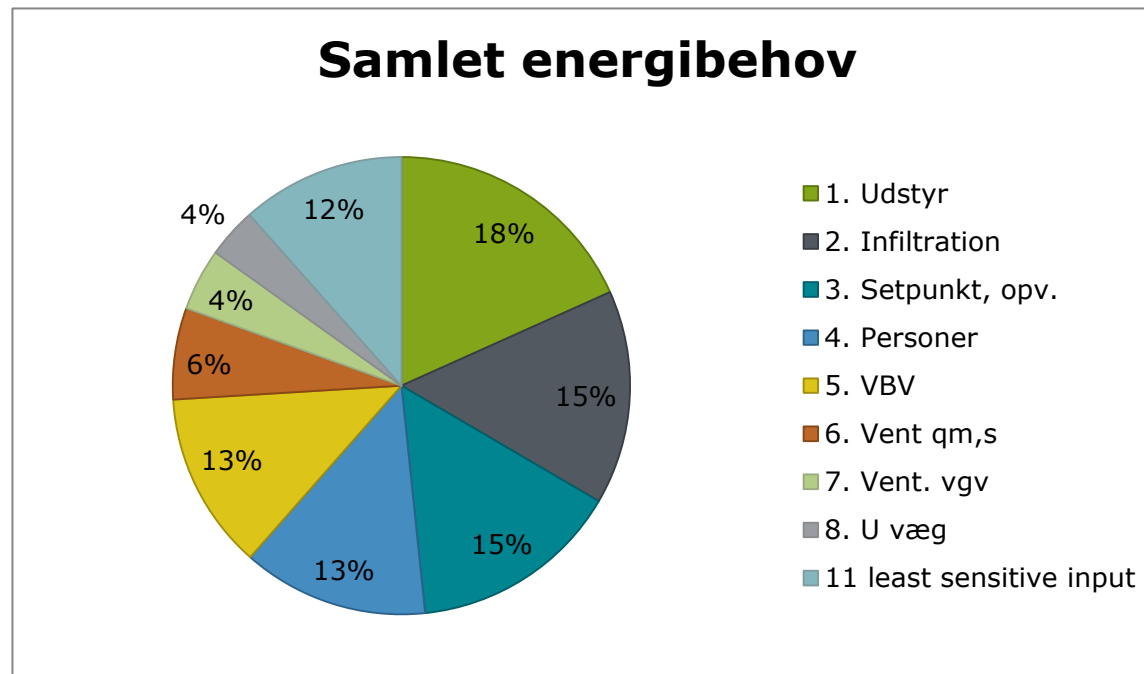


Spredninger for forskjellige output



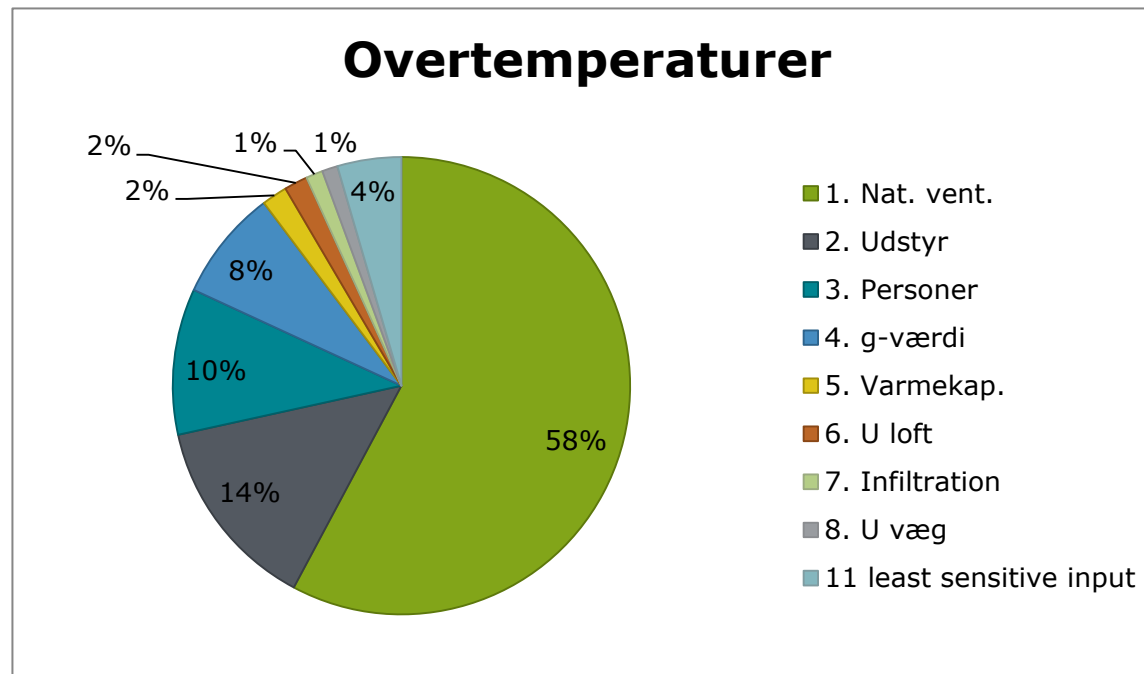
Global Følsomhedsanalyse

- Studiet af hvordan usikkerhed i en models output kan tilskrives forskellige usikkerheder i modellens inputs.
- ...aka. "hvad betyder mest?"



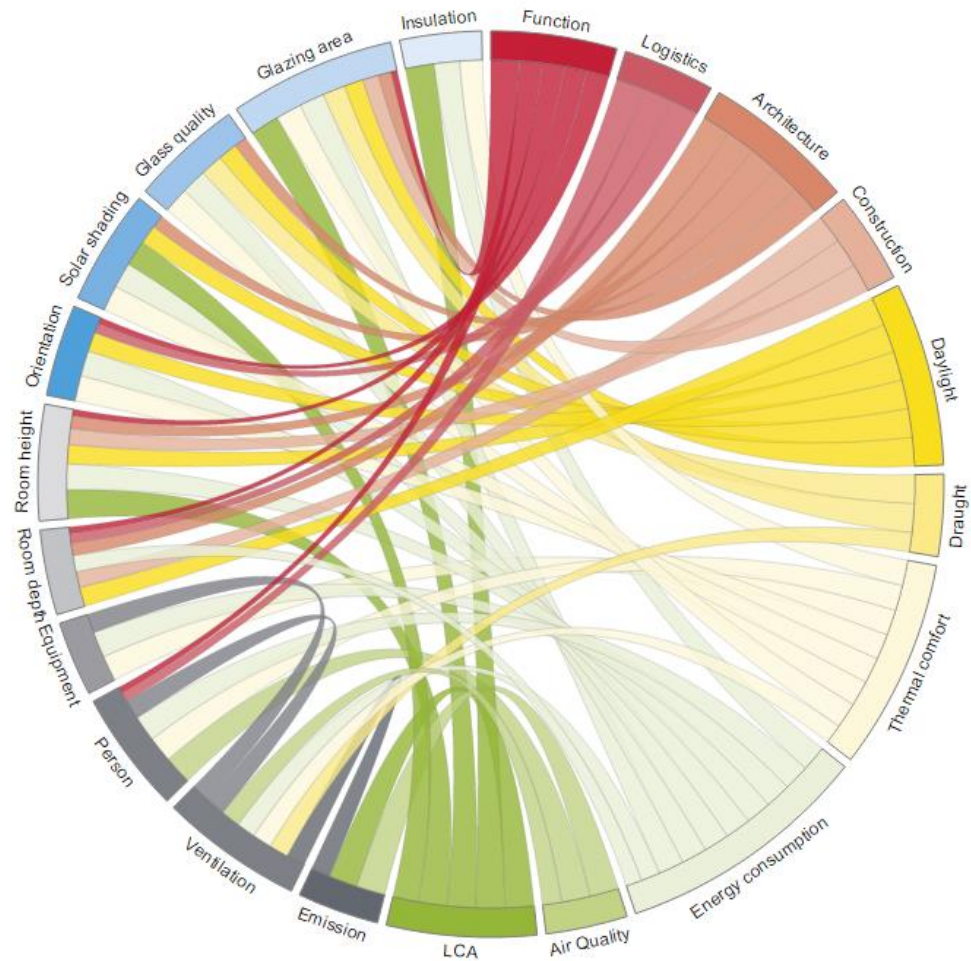
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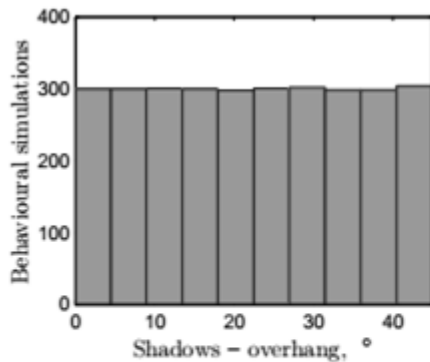
PAS PÅ... ensidigt fokus på energi

- Ændringer kan påvirke:
 - Termisk komfort
 - Dagslys
 - Materialeforbrug
 - Brugen af bygningen
 - OSV.

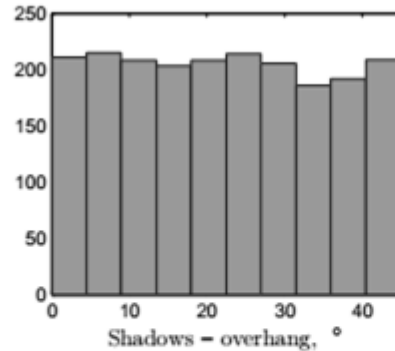


Monte Carlo Filtering

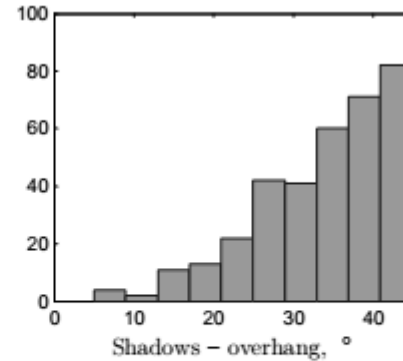
1. Lav **uniforme** inputfordelinger
2. Foretag Monte Carlo simuleringer (1000+)
3. Filtrer resultaterne i forhold til krav/ønsker
4. Observér hvilke input, der giver acceptable resultater



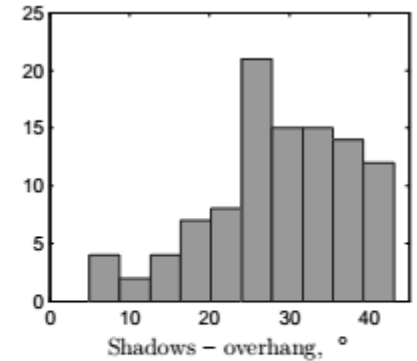
(a) No filtering



(b) One filter:
- Energy



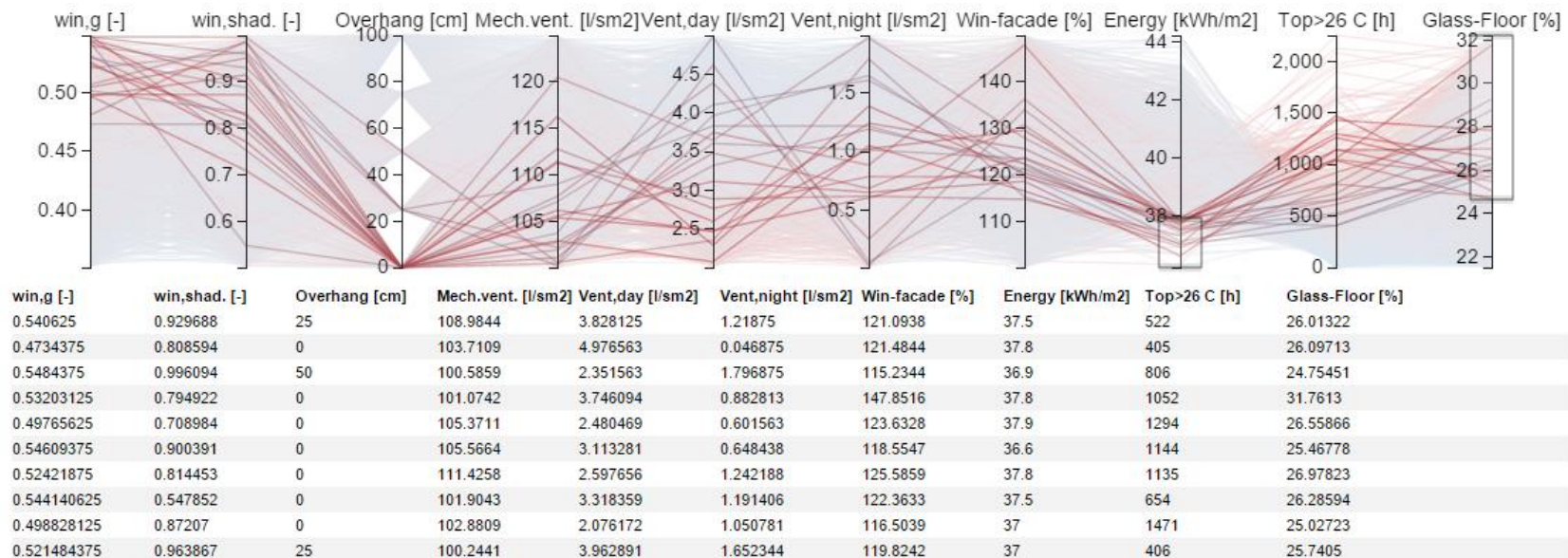
(c) Two filters:
- Energy
- Thermal



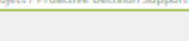
(d) Tree filters:
- Energy
- Thermal
- Daylighting

Interaktiv analyse

- Analysér sammen med arkitekt, bygherre og entreprenør



- Se mere på buildingdesign.moe.dk → "research project" (forventet "klar" ved udgangen af november)



THE CHALLENGE

ARCHITECTURAL ENGINEERING -

RESEARCH PROJECT -

MOE | LABS -

ABOUT -

Research Project / Proactive Decision Support

Proactive design support

For decades, building performance simulations have been used for code compliance and evaluation of different design options. Unfortunately, **building simulations are evaluative in nature and give little or no guidance** on how to improve the design. Moreover, the design flow between architects and engineers are often **iterative and time-consuming** due to the back-and-forth exchange of design proposals and their consequences on performance. During the early stages, the opportunities are great and design evolves rapidly which challenges the engineer to provide appropriate decision support in time. Making **good decision in the early stages** will open up for better performance and ease the work load during later detailed stages.

The **concept of proactive design** covers a variety of ideas

- Guide decision-making rather than evaluate options
- Anticipate needs and questions of architects, contractors, and building owners
- Explore vast design spaces prior to meetings and workshops
- Focus on things that matter most in holistic

This page explains the background for proposed concept whereas a detailed description and examples are given in here.

Read more



BuildingDesign

THE CHALLENGE ARCHITECTURAL ENGINEERING - RESEARCH PROJECT - MORE LABS - ABOUT -

Research Project / Demonstration of Proactive Building Simulations



Demonstrating the Design Concept

The development of a proactive and holistic design approach is part of a 3-years long research project between IOE and Aalborg University. The ideas behind the concept are described here whereas a comprehensive demonstration of the workflow is given below. The following list includes examples of typical, relevant questions that often arise during early design stages. Through such issues are normally troublesome to deal with due to the large variability and uncertainties of the design.

- How do we meet energy requirements with lowest costs?
- Can we increase the window areas?
- Which parameters matter's most right now?
- What are the consequences of different design choices?
- How we considered all options?
- How robust are the results towards changes or user behavior?

Road noise

Modelling Global Design Space

In line with common practice, the first step is set up a simulation model based on the latest design proposal. This may be referred to as the reference model or baseline model. In order to explore a large global design space, the design team must assign probability functions to inputs in order to describe their variability or uncertainty. In early design stages, discrete or continuous uniform distributions are suitable to describe the variability. As an example, wall insulation thickness may vary significantly but the design team may assume minimum and maximum values of e.g. 150 mm and 300 mm:



Variable inputs

h_1 h_2 h_3

Møntebanen Building Simulation



x 10 000

After setting up the variable inputs, thousands of simulations are executed in order to explore a large global design space. Subsequently, the extensive simulation data is analyzed using statistical techniques and interactive illustrations as shown below.



Output distributions

h_1 h_2 h_3

Road noise