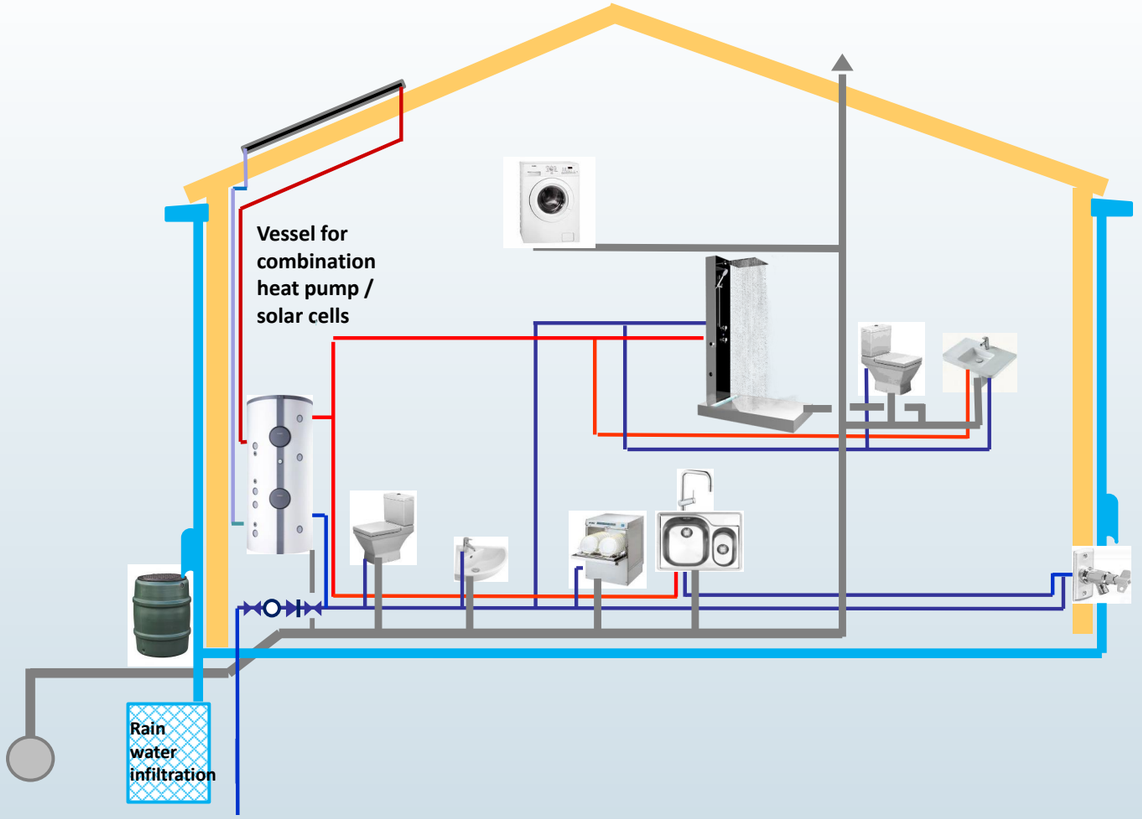
Using a stochastic demand model to design building installations

CIB W062 - Water Supply and Drainage for Buildings

Outline

1. Designing water supply and drainage for buildings
2. Developing a stochastic demand model (SIMDEUM)
3. Validating SIMDEUM
4. Using SIMDEUM to design water supply and drainage for buildings
5. Conclusions



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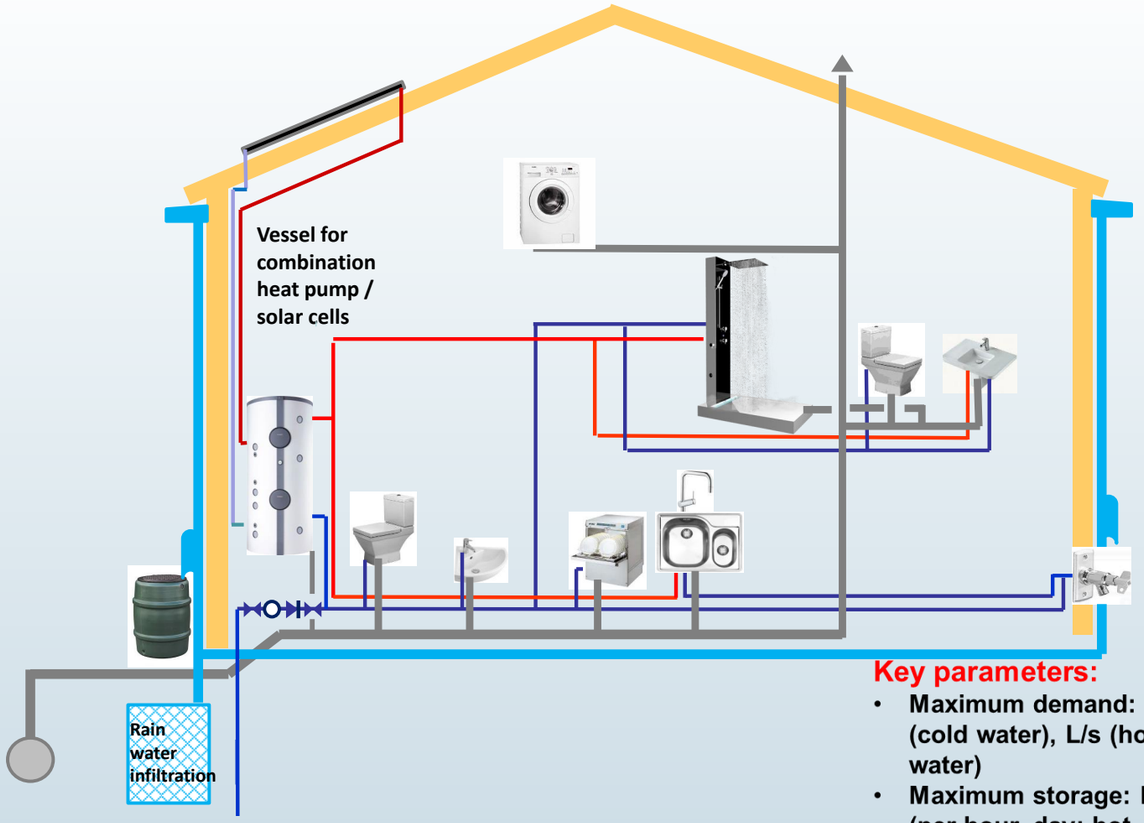


Key parameters:

- Maximum demand: L/s (cold water), L/s (hot water)
- Maximum storage: L (per hour, day; hot water)
- Maximum discharge
- Water quality (demand and discharge)

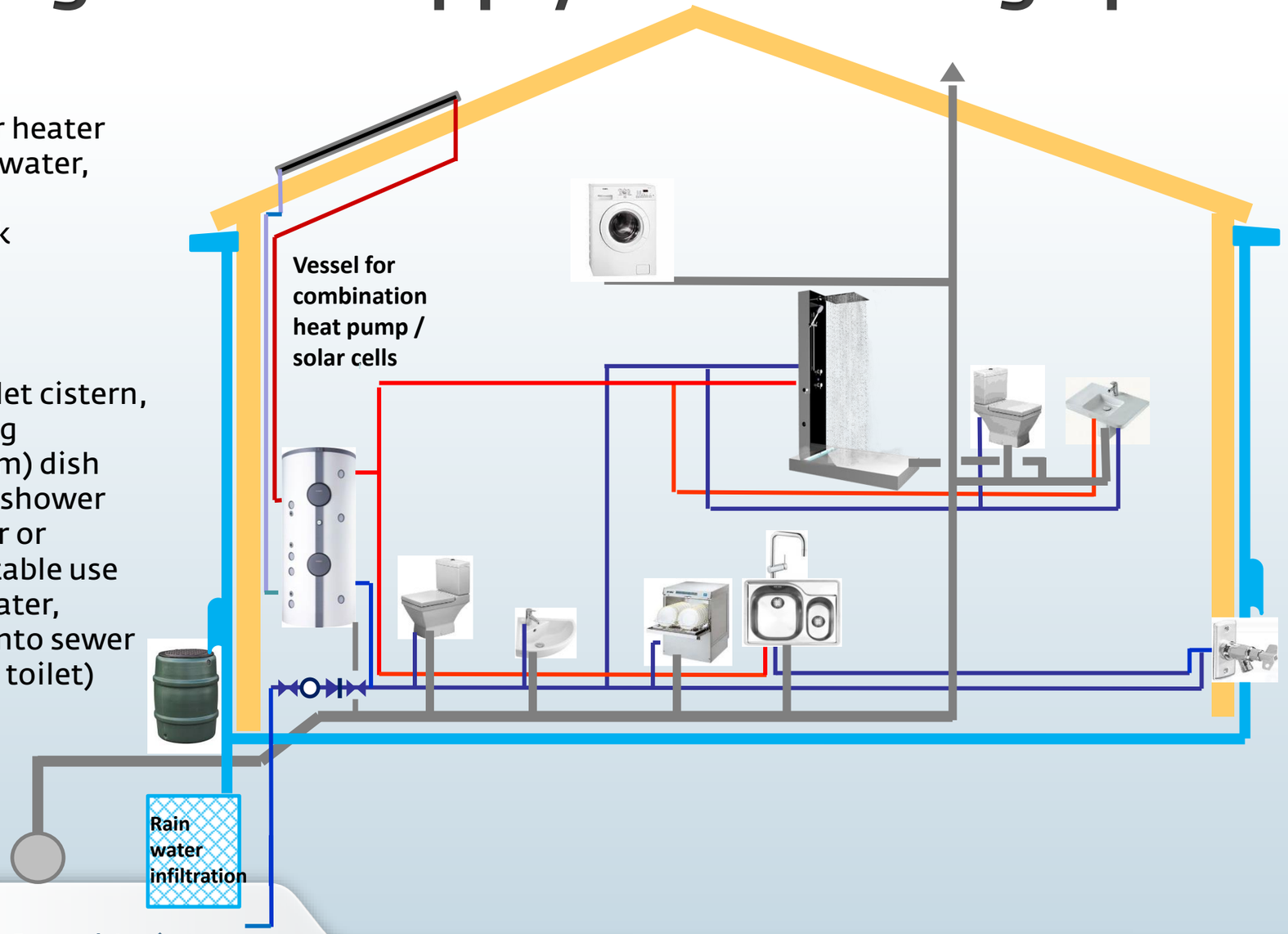
Designing water supply and drainage for buildings

What to design

- Pipe diameters
- Size and type of water heater
- Size of drainage (rain water, sewer)
- Size of rain water tank

Novel technologies

- Save water: 1 litre toilet cistern, 1 litre (ozone) washing machine, 1 litre (steam) dish washer, recirculation shower
- Using light grey water or rainwater for non-potable use
- Infiltrate light grey water, instead of discharge into sewer
- Vacuum sewer (+ new toilet)
- Adding food grinder



Requirements, trade-off between

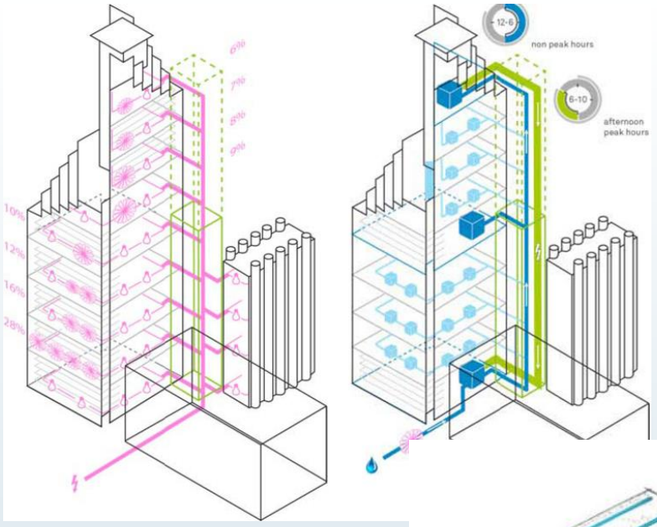
- Comfort: pressure, temperature, no smells, no sounds
- Hygiene: *Legionella* prevention
- Sustainability: energy, material
- Cost: installation and use

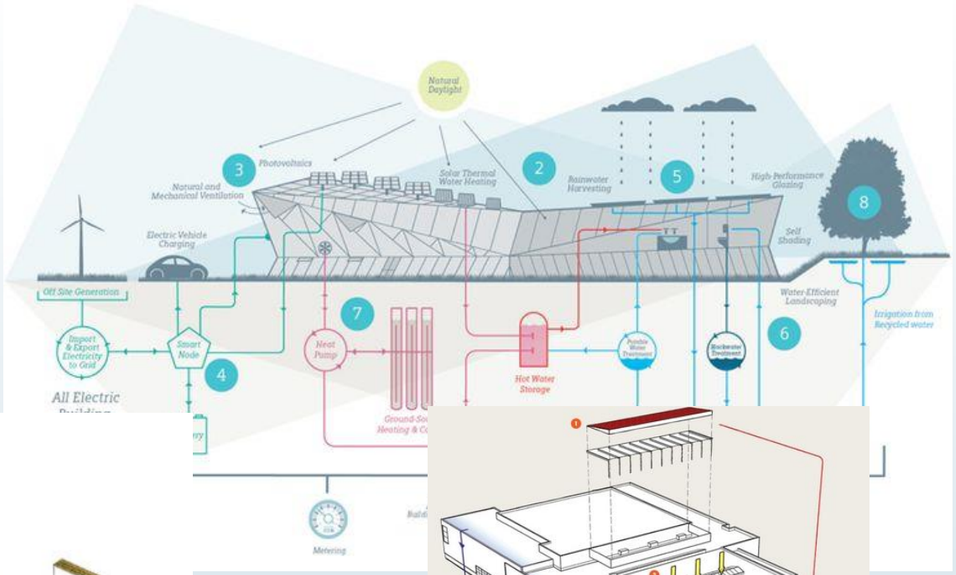
Key parameters:

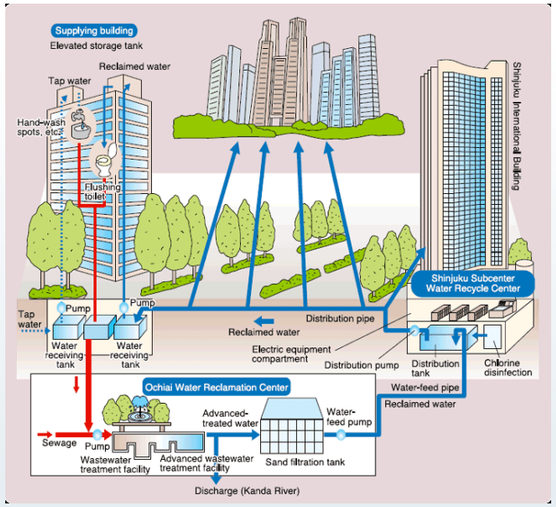
- **Maximum demand: L/s (cold water), L/s (hot water)**
- **Maximum storage: L (per hour, day; hot water)**
- **Maximum discharge**
- **Water quality (demand and discharge)**

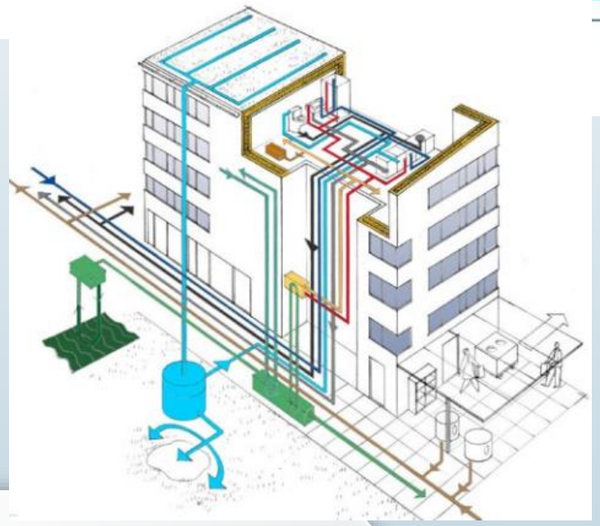
For several types and sizes of buildings

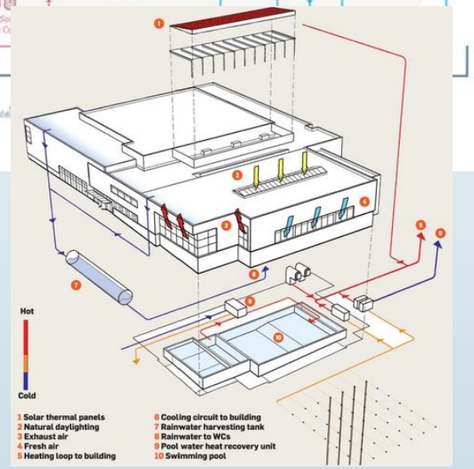
Apartment buildings, offices, hotels, nursing homes, …

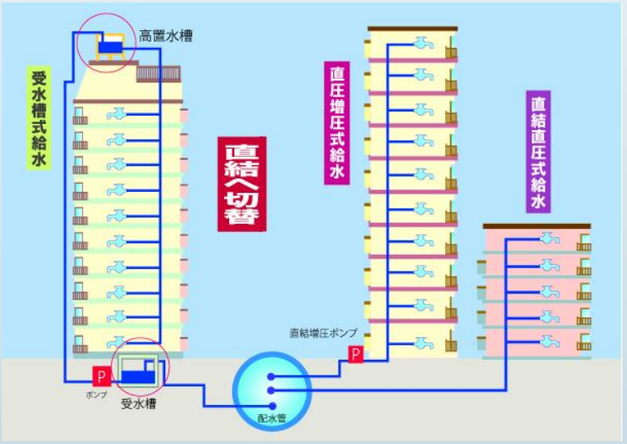












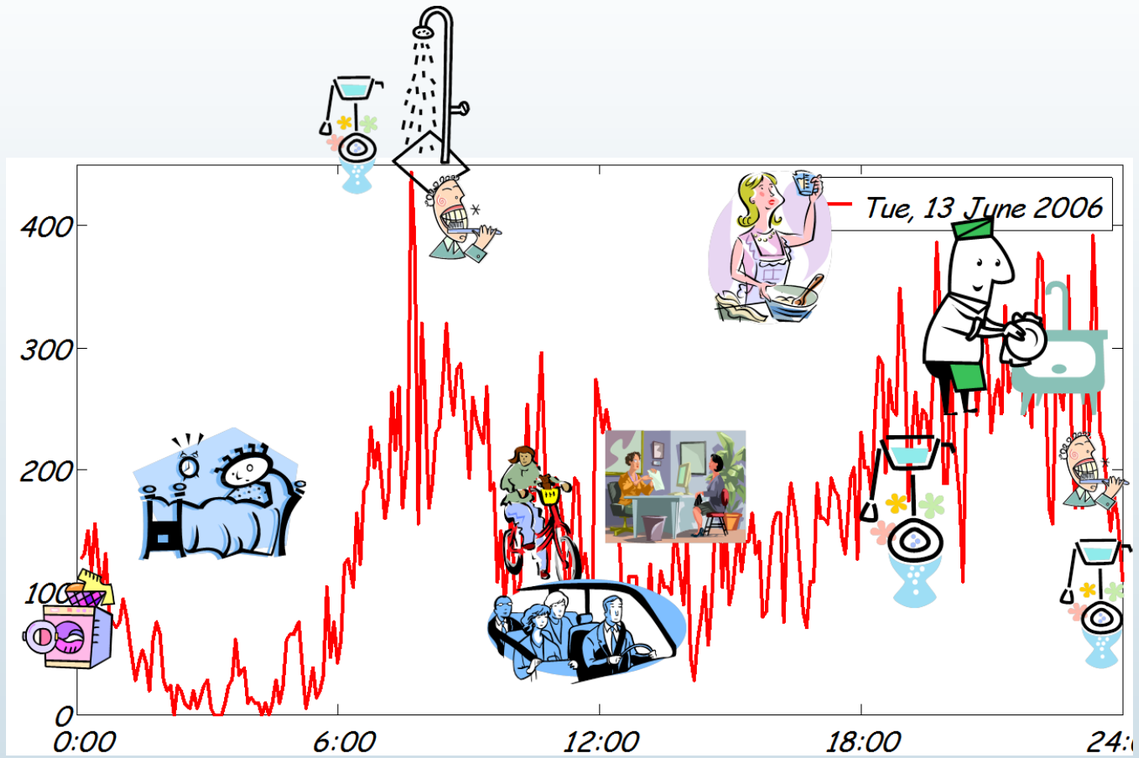
Demand is influenced by appliances and users

Volume determined by:

- **Demand of appliance: toilet, washing machine, dishwasher, …**
- **Q (of appliance) x Duration (user): shower, washing hands, tooth brushing, …**
- **Demand of user: filling dish bucket, water can, bath, …**

Time of water demand determined by:

- **User (presence, awake or not)**



RESIDENTIAL WATER DEMAND OVER A DAY

How to determine all key parameters?

Key parameters:
- Maximum demand: L/s (cold water), L/s (hot water)
- Maximum storage: L (per hour, day; hot water)
- Maximum discharge
- Water quality (demand and discharge)

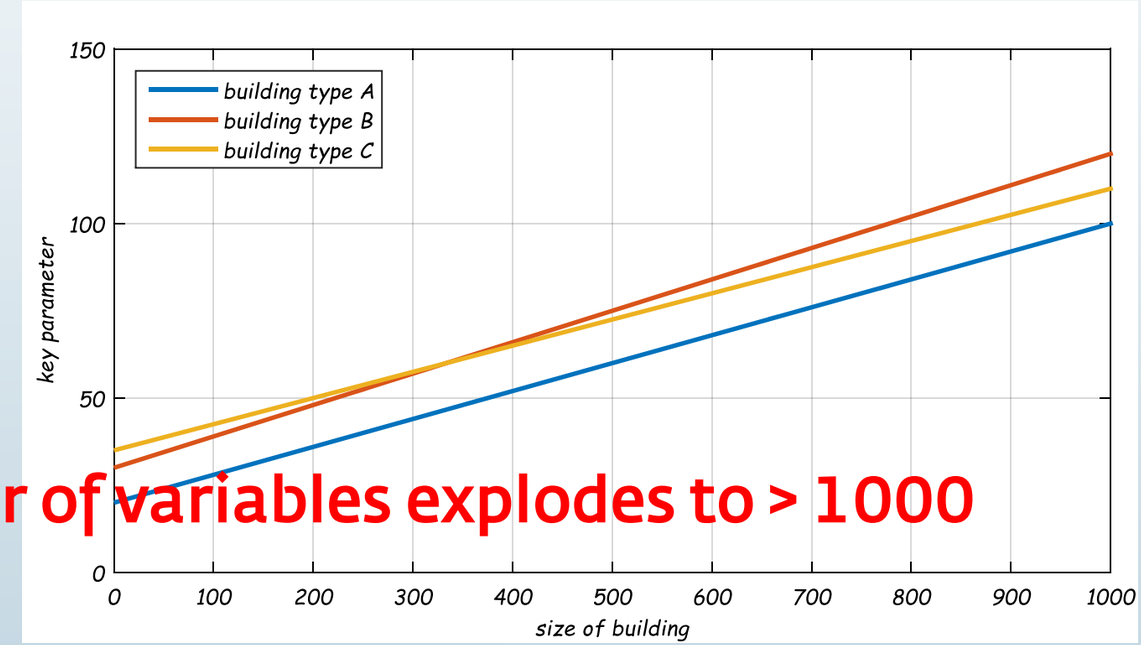
For all types of buildings:

- Apartment buildings with studios for young adults, two room apartments for senior citizens, three room apartments for families, penthouses, etc.
- Hotels for tourists, business hotels, with conference facilities or theatre, with various comfort classes in shower types, etc.
- Offices with or without urinals
- Nursing homes, assisted living facilities, etc.

And for various sizes of buildings

And for various types of water qualities: potable water, grey water, black water, rainwater, …

And for cold and hot water



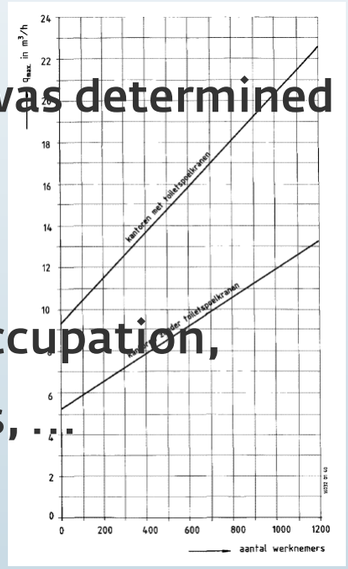
Number of variables explodes to > 1000

Measuring key parameters

Key parameters:
- **Maximum demand: L/s (cold water), L/s (hot water)**
- **Maximum storage: L (per hour, day; hot water)**
- **Maximum discharge**
- **Water quality (demand and discharge)**

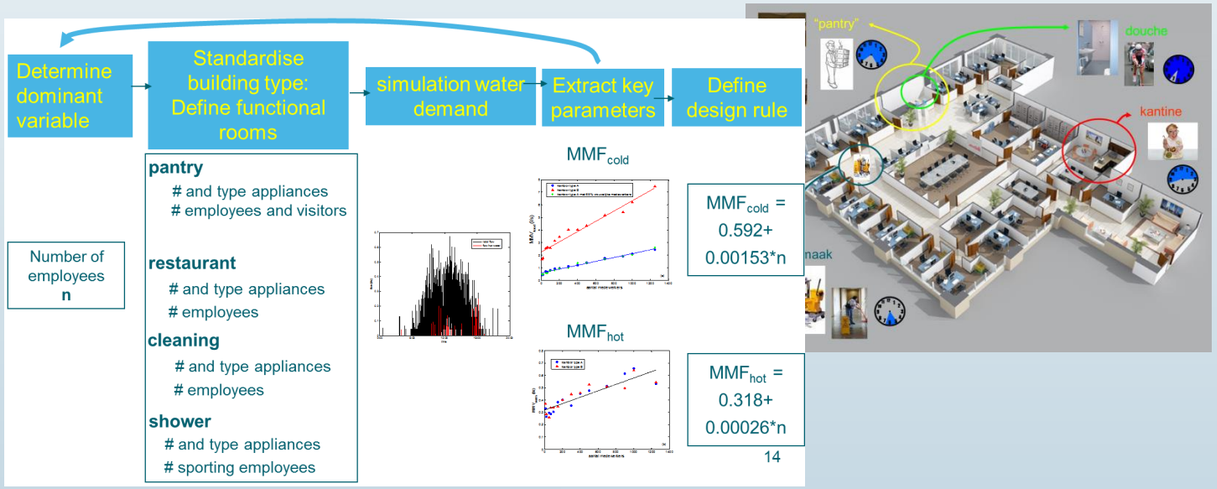
In the **1980s** measurements were done in NL:

- Various apartment buildings, offices, schools, care homes, sports facilities
- Only total cold water at the water meter was measured
- Only maximum demand (L/s) was determined as a function of building size
- Since then: changes in office occupation, coffee machines, toilet cisterns, …



Nowadays, simulations provide an alternative:

- All types and sizes of buildings are possible with various appliances and types of users
- All subsets can be “measured” (cold, hot, clean water, light grey water, black water, …)
- All temporal scales (per s, min, h, day)



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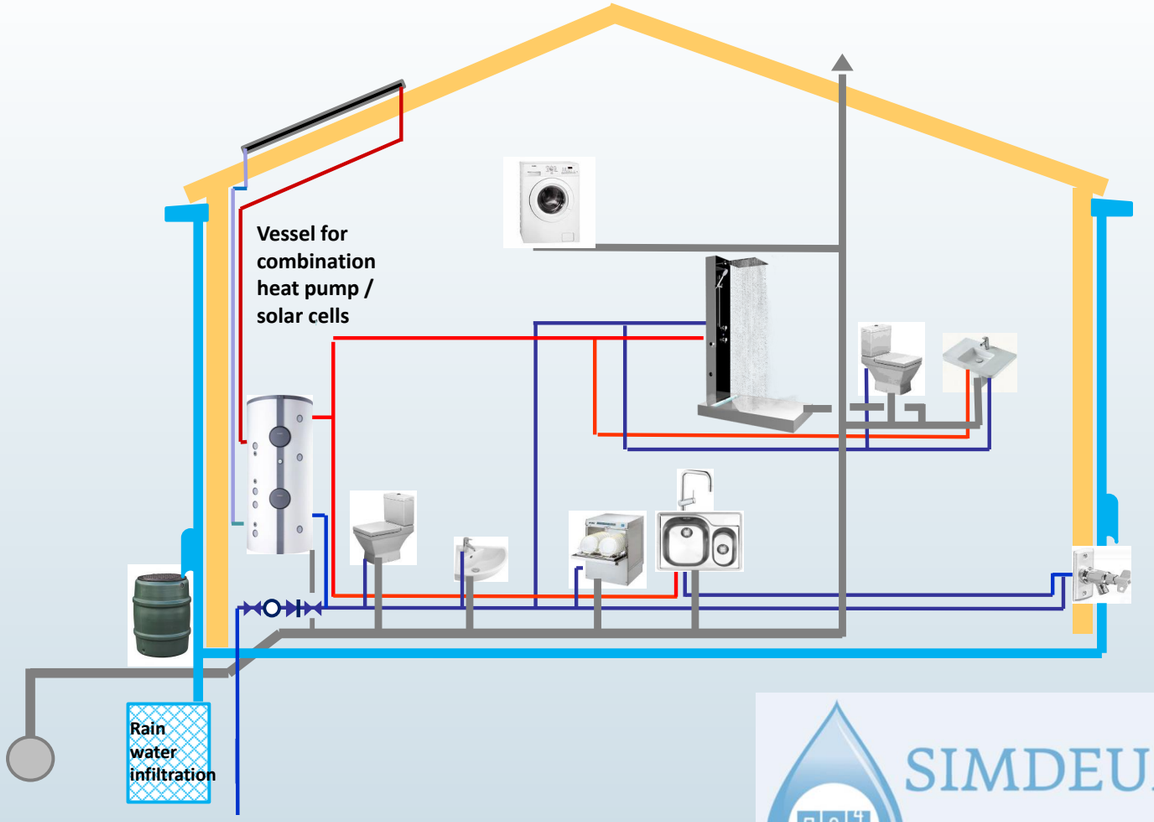


SIMDEUM®

SIMDEUM: simulation of demand, an end-use model

Stochastic model for (non)-residential water demand

KWR Watercycle Research Institute

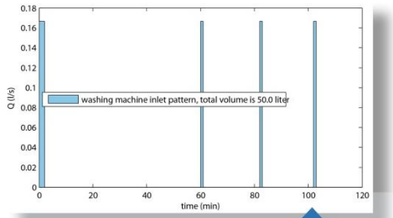


Fig 3 Inlet pattern of a typical Dutch washing machine

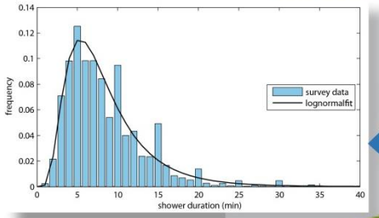


Fig 2 Duration of taking a shower

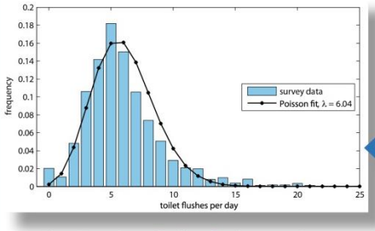
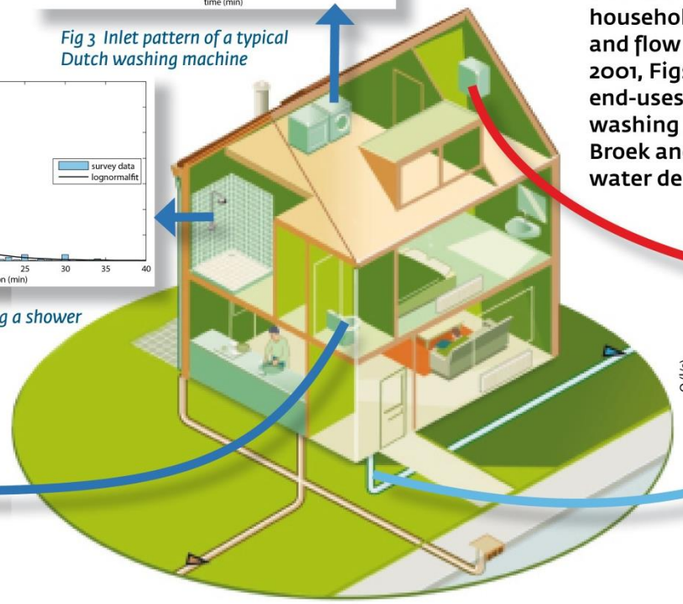


Fig 1 Number of toilet flushes per day



Materials and Methods

A water demand end-use model was developed to predict water demand patterns with a small time scale (1 second) and small spatial scale (residence level). The end-use model is based on statistical information of users and end-uses: census data such as the number of people per household and their ages; the frequency of use; duration and flow per water-use event (Foekema and Engelsma 2001, Figs. 1-3); occurrence over the day for different end-uses such as flushing the toilet, doing the laundry, washing hands, etc (Foekema and Engelsma 2001; Van der Broek and Breedveld 1995). With this approach, residential water demand patterns can be simulated (Fig. 4).

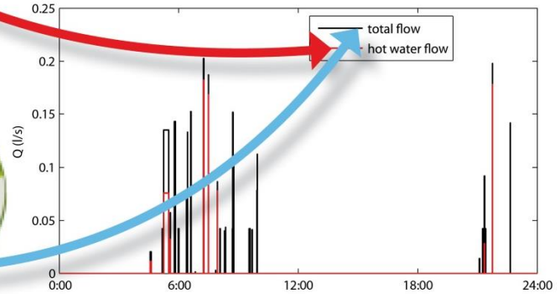


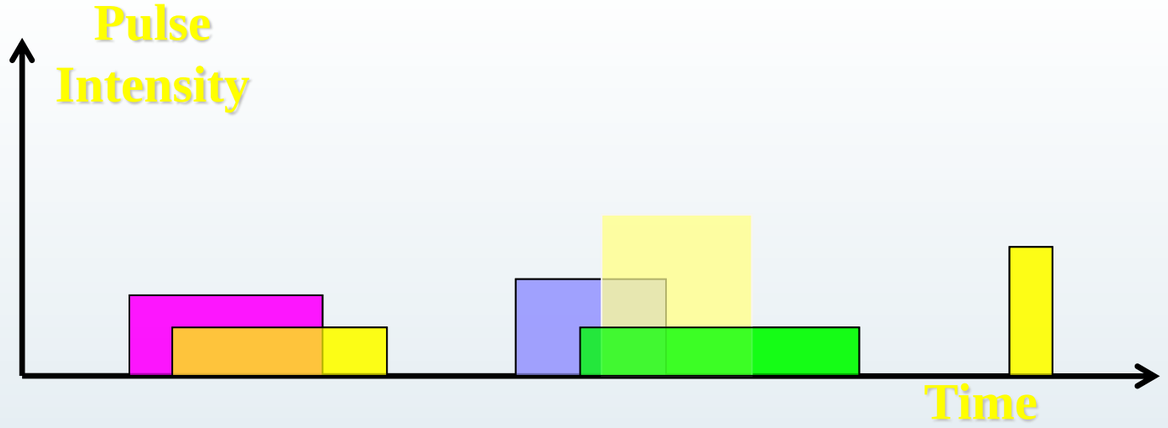
Fig 4 Simulated diurnal flow pattern for a single home

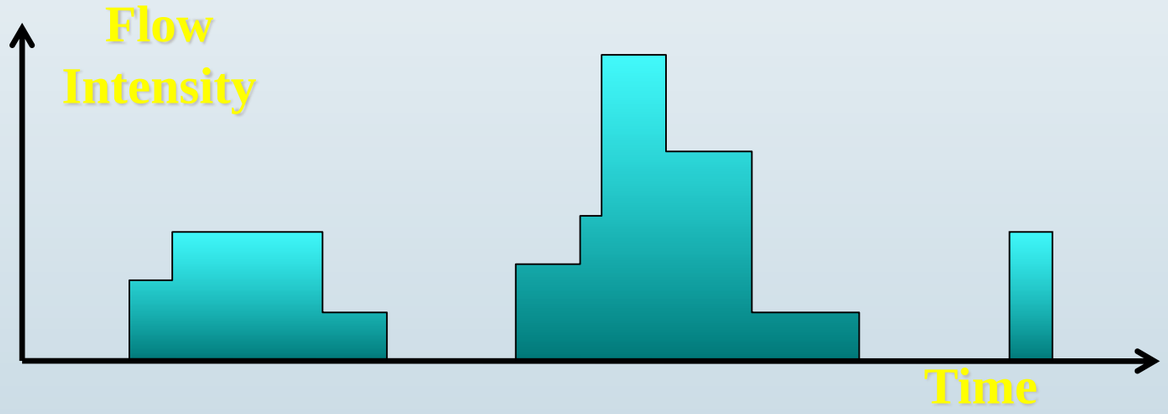
Basic principle of SIMDEUM

Add blocks of water demand at various intensities (L/s), durations (s) and time of occurrence (HH:MM)

$$B(I, D, \tau) = \begin{cases} I & \tau < T < \tau + D \\ 0 & elsewhere \end{cases}$$

$$Q = \sum B(I, D, \tau)$$





Source: Buchberger, 2007

SIMDEUM: parameters follow from surveys and information on appliances

When did you get up, leave the house, go to bed?

τ

No flow measurements

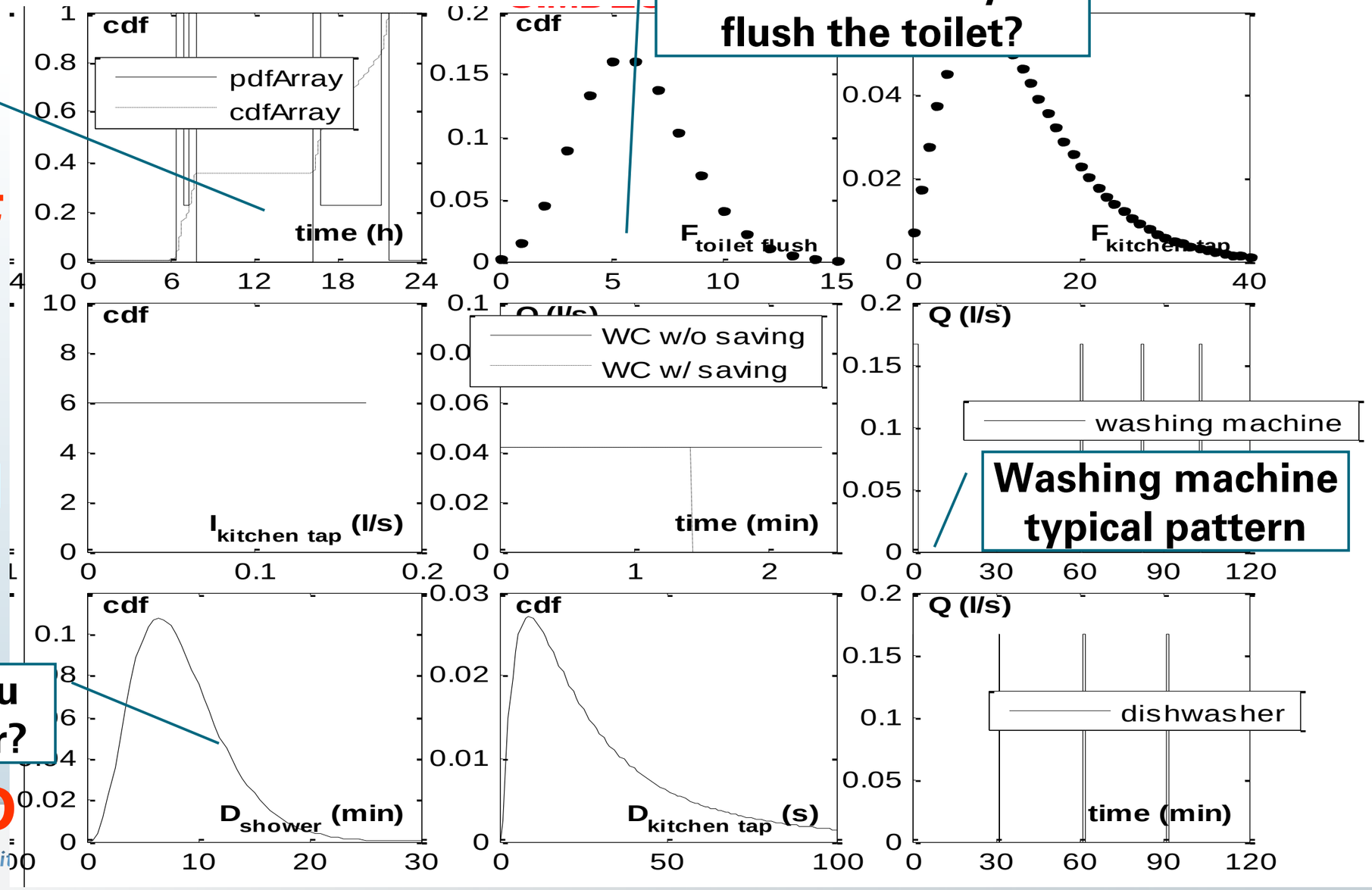
I

How long did you take a shower for?

D

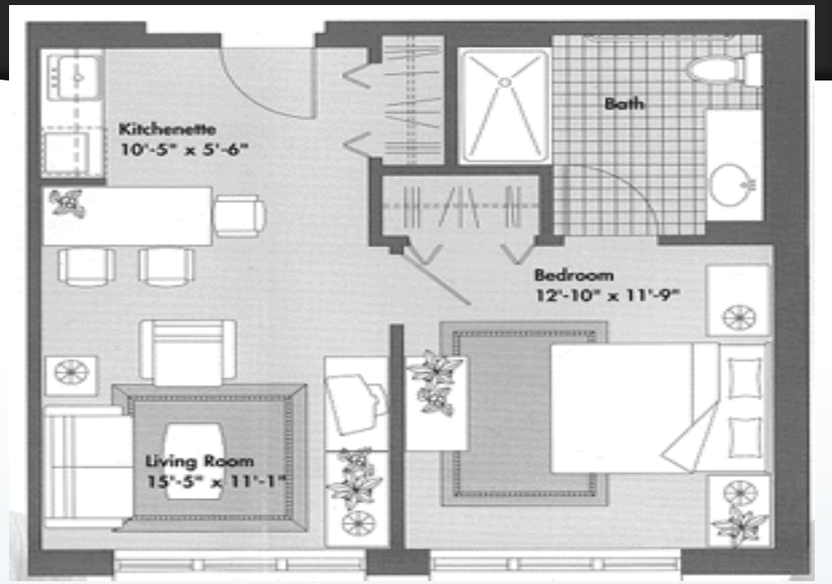
How often did you flush the toilet?

Washing machine typical pattern



SIMDEUM steps (1)

Apartment building – users and installation

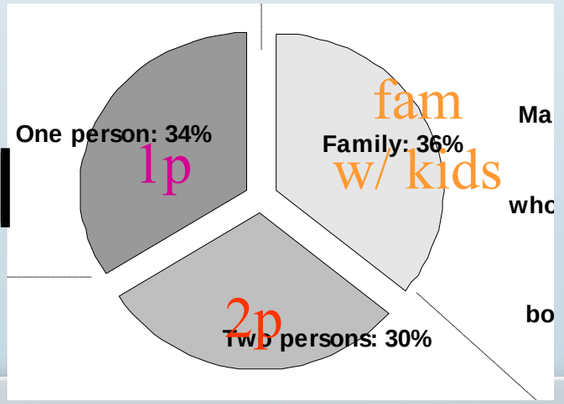


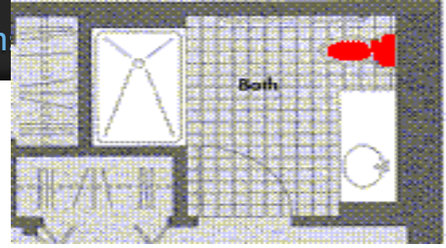
5 people: dad, mum, 3 children

Bathroom: bath, shower, toilet, sink

Kitchen: sink, dishwasher, washing machine

Average 2.3 people/home

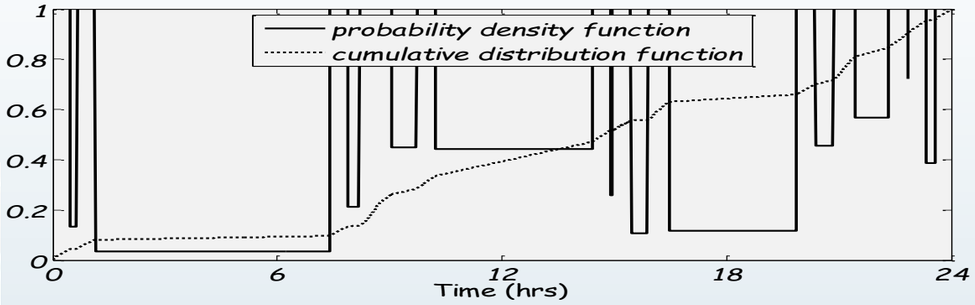




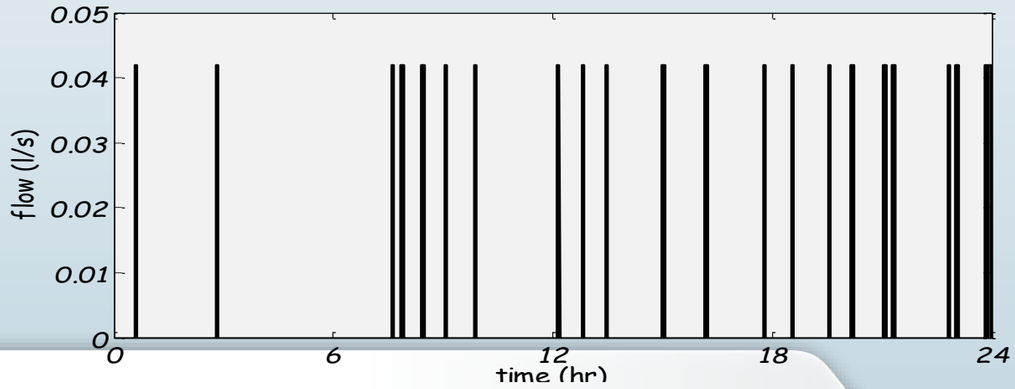
SIMDEUM steps (2)
Toilet flush demand

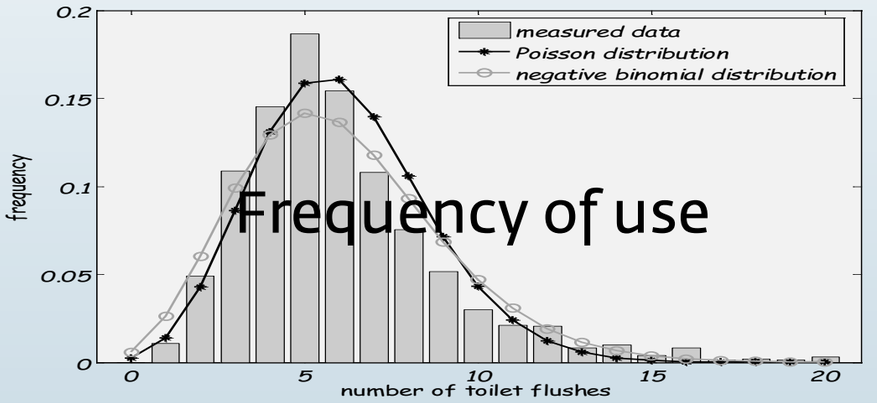
9 liter cistern

5 users, probability of use



Generate diurnal demand



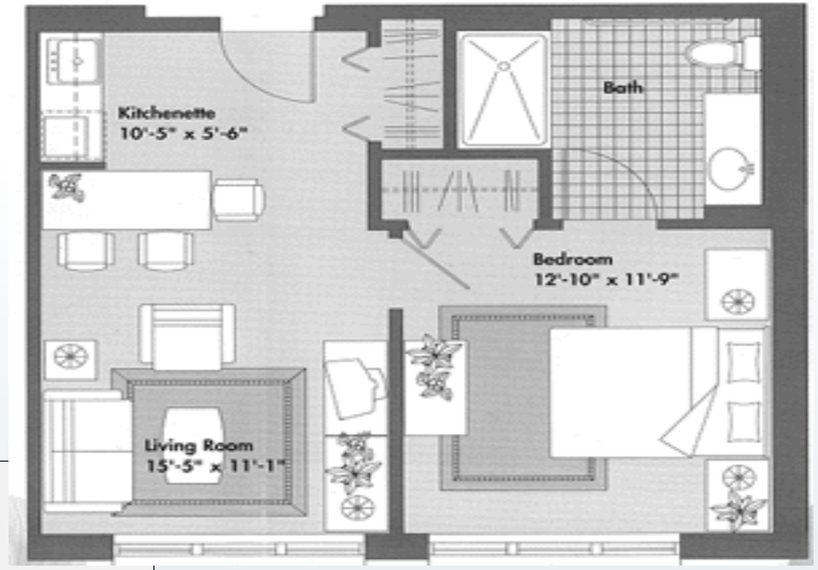


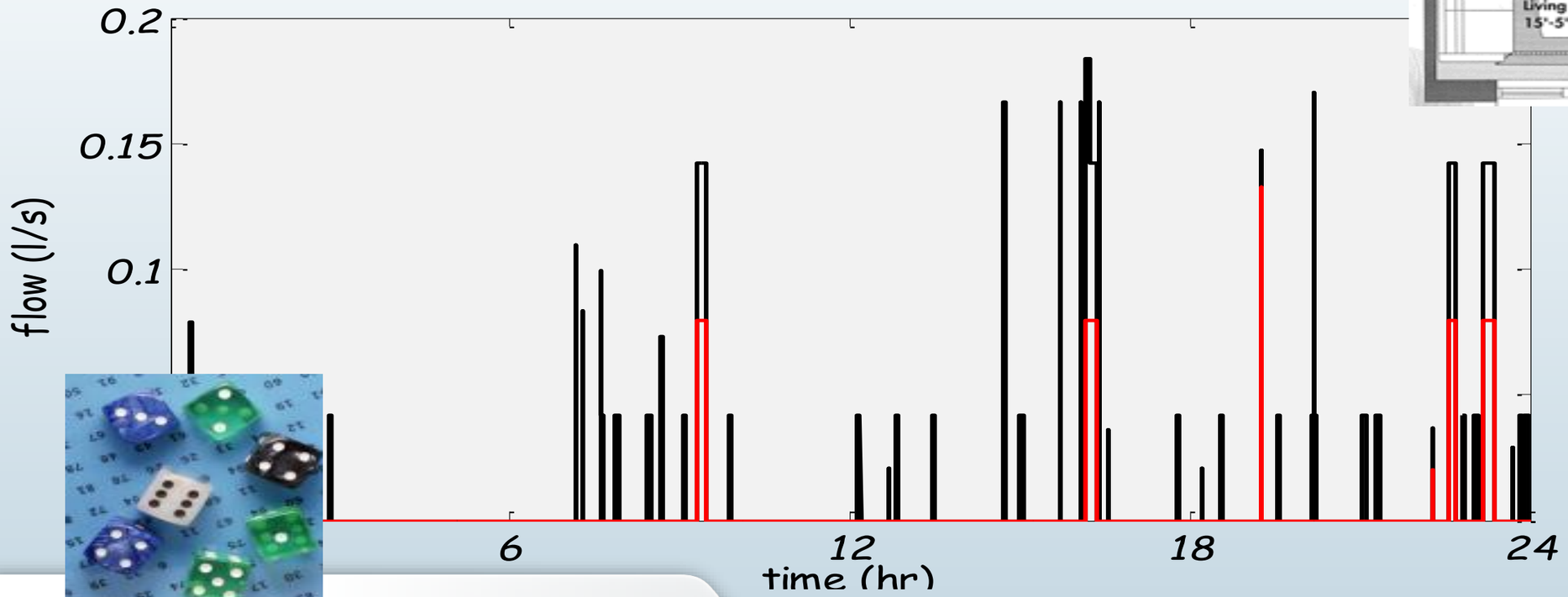
Frequency of use

SIMDEUM steps (3)

Total demand for one house

Toilet, shower, washing machine, etc





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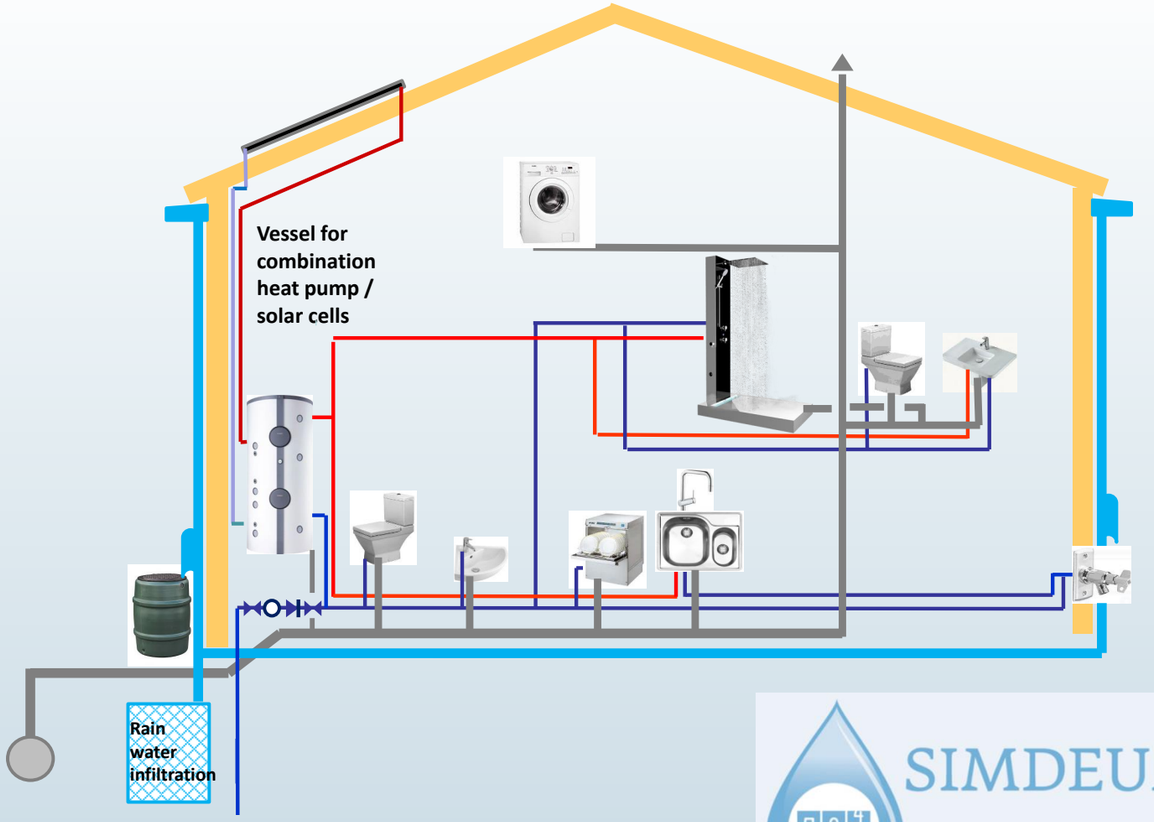

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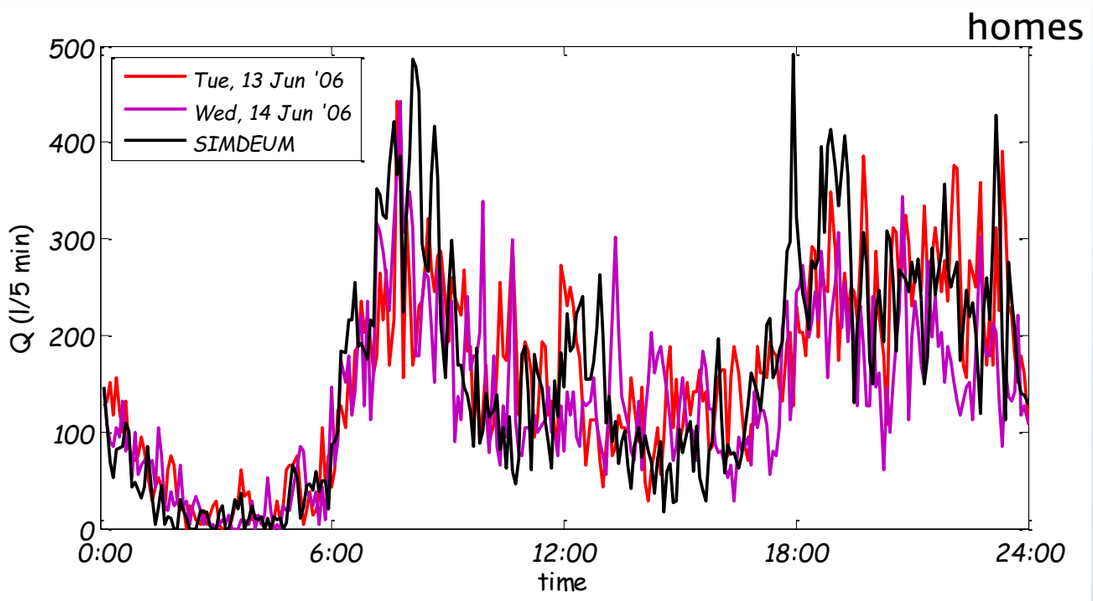
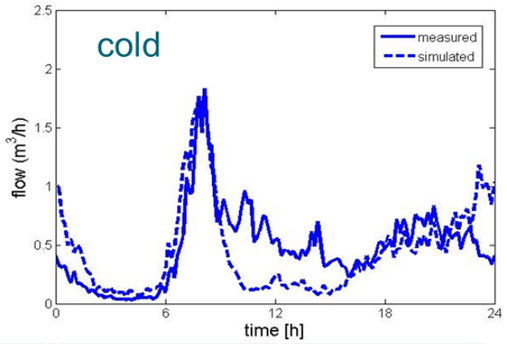
Validation of SIMDEUM (1)

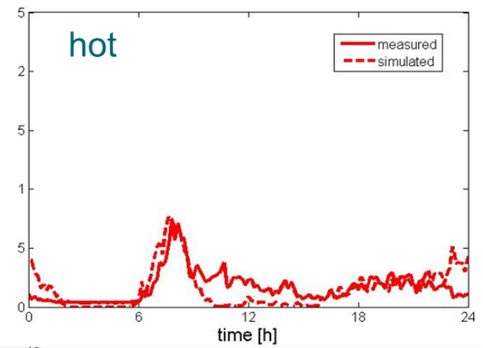
Demand patterns

Street 140 homes

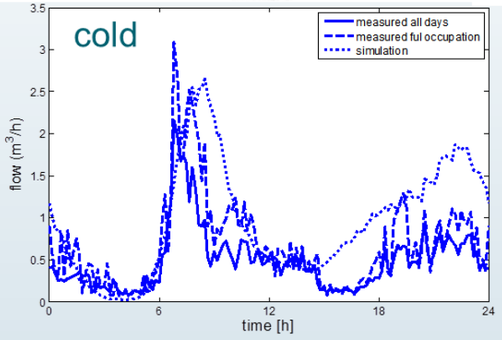


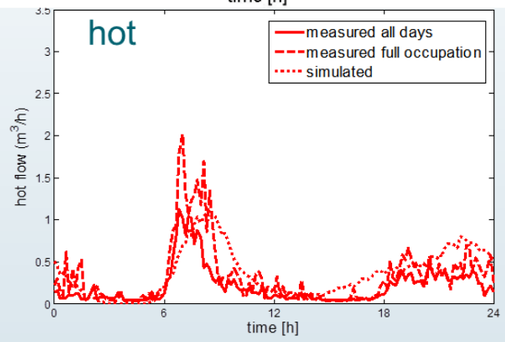
Apartment building



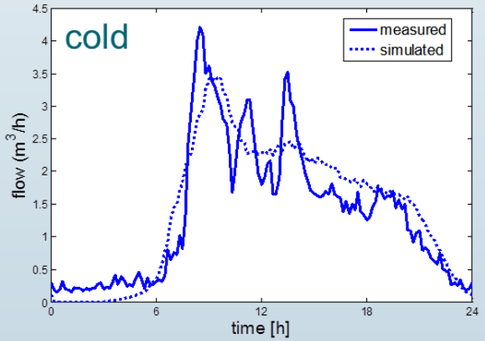


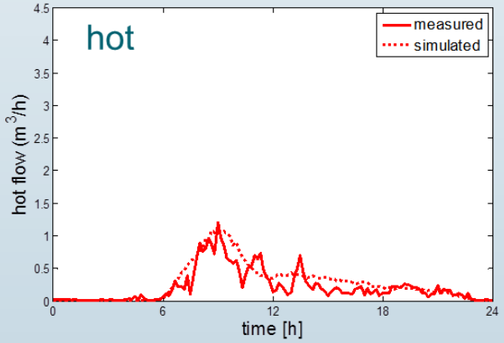
Hotel





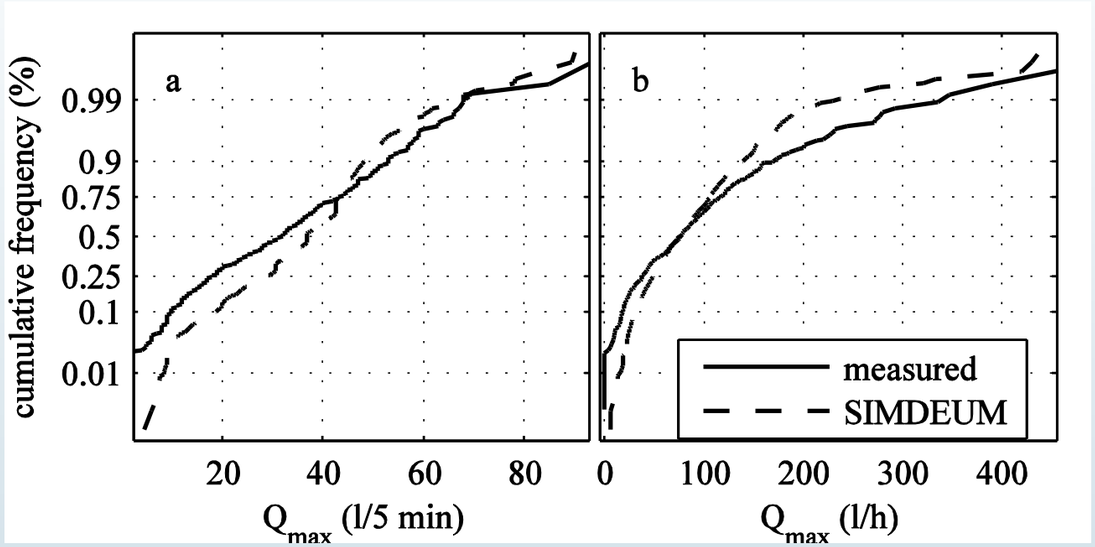
Nursing home



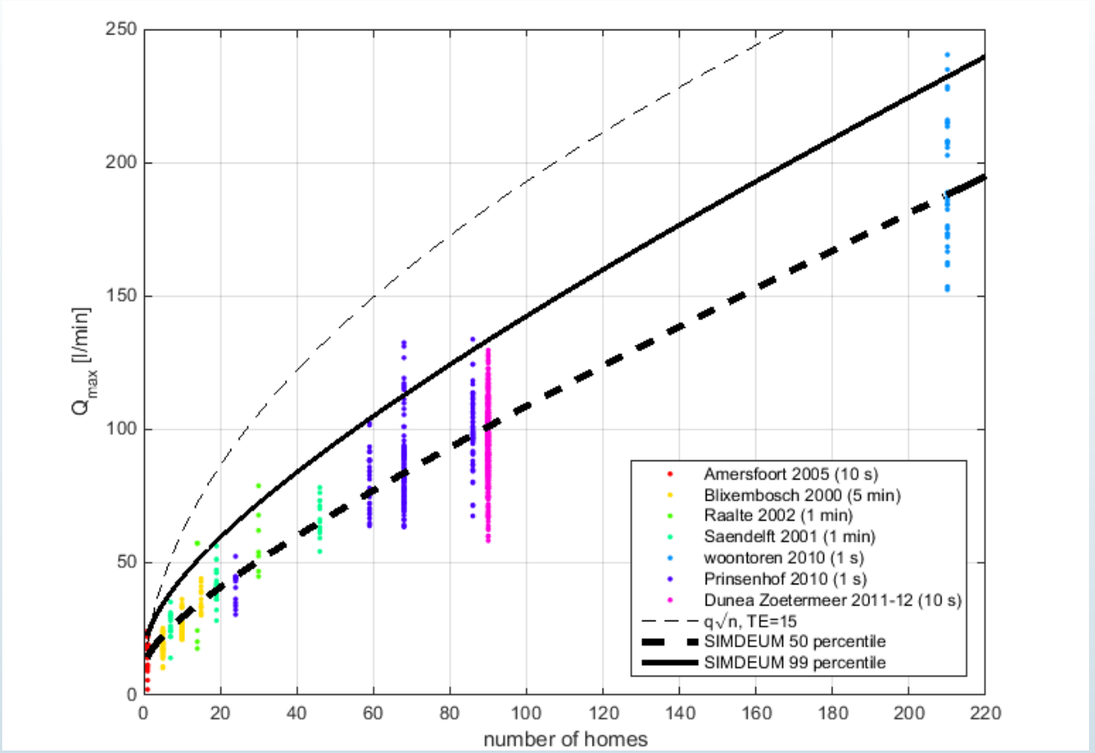


Validation of SIMDEUM (2)

Maximum flow velocities in (aggregation of) homes



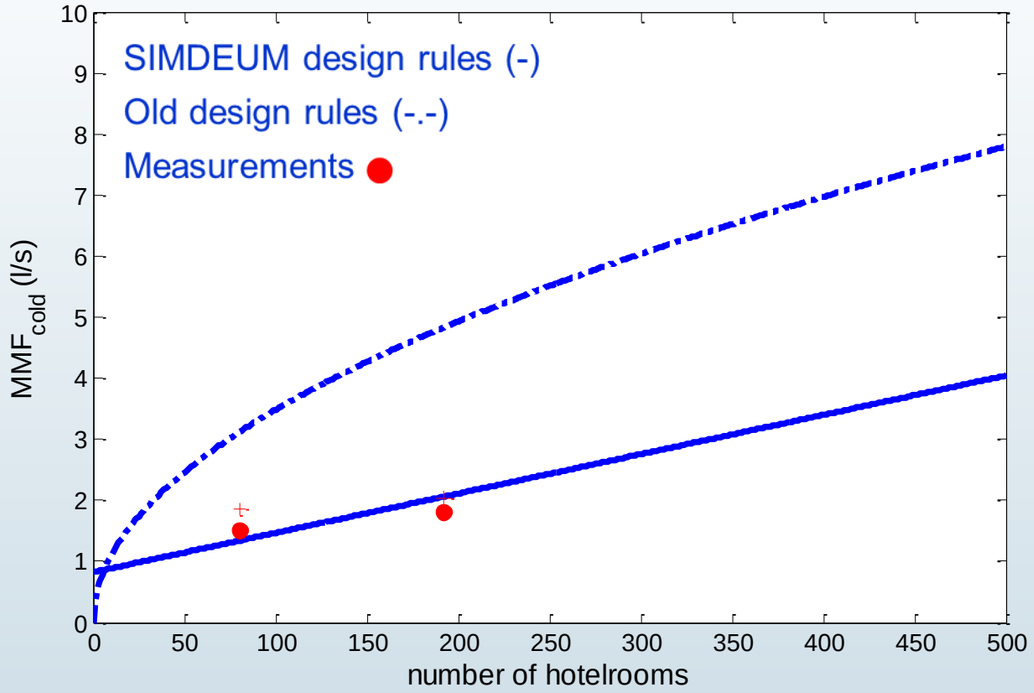
SINGLE HOME, 300 MEASURED PATTERNS, 100 SIMULATED PATTERNS



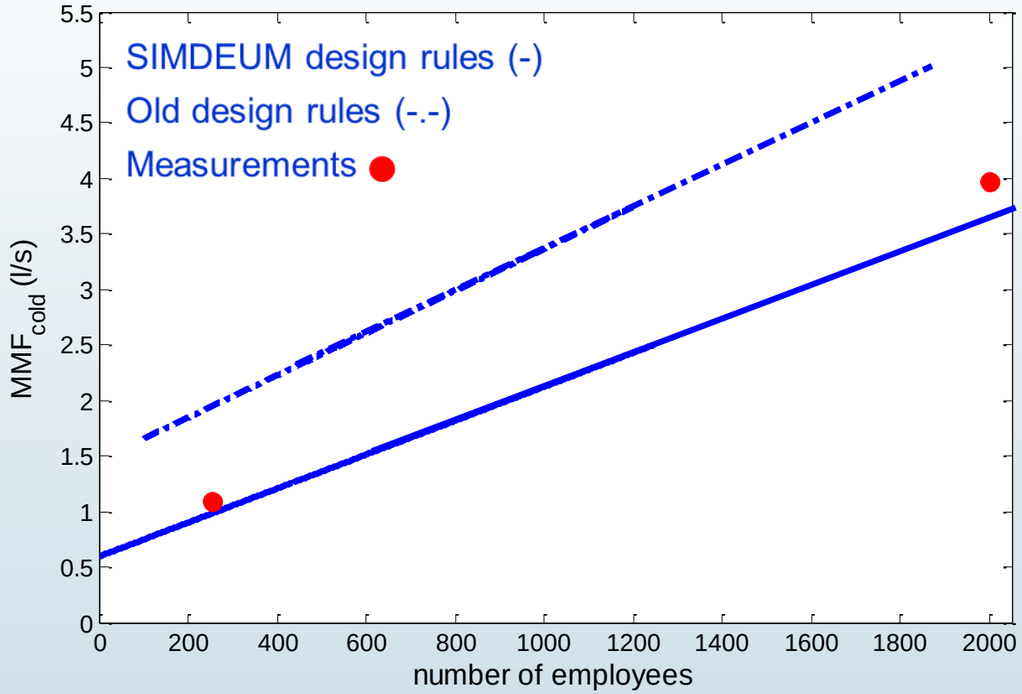
NOTE THAT Q MEASUREMENTS MAY INCLUDE EXTRA FLOW FOR WATER QUALITY SENSOR MEASUREMENTS

Validation of SIMDEUM (3)

Maximum flow velocities in non-residential buildings



HOTELS



OFFICES

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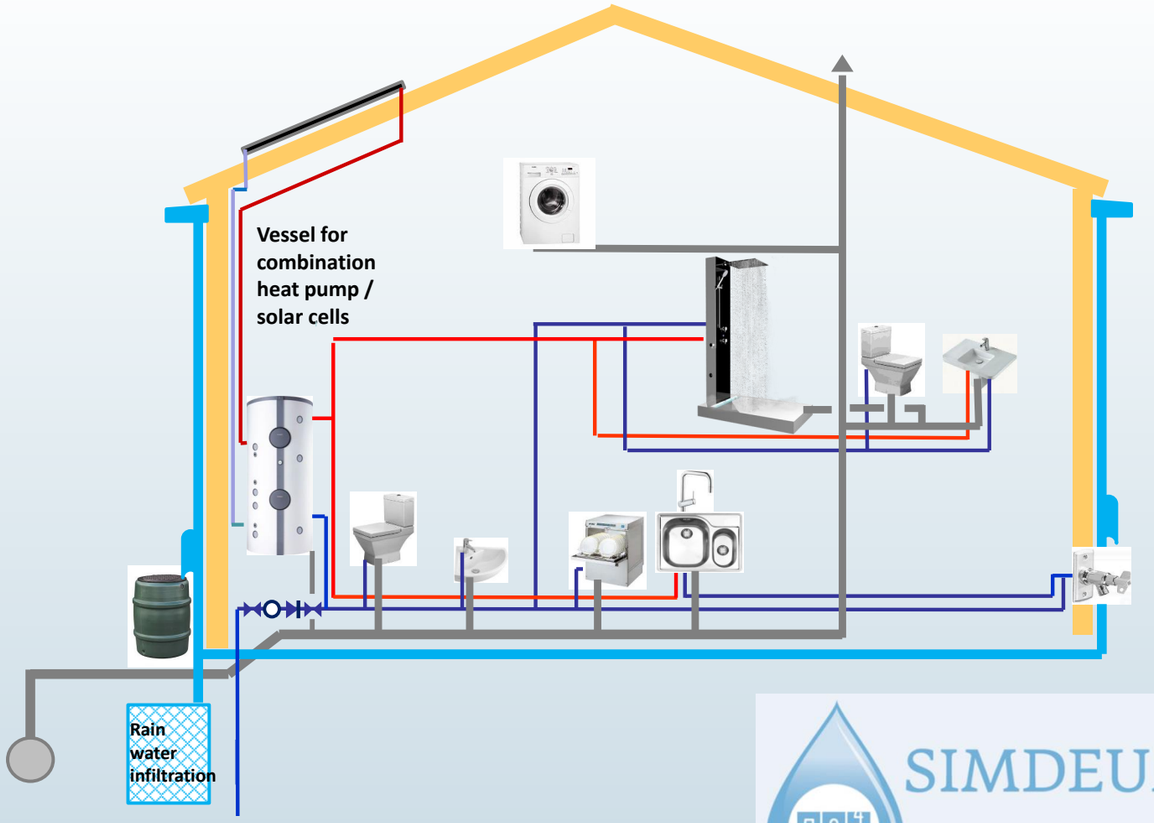


SIMDEUM®

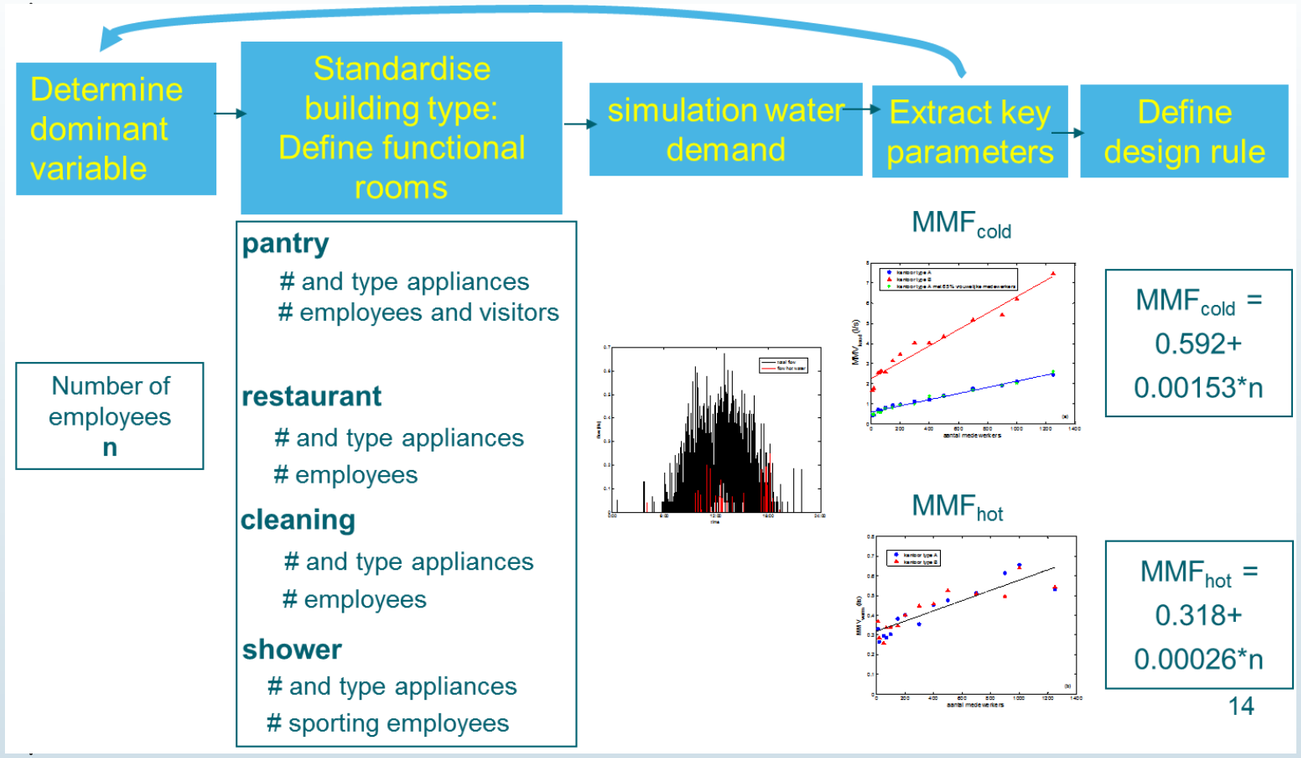
SIMDEUM to generate virtual measurement data
and extract key parameters from that

Key parameters:
- Maximum demand: L/s (cold water), L/s (hot water)
- Maximum hot water volume: L (per 10 min, per hour, per 2 hours, per day)

Building types:
- Residential buildings with 5 types of apartments
- Offices, 2 types
- Hotels, 4 types x 7 shower types
- Nursing homes, 4 types , w/wo bedpan flusher

Simulation settings:
- Temporal scale is 1 s
- Per building type 100 days of demand are simulated
- Max (key parameter) is 99 percentile
- Per building type 10 sizes (# apartments, # employees, # rooms, # of residents respectively)

Design rules:
- Linear fit through key parameters
- Potentially add small safety factor



SIMULATING OFFICE WATER DEMAND, EXTRACT KEY PARAMETER AND DEFINE DESIGN RULE

Making design rules available

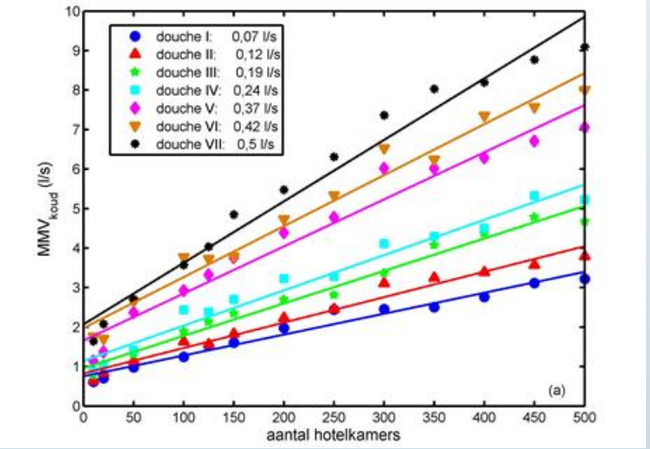
Design rules are in the official guideline:

ISSO-kontaktgroep. (2015). ISSO-Publicatie 55 Leidingwaterinstallaties voor woon- en utiliteitsgebouwen, Stichting ISSO, Rotterdam.

Design rules are build into spreadsheet and are available

Design rules are to be build into installation design software (VABI etc.)

Water use in hotels		
Building input data		
select hotel type	business hotel	
select shower type	shower III: 0.19 l/s	
number of hotel rooms	100	
Key Parameters		
MMF_cold	1.98	[l/s]
MMF_hot	1.04	[l/s]
MHWU in 10 minutes	442.53	[l]
MHWU in 60 minutes	1619.62	[l]
MHWU in 120 minutes	2546.76	[l]
MHWU in 24 hour	8013.25	[l]
MMF: maximum momnet flow		
MHWU: maximum hot water use		



Building your own SIMDEUM

Required input data

Appliances:

- Toilet, shower, bath, washing machine, dishwasher, kitchen tap, bathroom tap, (outside tap)
- Volume (L) or flow (L/s) and duration (s)

Reuse Dutch data, add specifics

Users:

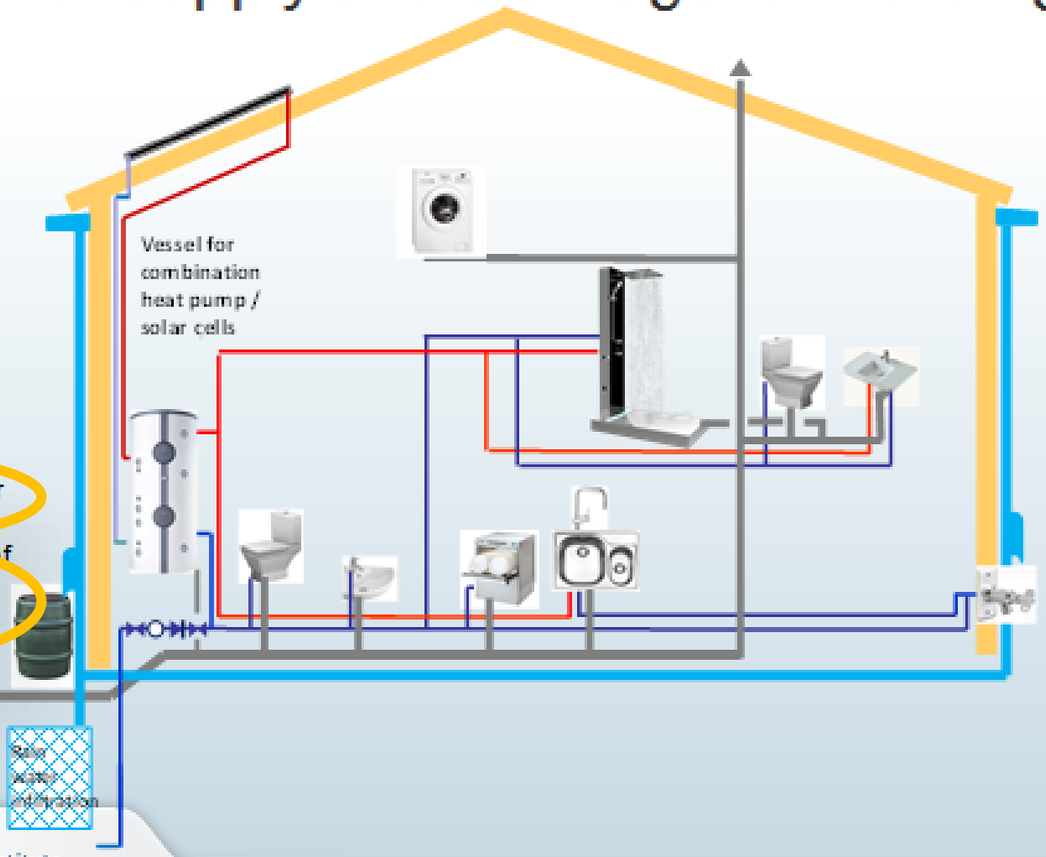
- Number: household size, number of employees, etc.
- Water using behaviour: shower duration, number of toilet flushes, required temperatures, etc.
- Diurnal pattern: sleep-wake-rhythm, shower in morning or evening, office hours, etc.

More applications of SIMDEUM

Talks by my colleagues

Designing water supply and drainage for buildings

What to design
- Pipe diameters
- Size and type of water heater
- Size of drainage (rain water, sewer)
- Size of rain water tank



Requirements, trade-off between
- Comfort: pressure, temperature, no smells, no sounds
- Hygiene: *Legionella* prevention
- Sustainability: energy, material
- Cost: inst use

C3 Agudelo-Vera
Customized design of residential grey water and rainwater systems using SIMDEUM

let cistern, 1
machine, 1
sher,
culation shower
- Using light grey water or rainwater for non-potable use
- Infiltrate light grey water, instead of discharge into sewer
- Vacuum sewer (+ new toilet)
- Adding food grinder

D11 Wei-Shan Chen
Water out shit in: a new paradigm for resource recovery

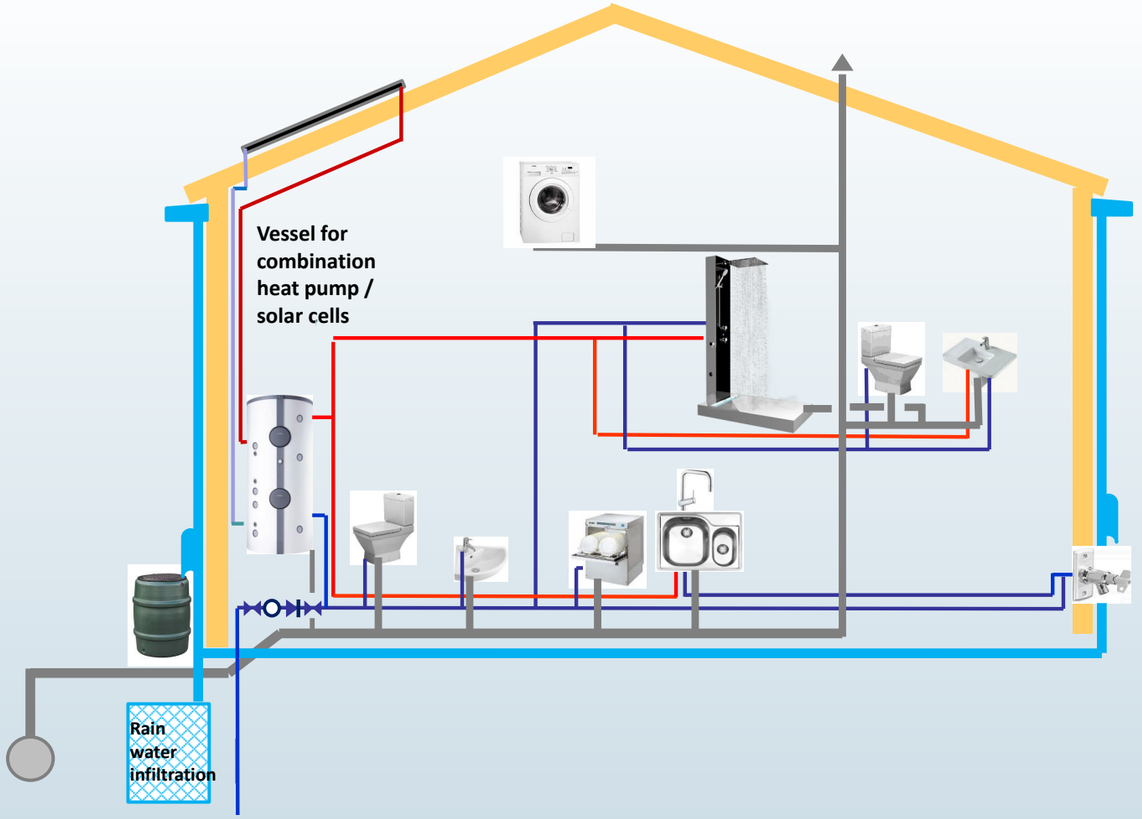
B2 Moerman
Decision support model for water heaters based on stochastic water demand modeling

Key parameters:
- **Maximum demand: L/s (cold water), L/s (hot water)**
- **Maximum storage: L (per hour, day; hot water)**
- **Maximum discharge**
- **Water quality (demand and discharge)**

KWR Watercycle Research Institute

Outline

1. Designing water supply and drainage for buildings
2. Developing a stochastic demand model (SIMDEUM)
3. Validating SIMDEUM
4. Using SIMDEUM to design water supply and drainage for buildings
5. Conclusions



Development and application SIMDEUM

For water supply in buildings

2003-06

Development SIMDEUM

2007-10

Development design rules:

- Residential buildings
- Non-residential buildings

2011-14

Validation design rules with measurements of cold and hot water:

- Residential buildings
- Non-residential buildings

2015-…

Update ISSO 55 contains design rules based on SIMDEUM

More applications of SIMDEUM

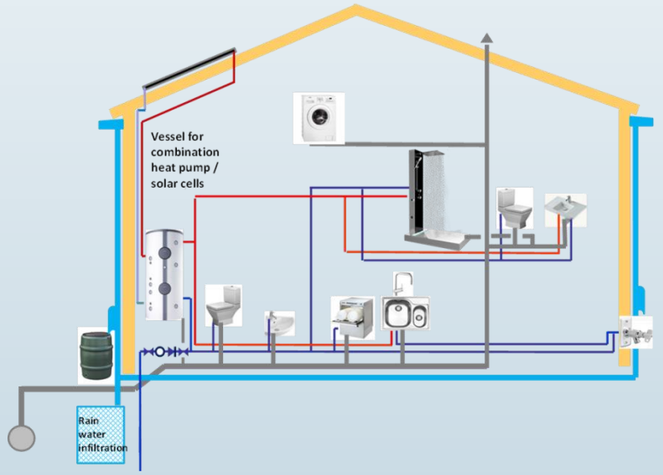
Conclusions

SIMDEUM is a validated tool to generate realistic stochastic water demands for residential and non-residential buildings

SIMDEUM can generate large dataset of “virtual measurement s” to inexpensively determine design rules for sizing of hot and cold water systems

SIMDEUM can be used for new technologies that are not yet on the market (i.e. no measurements possible)

SIMDEUM can be used for other types of buildings and other countries, with their specific input parameters



Using a stochastic demand model to design building installations

CIB W062 - Water Supply and Drainage for Buildings