Achieving Building Sustainability with Simulation Technologies

08 November 2016 (Tuesday), 9.00am - 1.00pm (Half Day)
Shah's Village Hotel, Petaling Jaya

ORGANISED BY MGBC

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Case Study on Benefit of Simulations

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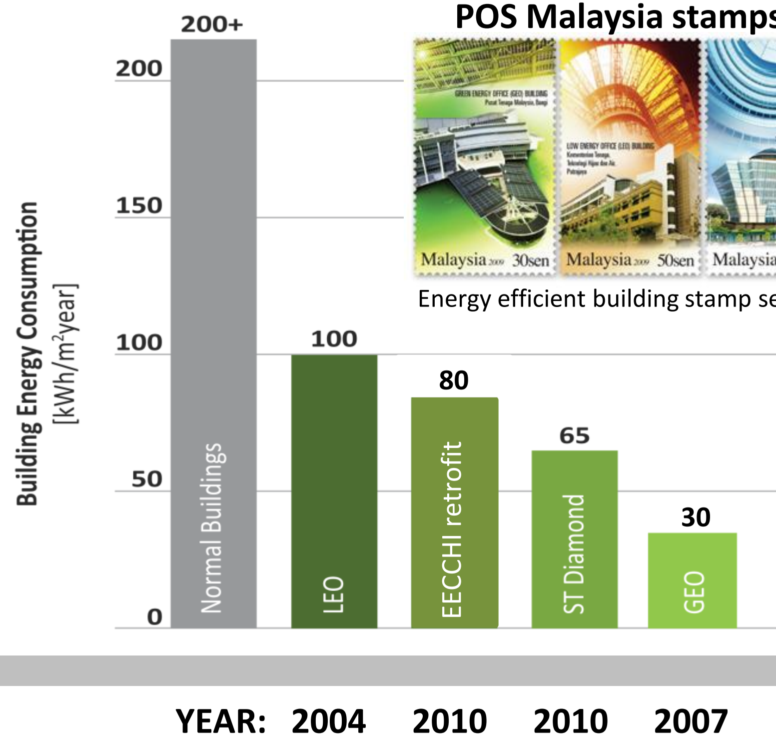
LEO Building

GEO Building

ST Diamond Building

EECCHI retrofit



POS Malaysia stamps

Energy efficient building stamp series

Here's the answer to

"Benefit of Simulations"

Measured Energy Data

for

New and Retrofitted Buildings

by IEN Consultants

all of which were optimised through extensive computer simulation

A real conversation that I had here in Malaysia.....

Courtesy of Gregers Reimann/IEN Consultants Sdn Bhd / Illustration by Rachel Chen Ruiqi

The Star newspaper, 16 August 2013

I optimised the design of buildings through computer simulation – and then they are built without any big surprises ☺

Problem of Over-Design for Buildings

Building owners get double-penalty of:

- Higher CAPEX

  (higher construction cost)

- Higher OPEX

  (higher operating cost)

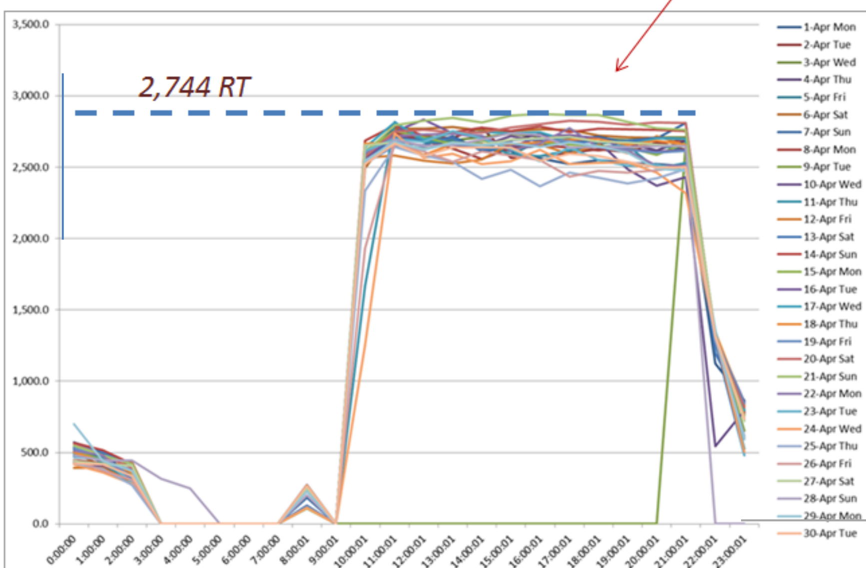
Cartoon by IEN Consultants / The Star newspaper (2014)

Case study 1: Building Simulation showed that the Chiller Plant could be Down-Sized

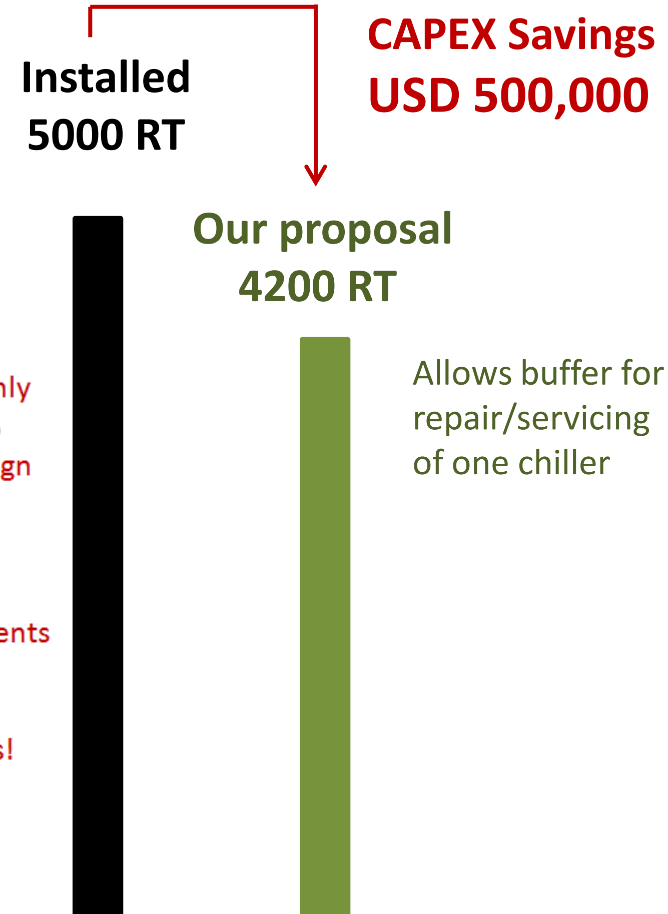
Measured cooling load
Malaysian Shopping Mall

Peak Cooling Rate = 40.9Btu/h.ft^2

which is only about **50%** of the design load!

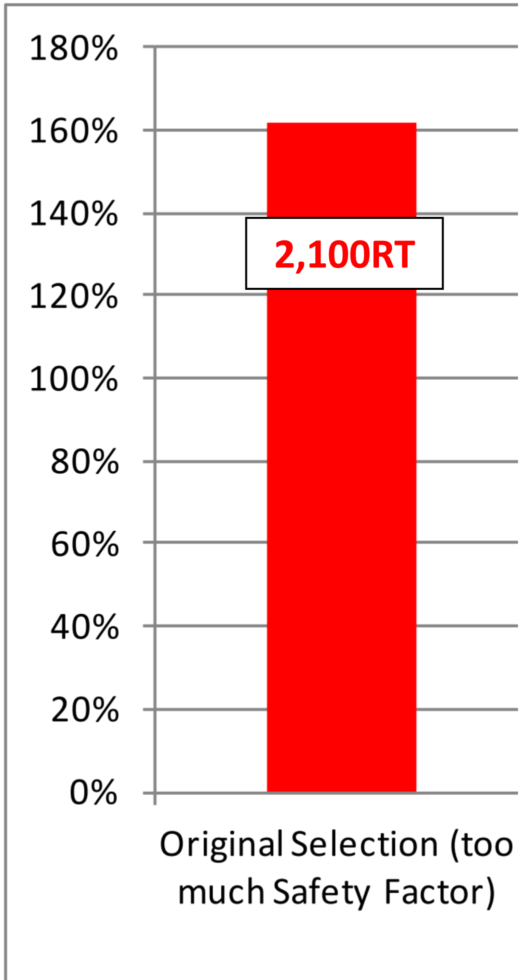


Measurements match our energy simulations!



Case study 2: Building Simulation showed that the Chiller Plant could be Down-Sized

Shopping mall project in Malaysia



Case study 2: Building Simulation showed that the Chiller Plant could be Down-Sized

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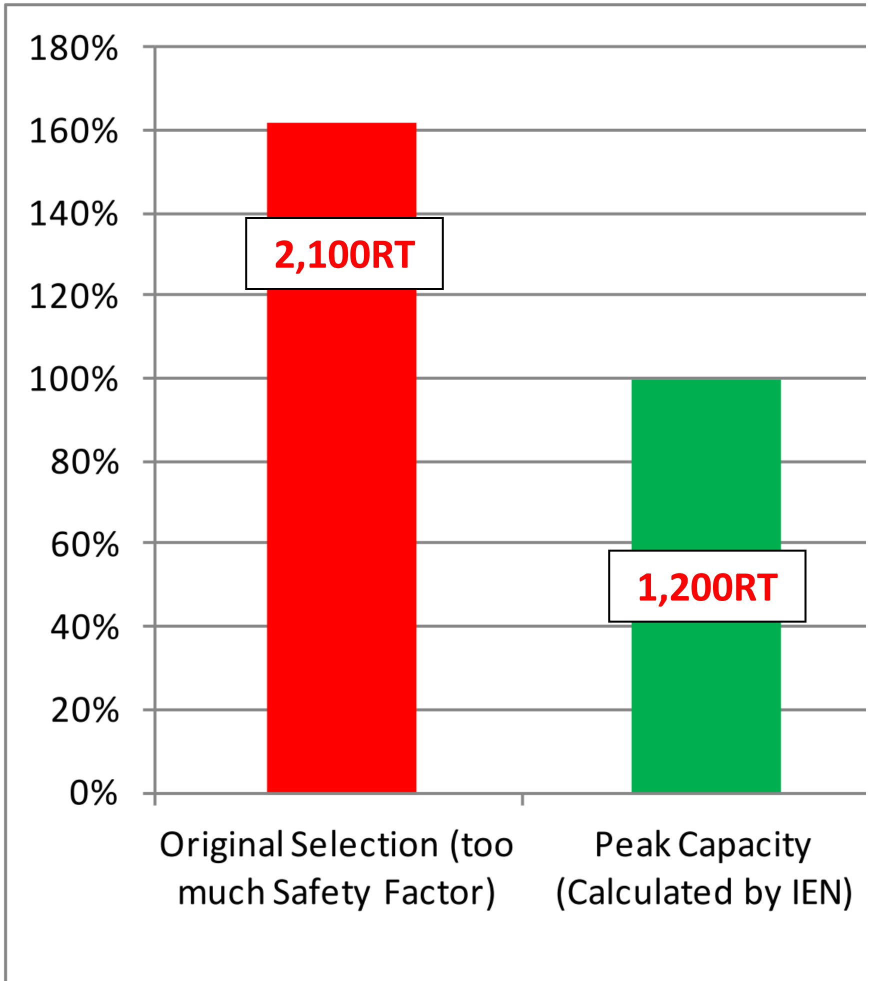

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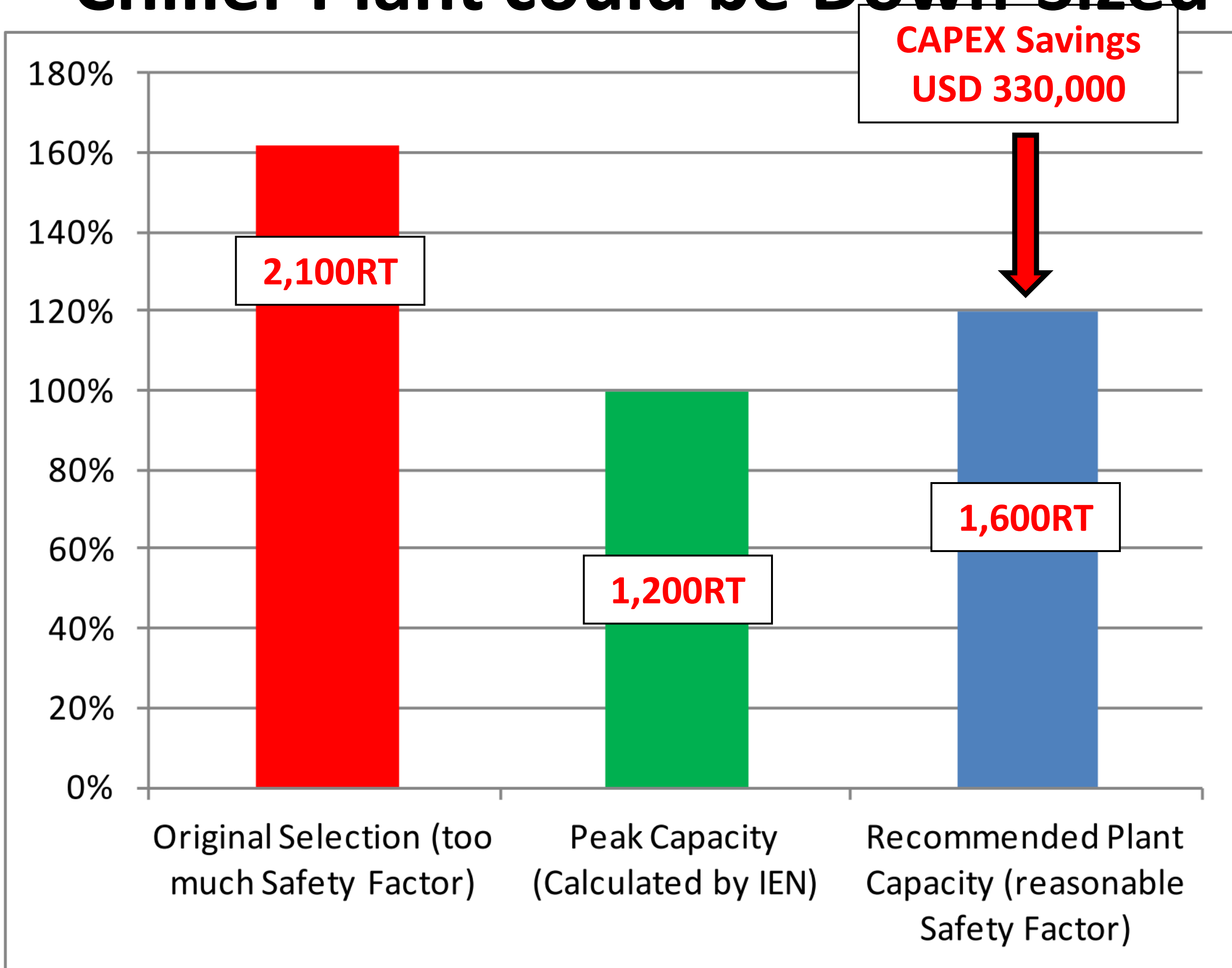
Shopping mall project in Malaysia



Think of Computer Building Simulation like Navigating with a Map of Varying Accuracy

Let’s move the market in this direction!

Accurate map	**Inaccurate map**	**No map**
		
=	=	=
Accurate computer simulation	Inaccurate computer simulation	No computer simulation
Building design can be optimised and over-design of systems minimised	**Building design can be improved and over-design of systems reduced**	**Building design relies on rules of thumb resulting in inefficient and over-designed systems**

Create a ‘Green Shopping List’ for Building Design Team

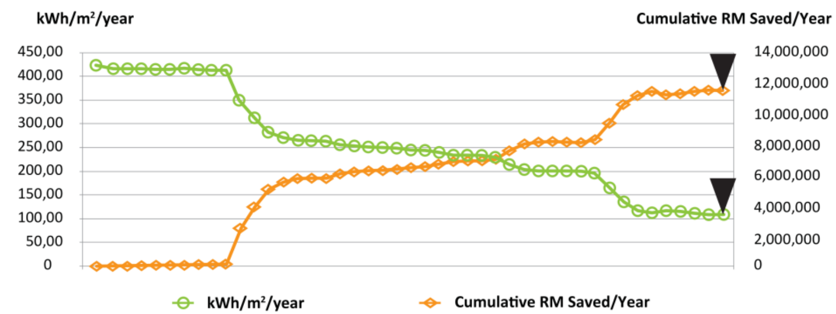
Computer simulation allows assessment of payback time & green Impact for each item

SUMMARY if all 42 items implemented:

Items	Descriptions	Total Building MWh/year	Tenant's MWh/year	Owner's MWh/year	Savings (MWh/yr)	Owner's kWh/m2/year	Running Cost/year	Cumulative MWh/year Saved	% Saved Cumulative	RM/year Saved per step	% Save per Step	Extra Budget Estimated (RM)
0	Base Case Grd Flr Doors 50% Open during Mall hours.	76,447	36,331	40,117		424	15,444,934					
1	4 nos of Revolving Doors proposed	75,952	36,331	39,621	496	419	15,254,052	496	1.24%	190,882	1.24%	300,000
2	Clear Glazing to Clear Low-E Single Glazing	75,900	36,331	39,569	52	418	15,234,221	547	1.36%	19,831	0.13%	361,871
3	Clear Low-E Glazing to High performance Dbl Glazing	75,848	36,331	39,518	52	418	15,214,343	599	1.49%	39,709	0.13%	904,678
4	Roof Insulation 25mm to 50mm	75,812	36,331	39,481	36	417	15,200,368	635	1.58%	13,974	0.09%	733,742
5	Roof Insulation 50mm to 100mm	75,785	36,331	39,454	27	417	15,189,958	662	1.65%	24,384	0.07%	1,760,981
6	Green Vegetated Roof	75,782	36,331	39,451	3	417	15,188,752	665	1.66%	1,206	0.01%	-
7	Brickwall to Aerated Light Weight Conc. 100mm	75,669	36,331	39,338	113	416	15,145,172	779	1.94%	43,580	0.28%	623,990
8	Brickwall to Aerated Light Weight Conc. 150mm	75,657	36,331	39,326	12	416	15,140,597	790	1.97%	48,155	0.03%	1,455,976
8a	Brickwall to Aerated Light Weight Conc. 200mm	75,649	36,331	39,319	8	415	15,137,632	798	1.99%	51,121	0.02%	-
9	VAV system instead of CAV system	69,627	36,331	33,297	6,022	352	12,819,204	6,820	17.00%	2,321,394	15.03%	-
10	CO2 sensor for fresh air intake for all AHU	66,091	36,331	29,760	3,537	314	11,457,543	10,357	25.82%	1,361,661	8.82%	750,000
11	Total Pressure 1000 down to 650 Pa. Larger Duct Sizes	63,180	36,331	26,849	2,910	284	10,337,054	13,267	33.07%	1,120,488	7.25%	-
12	Electronic Air Filter used for all AHU	62,029	36,331	25,698	1,151	272	9,893,910	14,418	35.94%	443,144	2.87%	1,400,000
13	Use of AirFoil Fan instead of Backward Curve for all AHU	61,506	36,331	25,176	523	266	9,692,638	14,941	37.24%	201,272	1.30%	300,000
14	Efficiency 1 motor for all AHU instead of Eff 2.	61,403	36,331	25,072	104	265	9,652,652	15,045	37.50%	39,986	0.26%	250,000
15	Heat Recovery Wheel for Cinema spaces only.	61,343	36,331	25,012	60	264	9,629,731	15,104	37.65%	22,921	0.15%	100,000
16	Chill Water Pump Head 30m down to 20m. Increase Pipe Sizes.	60,682	36,331	24,351	661	257	9,375,189	15,766	39.30%	254,542	1.65%	1,000,000
17	Chill Water Pump Head 20m down to 15m. Increase Pipe Sizes.	60,370	36,331	24,039	312	254	9,255,116	16,077	40.08%	120,073	0.78%	1,000,000
18	Chill Water Pump Efficiency 68% to 80%	60,230	36,331	23,899	140	253	9,201,079	16,218	40.43%	54,037	0.35%	108,000
19	Chill Water Motor Efficieny Type 1 instead of Type 2	60,204	36,331	23,873	26	252	9,191,204	16,243	40.49%	9,875	0.06%	270,000
20	Chill Water Constant Flow to Primary/Secondary variable	59,936	36,331	23,605	268	249	9,087,913	16,512	41.16%	103,291	0.67%	500,000
21	Condenser Water Pump Effciency 68% to 80%	59,623	36,331	23,292	313	246	8,967,515	16,824	41.94%	120,398	0.78%	50,000
22	Condenser Water Motor Efficiency Type 1 instead of Type 2	59,566	36,331	23,235	57	245	8,945,508	16,882	42.08%	22,007	0.14%	25,000
23	Condenser Water Pump head 35 down to 25m. Increase Pipe Size.	59,076	36,331	22,745	490	240	8,756,854	17,372	43.30%	188,655	1.22%	1,000,000
24	Condenser Water Pump head 25 down to 15m. Increase Pipe Size.	58,586	36,331	22,255	490	235	8,568,258	17,861	44.52%	188,596	1.22%	1,500,000
25	Cooling Tower Constant Speed to 2 speed Fan	58,479	36,331	22,148	107	234	8,526,994	17,969	44.79%	41,264	0.27%	112,000
26	Cooling Tower Constant Speed to variable fan speed	58,427	36,331	22,096	52	233	8,507,145	18,020	44.92%	61,113	0.13%	198,000
26a	Cooling Tower Fan Less, Constant Flow	58,170	36,331	21,840	257	231	8,408,233	18,277	45.56%	160,025	0.64%	150,000
27	Concourse Lights 35 W/m2 down to 20 W/m2	56,794	36,331	20,464	1,376	216	7,878,473	19,653	48.99%	628,672	4.07%	
28	Concourse Lights 20 W/m2 down to 10 W/m2	55,711	36,331	19,381	1,083	205	7,461,496	20,736	51.69%	1,045,649	6.77%	
29	Concourse Phillips 6.8W/m2 (200 lux)	55,368	36,331	19,037	344	201	7,329,188	21,080	52.55%	1,177,957	7.63%	3,331,361
30	Concourse Osram 7.0 W/m2 (200 lux)	55,389	36,331	19,058	1,405	201	7,337,390	21,059	52.49%	1,169,755	7.57%	2,871,613
31	Concourse Megaman 7.8 W/m2 (200 lux)	55,475	36,331	19,144	1,320	202	7,370,404	20,973	52.28%	1,136,741	7.36%	871,171
32	Concourse Night Light 10% down to 2.5%	55,422	36,331	19,091	53	202	7,350,068	21,026	52.41%	20,336	0.13%	Free. Management
33	Concourse Daylight Top Floor - 75%, 1st floor 75%, Grd 50%	55,109	36,331	18,778	313	198	7,229,611	21,339	53.19%	120,457	0.78%	1,400,000
34	Retail Lights & Small Power 100W/m2 down to 75W/m2	42,980	27,248	15,732	3,046	166	6,056,934	24,384	60.78%	1,172,677	7.59%	Free. Convince Retailer
35	Retail Lights & Small Power 75W/m2 down to 50W/m2	31,004	18,165	12,838	2,894	136	4,942,719	27,278	68.00%	1,114,215	7.21%	Free. Convince Retailer
36	Retail Lights & Small Power 50W/m2 down to 35W/m2	23,836	12,716	11,121	1,718	117	4,281,411	28,996	72.28%	661,308	4.28%	Free. Convince Retailer
37	Night Retail 30% down to 15%	21,938	11,249	10,689	432	113	4,115,276	29,428	73.36%	166,135	1.08%	Free. Convince Retailer
38	Chill Water Pump Head 25m. Condenser Water Pump Head 30m	22,400	11,249	11,151	-462	118	4,293,257	28,965	72.20% -	177,981	-1.15%	BaseCase Chiller
39	MS 1525 to Dunham Bush	22,168	11,249	10,919	232	115	4,203,985	29,197	72.78%	89,272	0.58%	1,957,975
40	MS 1525 to Carrier wt primary variable flow + variable condenser	21,832	11,249	10,583	336	112	4,074,439	29,534	73.62%	218,818	0.84%	1,092,130
41	MS 1525 to Trane Base	21,561	11,249	10,313	270	109	3,970,350	29,804	74.29%	322,907	0.67%	810,233
42	MS 1525 to Trane Chill Water Pump delta T high (dT=10F to 15F, Chill wa	21,773	11,249	10,524	-212	111	4,051,900	29,592	73.77%	241,357	-0.53% -	681,120

% Saving per step
0.67%

% Saving in Energy
68.53%



Green Mark Score [Points]	Additional Cost [RM]	Saving / Year [RM]	Payback Period [Years]	Energy Index [kWh/m2/y]	Total Saving in Energy [%]
97.5	32,206,000	10,640,000	<3	133	68.53%

POTENTIAL: **68% energy savings** and **3 year payback time**

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For unfamiliar territory, a map will be very helpful!

Case Study:

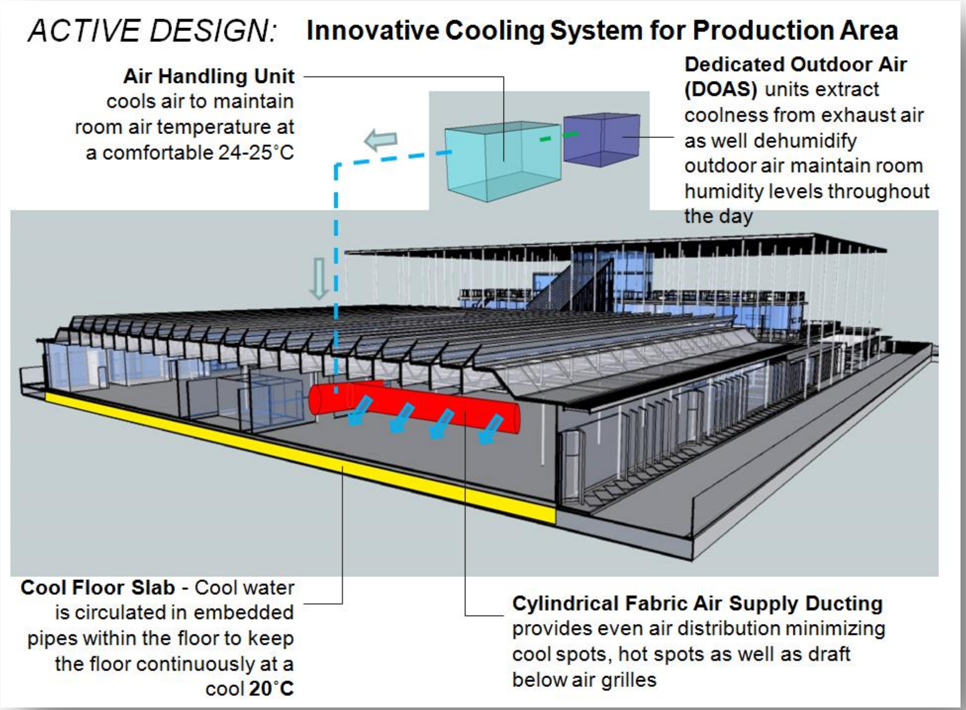
Air Conditioned Factory (Malaysia)

1. Cooling load can vary a lot from factory to factory (rule of thumb difficult to apply)

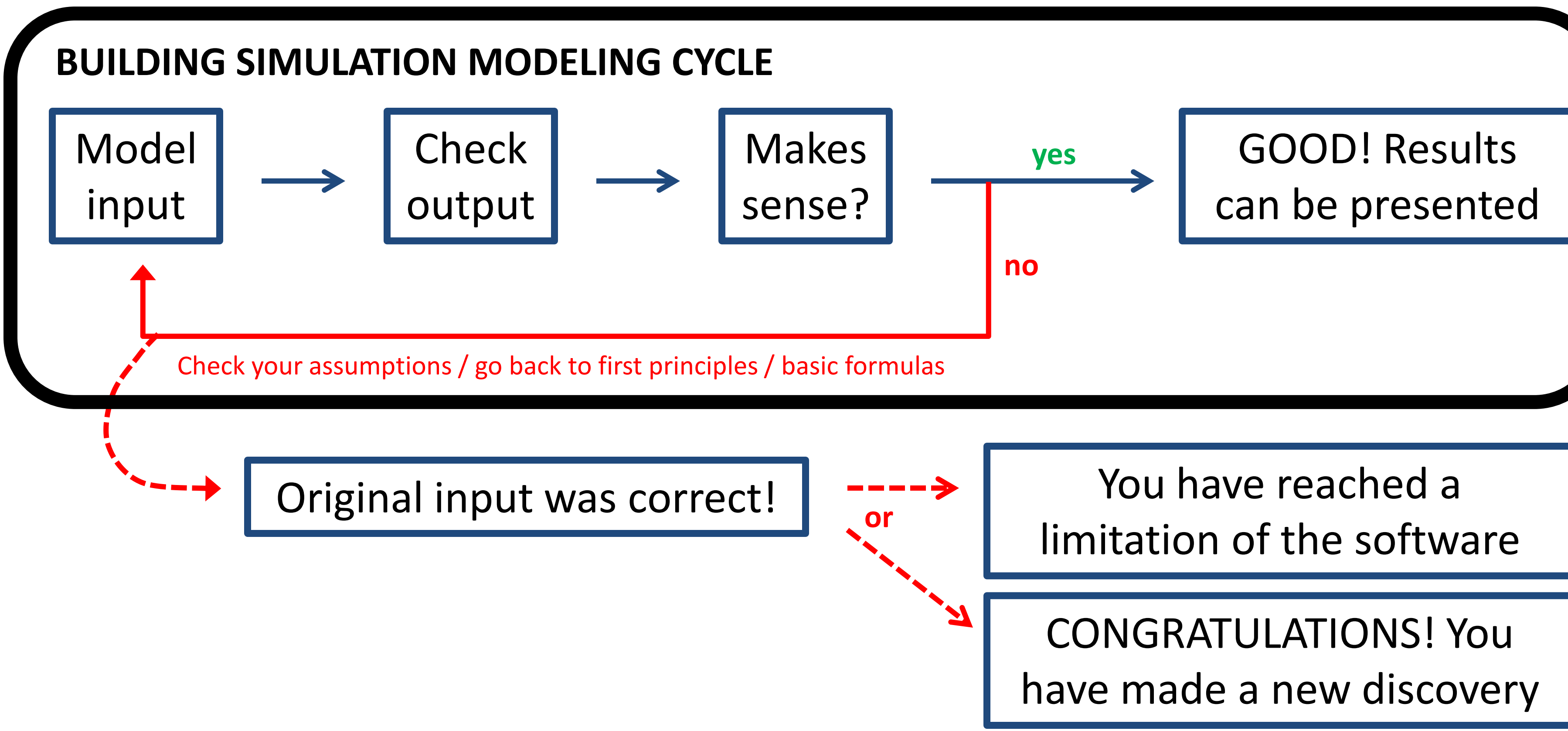
2. Roof architecture of factory might not be correctly modelled in simple HVAC-sizing softwares

Our energy model showed that the cooling system could be down-sized 3 times, saving a CAPEX of USD1 million!

Factory architecture and HVAC accurately simulated using IES software



”Energy Simulations are easy, making sense out of them is the challenge”



Check your model, Check your model, Check your model – and don't forget to Check your model!

30/07/2016

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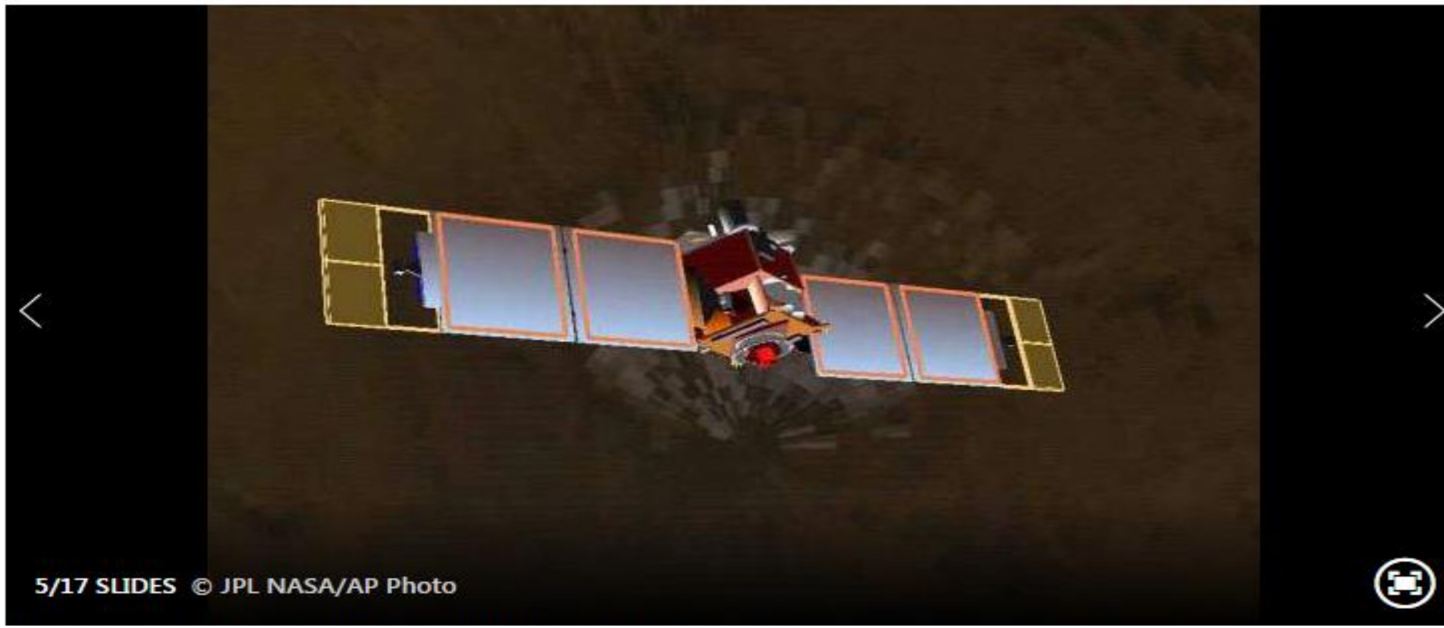

Check your model, Check your model, Check your model – and don't forget to Check your model!

16 of the most expensive mistakes in history

30/07/2016

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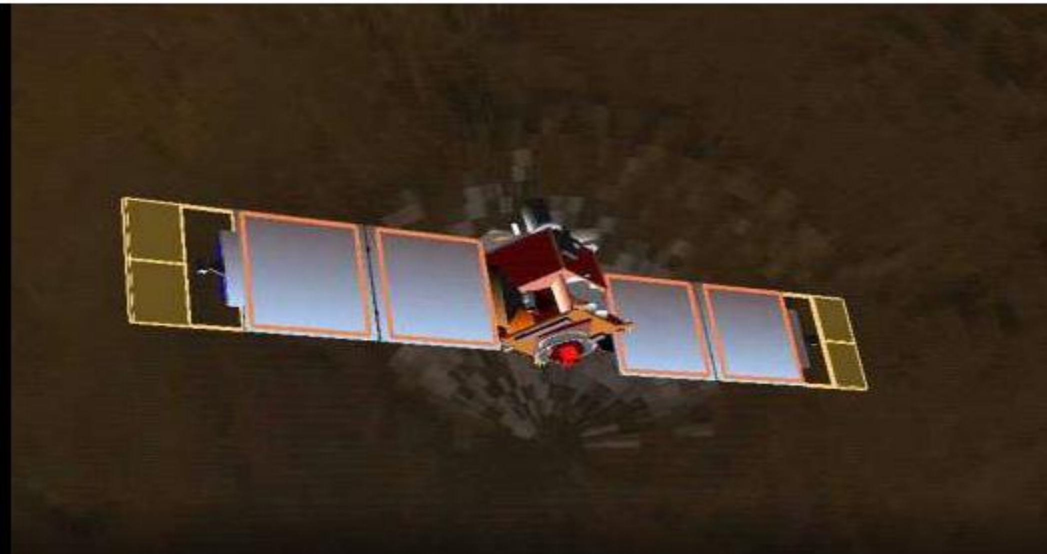


5/17 SLIDES © JPL NASA/AP Photo

MATHEMATICAL ERROR ENDS £80-MILLION NASA MARS PROBE

NASA spent around £80 million on the Mars Climate Orbiter, which was originally designed to study the climate on Mars. However, a small mathematical error proved to be the orbiter's undoing as NASA lost contact with the probe, and it was eventually destroyed over the planet in 1999.

Examples of 'trusting results blindly'

1. CO_2 meter that had an outdoor reading of about 200 ppm, even though outdoor CO_2 levels are about 400 ppm. Nevertheless, the Ph.D. lab-student insisted that the reading was correct

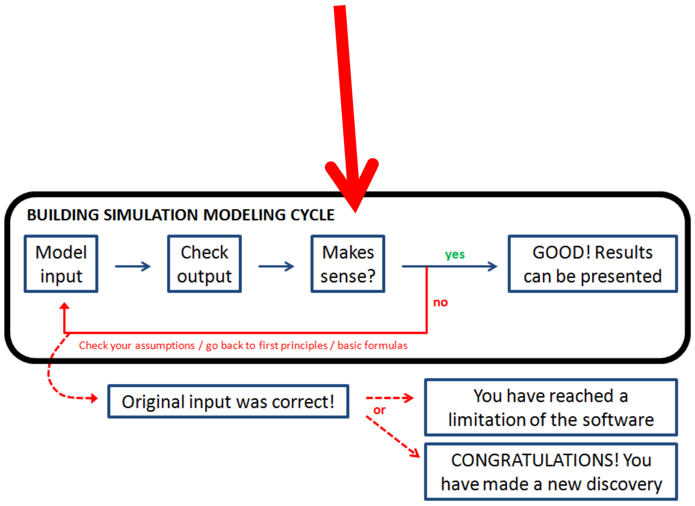
2. TVOC meter reading that had reading of 0, which made the university students think the meter was broken even though this was a perfectly probably reading

3. One of the big US building consultancy firms proudly presented an so-called optimised glare-free facade design option after 200+ iterations and countless annual computer simulations. However, it was immediately obvious that their glare model used was wrong rendering all the simulations worthless.

4. One of the big roofing contractors in Malaysia presented a simulation report that showed that the U-value requirement was met. However, our independent simulation in a more comprehensive 3D simulation software showed that the U-value was exceeded by 42%. The contractor had used an over-simplified software (for the last 20 years!)

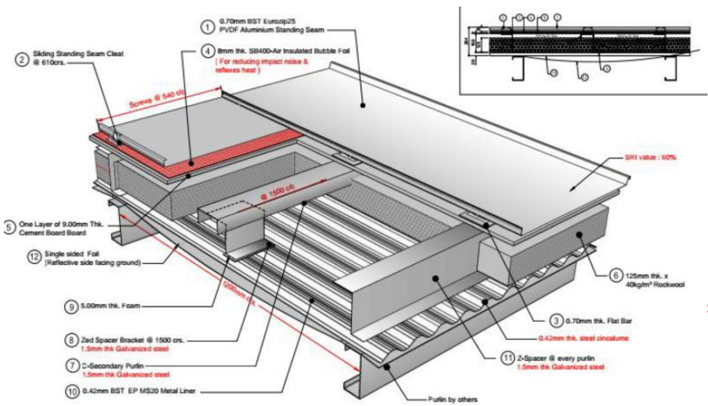
Please don't forget the most important question:

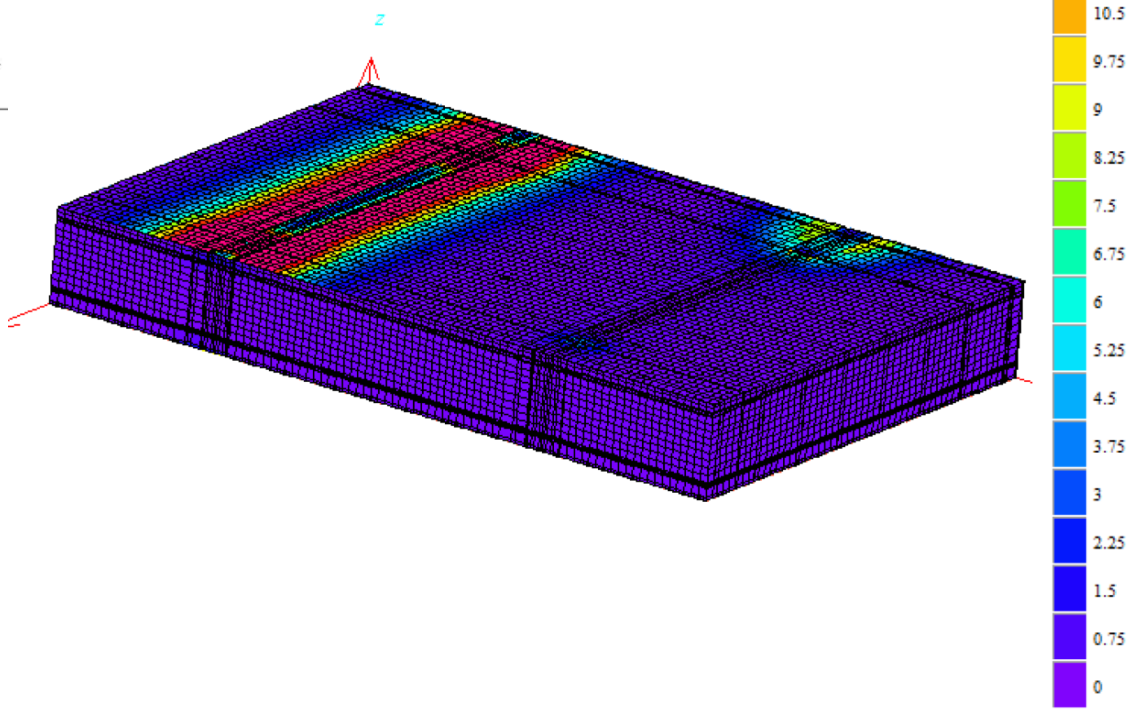
Do the results make sense?



Example: 3D Heat Flow through Constructions

42% higher U-value than simplified simulation (refer item 4 previous slide)





Example of not 'trusting results blindly'

Case Study:

24-hour air conditioned factory (Malaysia)

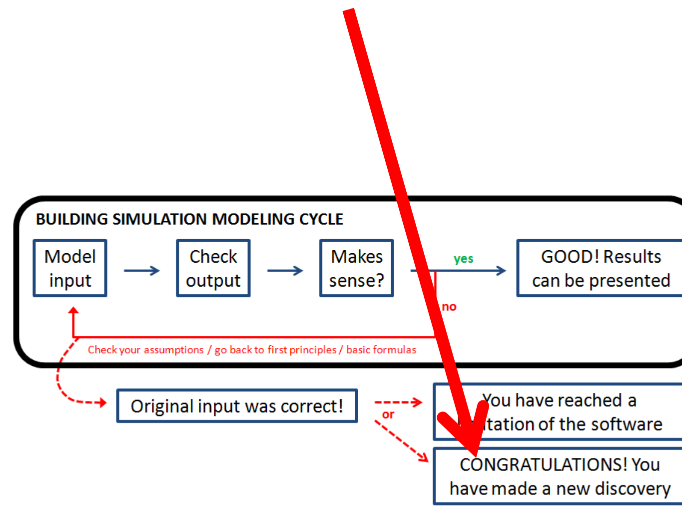
1. The base design was to insulate the entire factory floor by 50 mm. The floor is permanently cooled to 15°C with embedded floor slab cooling pipes

2. Value engineering prompted us to explore if we could save any roof insulation

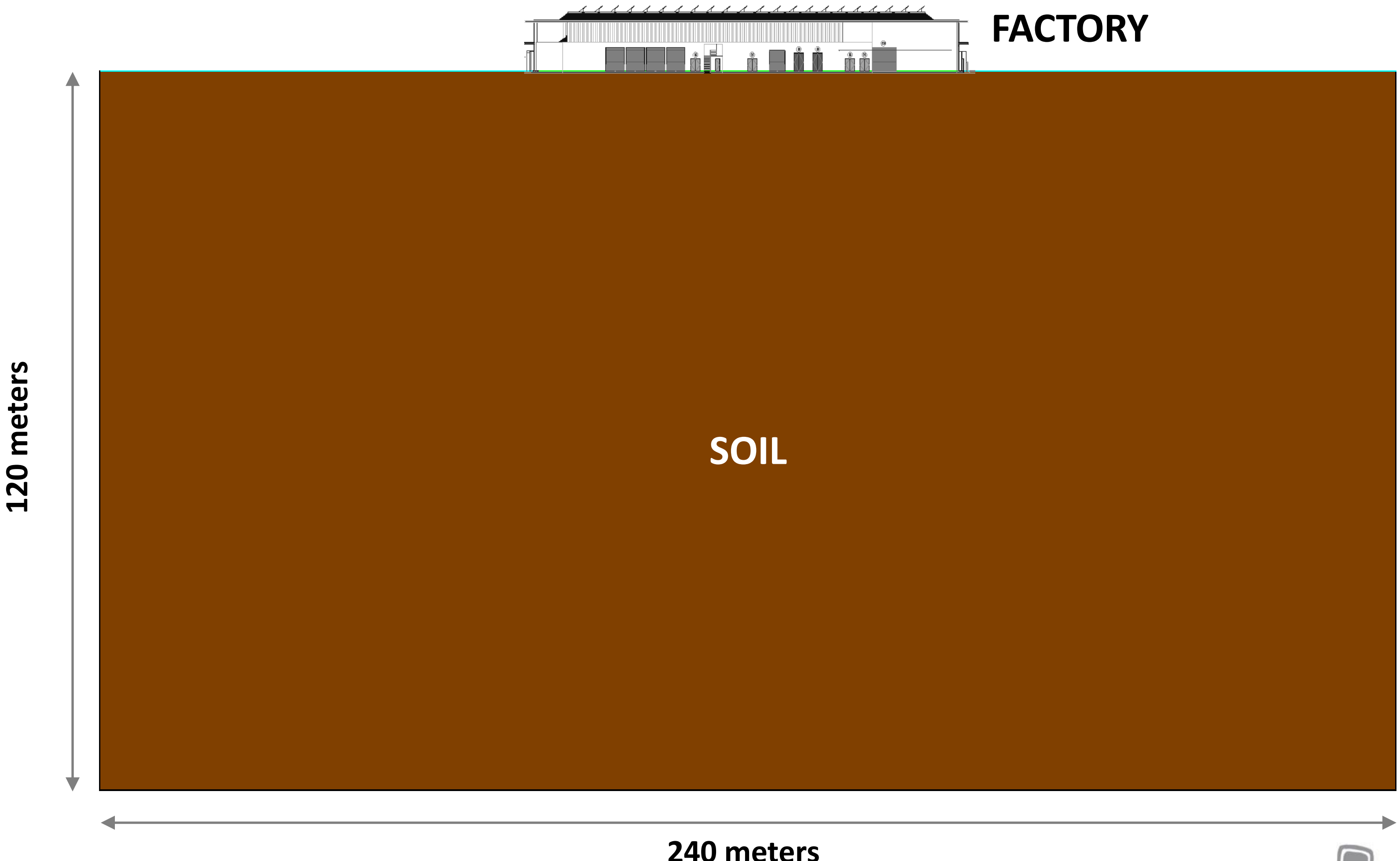
This is what we found.....
(see next slides)

Example of:

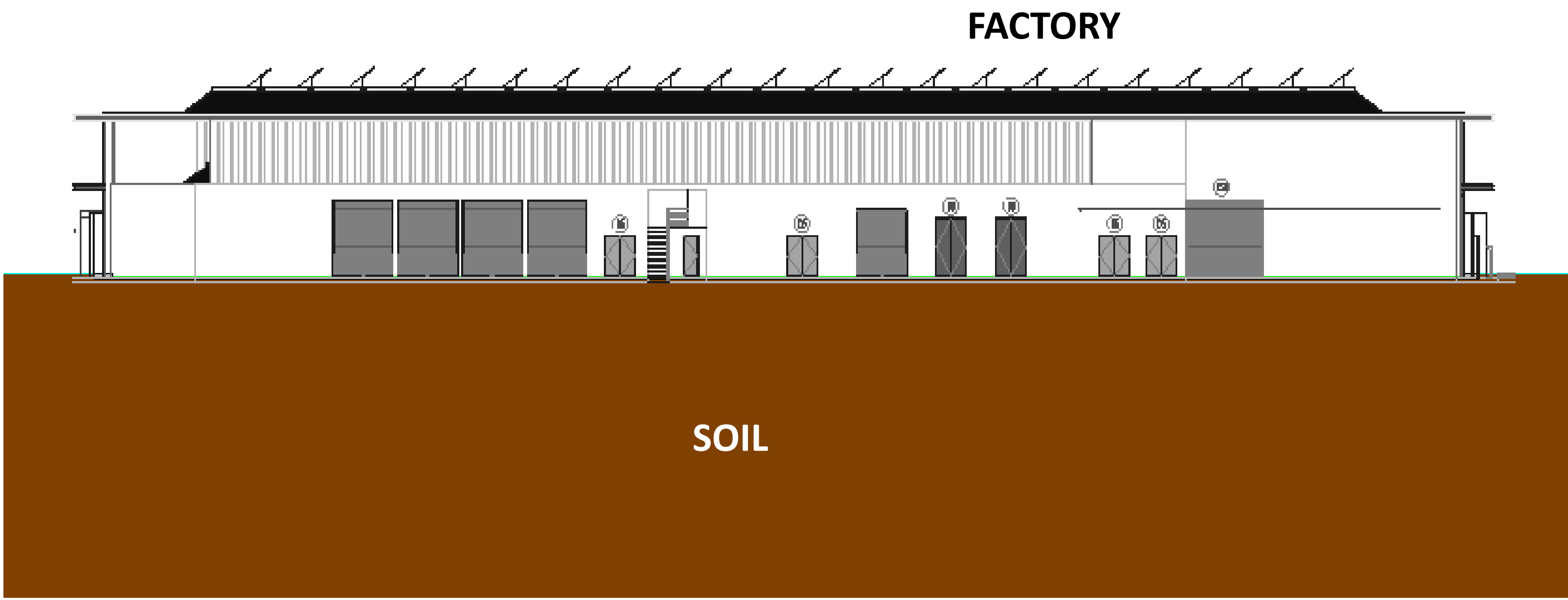
Making new discovery



Steady State Finite Element Model



Steady State Finite Element Model



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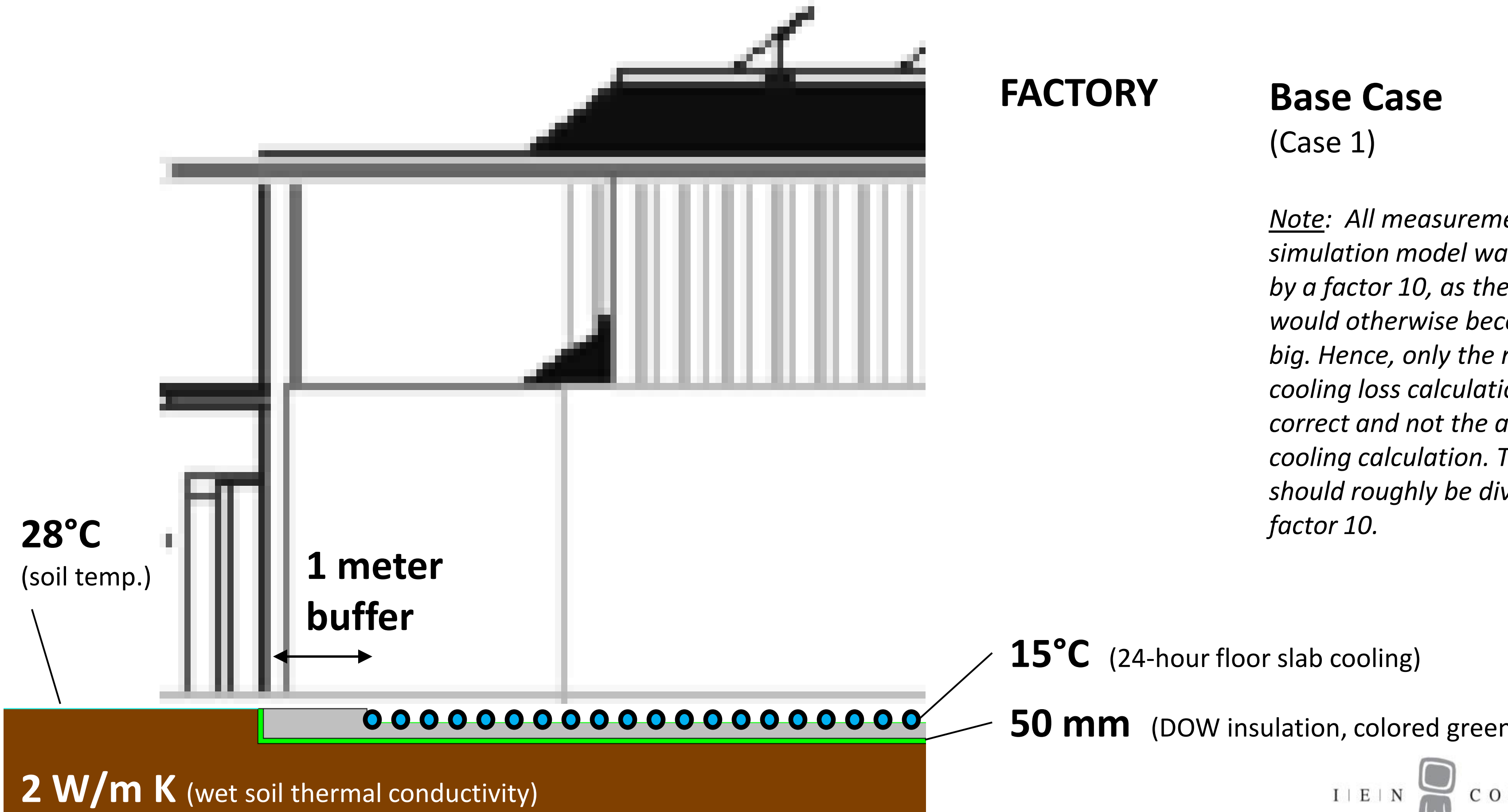

FACTORY

Base Case

(Case 1)

<u>Note</u>: All measurements in the simulation model was reduced by a factor 10, as the model would otherwise become too big. Hence, only the relative cooling loss calculation is correct and not the absolute cooling calculation. The latter should roughly be divided by a factor 10.

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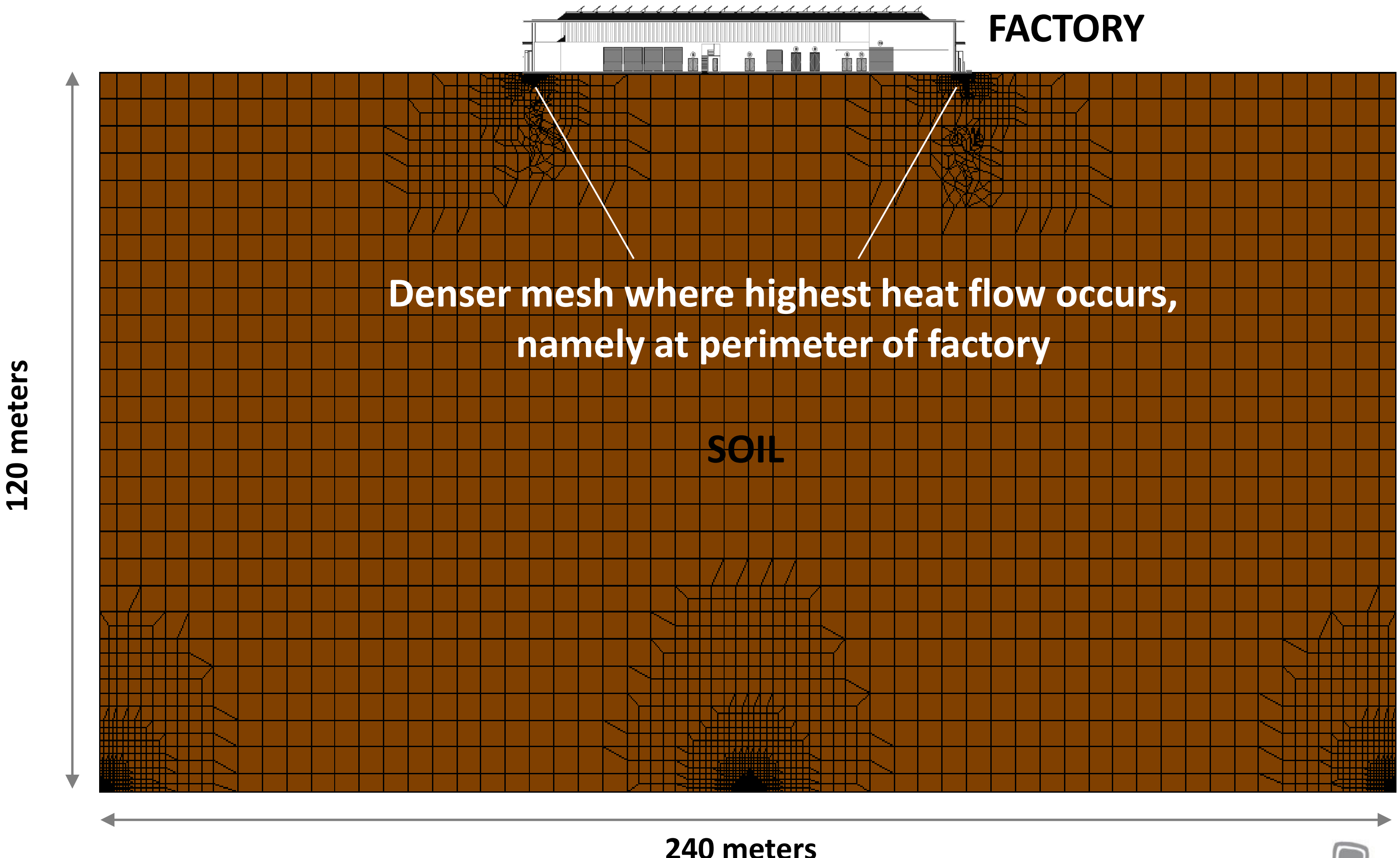
Steady State Finite Element Mesh



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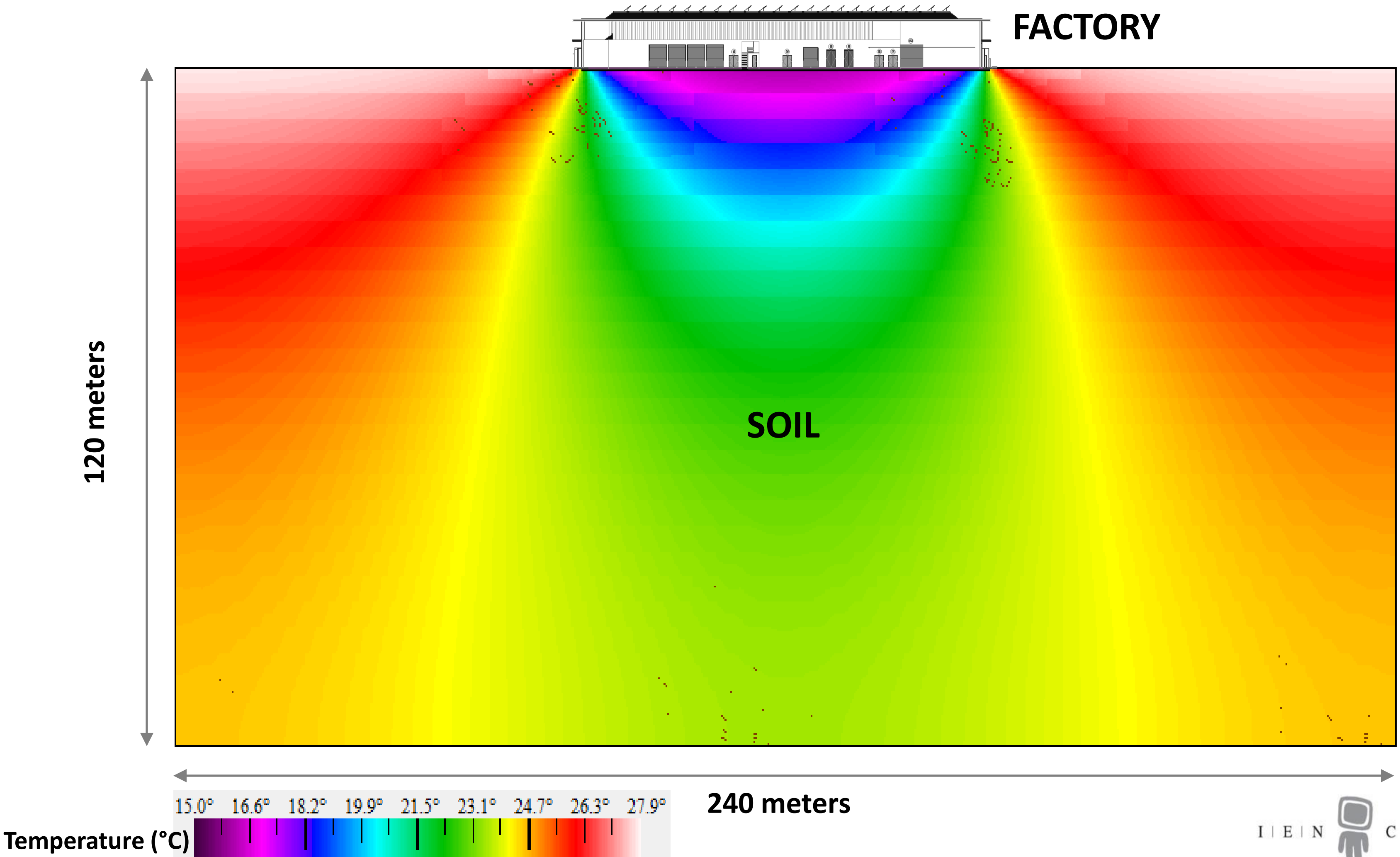
Simulated Temperature Profile



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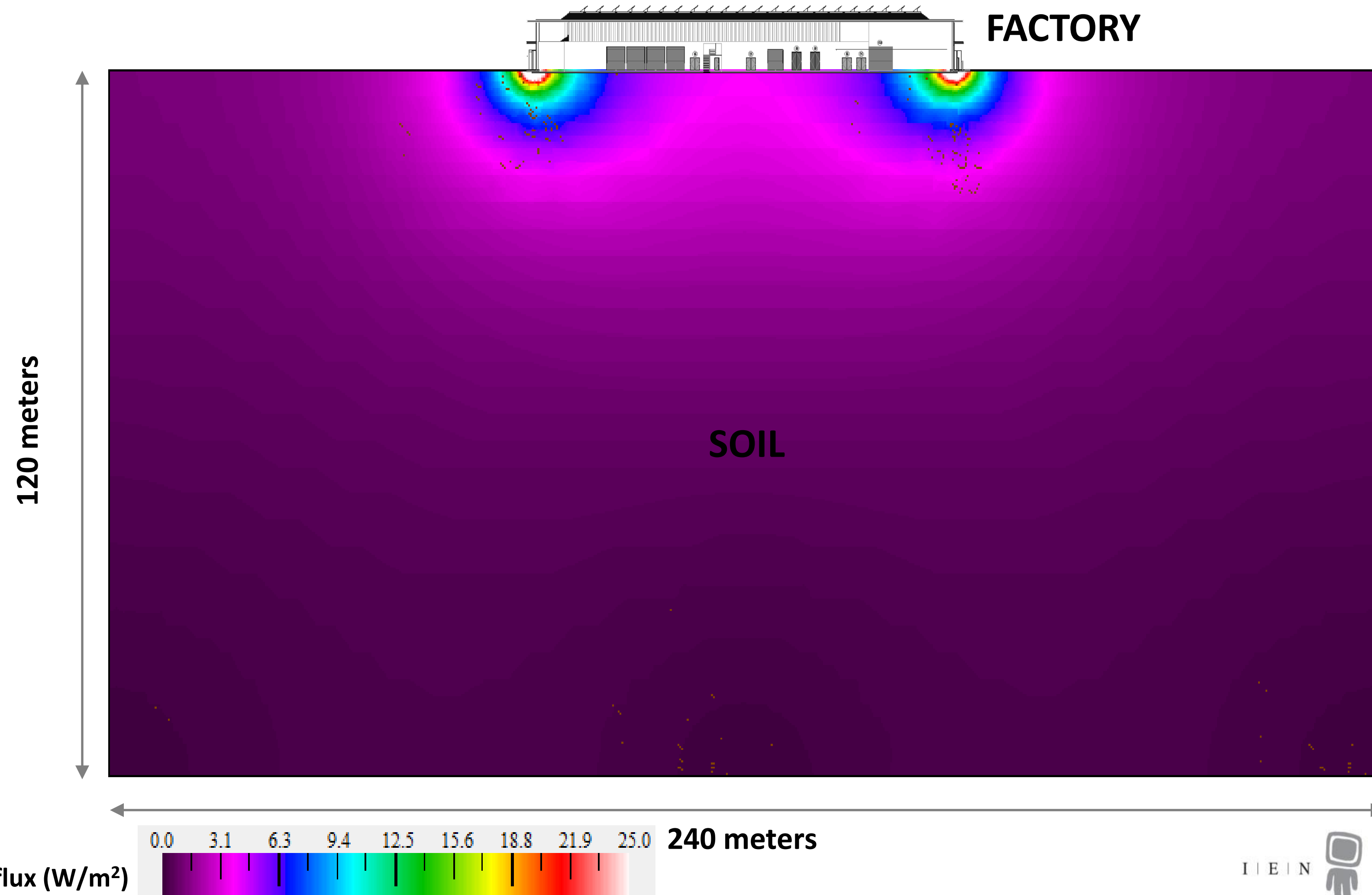
Simulated Heat Flux Profile



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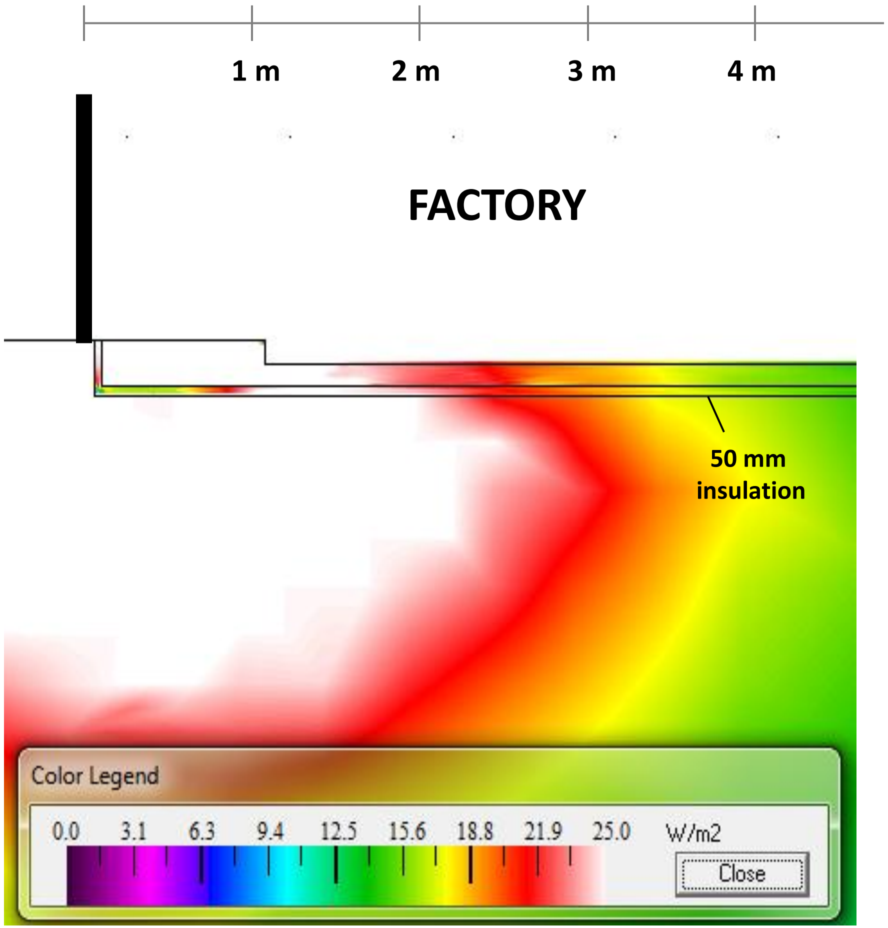
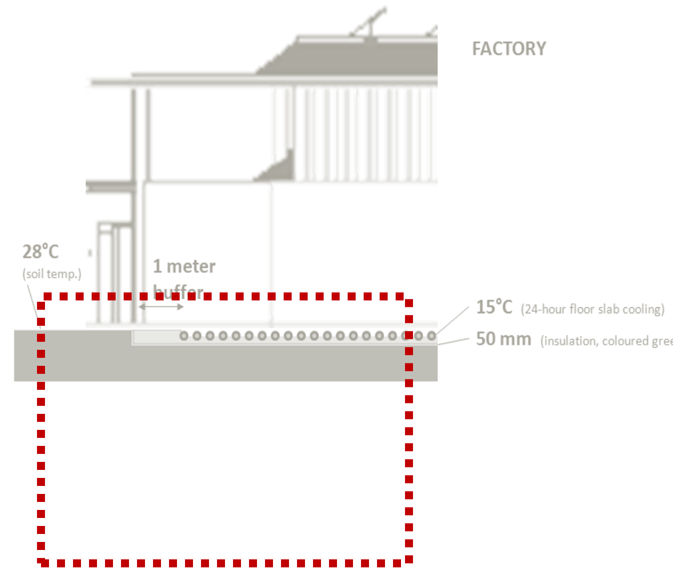
Factory Perimeter (Simulated Heat Flux Profile)



0 – 25 W/m2 scale



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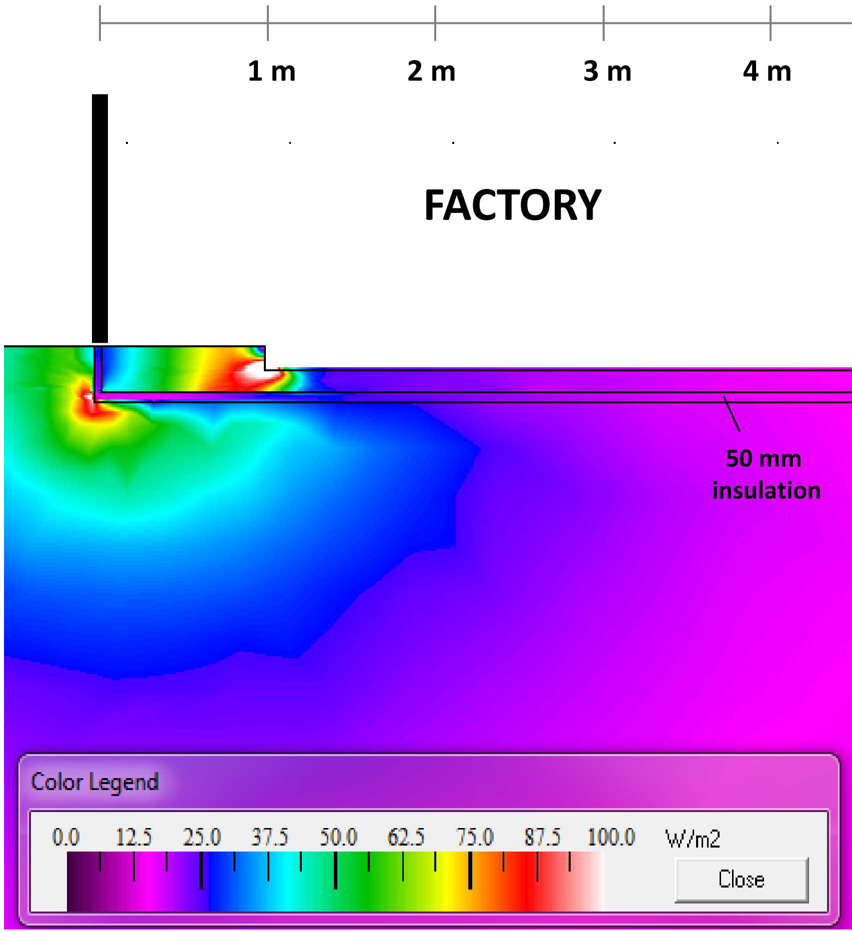
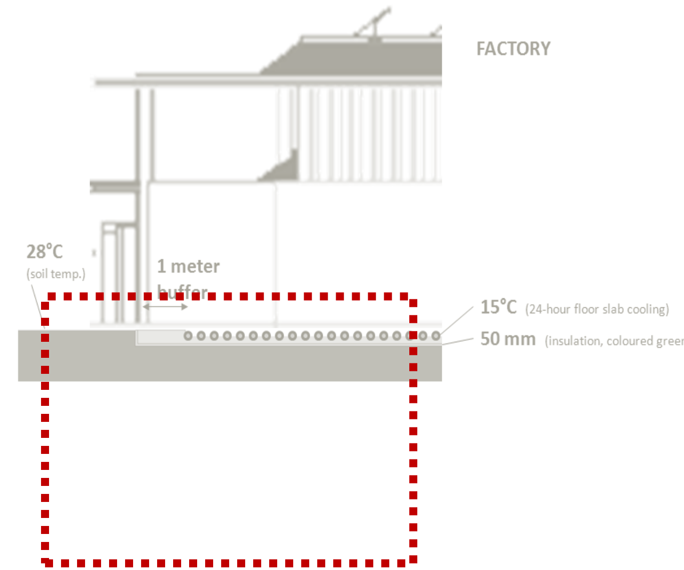


0 – 100 W/m2 scale



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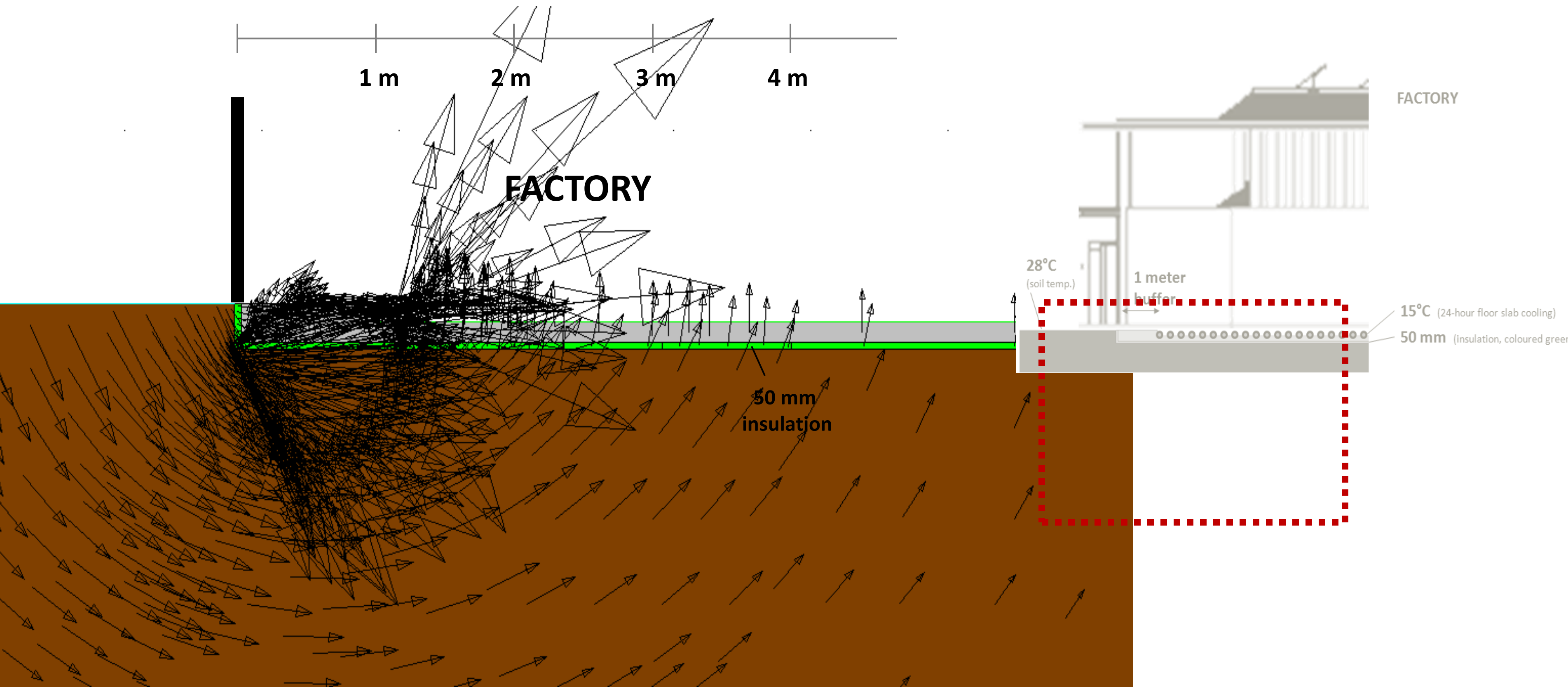
Factory Perimeter (Simulated Heat Flux Profile)

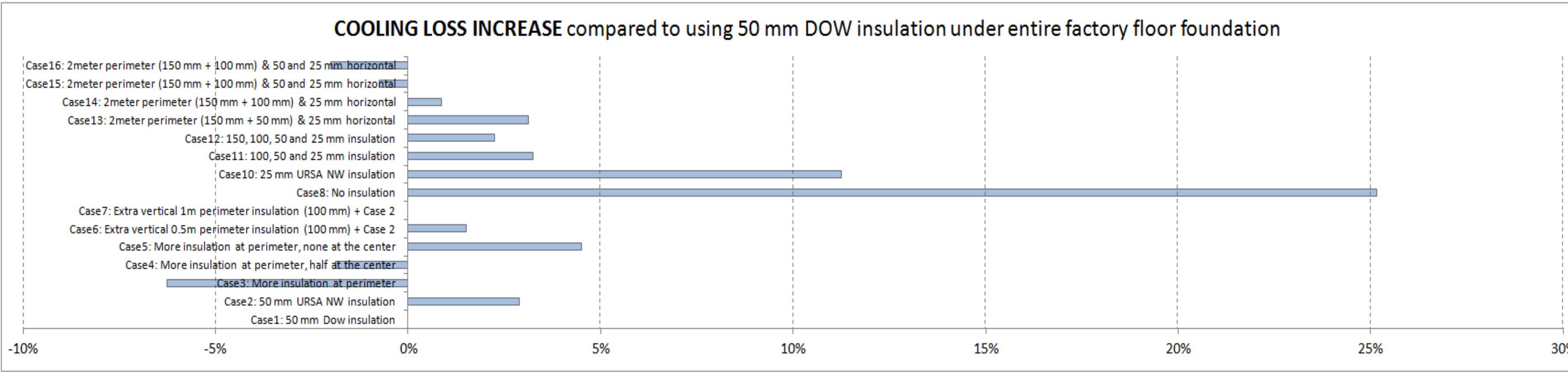


Heat flux arrows showing direction and quantity of heat flow

Different simulations cases

Case	Description	DOW Thermal conductivity (W/m K)	URSA NW Thermal conductivity (W/m K)	Horizontal insulation thickness from factory floor perimeter 0-1 meter	1-2 meter	2-3 meter	3-4 meter	4 meter and above	Vertical insulation thickness from factory floor perimeter Insulation depth	Insulation width
1	50 mm Dow insulation (**BASE CASE**)	0.028	0.034	50 mm DOW	50 mm DOW	50 mm DOW	50 mm DOW	50 mm DOW	500 mm	50 mm DOW
2	50 mm URSA NW insulation	0.028	0.034	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	500 mm	50 mm URSA NW
3	More insulation at perimeter	0.028	0.034	200 mm URSA NW	200 mm URSA NW	150 mm URSA NW	100 mm URSA NW	50 mm URSA NW	500 mm	200 mm URSA NW
4	More insulation at perimeter, half at the center	0.028	0.034	200 mm URSA NW	200 mm URSA NW	150 mm URSA NW	100 mm URSA NW	25 mm URSA NW	500 mm	200 mm URSA NW
5	More insulation at perimeter, none at the center	0.028	0.034	200 mm URSA NW	200 mm URSA NW	150 mm URSA NW	100 mm URSA NW	0 mm URSA NW	500 mm	200 mm URSA NW
6	Extra vertical 0.5m perimeter insulation (100 mm) + Case 2	0.028	0.034	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	1000 mm	100 mm URSA NW
7	Extra vertical 1m perimeter insulation (100 mm) + Case 2	0.028	0.034	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	1500 mm	100 mm URSA NW
8	No insulation	0.028	0.034	0	0	0	0	0	0	0
10	25 mm URSA NW insulation	0.028	0.034	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	500 mm	25 mm URSA NW
11	100, 50 and 25 mm insulation	0.028	0.034	100 mm URSA NW	100 mm URSA NW	50 mm URSA NW	50 mm URSA NW	25 mm URSA NW	500 mm	100 mm URSA NW
12	150, 100, 50 and 25 mm insulation	0.028	0.034	150 mm URSA NW	100 mm URSA NW	50 mm URSA NW	50 mm URSA NW	25 mm URSA NW	500 mm	150 mm URSA NW
13	2meter perimeter (150 mm + 50 mm) & 25 mm horizontal	0.028	0.034	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	2000 mm	150 and 50 mm
14	2meter perimeter (150 mm + 100 mm) & 25 mm horizontal	0.028	0.034	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	2000 mm	150 and 100 mm
15	2meter perimeter (150 mm + 100 mm) & 50 and 25 mm horizontal	0.028	0.034	50 mm URSA NW	50 mm URSA NW	25 mm URSA NW	25 mm URSA NW	25 mm URSA NW	2000 mm	150 and 100 mm
16	2meter perimeter (150 mm + 100 mm) & 50 and 25 mm horizontal	0.028	0.034	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	50 mm URSA NW	25 mm URSA NW	2000 mm	150 and 100 mm

Results



Graph	Cooling loss increase
Case1: 50 mm Dow insulation	
Case2: 50 mm URSA NW insulation	3%
Case3: More insulation at perimeter	-6%
Case4: More insulation at perimeter, half at the center	-2%
Case5: More insulation at perimeter, none at the center	5%
Case6: Extra vertical 0.5m perimeter insulation (100 mm) + Case 2	2%
Case7: Extra vertical 1m perimeter insulation (100 mm) + Case 2	0%
Case8: No insulation	25%
Case10: 25 mm URSA NW insulation	11%
Case11: 100, 50 and 25 mm insulation	3%
Case12: 150, 100, 50 and 25 mm insulation	2%
Case13: 2meter perimeter (150 mm + 50 mm) & 25 mm horizontal	3%
Case14: 2meter perimeter (150 mm + 100 mm) & 25 mm horizontal	1%
Case15: 2meter perimeter (150 mm + 100 mm) & 50 and 25 mm horizontal	-1%
Case16: 2meter perimeter (150 mm + 100 mm) & 50 and 25 mm horizontal	-2%

Recommendations ← Case4, Case12, Case16

See illustration on the following slides →→→

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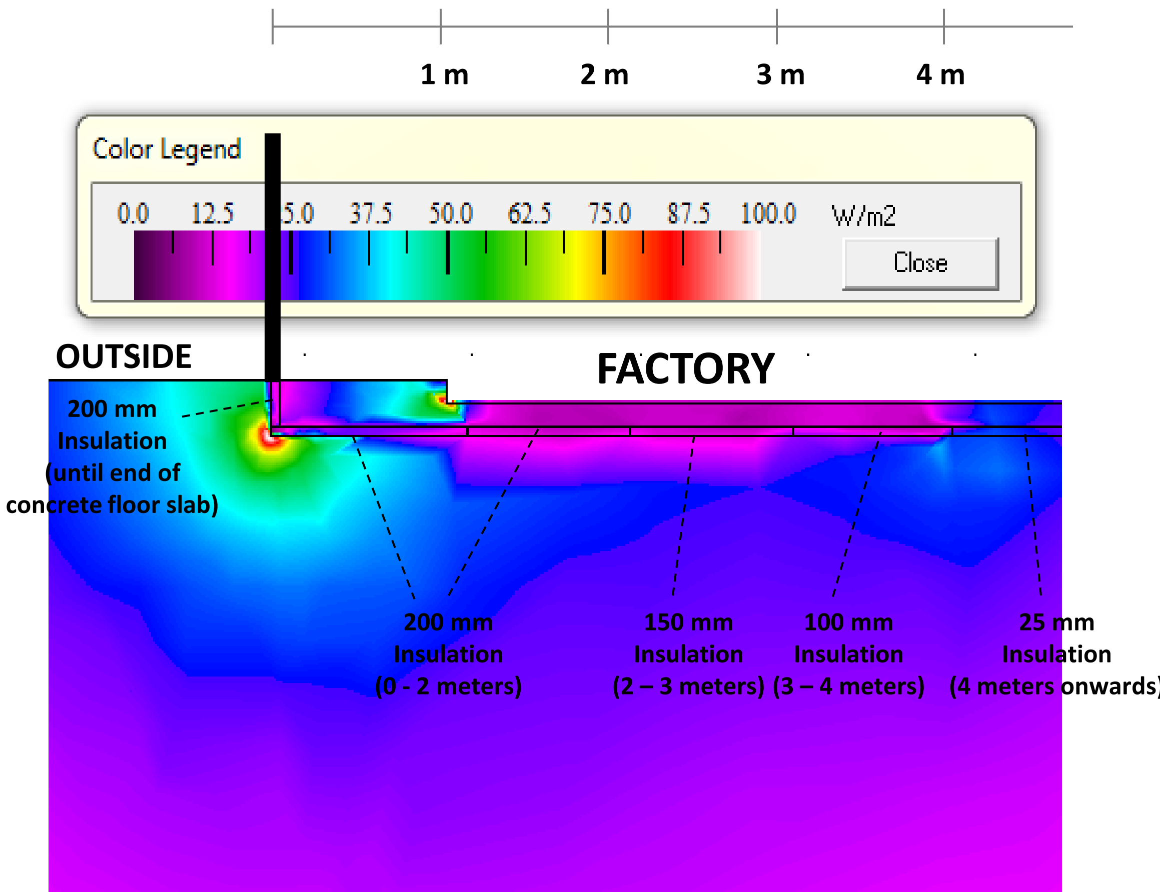
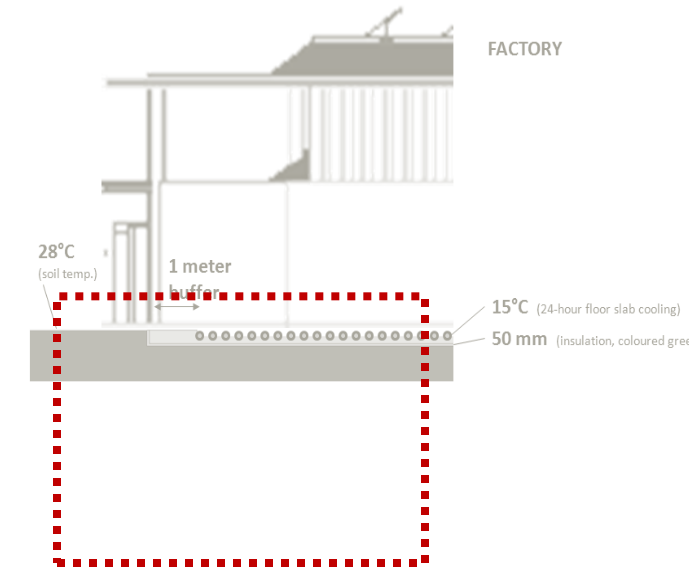
Heat Flux: Floor Slab Section Case 4





2% Extra Cooling
SAVING

Heat flux at factory floor perimeter (0 – 100 W/m2 scale)

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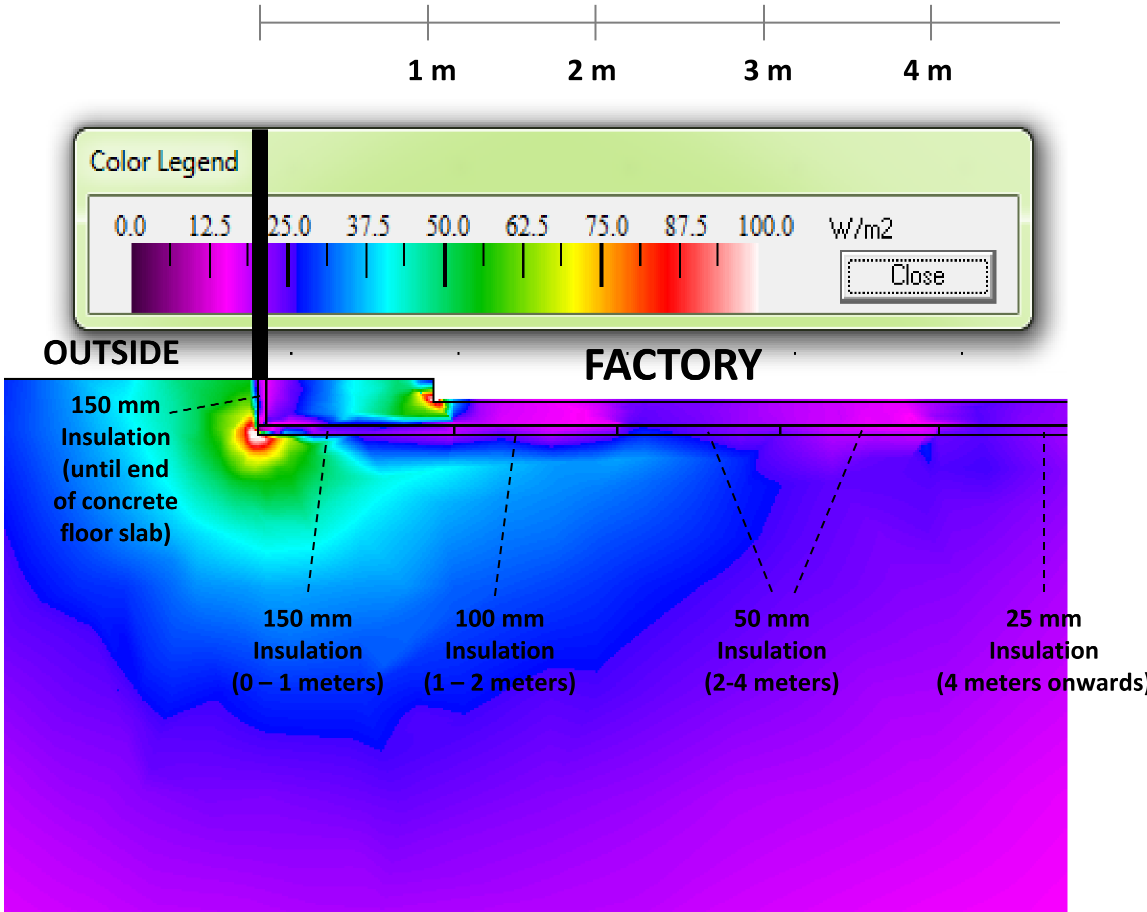
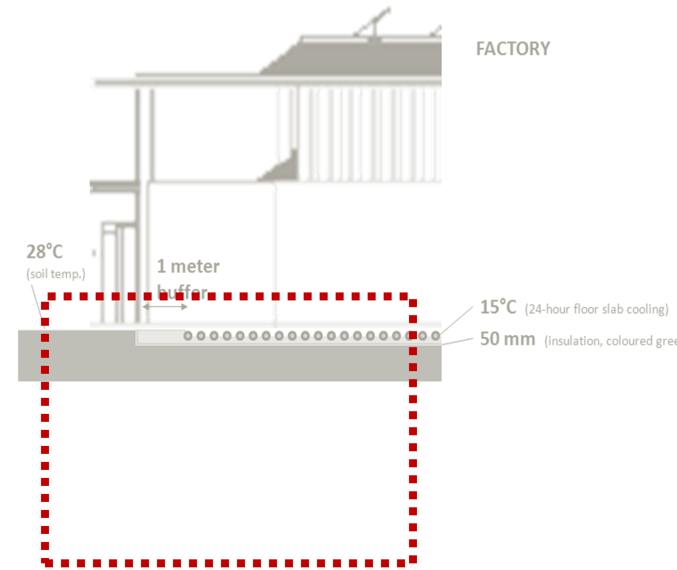
Heat Flux: Floor Slab Section Case 12





Heat flux at factory floor perimeter (0 – 100 W/m2 scale)

2% Extra Cooling
LOSS

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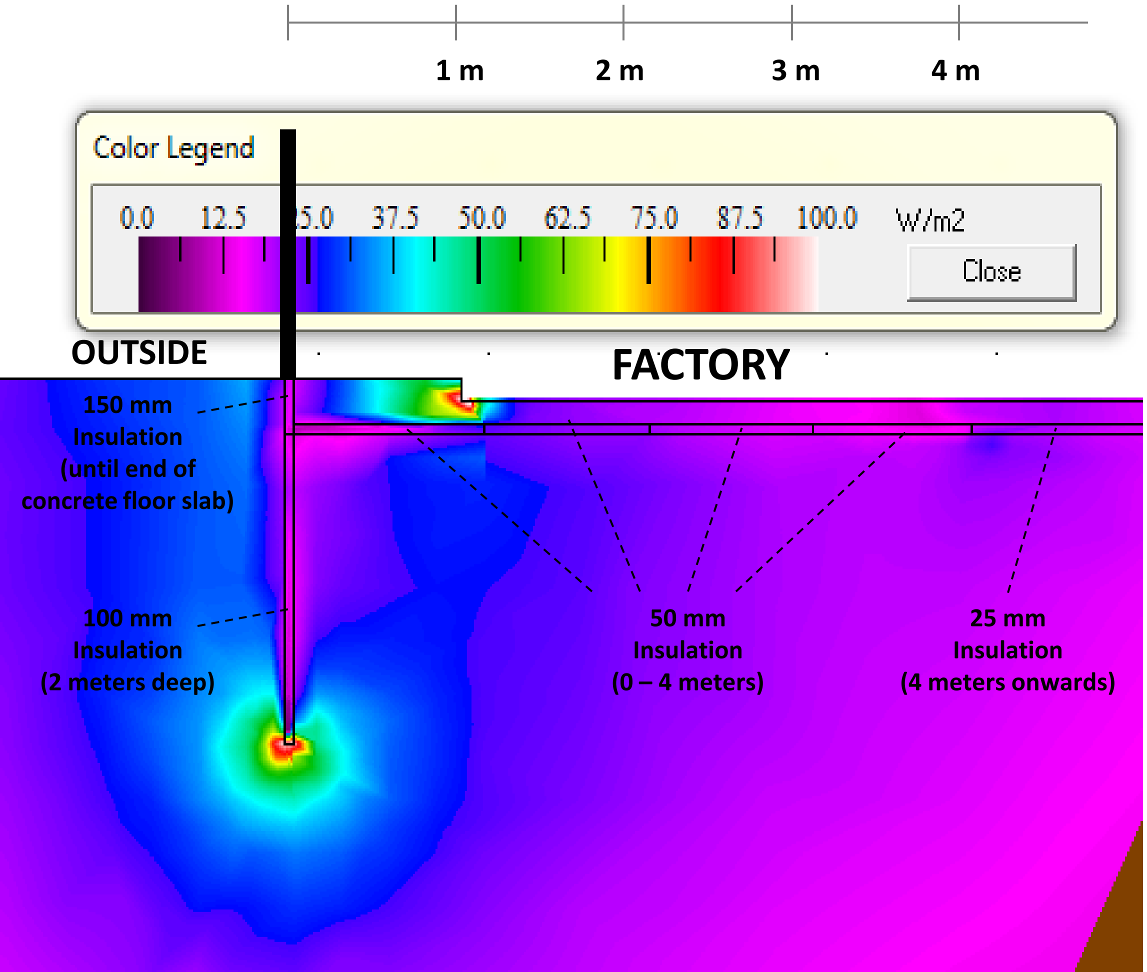
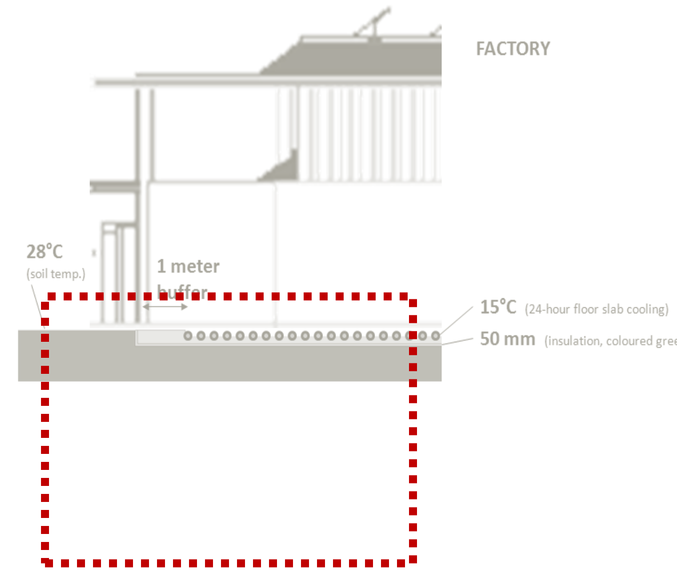
Heat Flux: Floor Slab Section Case 16



Heat flux at factory floor perimeter (0 – 100 W/m2 scale)



2% Extra Cooling **SAVING**

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Rain Water Harvesting
Optimising Tank Sizes & <u>Pump Sizes</u>

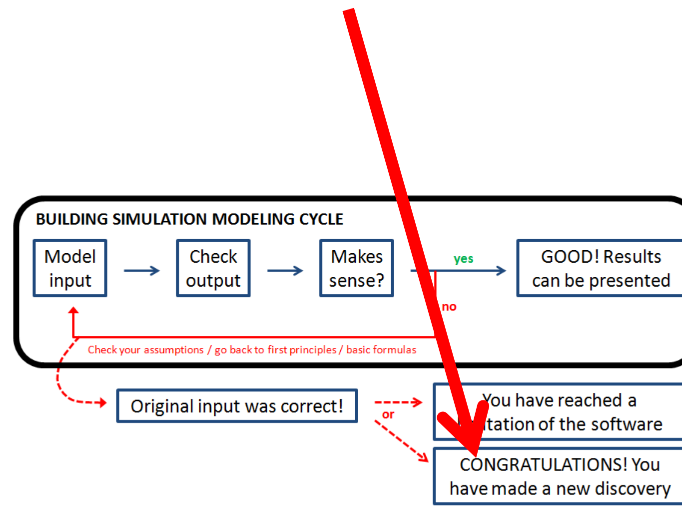
Case Study:

Office building in Putrajaya

1. Harvest rainwater for irrigation
2. Harvest AHU condensate
3. Harvest grey water

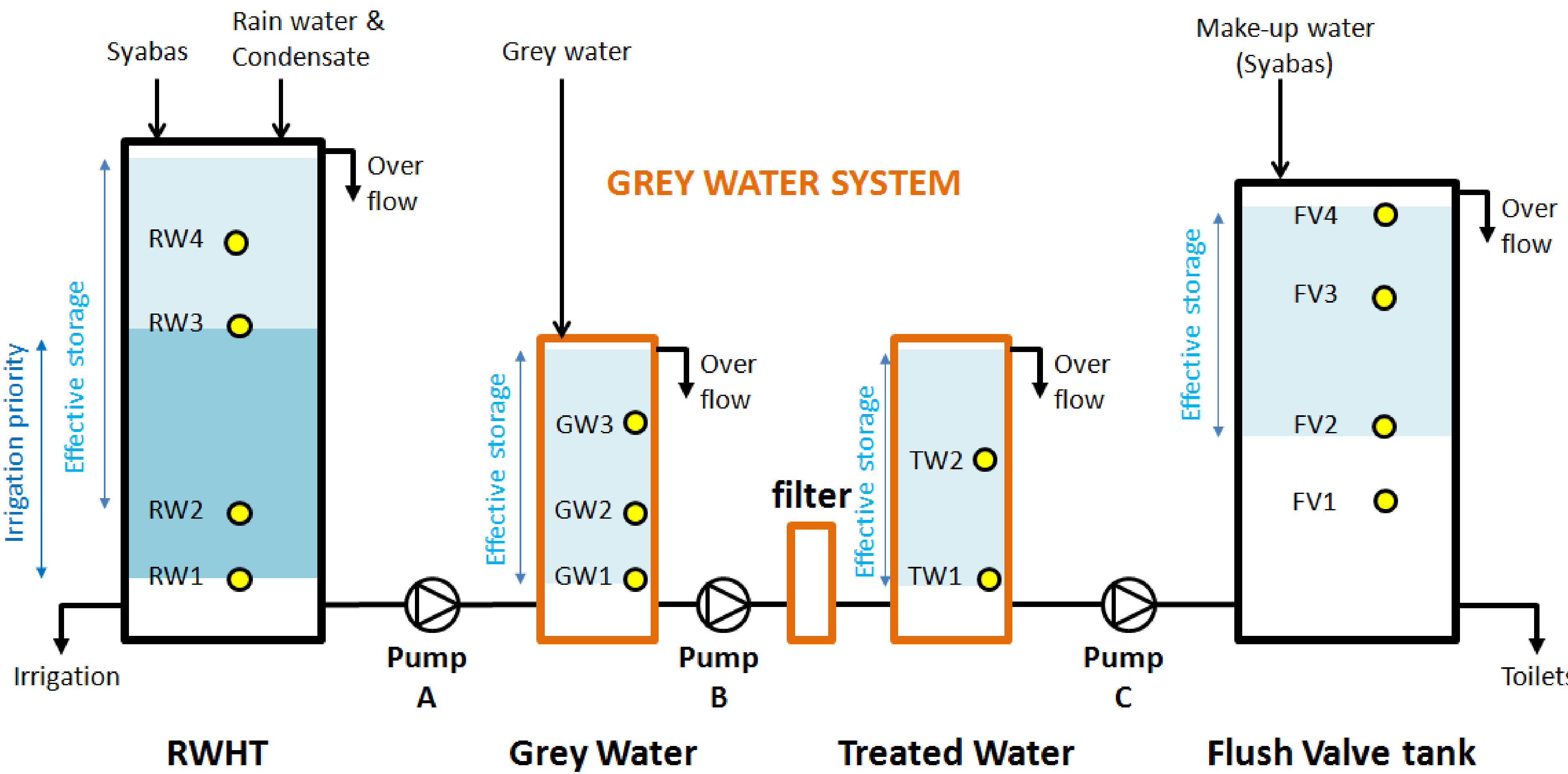
Example of:

Making 'new' discovery



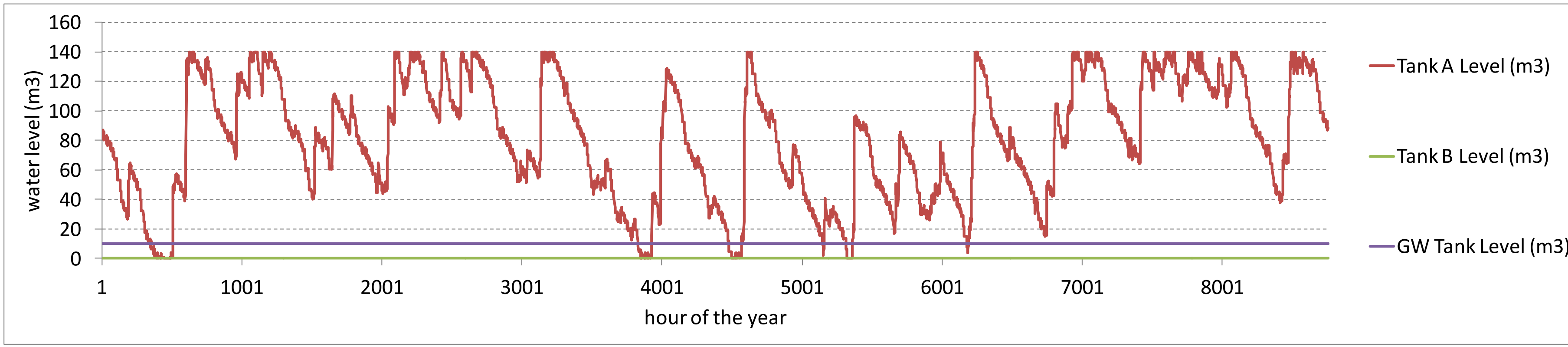
This is what we found.....
(see next slides)

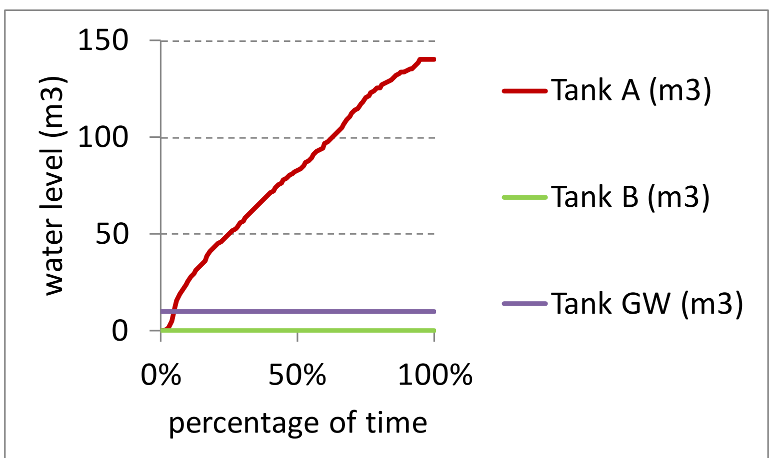
Water System Diagram



Water Level in Tanks

Effective storages: 140 m^3 / 84 m^3 (Tank A total / reserved for rainwater), 30 m^3 (Tank B), 10 m^3 (Grey Water Tank)
Pump capacities: 0 m^3/h (Pump A), 0 m^3/h (Pump B)

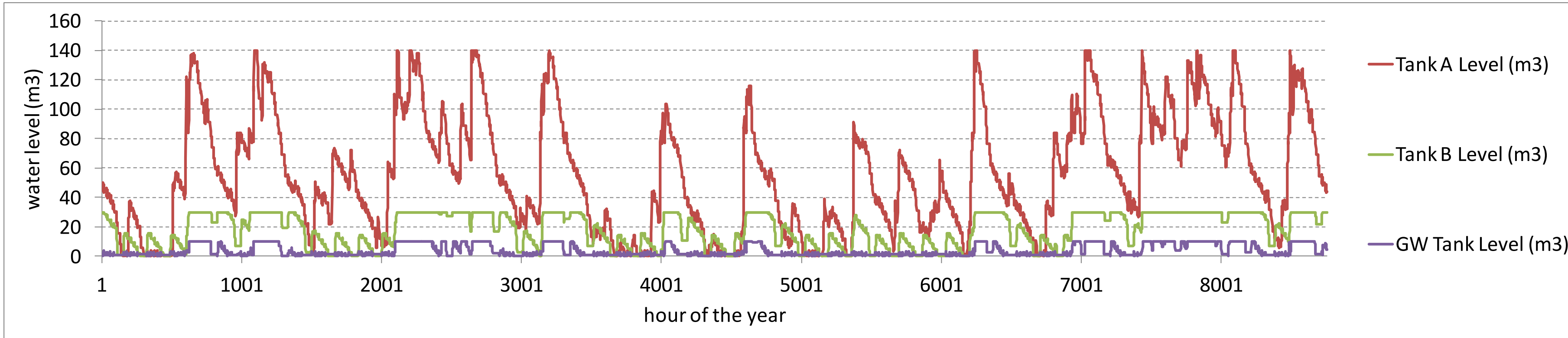


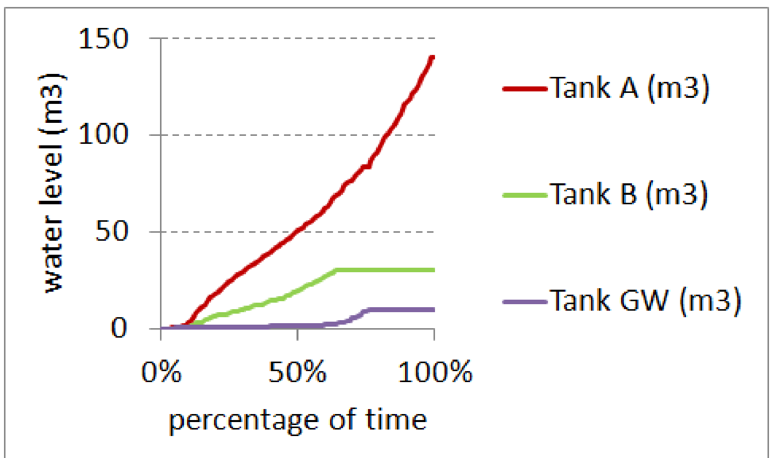


NON POTABLE WATER UTILISED	5,290	m3/year
Overflow from Tank A	1,179	m3/year
Overflow from GW Tank	3,852	m3/year

Water Level in Tanks

Effective storages: 140 m³ / 84 m³ (Tank A total / reserved for rainwater), 30 m³ (Tank B), 10 m³ (Grey Water Tank)
Pump capacities: 2.4 m³/h (Pump A), 2.4 m³/h (Pump B)





NON POTABLE WATER UTILISED	9,510	m3/year
Overflow from Tank A	273	m3/year
Overflow from GW Tank	537	m3/year

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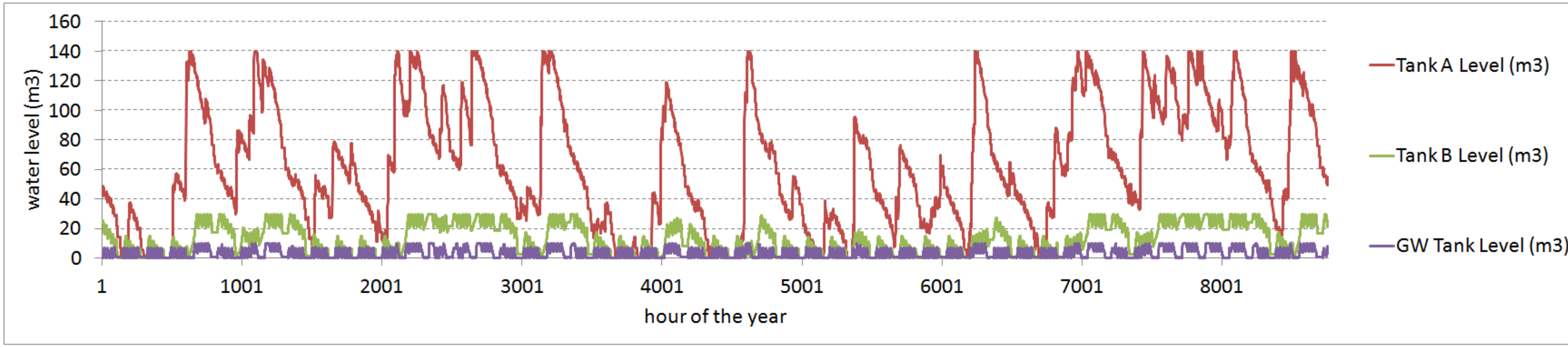
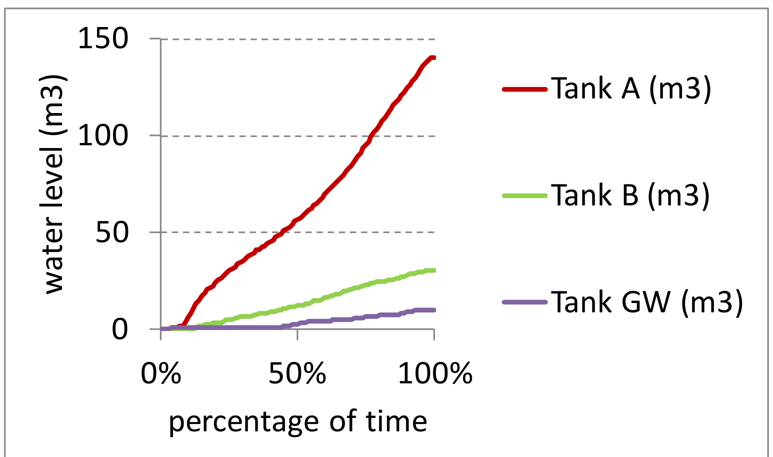
Water Level in Tanks

Effective storages: 140 m^3 / 84 m^3 (Tank A total / reserved for rainwater), 30 m^3 (Tank B), 10 m^3 (Grey Water Tank)

Pump capacities: 0.3 m^3/h (Pump A), 0.8 m^3/h (Pump B)





NON POTABLE WATER UTILISED	9,505	m3/year
Overflow from Tank A	592	m3/year
Overflow from GW Tank	223	m3/year

RECCOMENDATION:

- The annual hourly simulation shows that small pumps are sufficient to maximise the annual non-potable water yield
- Small pumps have the added advantage of having less start-stop cycles and reducing grey water filter costs

Concluding Remarks

- Building computer simulations are a very powerful tool to optimise building design – and to ’sell’ your ideas to the design team / client
- ALWAYS check the validity of your results
- .... and go an make new discoveries to bring the building industry forward!

Thank you

ANY QUESTIONS?

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