

Building simulation analysis for smartengine

Case studies in cellular offices and open-plan offices

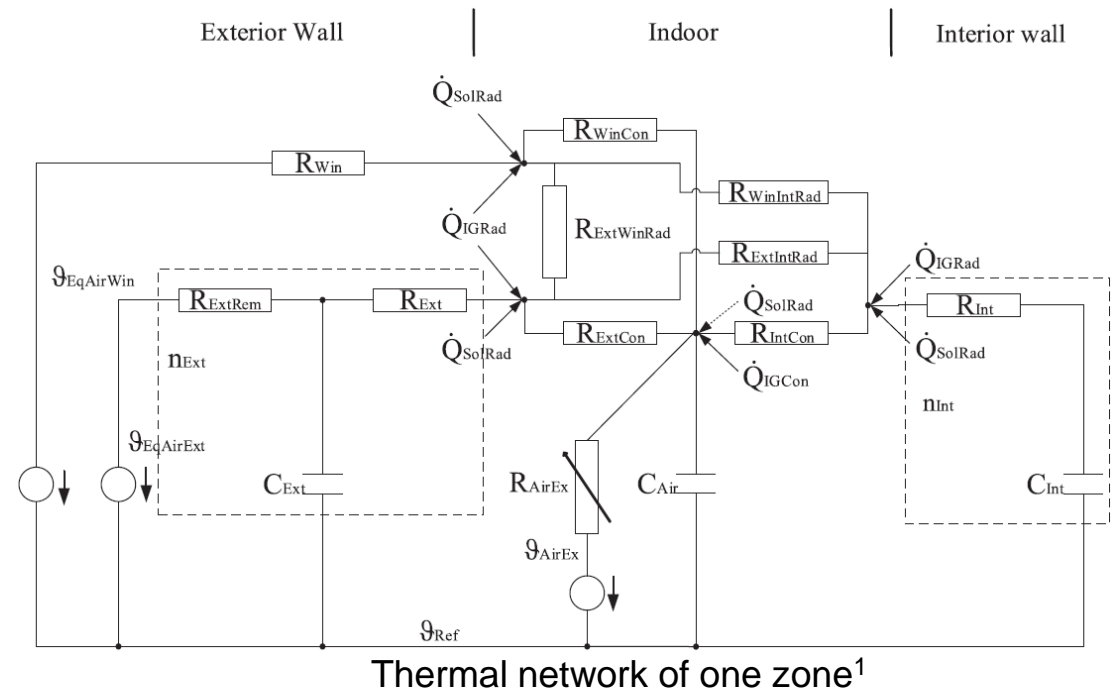
Motivation

- Potential of the demand-oriented mechanical ventilation and lighting in non-residential buildings
 - ≡ Achieving energy-saving
 - ≡ Without compromise of thermal comfort

- Analysis of applying smartengine + building automation in modern office buildings
 - ≡ Through building simulation methods
 - ≡ Case I: 4 cellular offices
 - ≡ Case II: 4 open-plan offices

Introduction of the building model for the thermal simulation

- A simplified multi-zone building model in the modeling language Modelica
 - ≡ Building geometry with consideration of orientation and building physics
 - = Conversion to thermal resistances (R) and capacities (C) via the tool TEASER¹, based on the German standard VDI 6007²
 - ≡ Model for internal gains (people, machine, lighting): intensity with time profiles
 - ≡ Homogenous air nodes for a single zone
 - ≡ Consideration of heat convection as well as heat radiation

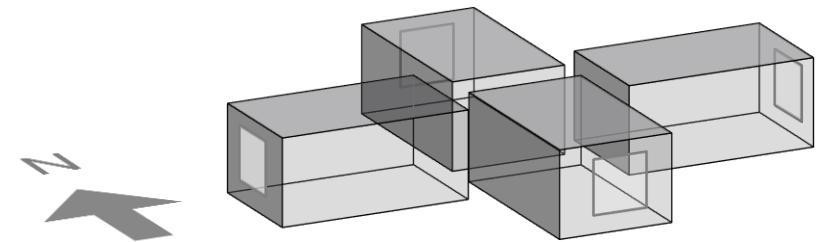


¹ TEASER: an open tool for urban energy modelling of building stocks. P. Remmen, M. Lauster, M. Mans, M. Fuchs, T. Osterhage, D. Müller. Journal of Building Performance Simulation, February 2017

² VDI 6007 Part 1 – Calculation of transient thermal response of rooms and buildings – Modelling of rooms. The Association of German Engineers (VDI). June 2015.

Input Parameters – Cellular Office

Variants	Reference Office North, East, South and West	smartengine-variant Office North, East, South and West
Weather data		
City	Düsseldorf	The same as reference
Building physics		
Building geometries	4 identical rooms with 21.73 m ² each Clear room height: 2.83 m Orientation: 4 zones facing N, O, W, S respectively	The same as reference
U-values of opaque components	Exterior wall: 0.213 W/(m ² ·K) Ceiling: 1.84 W/(m ² ·K) Floor: 1.84 W/(m ² ·K)	The same as reference
Windows	U-value of glazing: 0.9 W/(m ² ·K) g _{total} -value with sun shades (shading factor 0.25): 0.09 Solar irradiation threshold to activate sun shades: 150 W/m ²	The same as reference



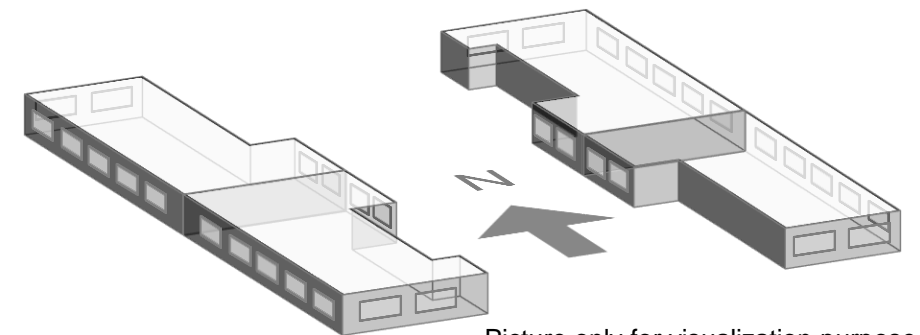
Picture only for visualization purpose

Input Parameters – Cellular Office

Variants	Reference Office North, East, South and West	smartengine-variant Office North, East, South and West
Heating and cooling		
Room temperature set points	21 °C: for heating 25.5 °C: for cooling	The same as reference
Ventilation		
Supply air temperature	21 °C: when outdoor temp. < 15 °C 18 °C: when outdoor temp. > 26 °C Gliding: when outdoor temp. between 15 & 26 °C	The same as reference
Infiltration	0.1 h ⁻¹	The same as reference
Volume flow of AHU	Constant in working hours 6.00 m ³ /(m ² h)	Variable in working hours Max. 6.00 m ³ /(m ² h)
Efficiency of heat recovery	0.68	The same as reference
dp total	1820 Pa	Variable
Elec. efficiency of AHU	0.631	Variable
Internal gains		
People	13.80 W/m ² + time profile	The same as reference
Machines	16.60 W/m ² + time profile	The same as reference
Lighting	5.43 W/m ² + on/off-profile	5.43 W/m ² + lighting control + time profile

Input Parameters – Open-plan Office

Variants	Reference Office NO, NW, SO, SW	smartengine-variant Office NO, NW, SO, SW
Weather data		
City	Erlangen	The same as reference
Building physics		
Building geometries	2 rooms with 385.3 m ² each and 2 rooms with 377.5 m ² each Clear room height: 2.83 m Orientation: 4 zones pictured below	The same as reference
U-values of opaque components	Exterior wall: 0.22 W/(m ² ·K) Ceiling: 0.17 W/(m ² ·K) Floor: 0.80 W/(m ² ·K)	The same as reference
Windows	U-value of glazing: 0.8 W/(m ² ·K) g _{total} -value with sun shades (shading factor 0.25): 0.09 Solar irradiation threshold to activate sun shades: 150 W/m ²	The same as reference

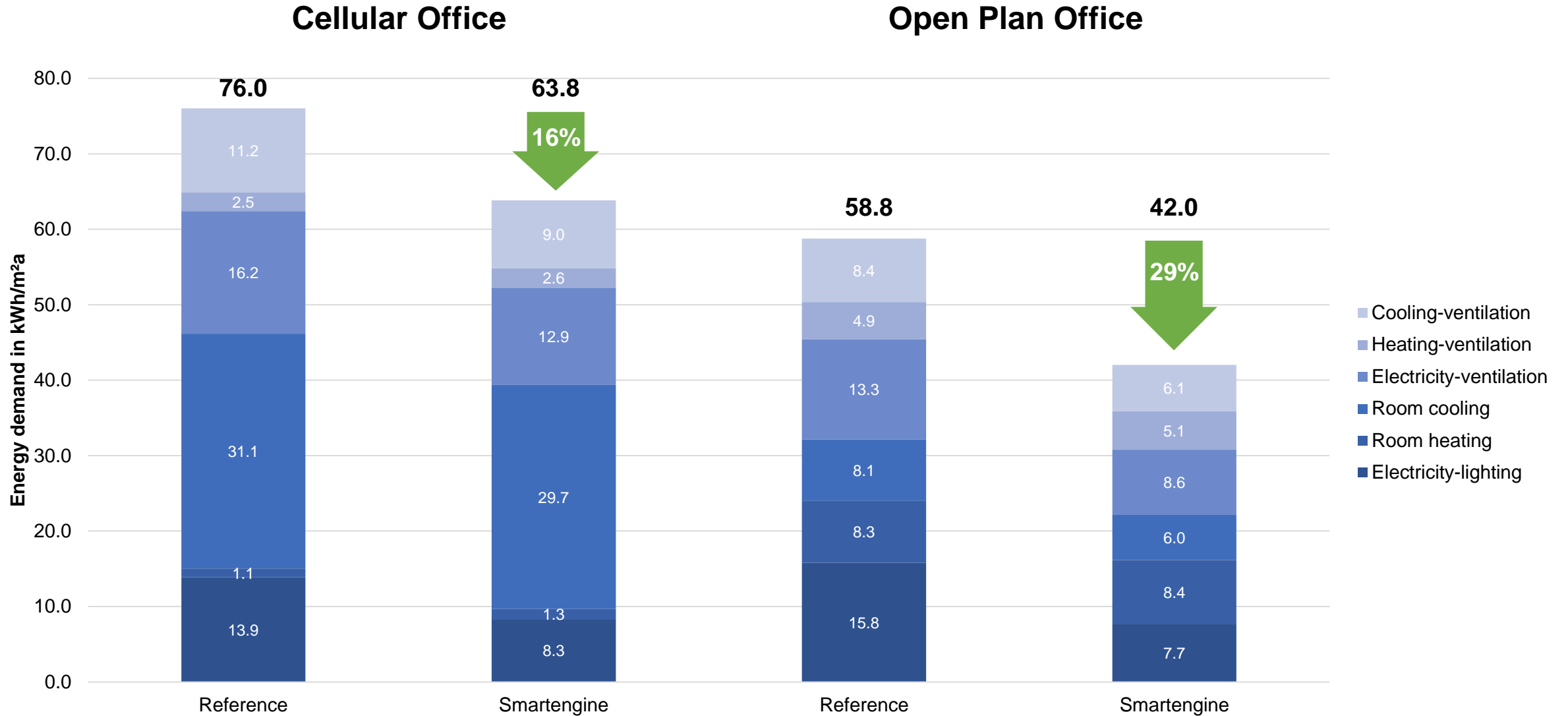


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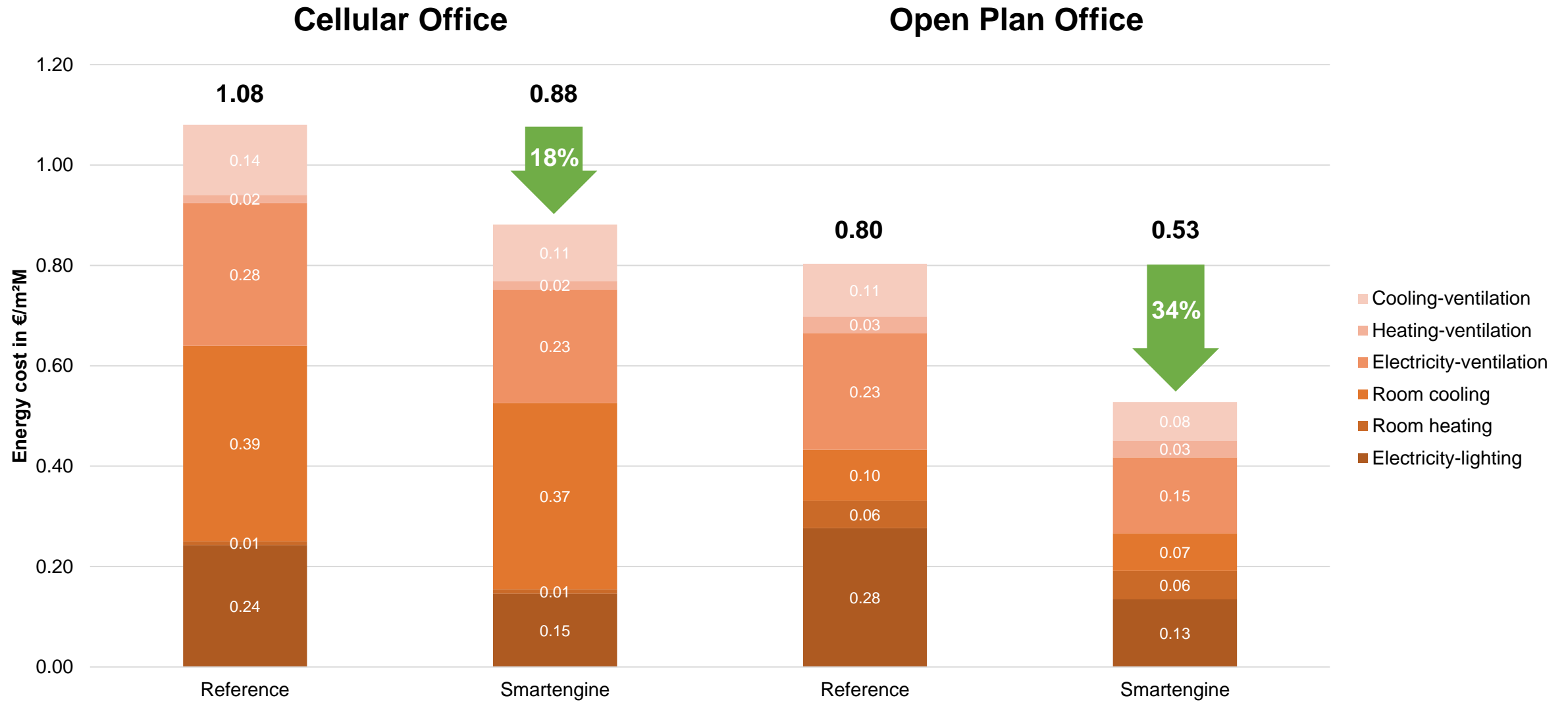
Input Parameters – Open-plan Office

Variants	Reference Office NO, NW, SO, SW	smartengine-variant Office NO, NW, SO, SW
Heating and cooling		
Room temperature set points	21 °C: for heating 25.5 °C: for cooling	The same as reference
Ventilation		
Supply air temperature	21 °C: when outdoor temp. < 15 °C 18 °C: when outdoor temp. > 26 °C Gliding: when outdoor temp. between 15 & 26 °C	The same as reference
Infiltration	0.1 h ⁻¹	The same as reference
Volume flow of AHU	Constant in working hours 4.89 m ³ /(m ² h)	Variable in working hours Max. 4.89 m ³ /(m ² h)
Efficiency of heat recovery	0.68	The same as reference
dp total	1820 Pa	variable
Elec. efficiency of AHU	0.631	variable
Internal gains		
People	9.50 W/m ² + time profile	The same as reference
Machines	9.50 W/m ² + time profile	The same as reference
Lighting	5.50 W/m ² + on/off-profile	5.50 W/m ² + lighting control + time profile

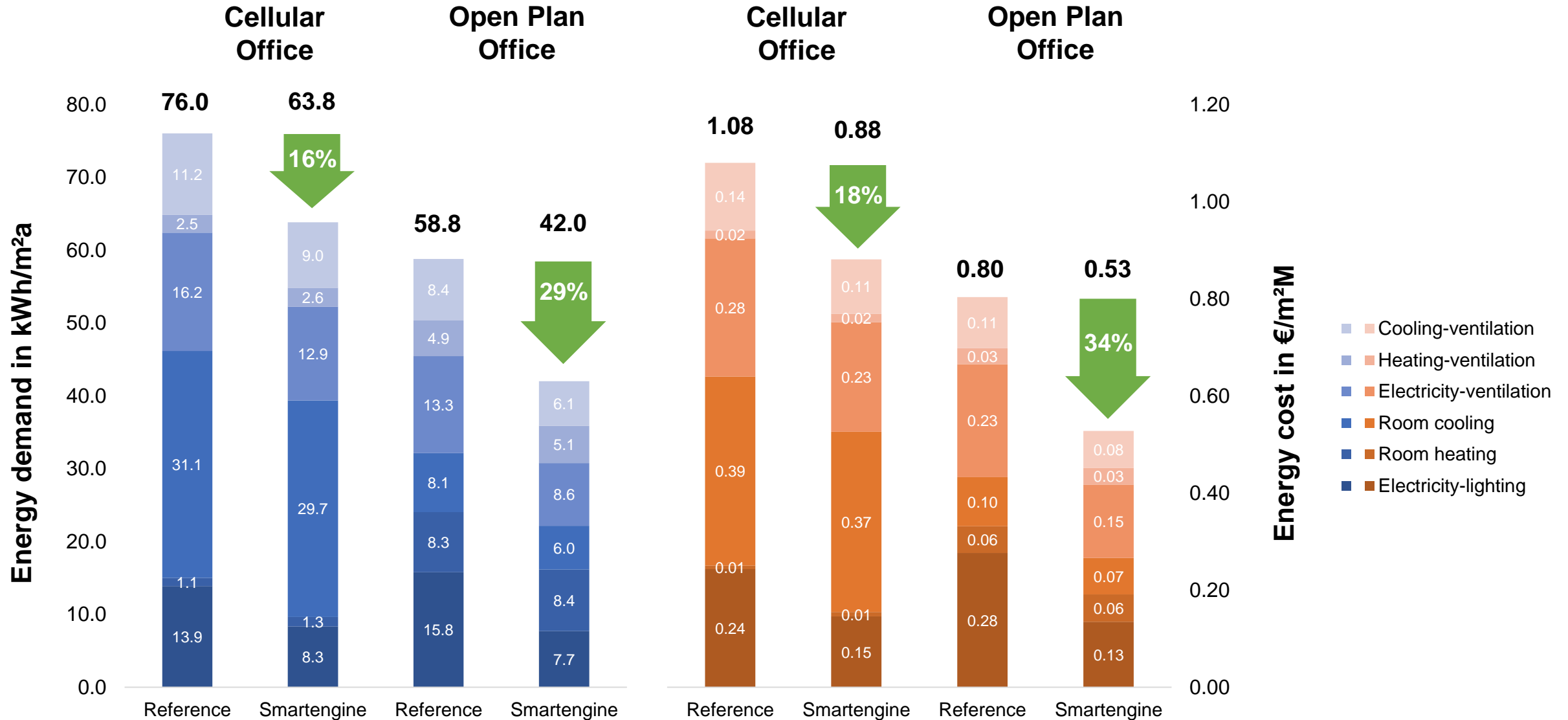
Results of RWTH study: energy demand



Results of RWTH study: energy costs



Results of RWTH study: energy demand & costs



Energy and cost savings between reference and smartengine-variant

■ Cellular office

Energy price		
Electricity price	€/kWh	0.21
Heating price	€/kWh	0.08
Cooling price	€/kWh	0.15

			Reference	Smartengine-Variant	Saving	Saving in percentage
Energy demand	Electricity-lighting	kWh/m ² a	13.89	8.34	5.55	40%
	Room heating	kWh/m ² a	1.14	1.32	-0.18	-16%
	Room cooling	kWh/m ² a	31.13	29.71	1.42	5%
	Electricity-ventilation	kWh/m ² a	16.25	12.90	3.35	21%
	Heating-ventilation	kWh/m ² a	2.47	2.59	-0.12	-5%
	Cooling-ventilation	kWh/m ² a	11.16	8.97	2.19	20%
Energy cost	Electricity-lighting	€/m ² M	0.24	0.15	0.10	40%
	Room heating	€/m ² M	0.01	0.01	0.00	-16%
	Room cooling	€/m ² M	0.39	0.37	0.02	5%
	Electricity-ventilation	€/m ² M	0.28	0.23	0.06	21%
	Heating-ventilation	€/m ² M	0.02	0.02	0.00	-5%
	Cooling-ventilation	€/m ² M	0.14	0.11	0.03	20%
	Sum	€/m²M	1.08	0.88	0.20	18%

Energy and cost savings between reference and smartengine-variant

■ Open-plan office

Energy price		
Electricity price	€/kWh	0.21
Heating price	€/kWh	0.08
Cooling price	€/kWh	0.15

			Reference	Smartengine-Variant	Saving	Saving in percentage
Energy demand	Electricity-lighting	kWh/m ² a	15.79	7.70	8.09	51%
	Room heating	kWh/m ² a	8.26	8.45	-0.19	-2%
	Room cooling	kWh/m ² a	8.11	5.99	2.11	26%
	Electricity-ventilation	kWh/m ² a	13.29	8.64	4.65	35%
	Heating-ventilation	kWh/m ² a	4.92	5.10	-0.18	-4%
	Cooling-ventilation	kWh/m ² a	8.42	6.12	2.30	27%
Energy cost	Electricity-lighting	€/m ² M	0.28	0.13	0.14	51%
	Room heating	€/m ² M	0.06	0.06	0.00	-2%
	Room cooling	€/m ² M	0.10	0.07	0.03	26%
	Electricity-ventilation	€/m ² M	0.23	0.15	0.08	35%
	Heating-ventilation	€/m ² M	0.03	0.03	0.00	-4%
	Cooling-ventilation	€/m ² M	0.11	0.08	0.03	27%
	Sum	€/m²M	0.80	0.53	0.28	34%

