

A healthy and circular headquarter

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P5 Presentation

MSc Building Technology

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Background

Indoor comfort

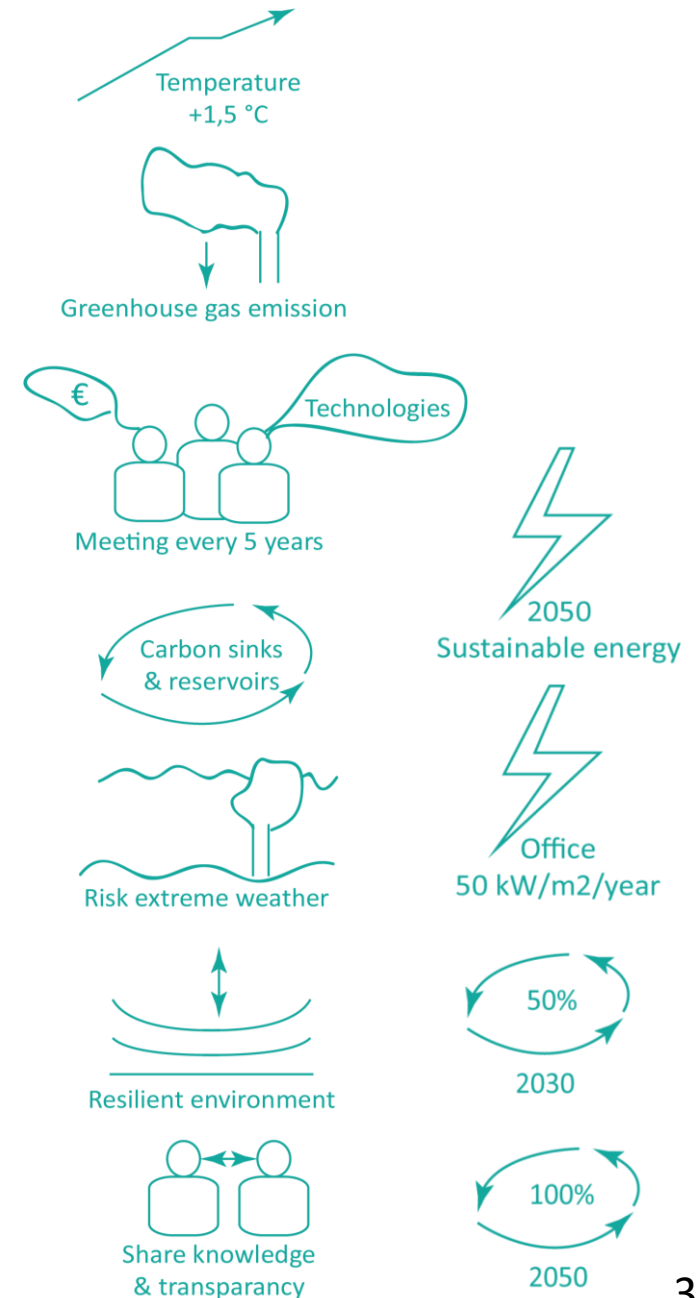
- Building users are changing
- Improved technology

'Paris proof'

- Energy 50 kWh/m² per year
- 100% circularity in 2050

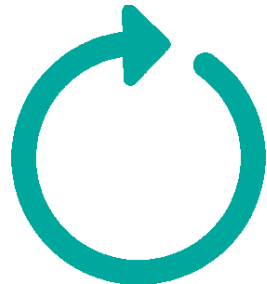
Case study

- Employees are doubled since 1999
- Existing installation is 20 years old
- Indoor comfort is criticized by employees



Problem statement

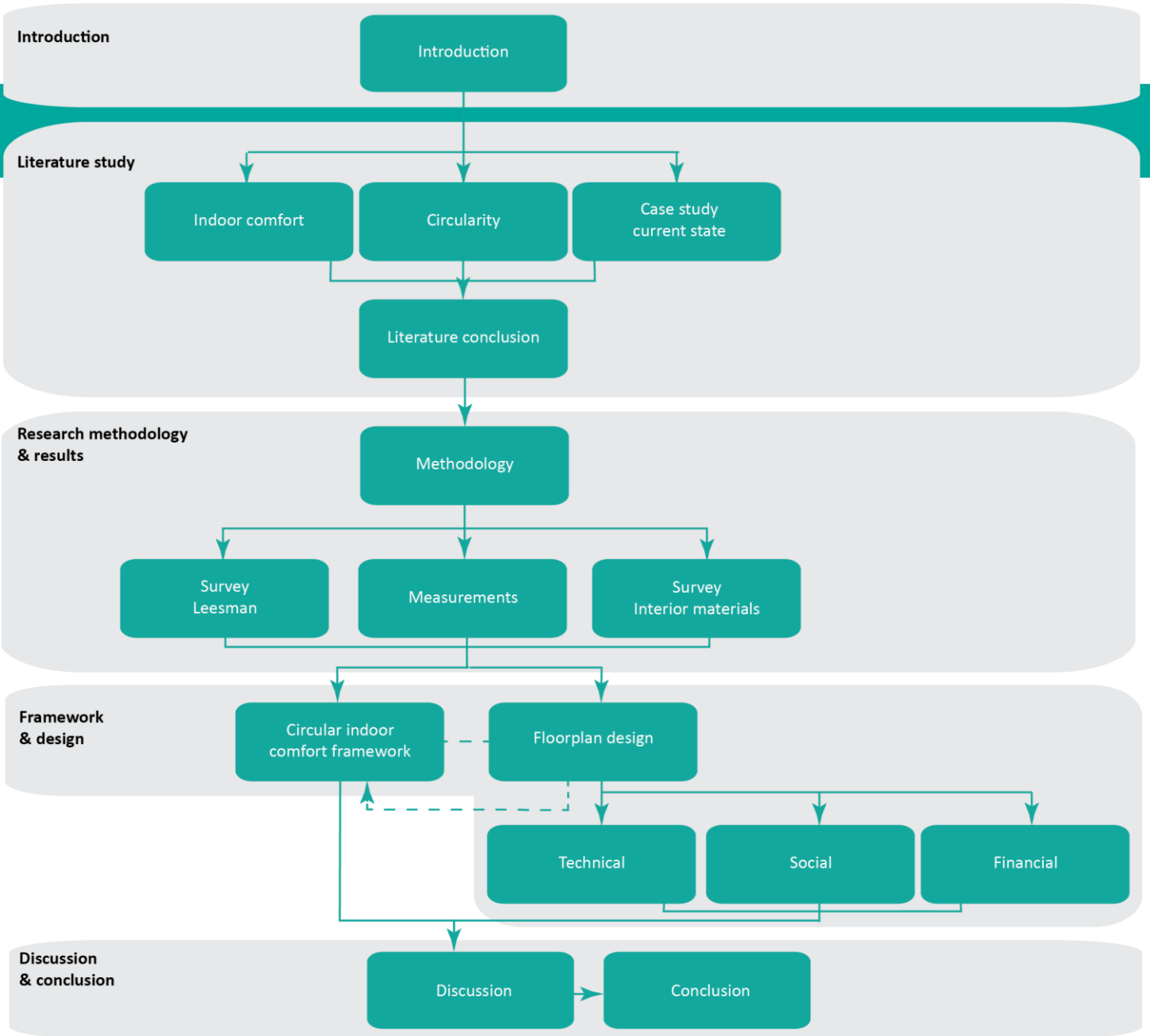
The building users are **criticizing the indoor comfort** in the headquarter of a bank in the Netherlands, the **building materials are end-of-life** and the building is **using a large amount of energy**.



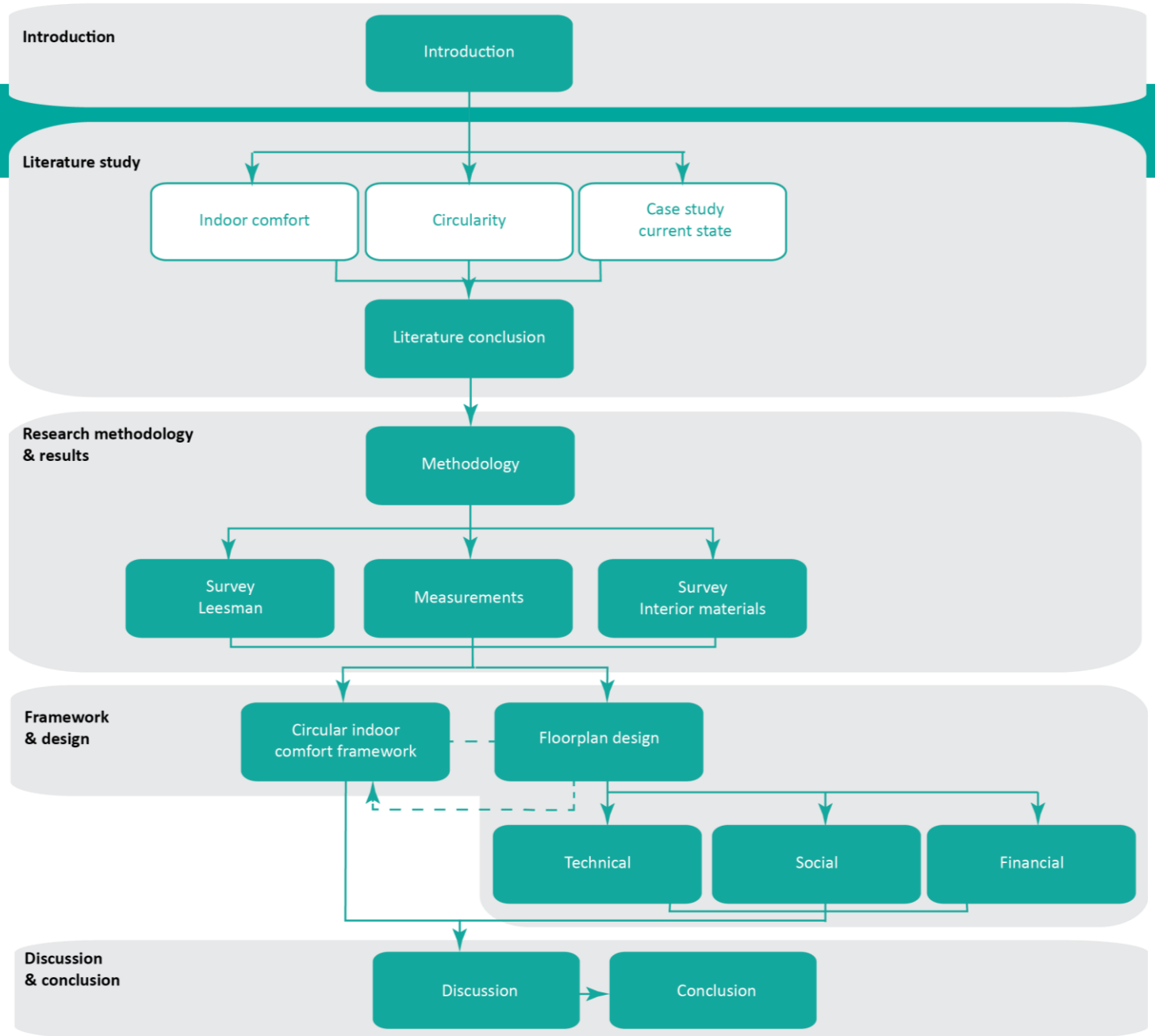
Research question

‘How can the **indoor comfort** be improved in a **circular way** by creating an **optimal floorplan** including the interior and technical aspects for, the case study, **one pilot floor of the headquarter of a bank** in the Netherlands, while taking the **energy consumption** into account?’

Methodology

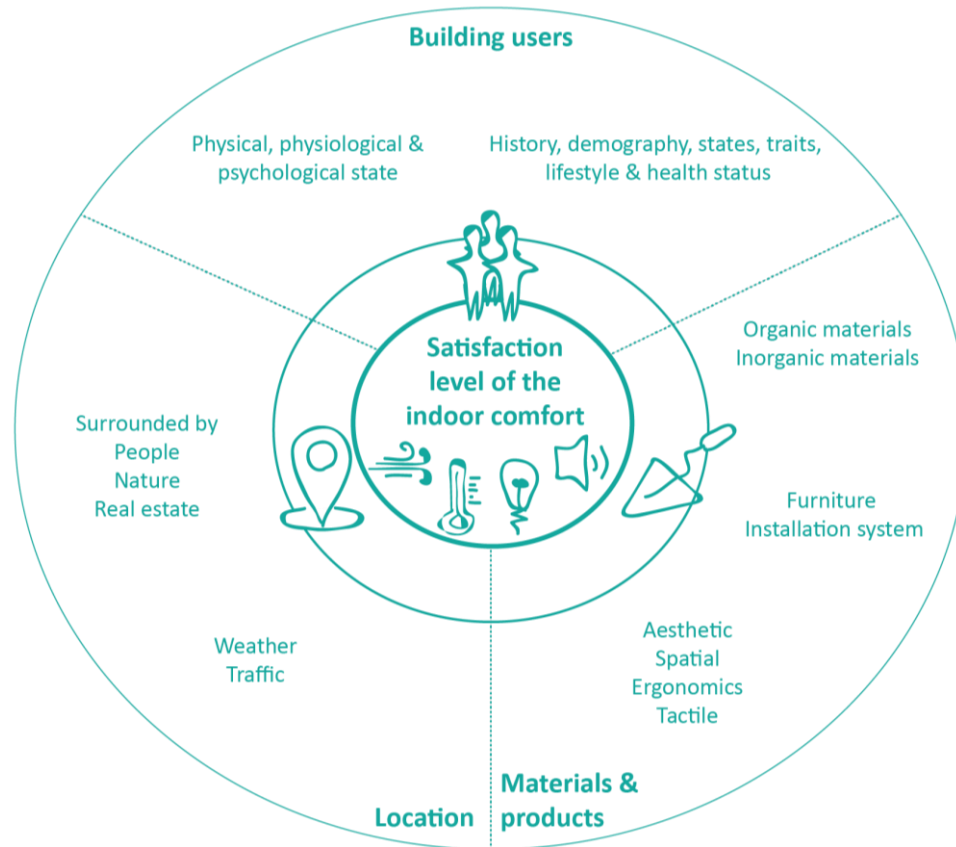


Literature study

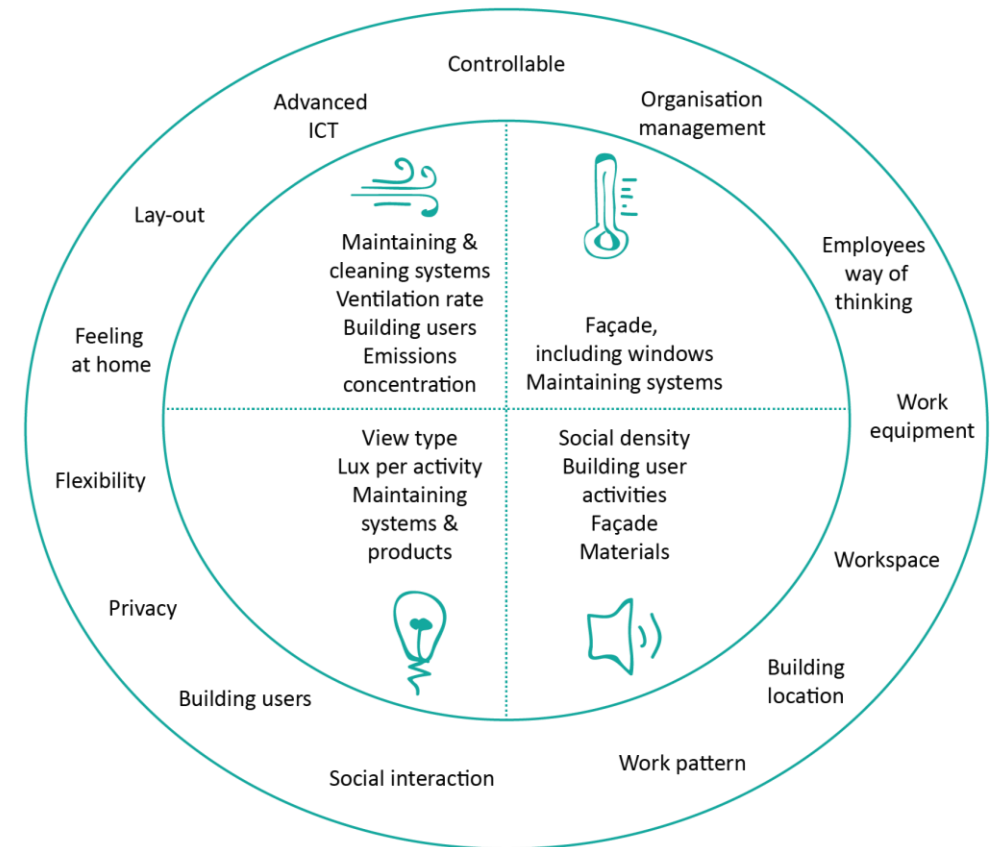


Indoor comfort

Influence factors



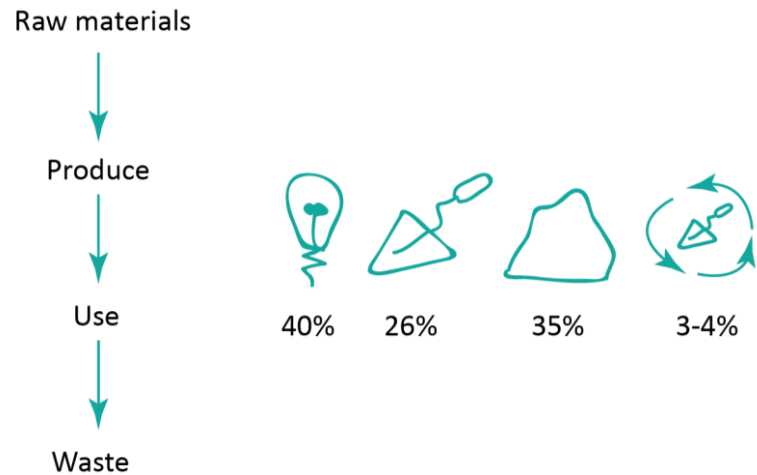
General indoor comfort



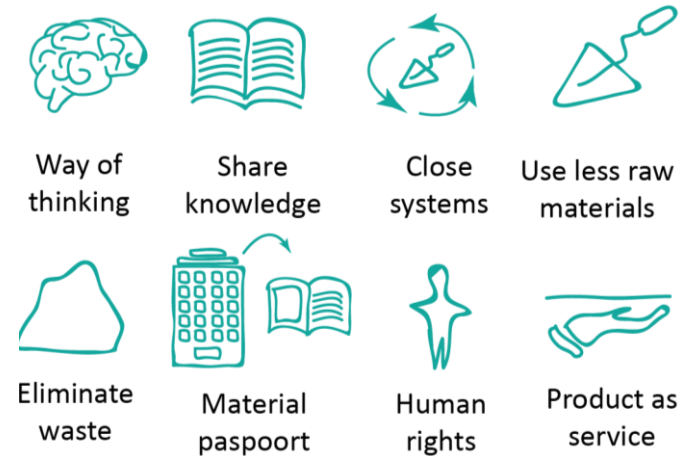
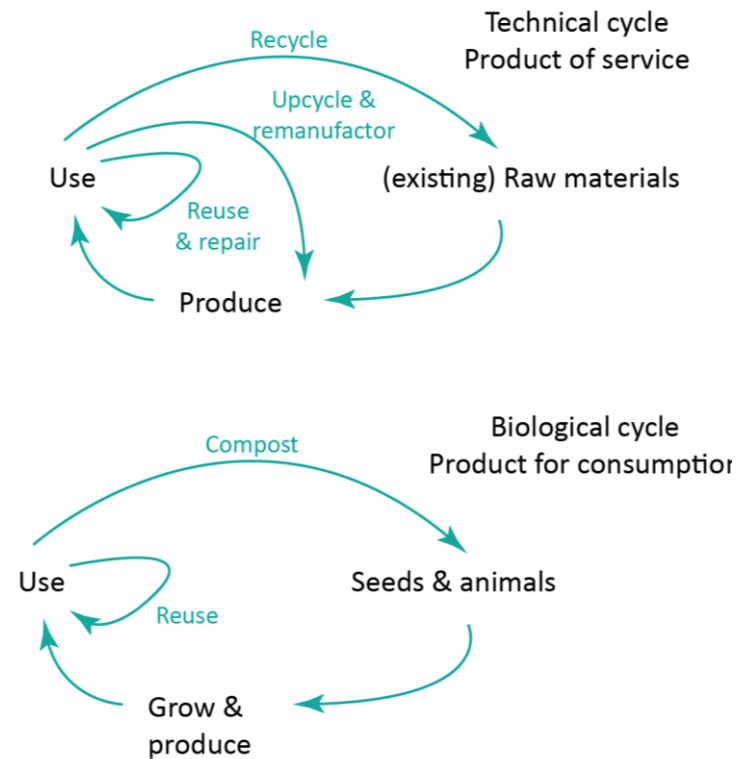
Office indoor comfort

Circularity

Linear building environment



Circular building environment

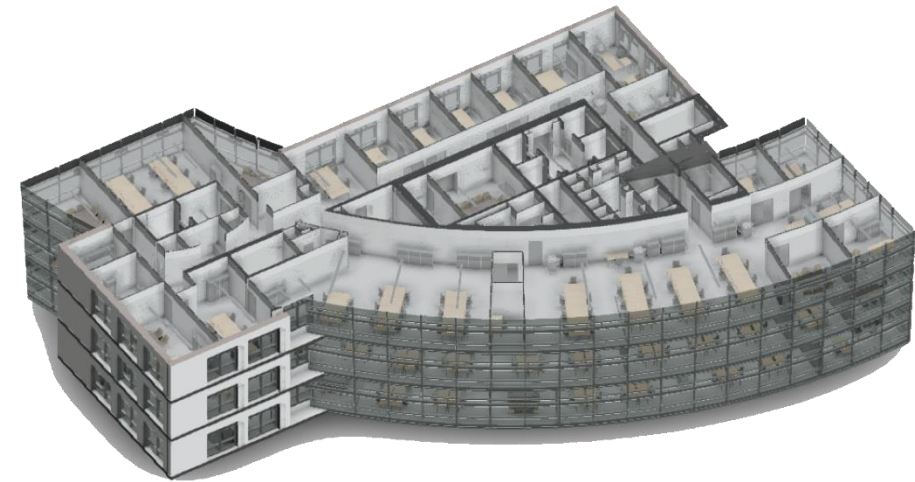
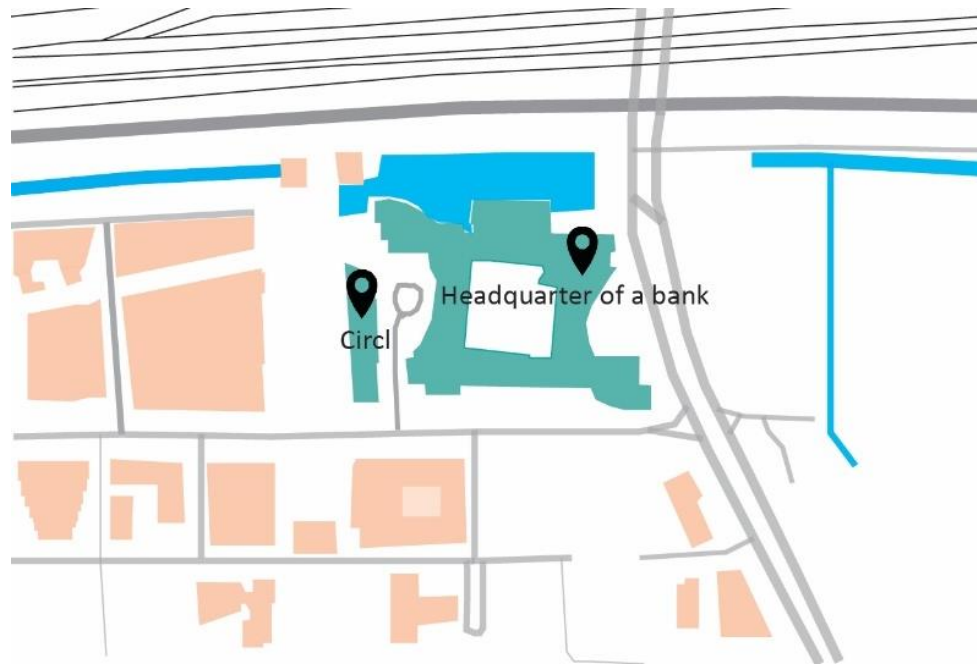


'New Stepped Strategy' base on circularity:

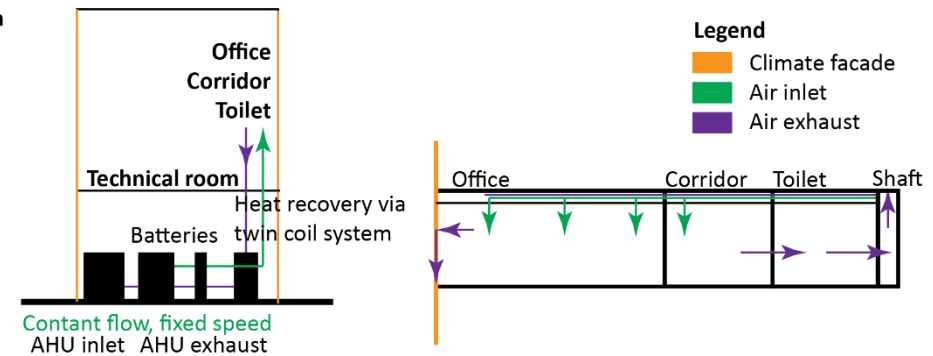
- 1) Sources
- 2) Interventions without energy
- 3) Interventions with renewable energy

Case study

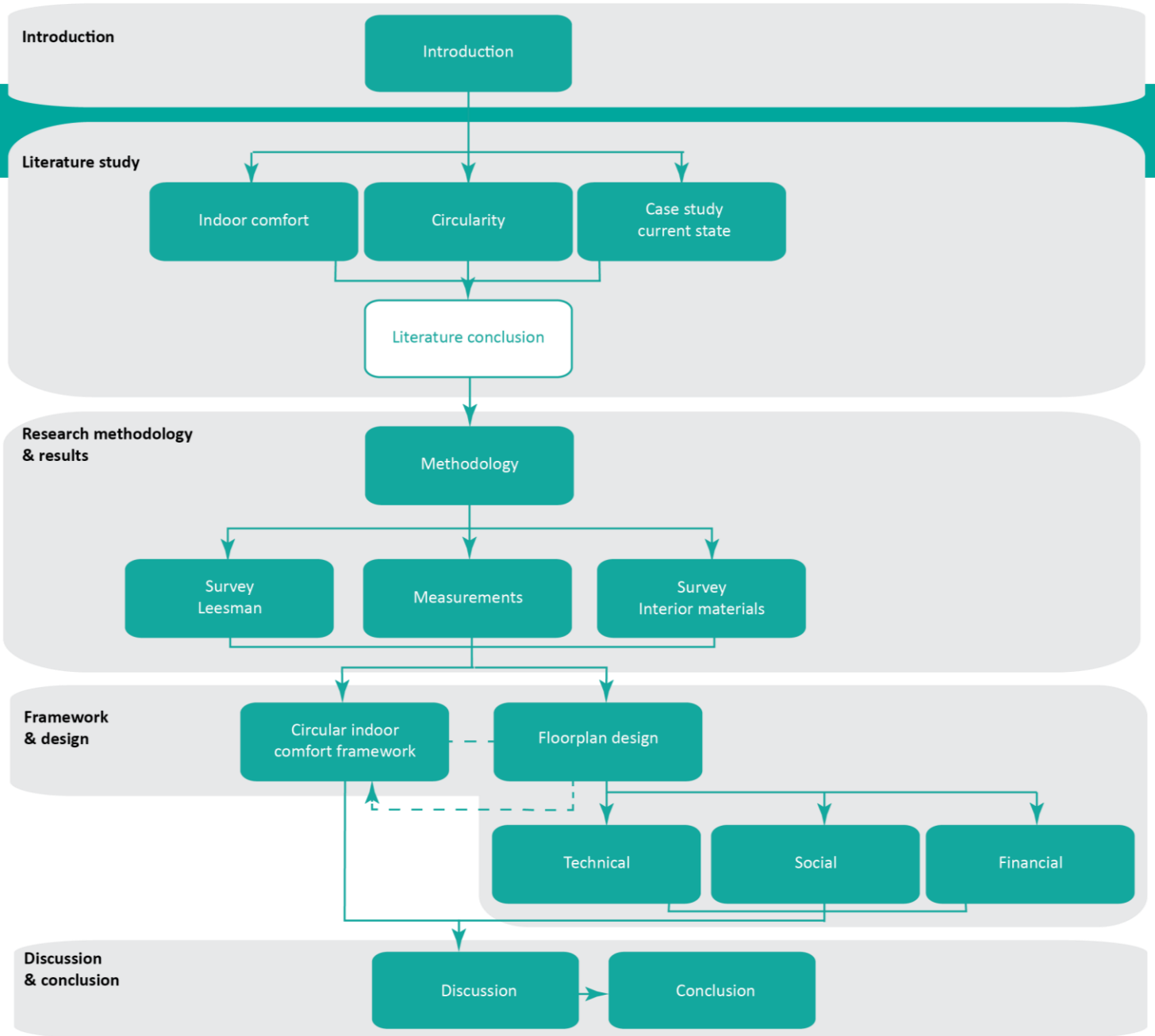
The headquarter of a bank in the Netherlands



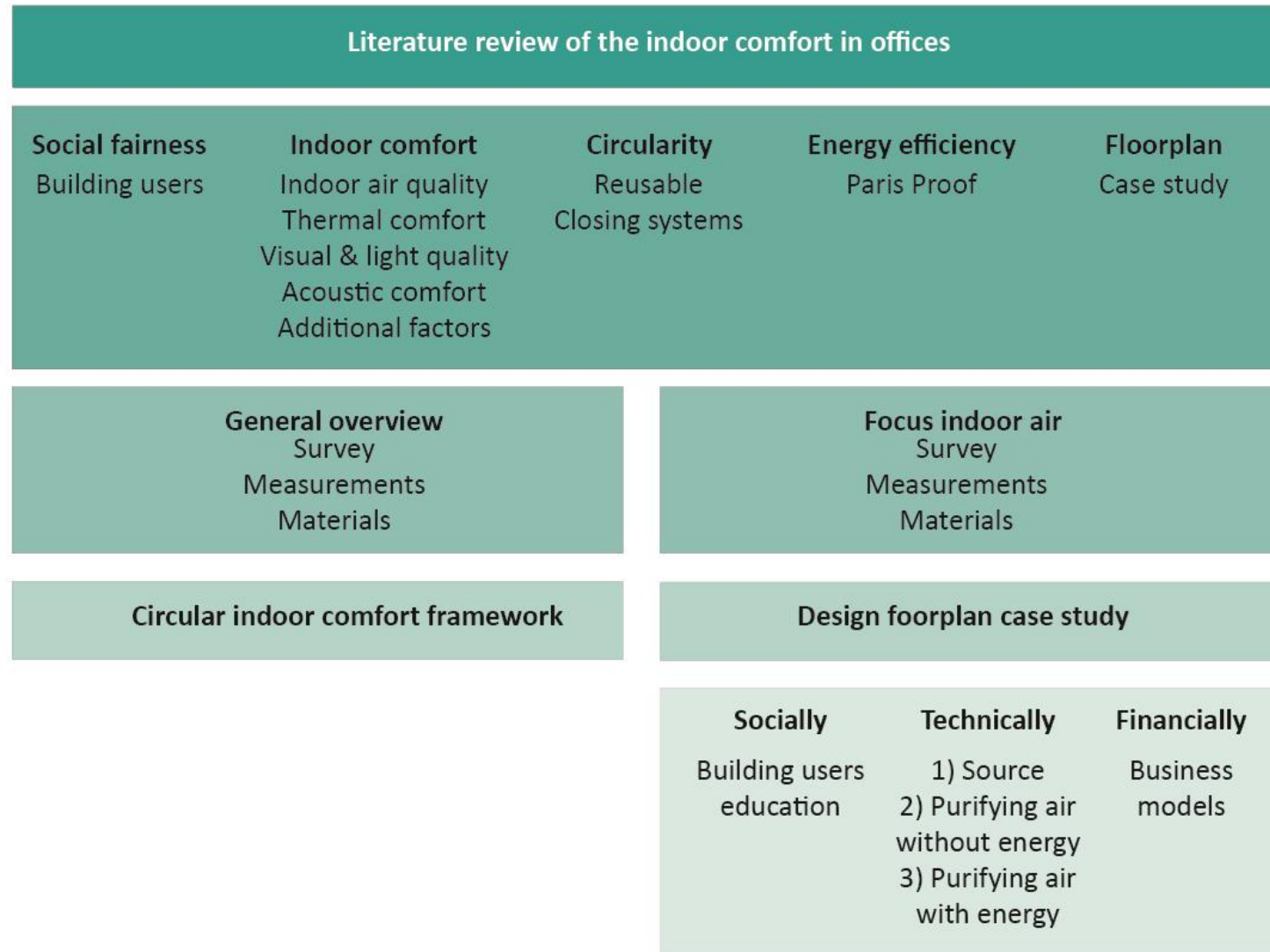
Air system



Literature results



Literature study review



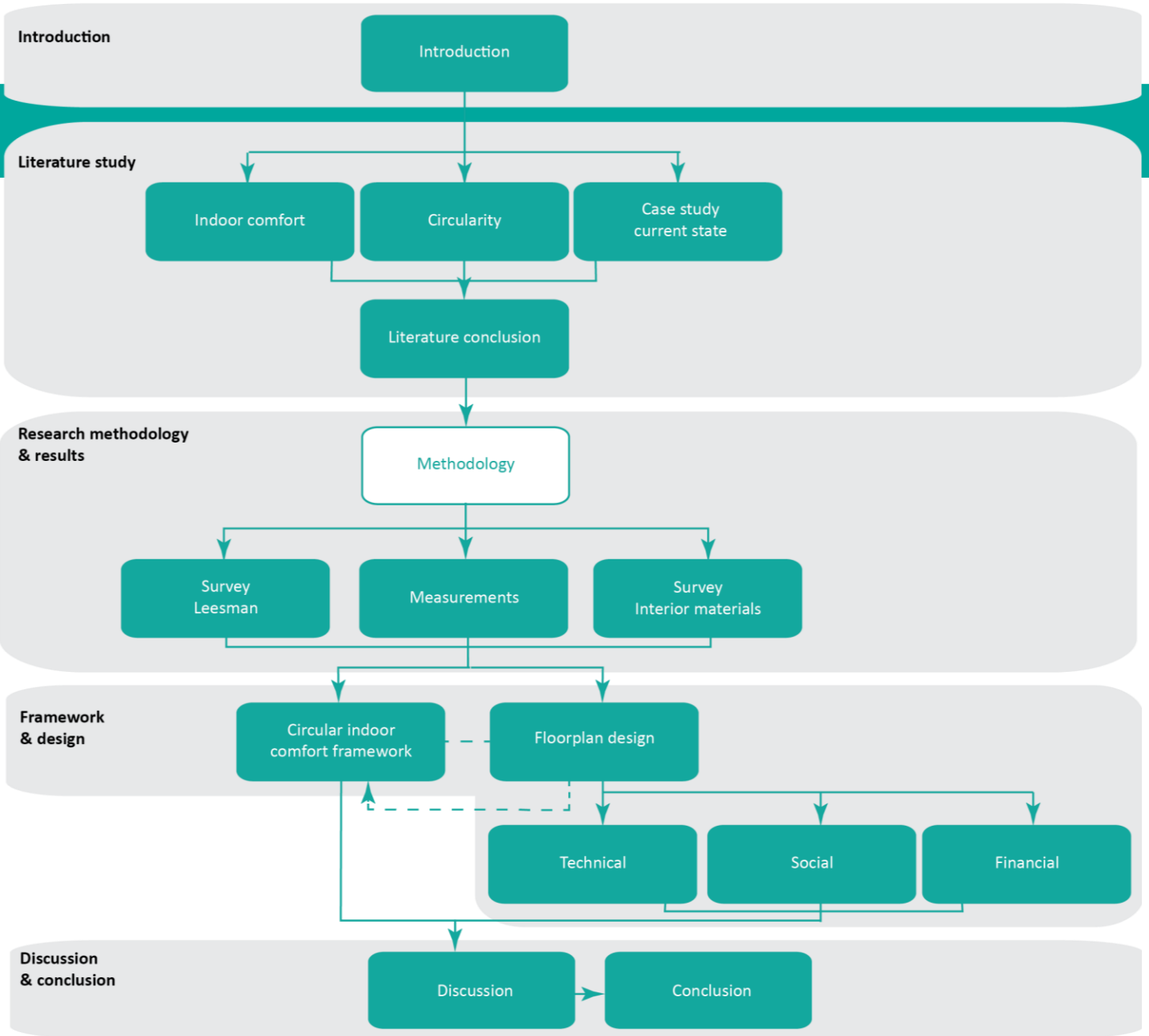
Literature study review

Plant capacity



Advantages	Disadvantages
Remove VOCs	Maintenance
Carbon dioxide convert into oxygen	Low positive influence on relative humidity, temperature and background noise level
Low cost	Plants need water and nutrients
Environmental friendly	Some plants cannot purify the VOCs from the air
Influence physical state building users	
Nature aesthetics	

Methodology



Materials & survey

Material analyses

- Circular
 - Raw materials & lifespan
 - Demountable or detachable
 - Remanufacture
 - Recycle or upcycle
- Indoor comfort
 - Influence factor health
 - Toxic gasses & cleaning

Survey analyses

- General information
- Workplaces
- Activities
- Workplace facilities

Measurements

Measurement devices

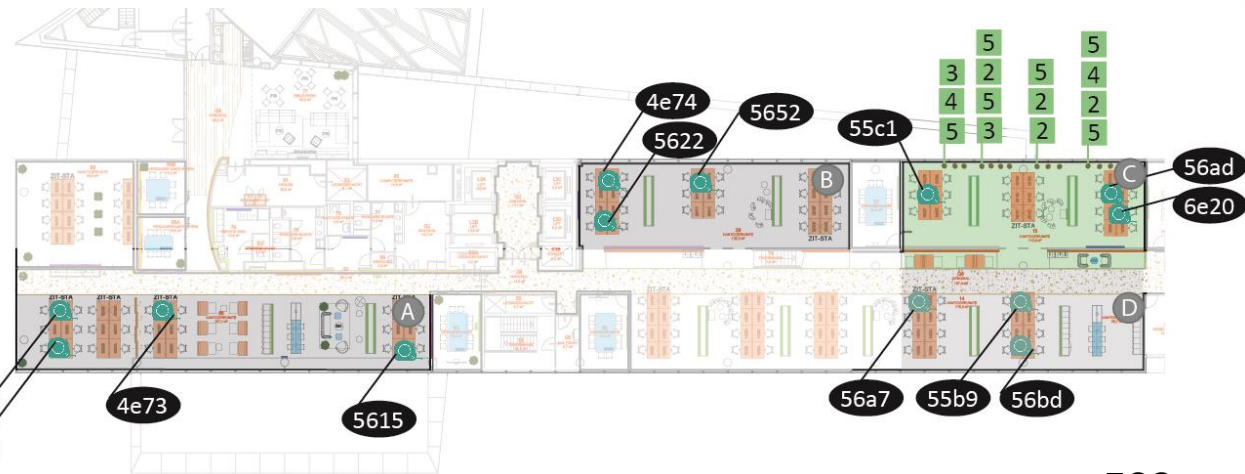
Measurement areas with plants

Measurement areas without plants



Plant species

- 1) Aglaonema Silver Queen
- 2) Scindapsus Aureus
- 3) Chlorophytum Comosum
- 4) Hemigraphis alternata
- 5) Hedera helix



E03



A11

Measurements

Number criteria				
Category	Subcategory	Requirement	Equipment	Accuracy
General	Spatial	Per person office space >4 m ²	Floorplan	*
Visual & lighting control	Emergency lighting	Emergency light <75 occupants	Floorplan	*
Acoustic comfort	Contact sound level	<59 dB	GreenMe cubes	± 3 dBA
		<57 dB	GreenMe cubes	± 3 dBA
	Contact sound level Building installation sound level	<40 dB	GreenMe cubes	± 3 dBA
		Building installation sound level	<35 dB	GreenMe cubes
General	Plants	Reduce VOC	GreenMe cubes	> 0,1 ppm
	Spatial	Kitchens, chemical storages & printers in another room	Floorplan	*
Visual & lighting control	Illumination	Minimum 500 lux	GreenMe cubes	± 2%
	View	50% view from desk	View plan	*
Thermal comfort	Temperature	Winter 20-24 °C	GreenMe cubes	± 0,2 °C
		Summer 20-26 °C		
		Variation of at least 3 °C across open space over 200 m ²		
	Relative humidity	30-70 % or ventilating heat exchange wheel	GreenMe cubes	± 2%
	Thermal zone	Maximum thermal zone per 60m ² or 10 occupants	Floorplan	*
Air quality	VOC	<100 µg/m ³ per 30 min.	GreenMe cubes	> 0,1 ppm
	Carbon dioxide concentration	<800 ppm	GreenMe cubes	± 30 ppm
		<600 ppm	GreenMe cubes	± 30 ppm

Measurements

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		<600 ppm	GreenMe cubes	± 30 ppm

Plants



Silver Queen

Nicotine
and formaldehyde



Scindapsus Aureus

Methanal,
benzene,
and trichloro ethylene



Chlorophytum Comosum

Various harmful gases



Hemigraphis Alternata

Benzene, toluene,
octane, trichloroethylene,
and terpene



Aglaonema

Ammonia
and formaldehyde



Sansevieria Trifasciata

Benzene,
Toluene, and xylene



Spathiphyllum Hybride

VOCs



Dracaena Deremensis

Benzene,
toluene, and xylene



Hedera Helix

Benzene, toluene,
octane, trichloroethylene, terpene,
and formaldehyde

Case study results

The indoor comfort is not always according to the regulations & does not always meet the requirements of the building users.

Survey analyses

Profile building users

Indoor comfort experience

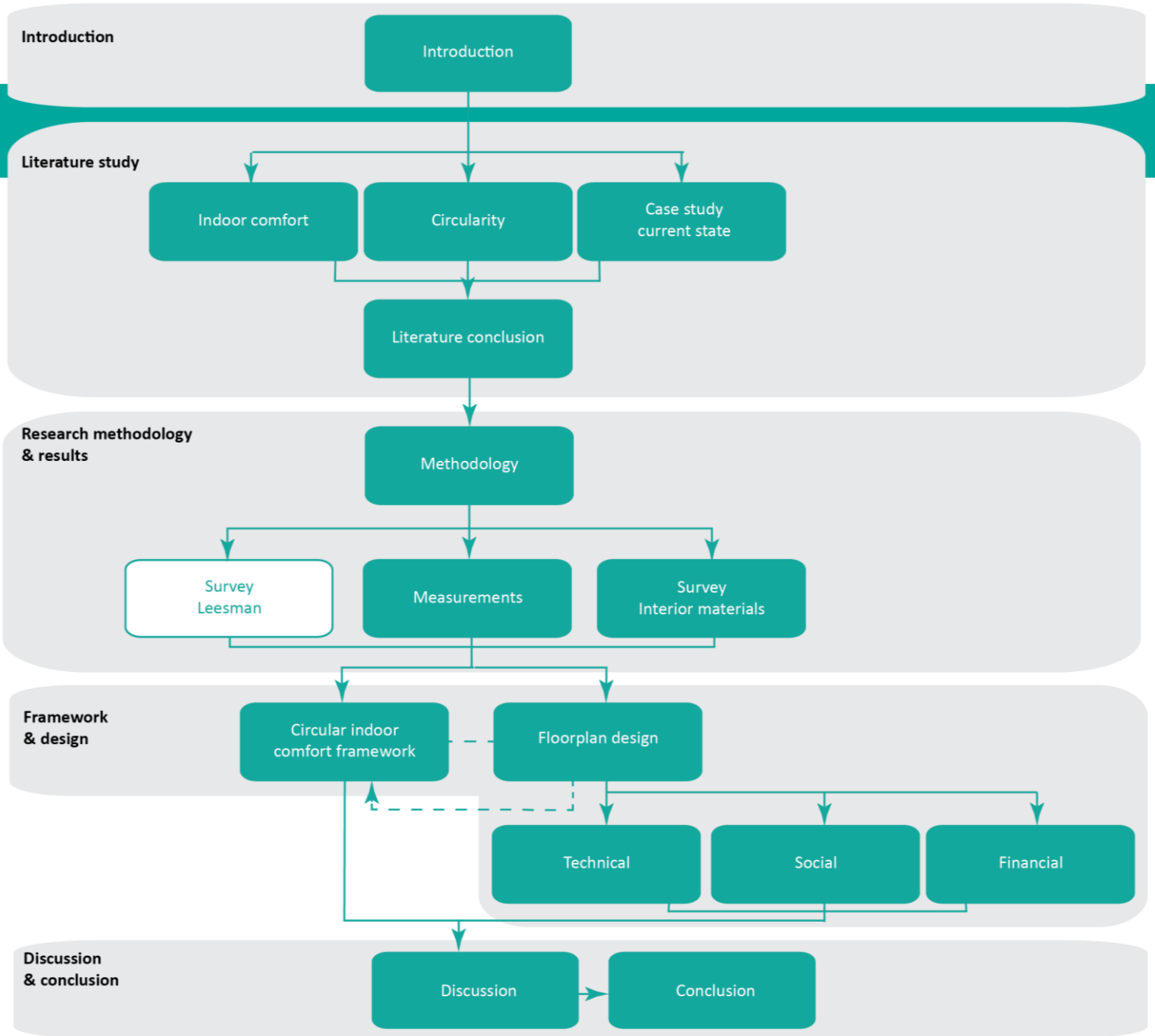
Measurement analyses

Indoor comfort regulations

Material analyses

Interior materials and products

Survey



Survey analyses

Survey

Performed: 11th September 2019

till 27th September 2019

Responds rate: 21%, 1311 employees

Leesman[®]

Profile building users

- Mostly men 59%
- Age between 25-64 years
- Shared work space
- Various locations
- Full-time employed
- 50% working >12 years
- Building occupied 10:00-16:00 >3000

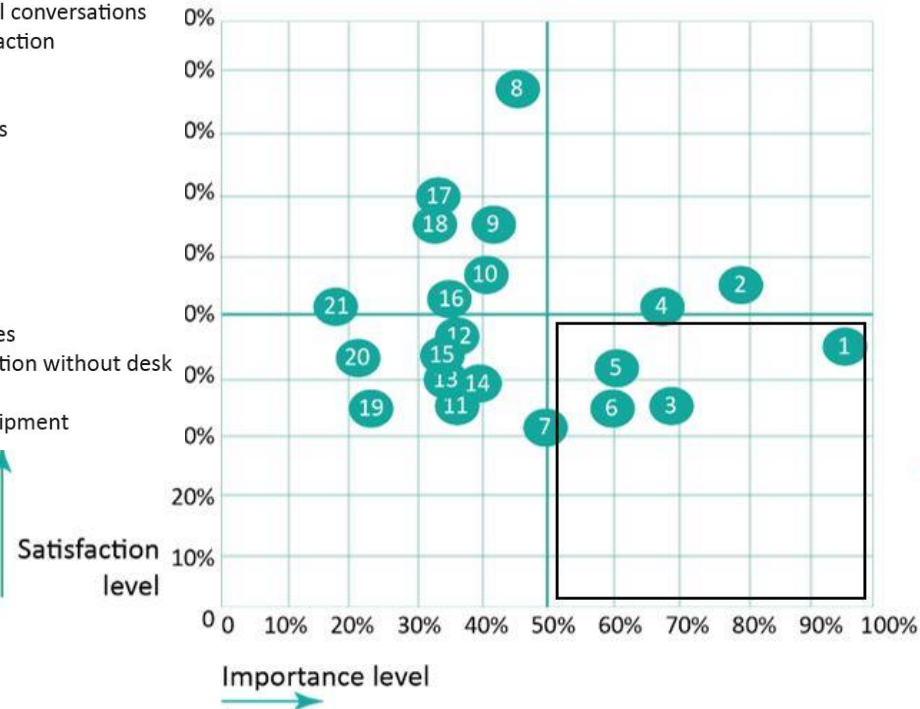
Survey analyses

Indoor comfort experience

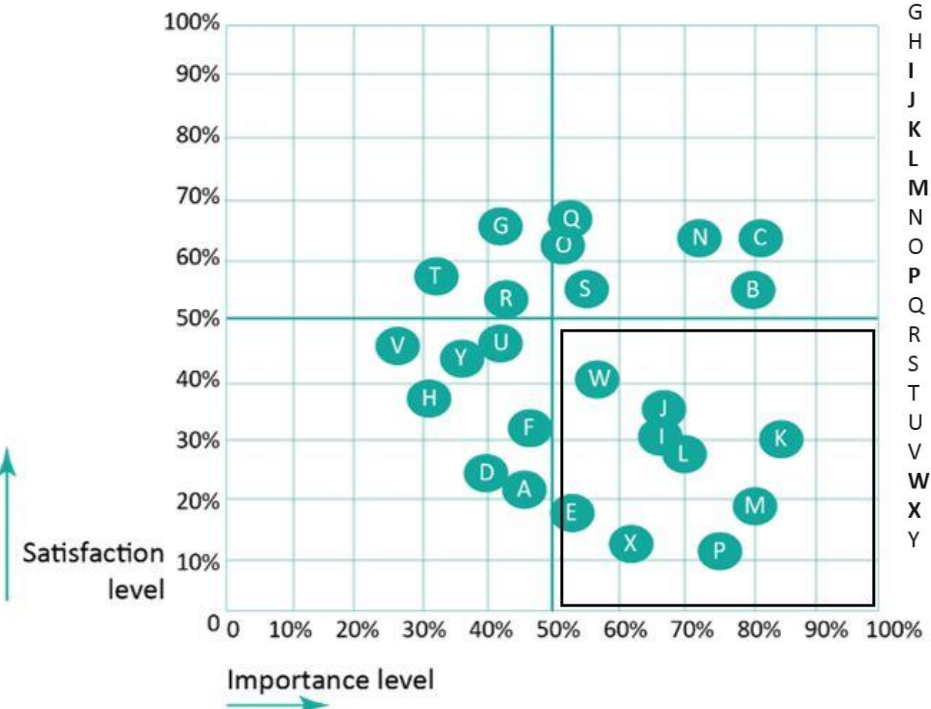
Activity

- 1 Individual concentration at desk (3)
- 2 Scheduled meetings
- 3 Phone calls (8)
- 4 Informal spontaneous meeting
- 5 Collaborate concentration (13)
- 6 Reading (11)
- 7 Business confidential conversations
- 8 Informal social interaction
- 9 Relax and break
- 10 Collaborate creative
- 11 Private conversations
- 12 Big meetings
- 13 Audio conference
- 14 Thinking
- 15 Video conference
- 16 Guests meetings
- 17 Routine tasks
- 18 Learn from colleagues
- 19 Individual concentration without desk
- 20 Paper or materials
- 21 Use of technical equipment

Activities



Workplace & facilities



Workplace & facilities

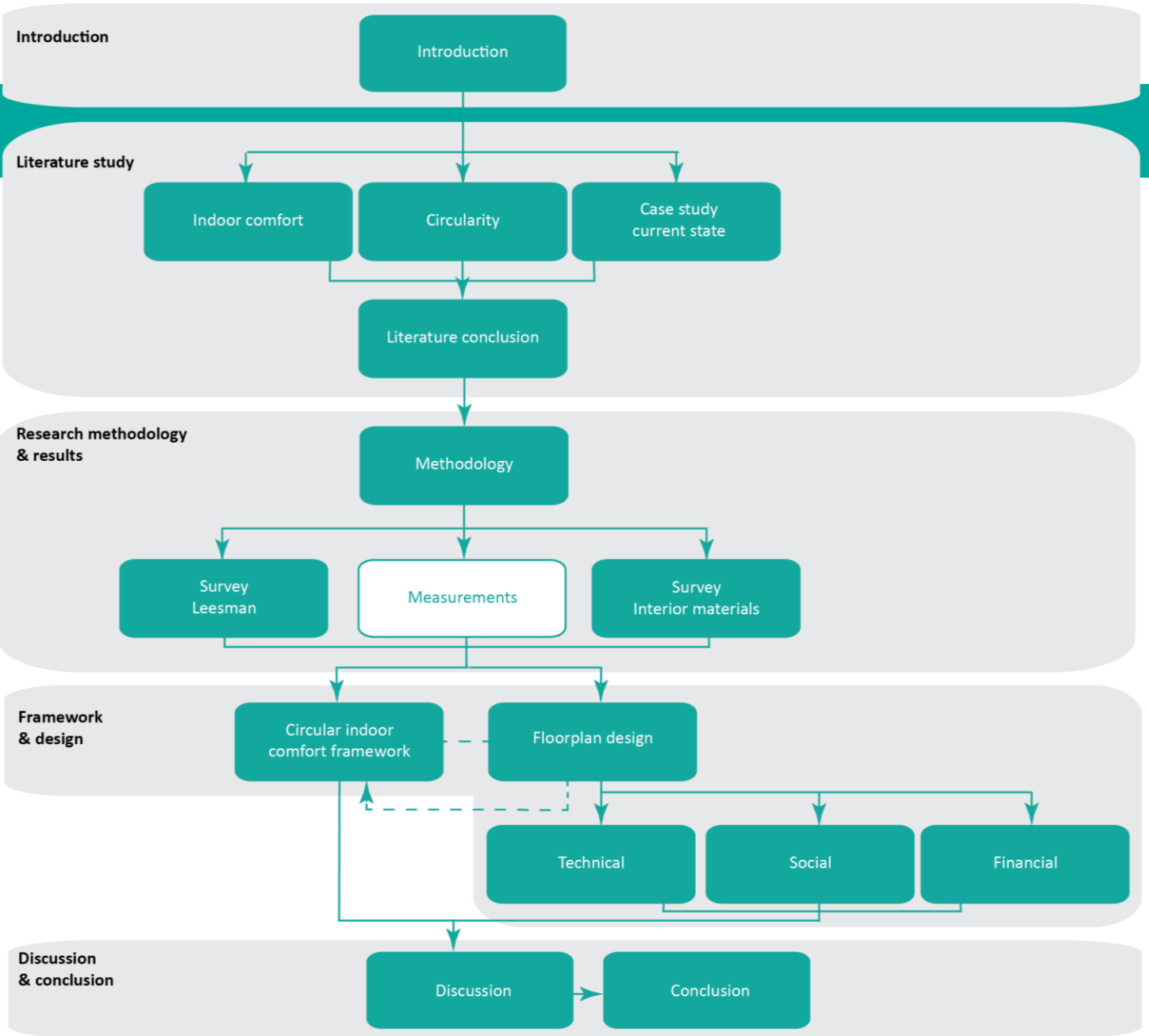
- A Personalize your workplace
- B Chair
- C Desk
- D Separation desk and working space
- E Colleagues passes by workplace (7)
- F Space between work spaces
- G Accessibility colleagues
- H Audiovisual equipment
- I Room reservation systems (9)
- J Meeting room big (10)
- K Meeting room small (4)
- L Indoor air quality (5)
- M Thermal comfort (2)
- N Daylight
- O Artificial light
- P Acoustic comfort (1)
- Q Accessibility elevators and stairs
- R Art and photography
- S Atriums and common areas
- T General appearance
- U Informal workplaces break areas
- V Internal signage
- W Flowers and plants (12)
- X Silence room 1-2 persons (6)
- Y Variety of workplaces

Survey analyses

Indoor comfort experience top 13 improvements

General conclusion survey			
Rating number	Activities, workplace or facilities	Satisfaction level	Importance level
1	Acoustic comfort	13,9%	75,1%
2	Thermal comfort	19,1%	80,7%
3	Individual concentration at desk	45,9%	95,7%
4	Meeting room small	31,8%	86,3%
5	Indoor air quality	28,6%	71,0%
6	Silence room 1-2 persons	13,9%	62,0%
7	Colleagues passes by workplace	18,3%	53,0%
8	Phone calls	35,7%	68,2%
9	Room reservation systems	30,3%	66,4%
10	Meeting room big	35,0%	67,5%
11	Reading	35,4%	60,3%
12	Flowers and plants	43,1%	55,5%
13	Collaborate concentration	43,2%	60,9%

Measurements



Measurement analyses

Properties measured floor plans

Performed: Tuesday 18th February till Monday 9th March 2020

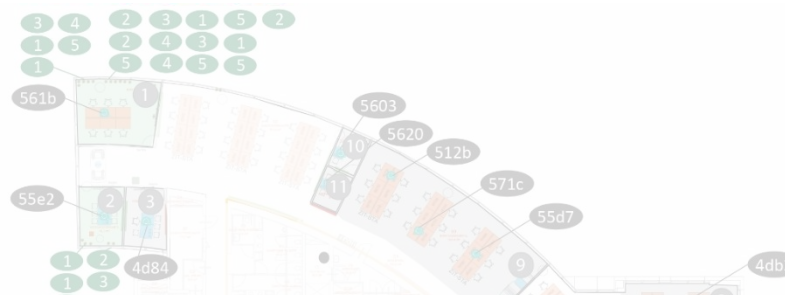
Plants placed: Tuesday 25th February till Monday 9th March 2020

Calculation: Ventilation capacity lower 45m³/h/p.p.



E03

946,2m² – 160 building users
128 desk – 71 meeting spaces
Measurement devices places
>100m², open spaces



A11

800,1m² – 113 building users
90 desk – 82 meeting spaces
Measurement devices places
>5m² - <30m², closed spaces



Measurements analyses

Average measured values exceeding the permitted values during office hours



- CO₂ concentration > 800 ppm 1,7%
- CO₂ concentration > 600 ppm 23,6%
- TVOC concentration > 0,155 ppm 0,0%



- Temperature < 20°C and > 24°C 10,5%
- Relative humidity < 30% and > 70% 14,6%



- Light (lux) < 500 lux 72,2%
- Flicking light (Hz) > 0 and < 50 Hz 2,6%



- Background average sound level > 57 dB 2,0%
- Background maximum sound level > 57 dB 25,5%
- Installation sound level > 40 dB 0,0%

Measurements analyses

KNMI measurements

18th February till 9th March 2020



Date	Average T (°C)	Normal T (°C)	Average RH (%)	Normal RH (%)
Week 1 Average	7,8	3,3	78	83
Week 2 average	5,4	4,1	81	83
Week 3 average	6,5	5,0	81	83
Total average	6,6	4,2	80,1	83,0

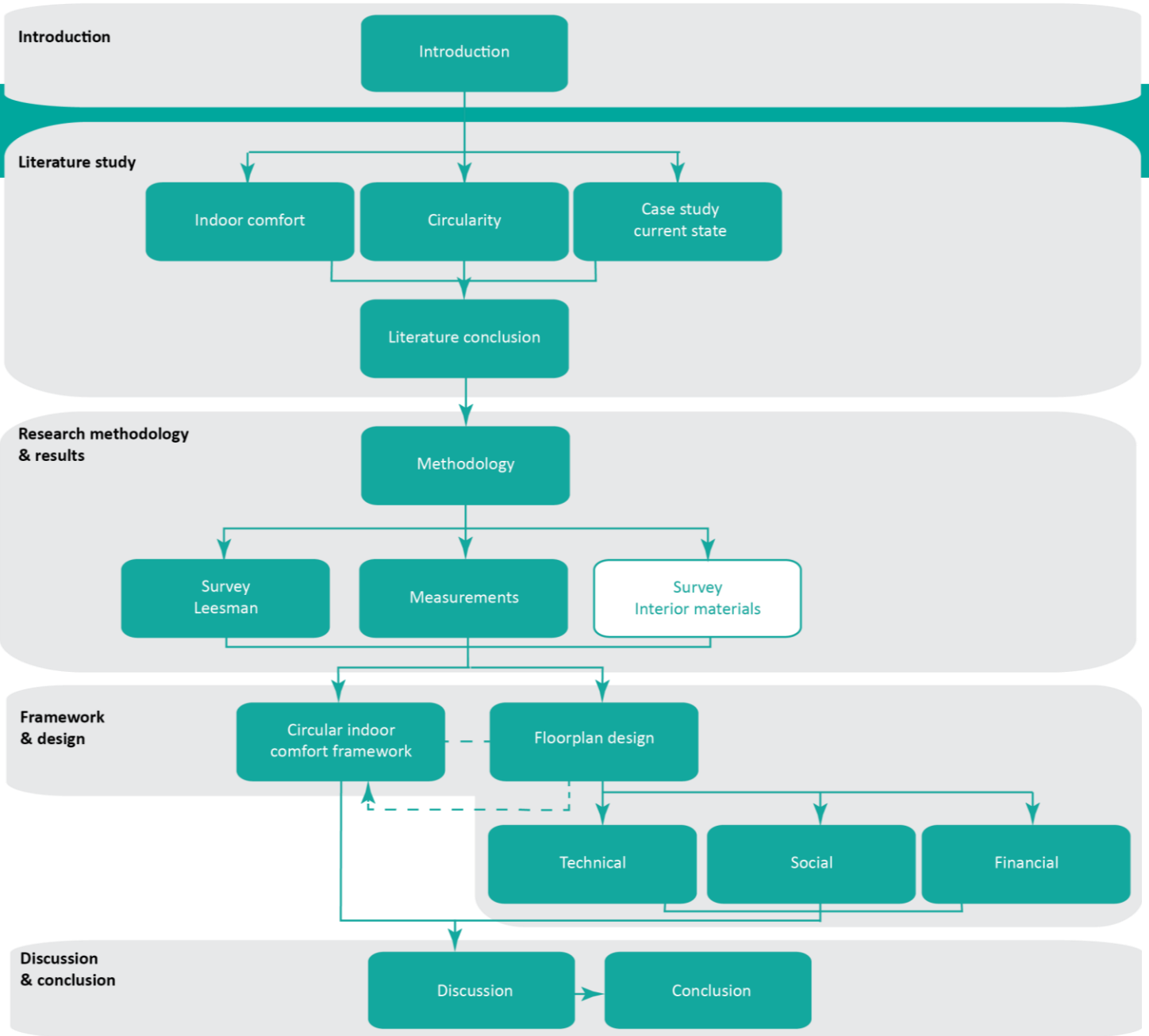


CO₂ concentration in outside air increases during the last few decades

1959 316 ppm

2017 400 ppm

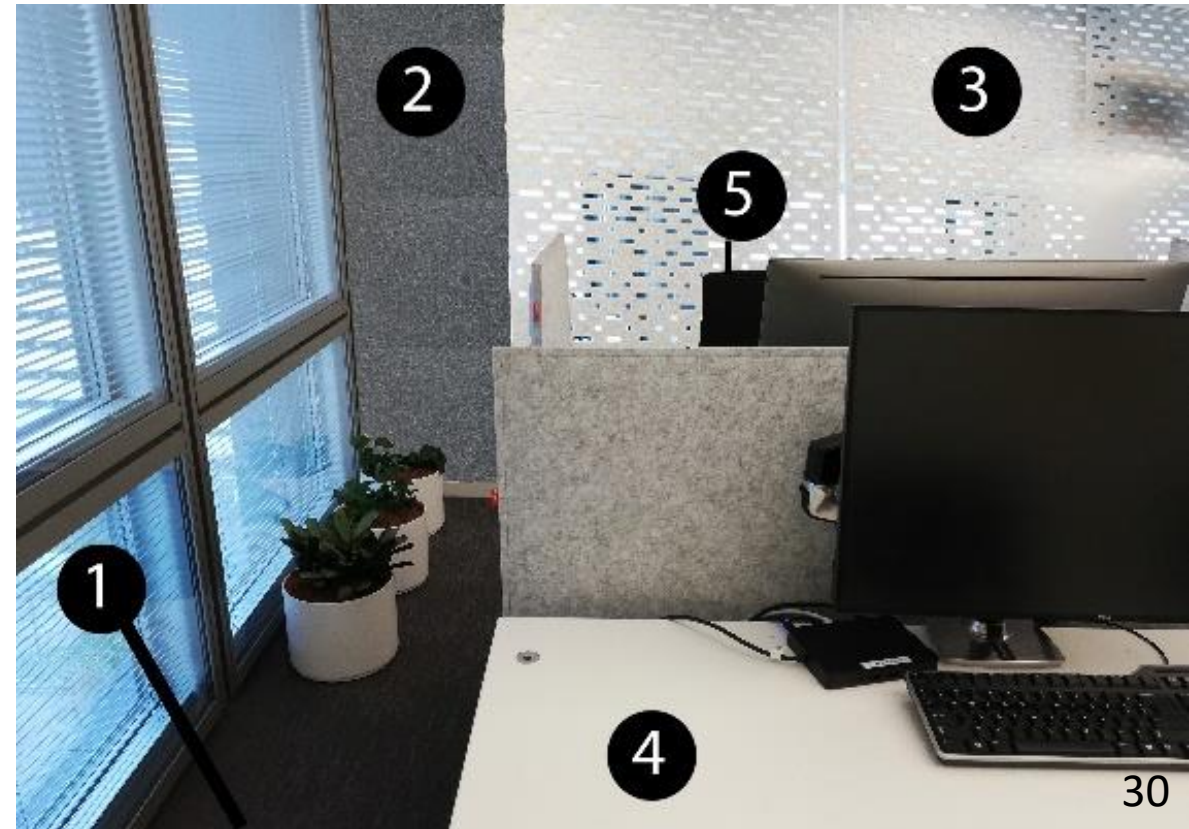
Interior materials



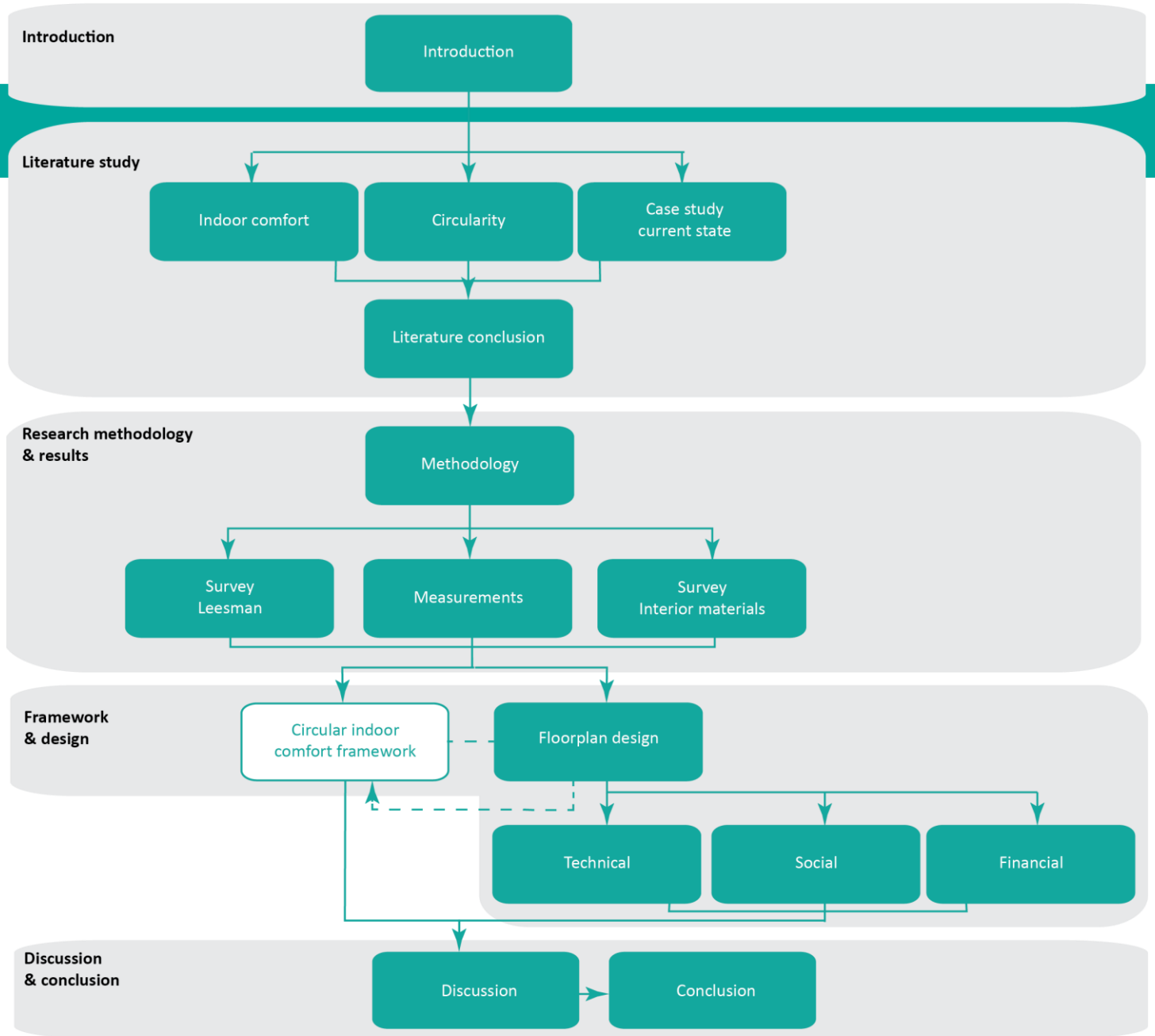
Material analyses

Products

- | | |
|-------------------|------------------------------|
| ① Floor finish | Carpet Desso Wave |
| ② Wall finish | Felt Viltex |
| ③ Space divider | In-Felt panels Wave |
| ④ Workplace desk | Gispen TMNL Dual workstation |
| ⑤ Workplace chair | HAG Futu NPR |



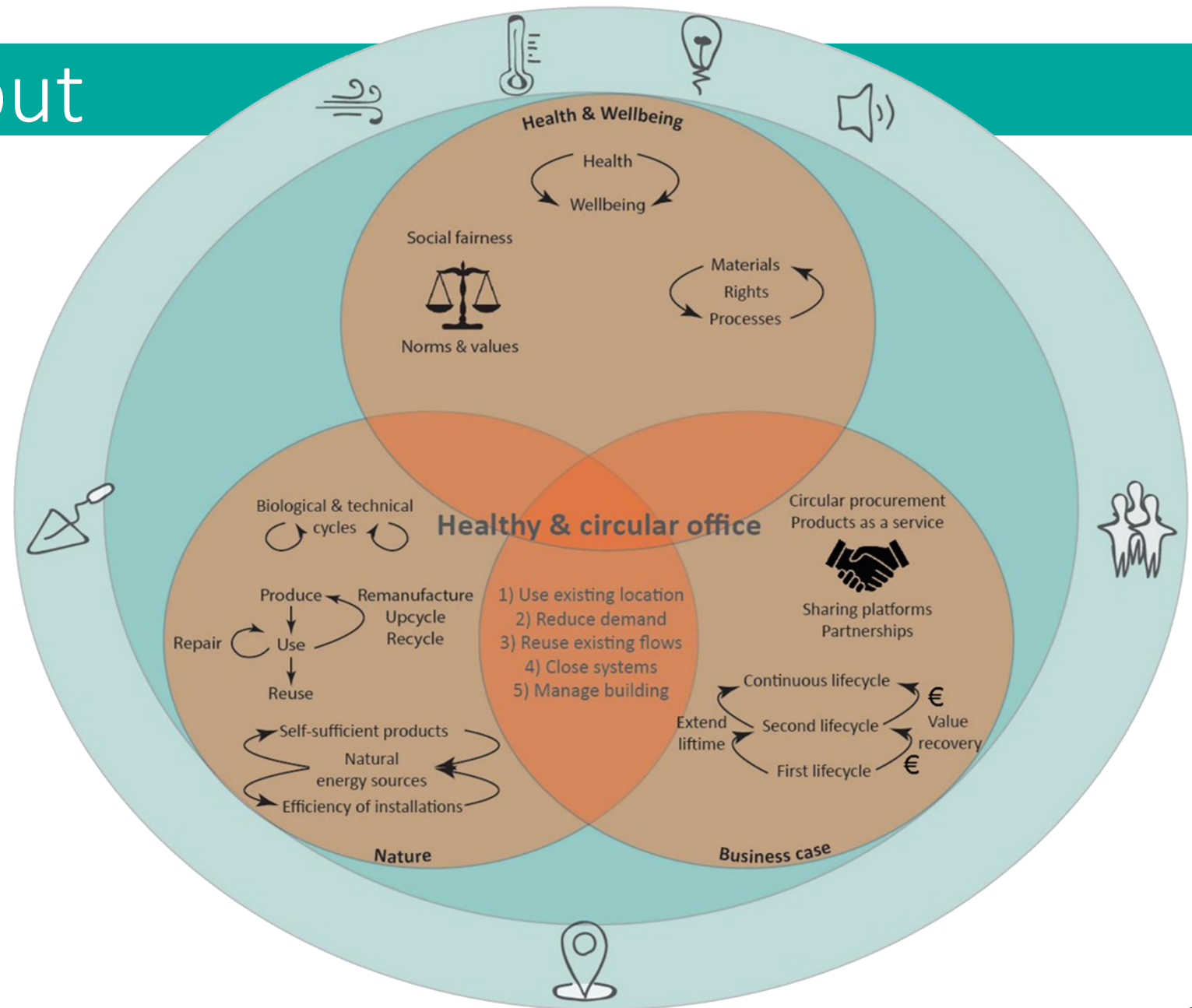
Framework



Framework lay-out

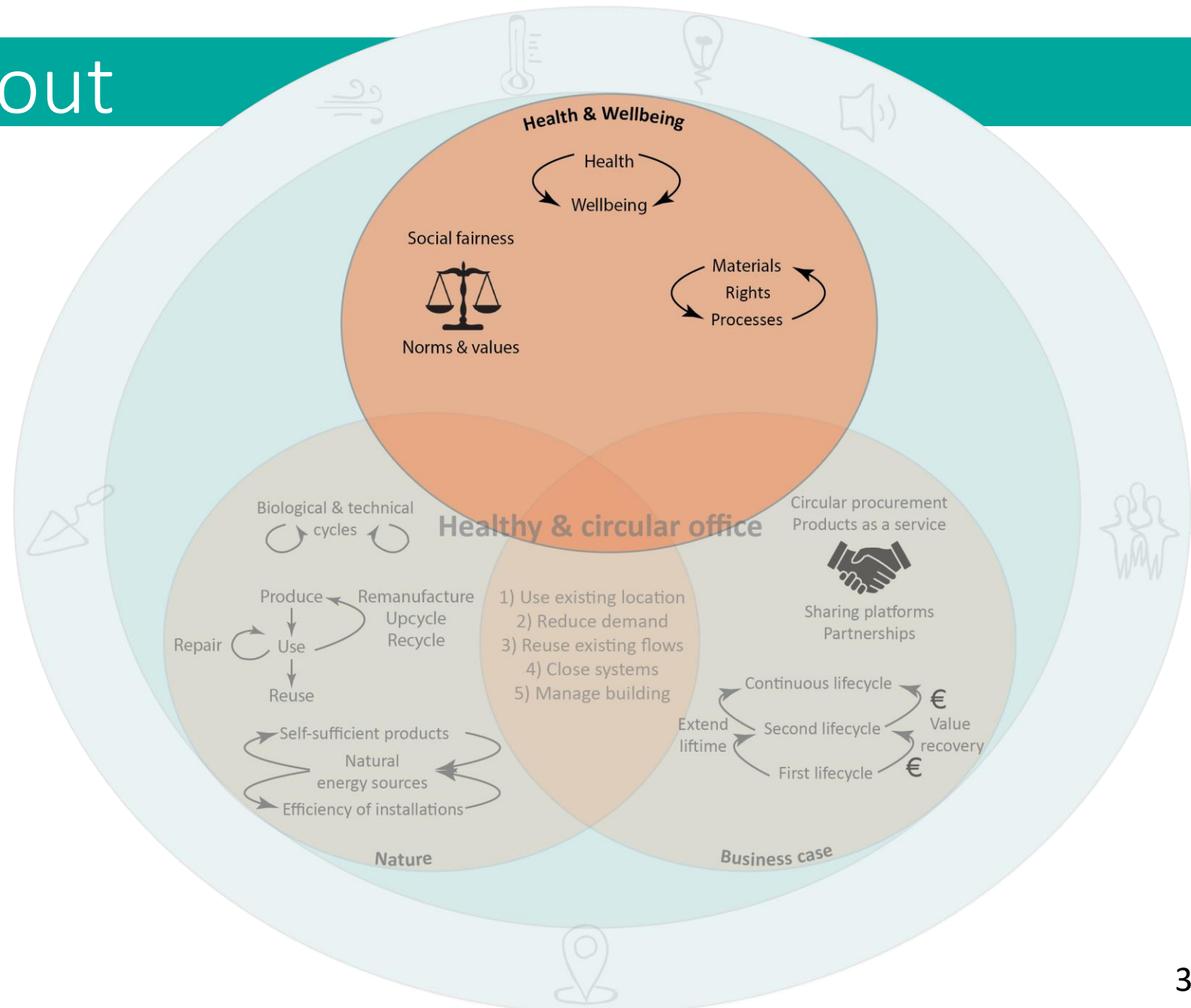
General elements

- Stressors
- Building users
- Location
- Materials & products



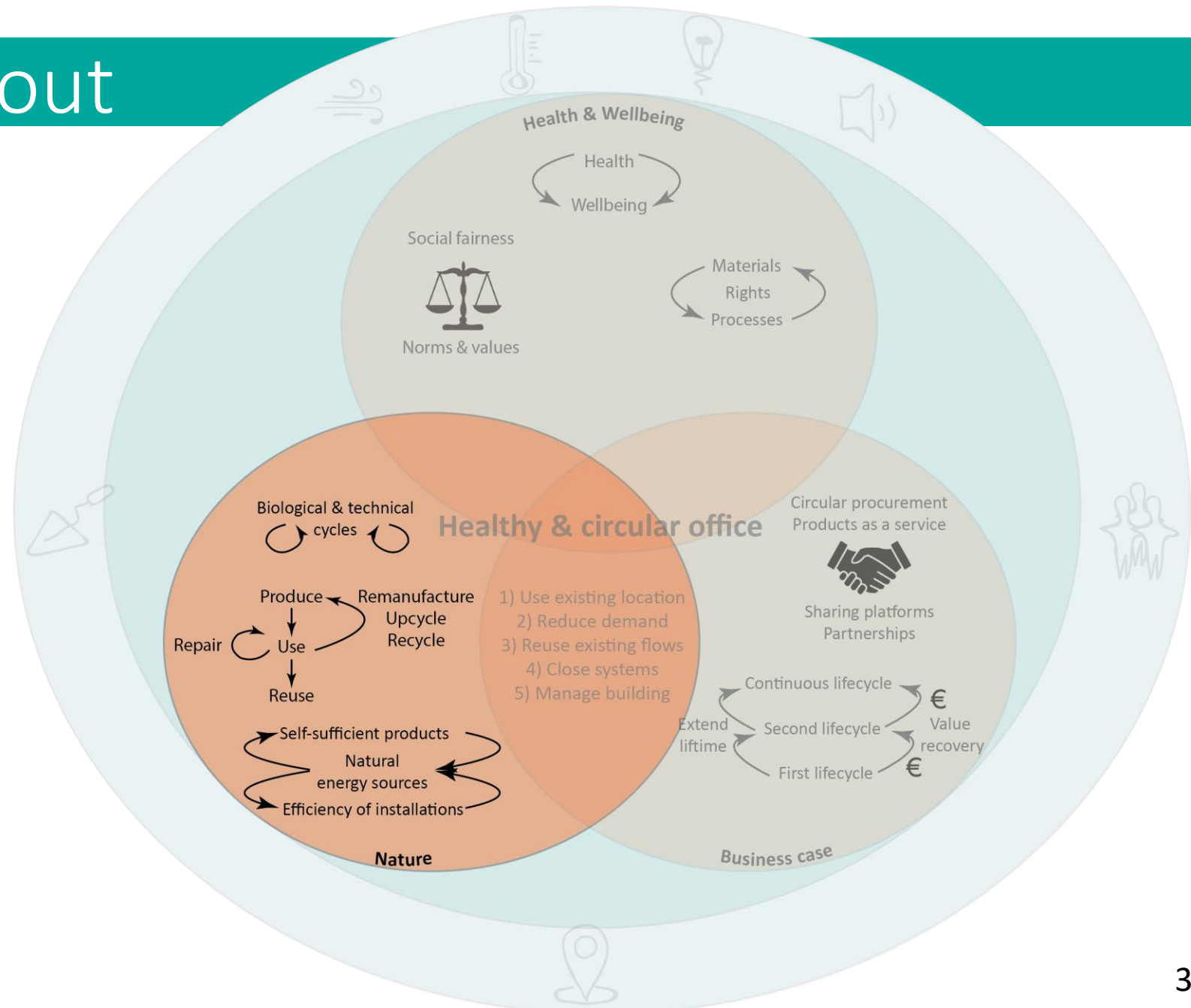
Framework lay-out

Health & wellbeing



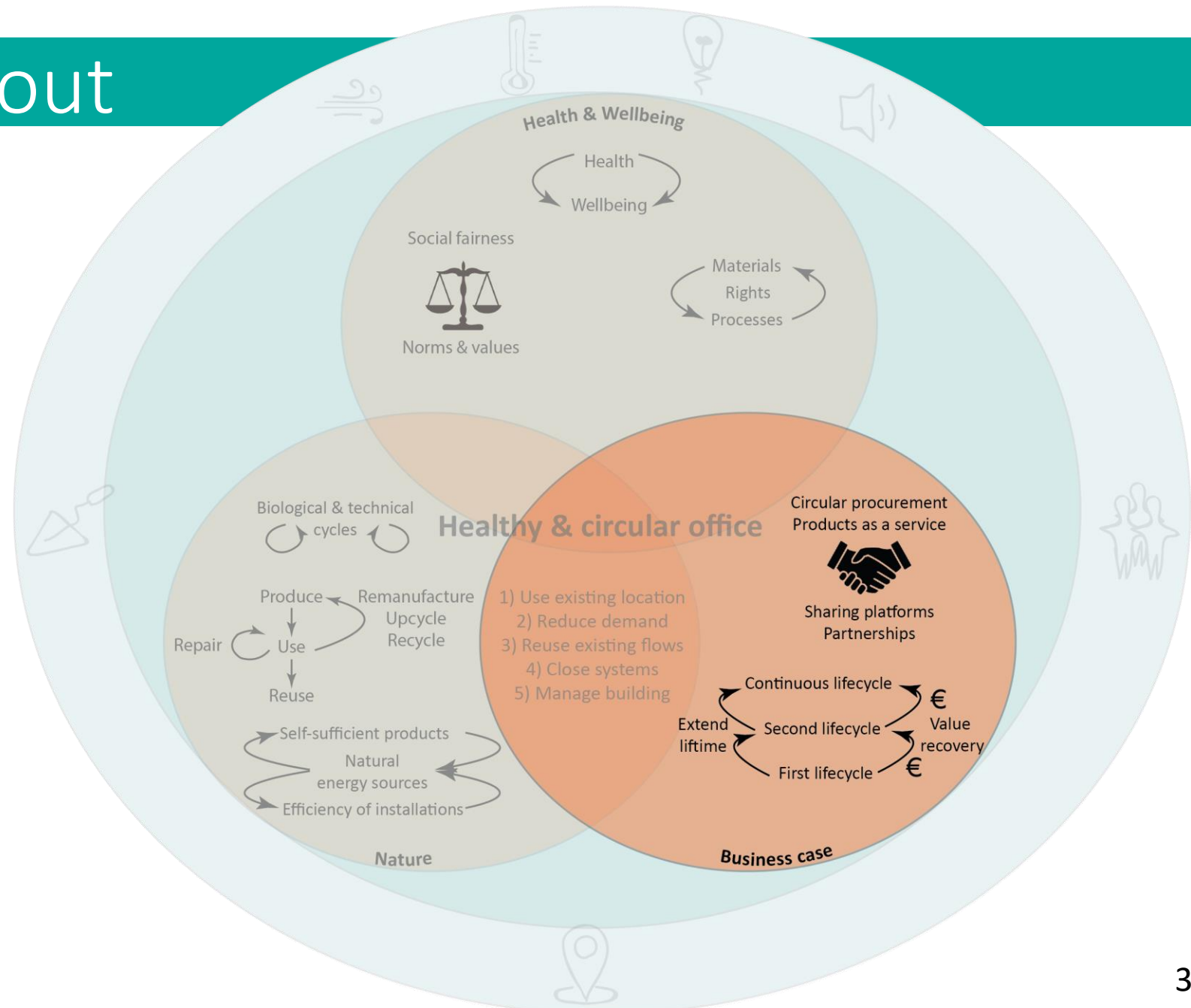
Framework lay-out

Nature

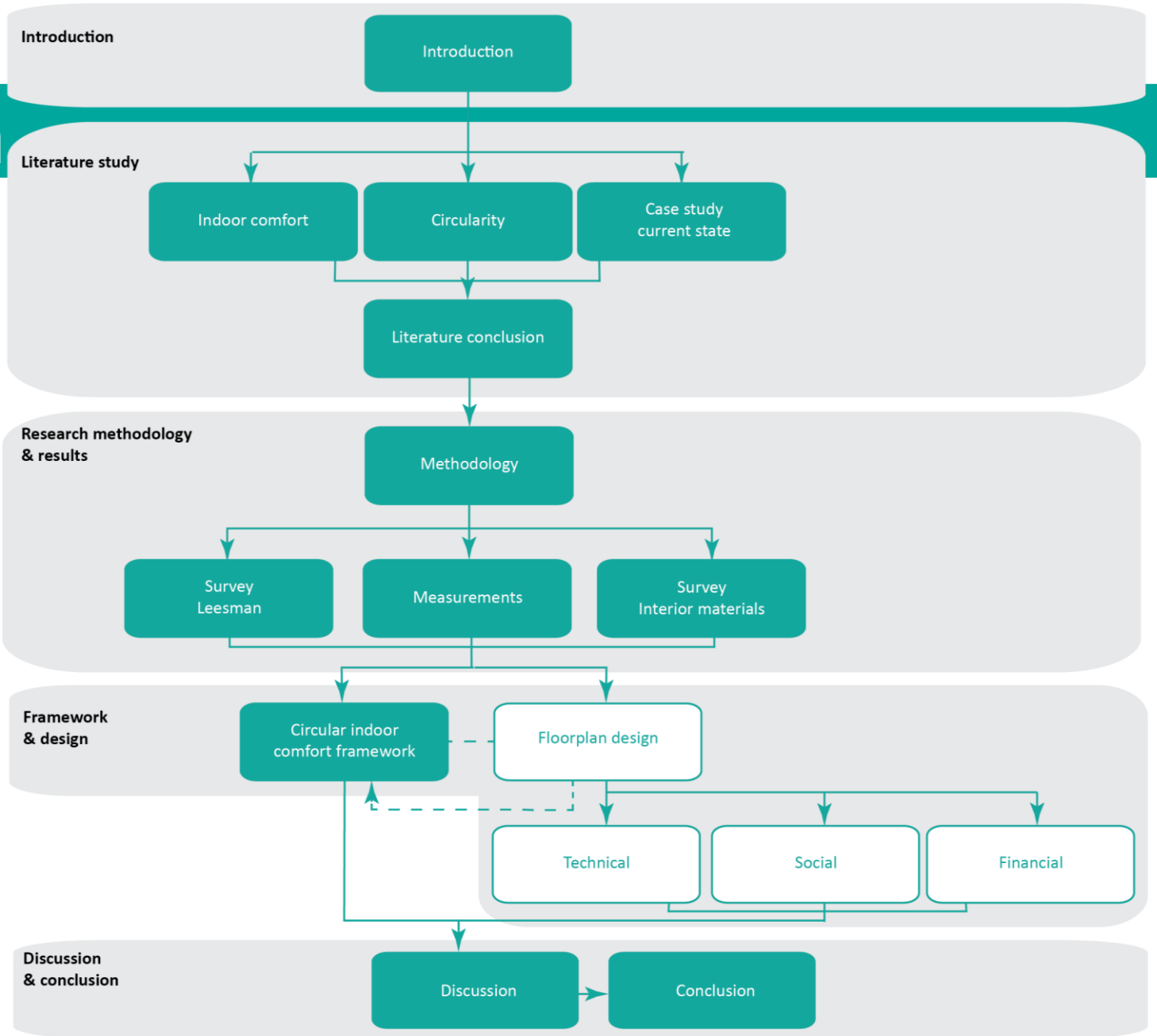


Framework lay-out

Business case



Case study design



Case study measures

Circular Indoor Comfort Step Strategy:

- 1) Improving the source
- 2) Improving situation without energy
- 3) Improving situation with renewable energy
- 4) Improving processes

Case study measures-indoor air

Possible stressor indoor air quality

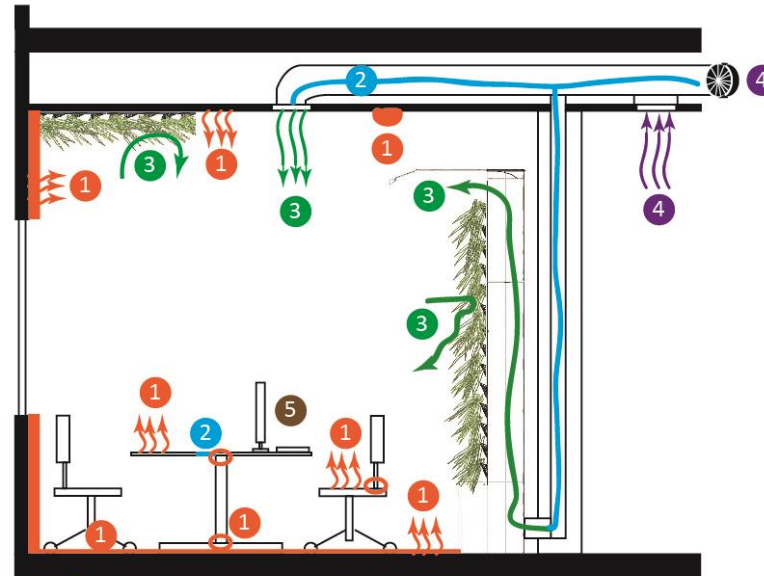
1 Low emissions and occupancy



3 High quality fresh air



4 Air exhaust and heat recovery wheel

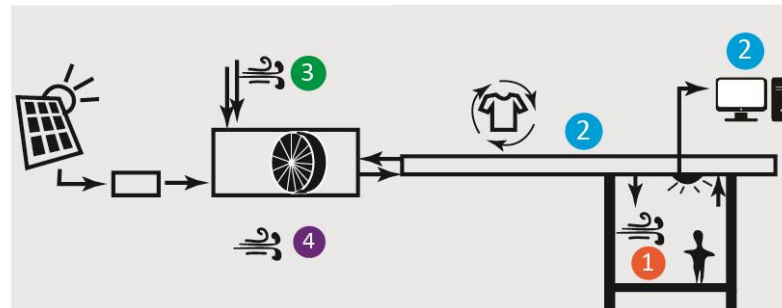


- 1 Low emissions and occupancy rate
- 2 Enough air supply
- 3 High quality fresh air
- 4 Air exhaust
- 5 Inform building users

2 Enough air supply



5 Inform building users



Case study measures-plant wall

Living plant wall

Plant purifying capacity



Characteristics leaves



Productivity



Relative humidity



Circularity



Combination ventilation system and plants



Sound level reduction



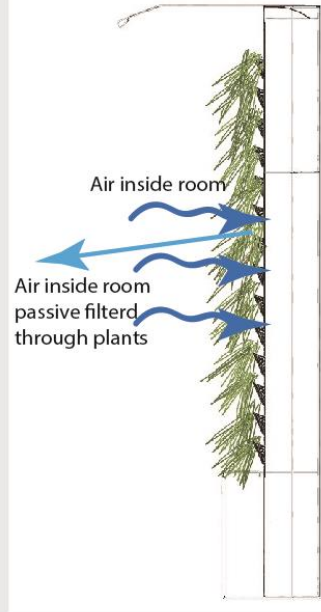
Cost and flows



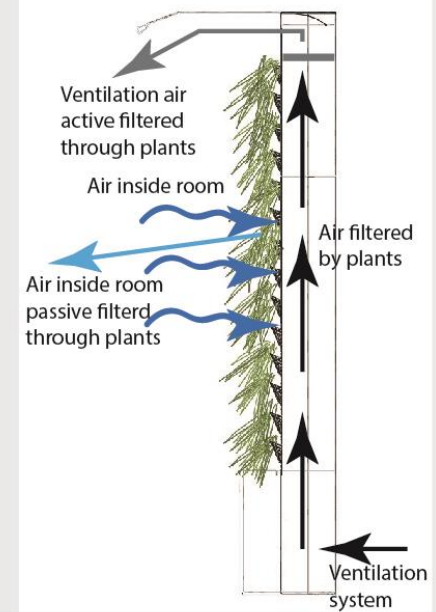
Case study measures-plant wall system

Living plant wall systems and plants species

Passive living green wall system



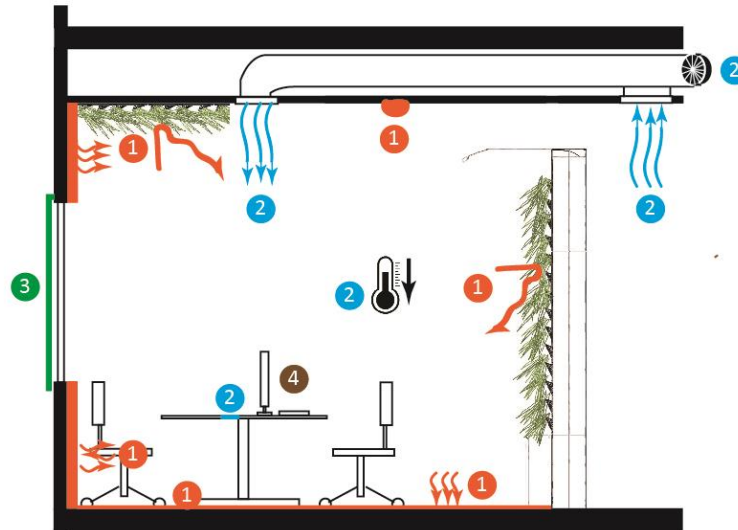
Active living green wall system



Case study measures-thermal

Possible stressor thermal comfort

1 Regulate thermal comfort



- 1 Regulate thermal comfort
- 2 Right temperature and relative humidity
- 3 Regulate daylight
- 4 Inform building users

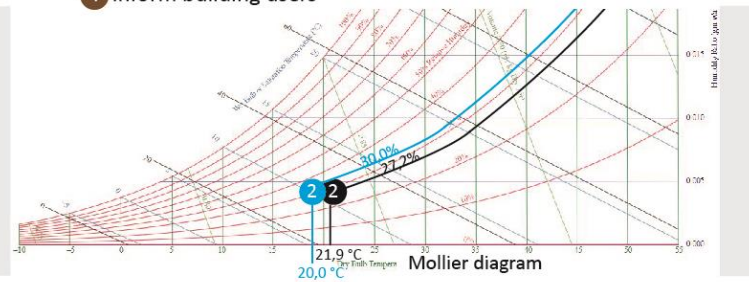
2 Right temperature and relative humidity



3 Regulate daylight



4 Inform building users



Case study measures-light

Possible stressor light quality

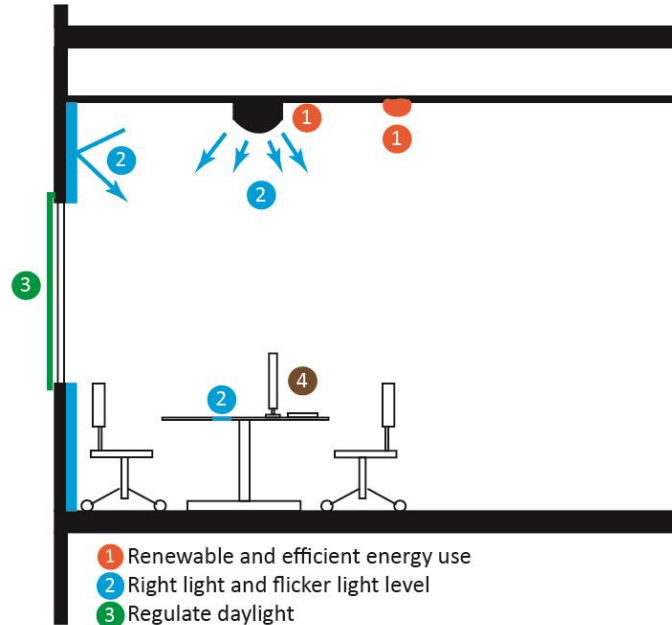
1 Renewable and efficient energy use



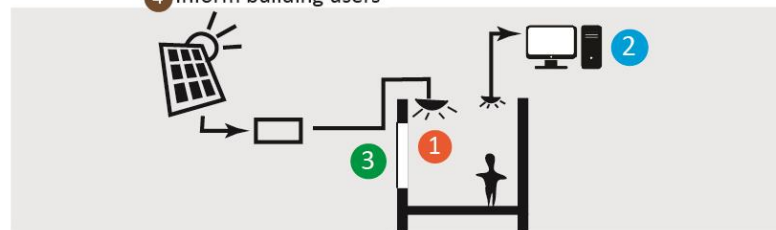
3 Regulate daylight



4 Inform building users



- 1 Renewable and efficient energy use
- 2 Right light and flicker light level
- 3 Regulate daylight
- 4 Inform building users



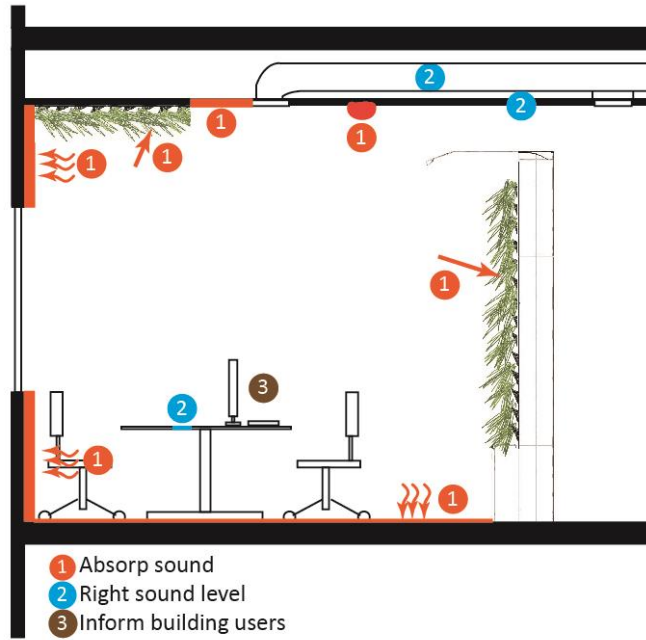
2 Right light and flicker light level



Case study measures-acoustic

Possible stressor acoustic comfort

1 Absorp sound



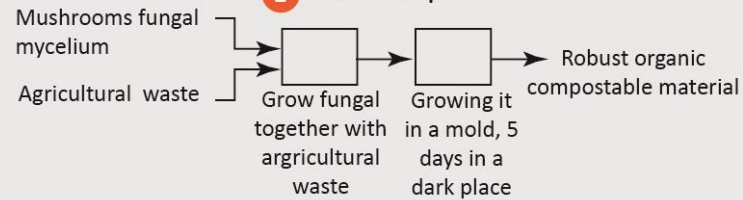
2 Right sound level



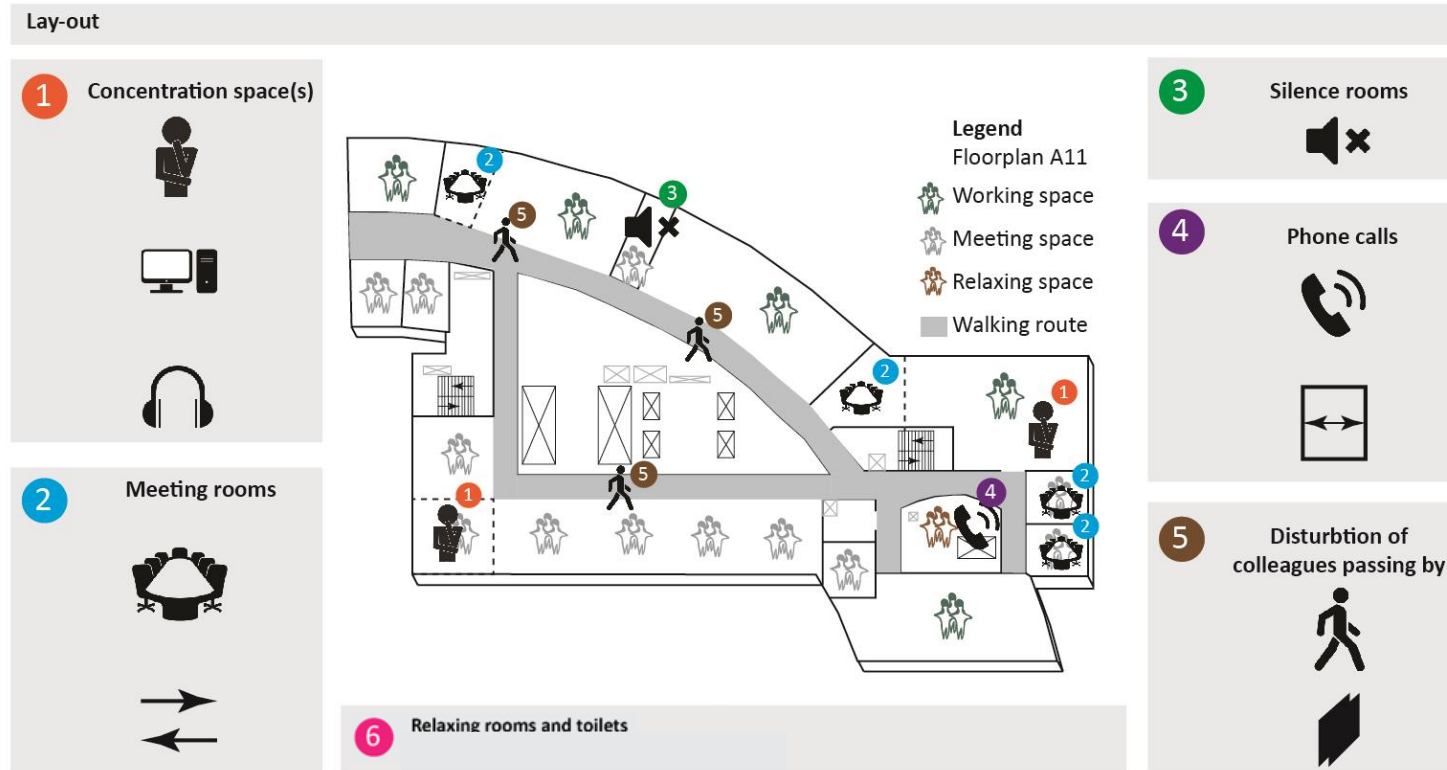
3 Inform building users



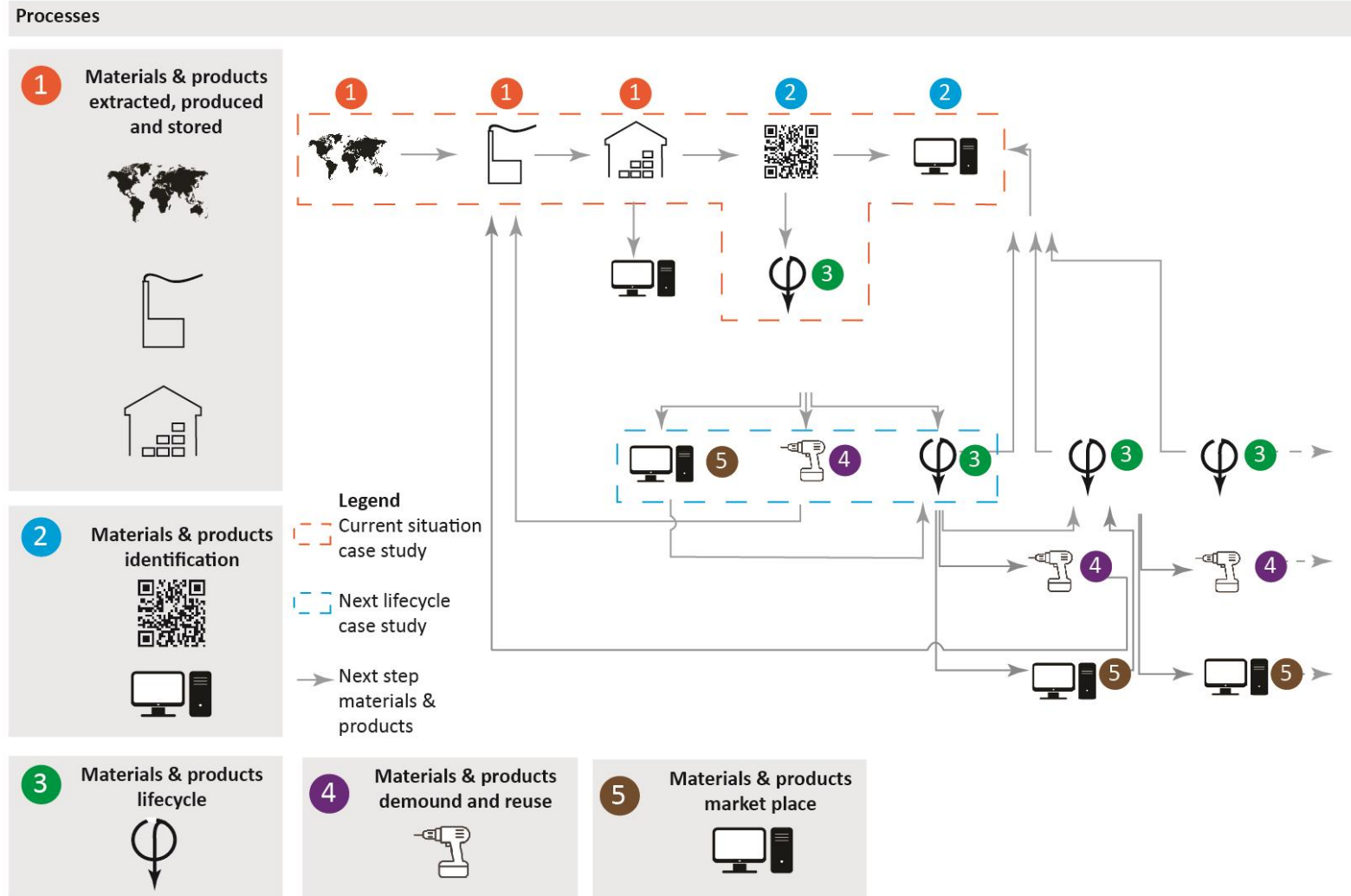
1 Mushroom process



Case study measures lay-out

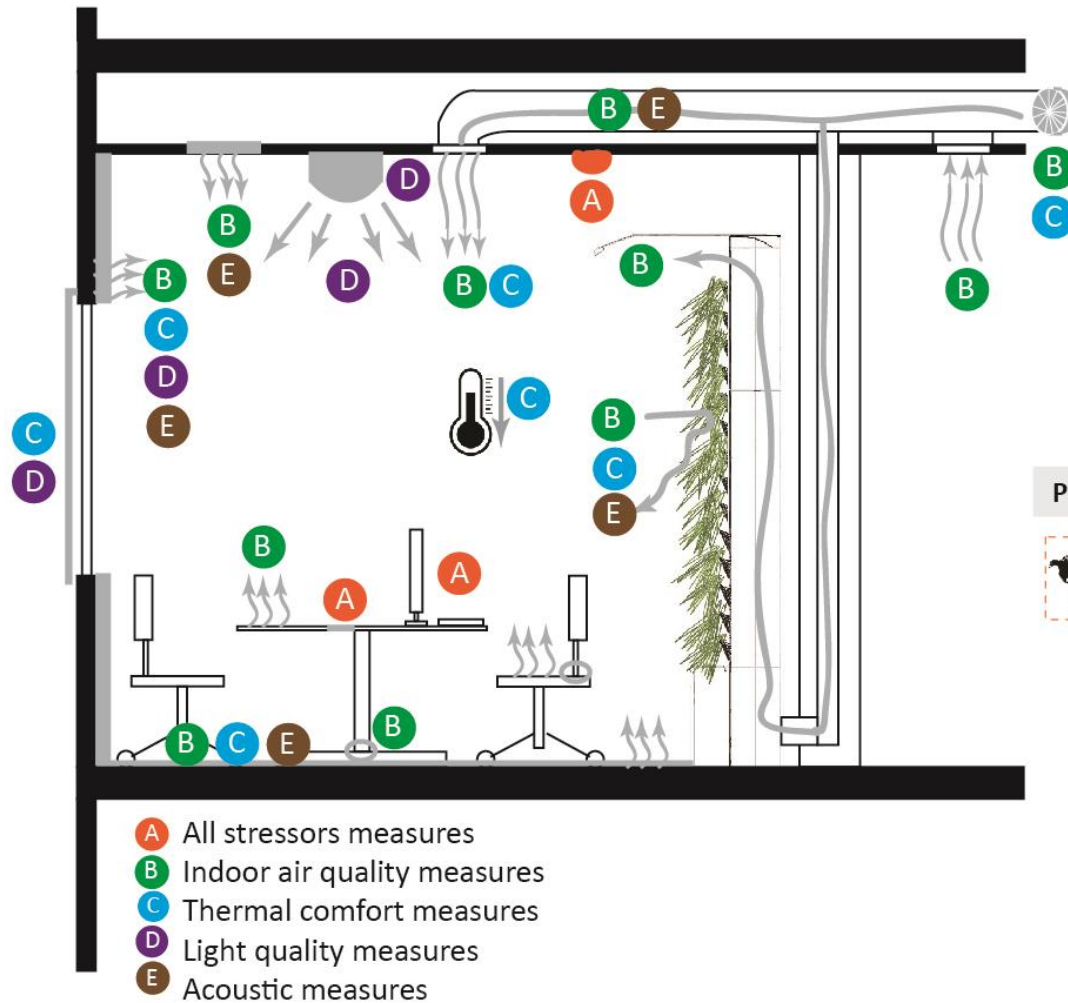


Case study measures-process

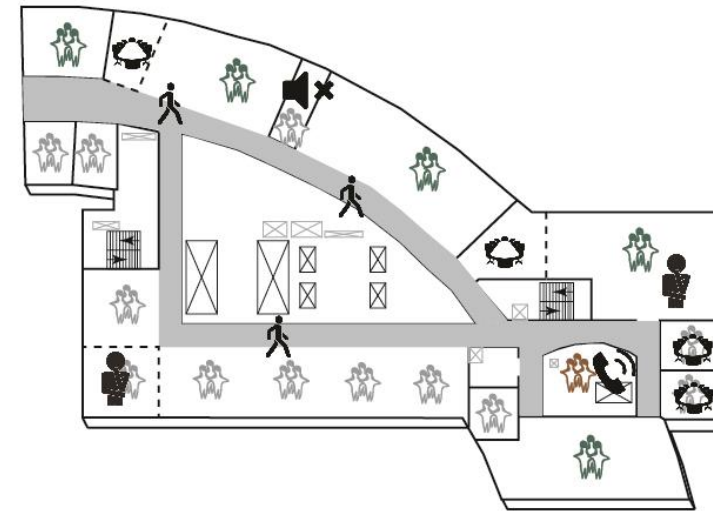


Case study design-measures

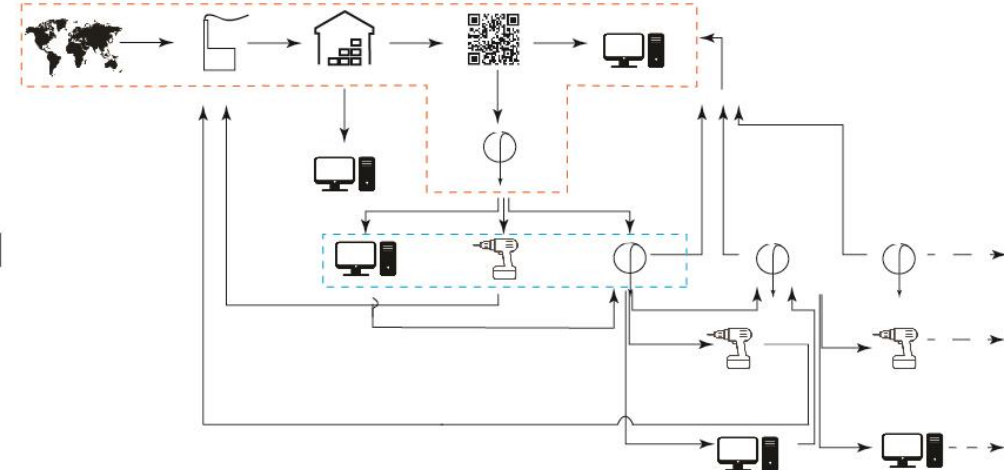
Indoor stressor measures



Lay-out measures



Process measures






Conclusion

‘How can the **indoor comfort** be improved in a **circular way**, by creating an optimal floorplan including the interior and technical aspects for, the case study, one pilot floor of the headquarter of a bank in the Netherlands, while taking the **energy consumption** into account?’.






Conclusion

Combining circularity with innovations and indoor comfort

Not heating, when the temperature is above 20°C. Results in smaller humidification system capacity

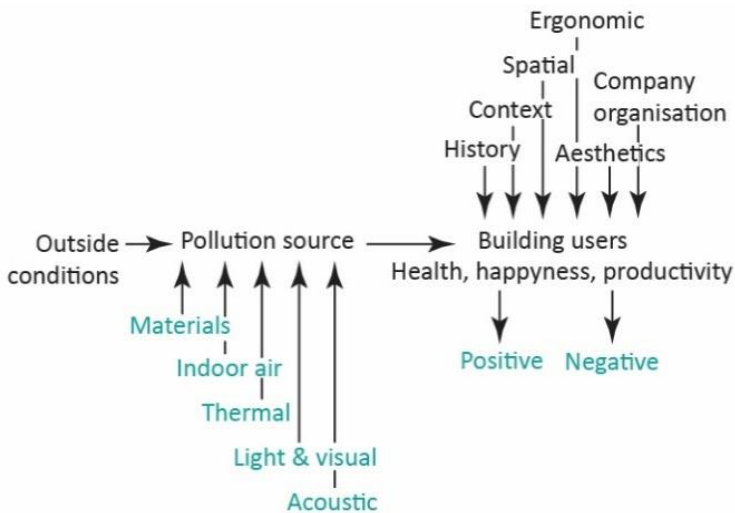
-  Higher relative humidity level
-  Less materials and energy use
-  Less use of space

Smaller ventilation and humidification system capacity, by adding plant walls

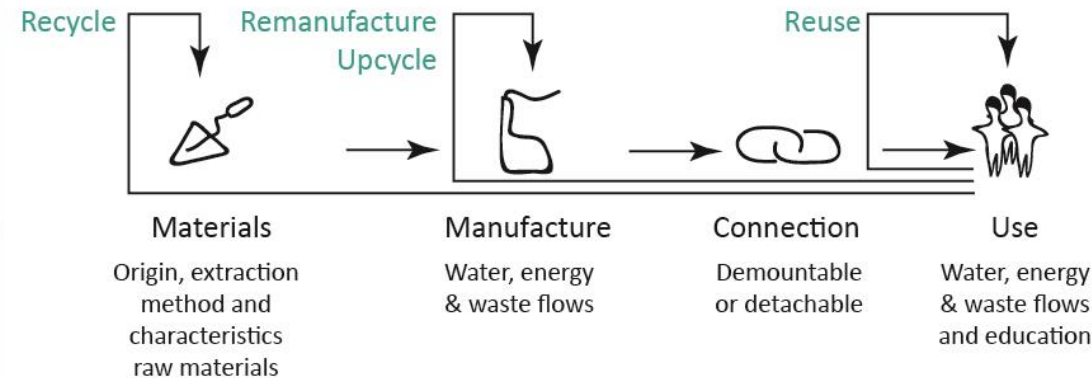
-  Natural fresh air supply
-  Absorption of background sound
-  Increase relative humidity level
-  Less materials and energy use
-  Less use of space

Conclusion

Indoor comfort



Circularity



Energy consumption

‘Circular Indoor Comfort Step Strategy’:

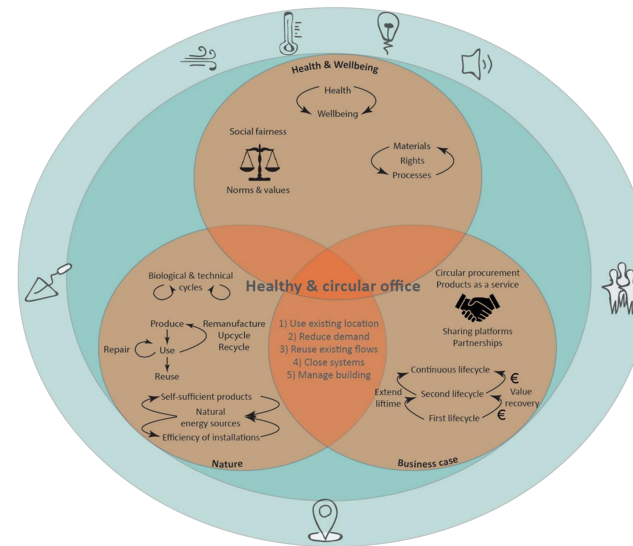
- 1) Improving the source
- 2) Improving situation without energy
- 3) Improving situation with renewable energy
- 4) Improving processes

Conclusion

Pilot floor

- Building users rated indoor comfort
Satisfaction level 20,5%
Importance level 75,6%
- Measurement devices measured 21,6% time during office hours exceed permitted values
- Materials mostly not demountable

Framework



Optimal floorplan

- Interior aspects improve building users activities
- Technical aspects improve multiple stressors
- Half measures use only embodied energy

Recommendations case study



- Higher ventilation system capacity, min. 45m³/h/p.p. & permitted CO₂ concentration
- Using purifying capacity of plants, removing peaks in CO₂ and VOC in rooms <30m²

Recommendations case study



- Higher ventilation system capacity, min. 45m³/h/p.p. & permitted CO₂ concentration
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- Engineer and install humidification system
- No heating, when the temperature >20°C, to increase the relative humidity
- Using the plants to increase the relative humidity in rooms <30m²

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- Using the background sound absorbing capacity of plants in rooms <30m²
- Adding background sound absorbing materials on the walls

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- Adding only materials without VOCs and environmental harmful additives

Recommendations case study



- Add flicker light requirements of <0 Hz or >50 Hz in PoR
- Add permitted exceedances in % or adjust formulas as 'Adaptive Temperature Limits' in PoR

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- Perform the measurements after the renovation, during every season



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- with the same brand measurement devices
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- Taking into account every factor that influence the indoor comfort or circular approach of each measure

