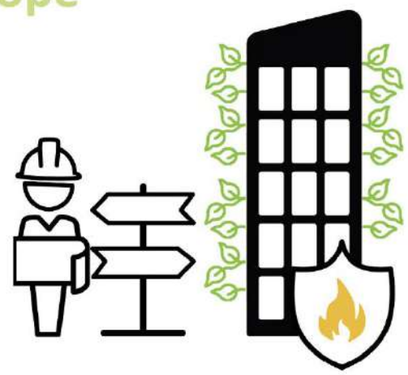
Fire safety of vertical greenery systems

A decision-making framework for safely greening the building envelope



Graduation Building Technology
Carmen Guchelaar - 4661427

P5 Presentation

First mentor:	Ir. A. C. Bergsma
Second mentor:	Dr. ir. M.Ottelé
Delegate examinor:	Ir. P.S. van der Putt
Guest supervisor:	Ir. P. Hoondert
Guest supervisor:	Ir. B. Peters

25/06/2024

Table of contents

Research proposal

- Problem statement
- Research objective and question
- Research framework

Literature research

- VGS classification
- Fire safety relevant for VGS

Risk analysis

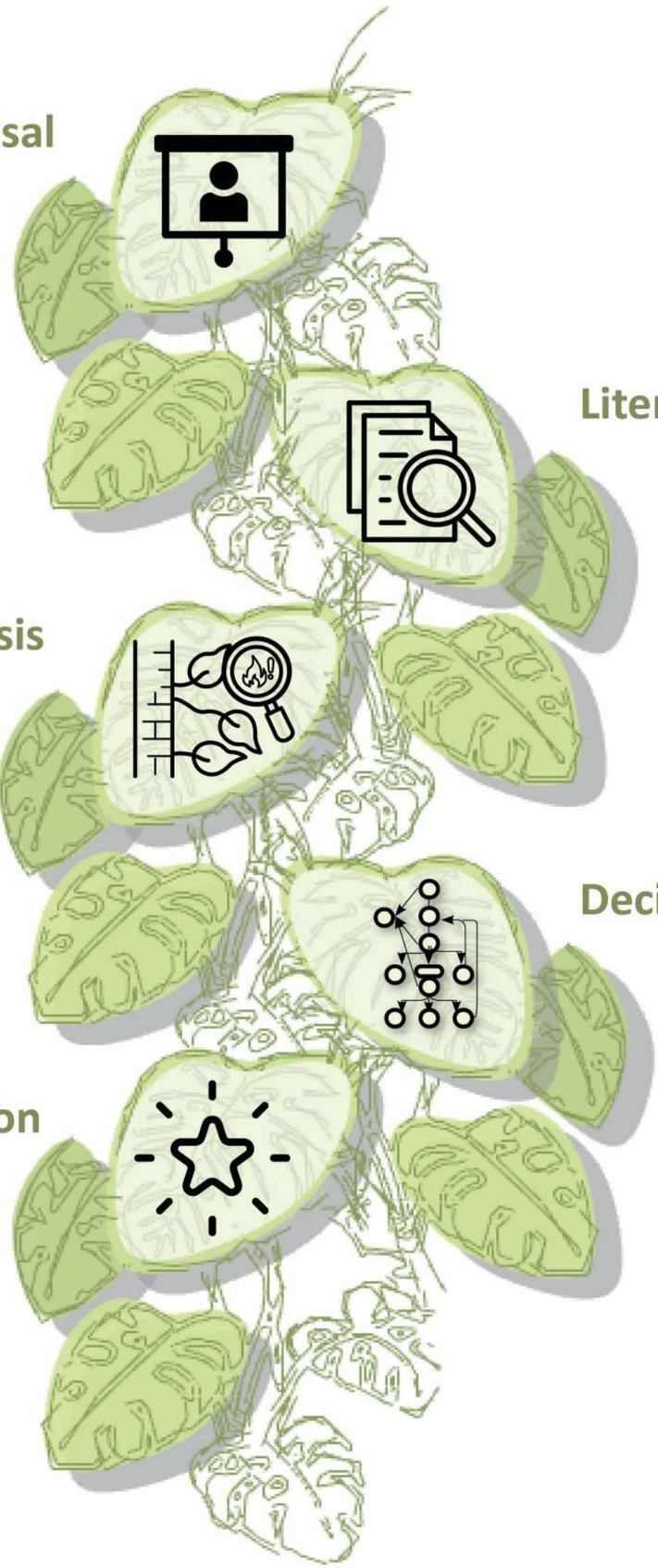
- ‘What-if’ and case-study scenarios
- Parameter overview
- Weighing & evaluation

Decision-making framework

- Use in design process
- Infographic
- Simple tool example
- Detailed tool example

Conclusion

- Conclusions
- Discussion and limitations



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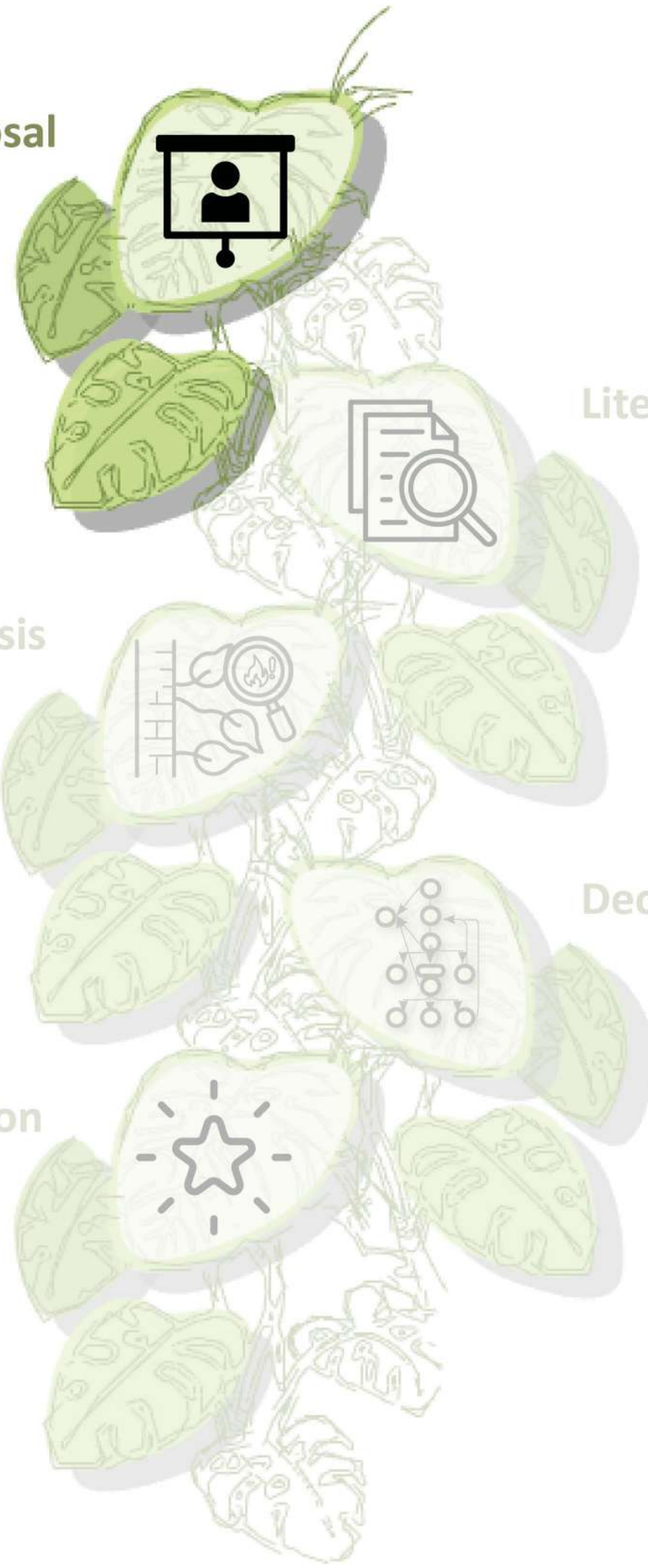

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Problem statement

People living in urban areas

Healthy city living essential

Lack of space in cities

Use vertical surfaces

Fire safety concerns

Discourages use and can cause unsafe situations

Vertical greenery systems

FIRE SAFETY CONCERN OVER GREEN WALLS

PUBLISHED AUTHOR SHARE

23 August 2021

Safety reporting body CROSS-UK published a report earlier this month highlighting the fire risks from poorly maintained green walls, as changes to fire safety law mean that the external walls will become part of fire risk assessments.

(FPA, 2021)

Green walls and the question of fire compliance

MARCH 17, 2021 ANDREW BARNETT Fire

The installation of vertical green systems, also known as green walls, is a growing trend in modern construction and fit-out [1]. In Sydney, the prominent building that comes to mind is Lendlease's One Central Park in Chippendale (constructed circa 2014) which supports over 1,120 m2 of vertical garden arrangements absorbed into its clean glazed facades.

One Central Park, Chippendale NSW

(Barnett, 2021)

SUSTAINABILITY & FIRE SAFETY

Living walls guidance and fire testing is "inconsistent and inappropriate" says leading fire engineering academic

While outdoor so called 'living walls' can improve air quality and public wellbeing, Professor Ed Galea, Fire Safety Engineering Group Director at the University of Greenwich, says that the current guidance is inconsistent and not fit for purpose.

To define living walls – also known as green walls or vertical gardens – these are structures covered in living plants that can be installed onto building walls.

Speaking at the Tall Buildings Conference held alongside FIREX in May, Galea said that although external living walls undoubtedly provide improve public health and wellbeing, and introduce biodiversity to our cities, their fire safety implications mustn't be ignored.

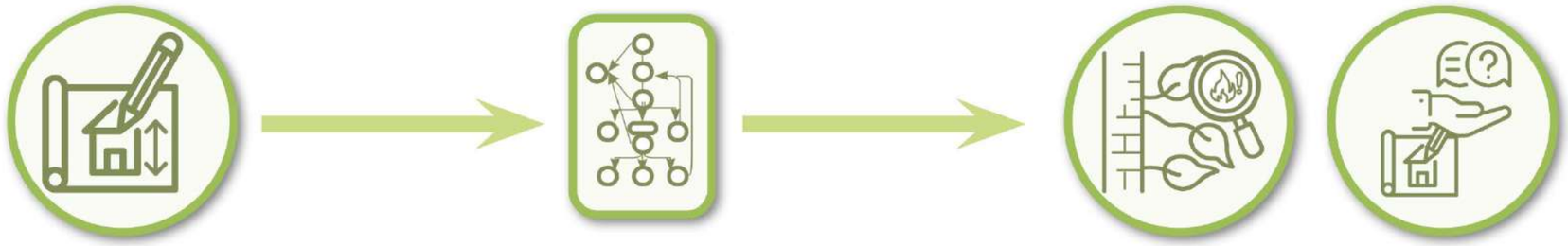
Credit: Chris Jones/AlamyStock

(Alalouff, 2023)

Research objective

Increase awareness and understandig of fire safety of VGS:

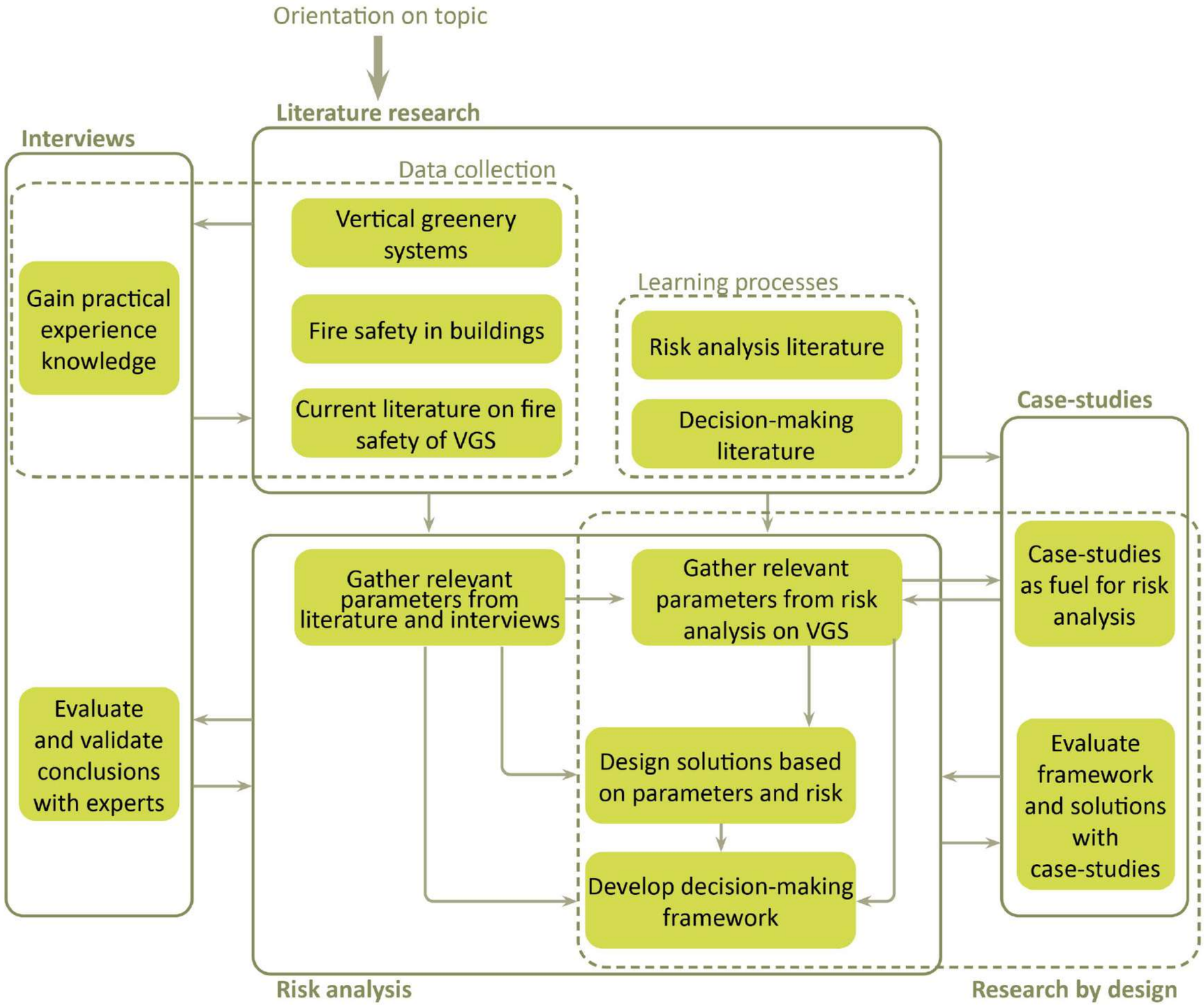
- analyse fire risks of vertical greenery systems
- design solutions connected to risks
- develop design-oriented decision-making framework



Research question

*"How can a decision-making framework help guide the design process for outdoor **vertical greenery systems** which provides responsible **fire risk management** relevant to a building's characteristics?"*

Research framework



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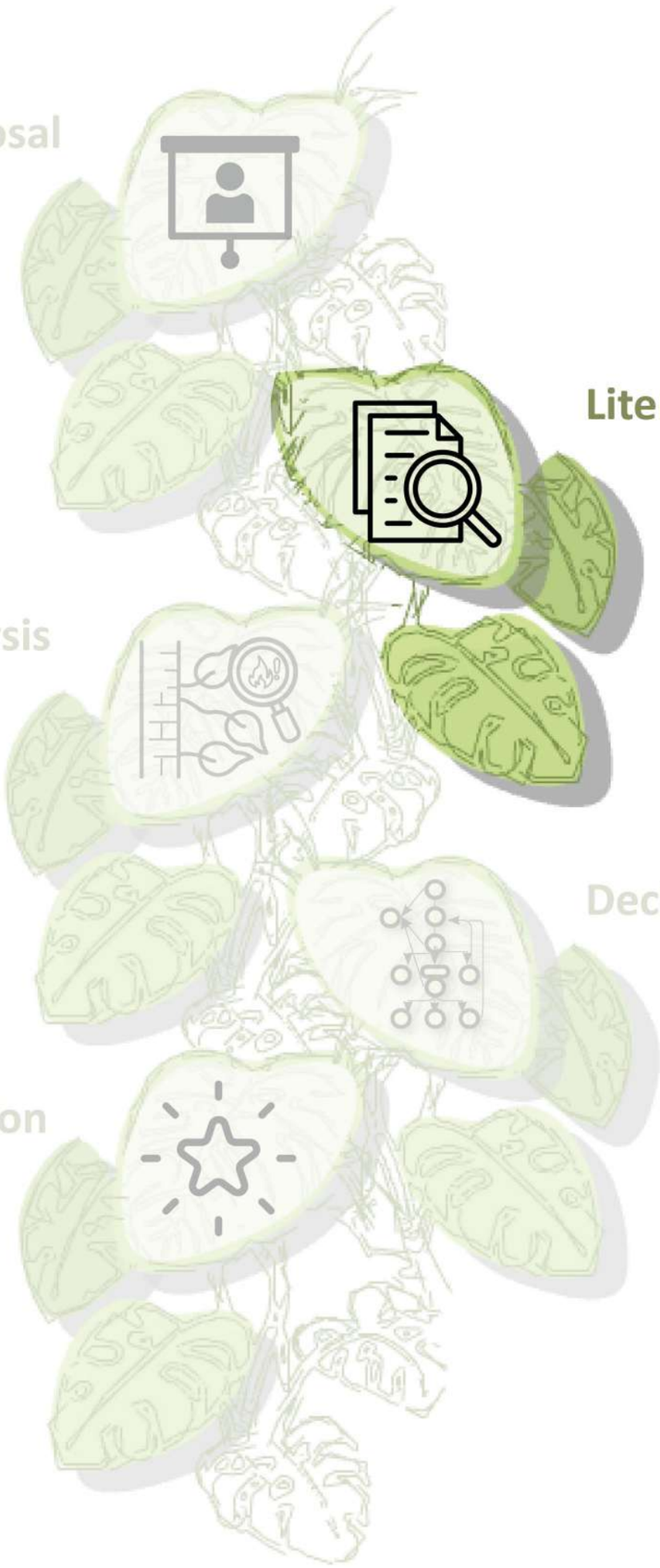

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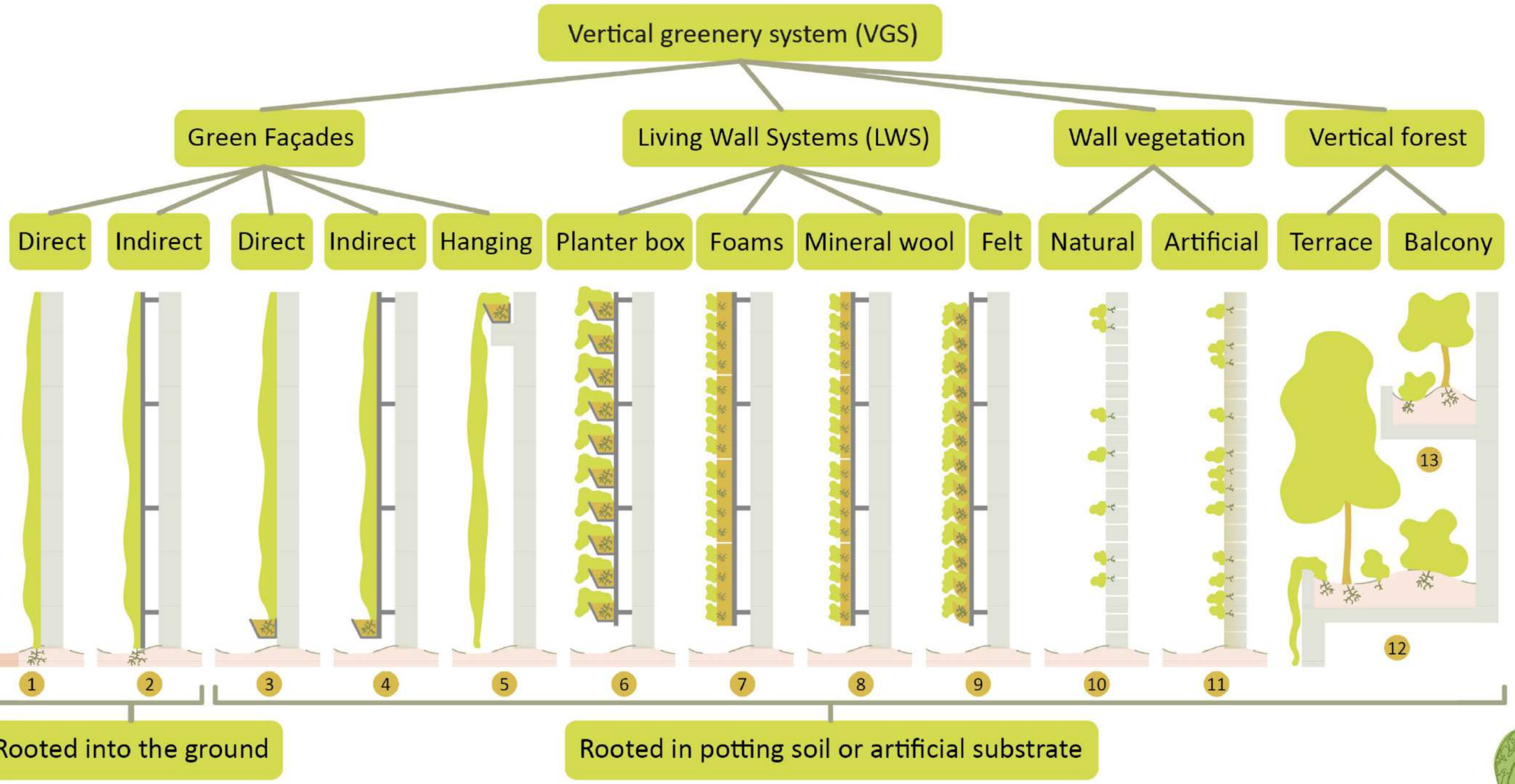
Classification of VGS



Vertical greenery systems (VGS)

Differences between systems

Not dependent on irrigation

Green Façades

Direct | Indirect | Direct | Indirect | Hanging

Living Wall Systems (LWS)

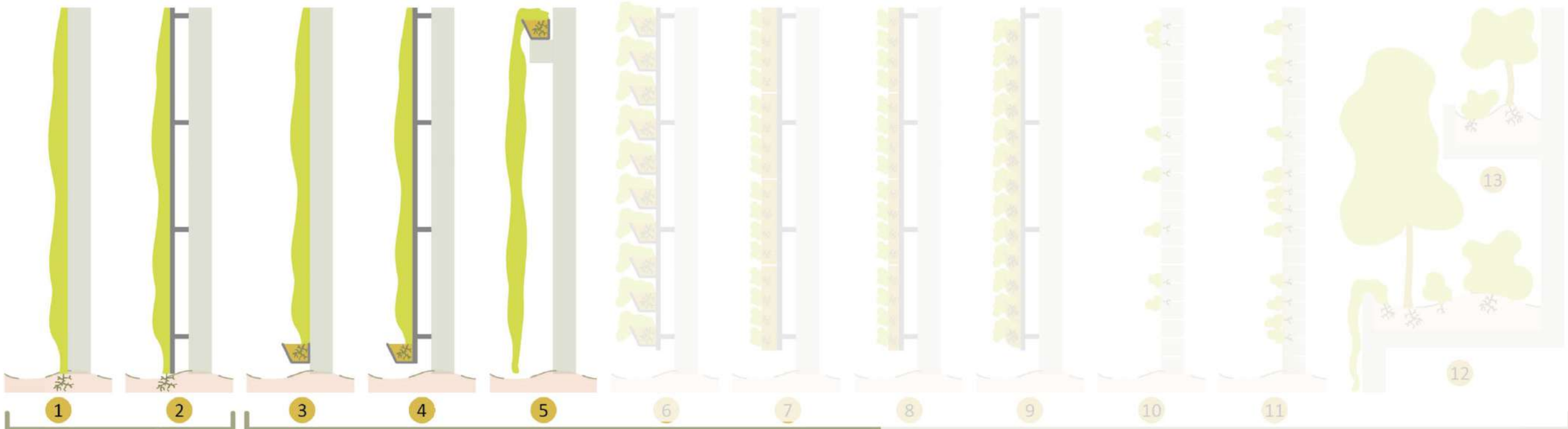
Planter box | Foams | Mineral wool | Felt

Wall vegetation

Natural | Artificial

Vertical forest

Terrace | Balcony



Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Small amount of material use and low maintenance

Green Façades

Direct | Indirect | Direct | Indirect | Hanging

Living Wall Systems (LWS)

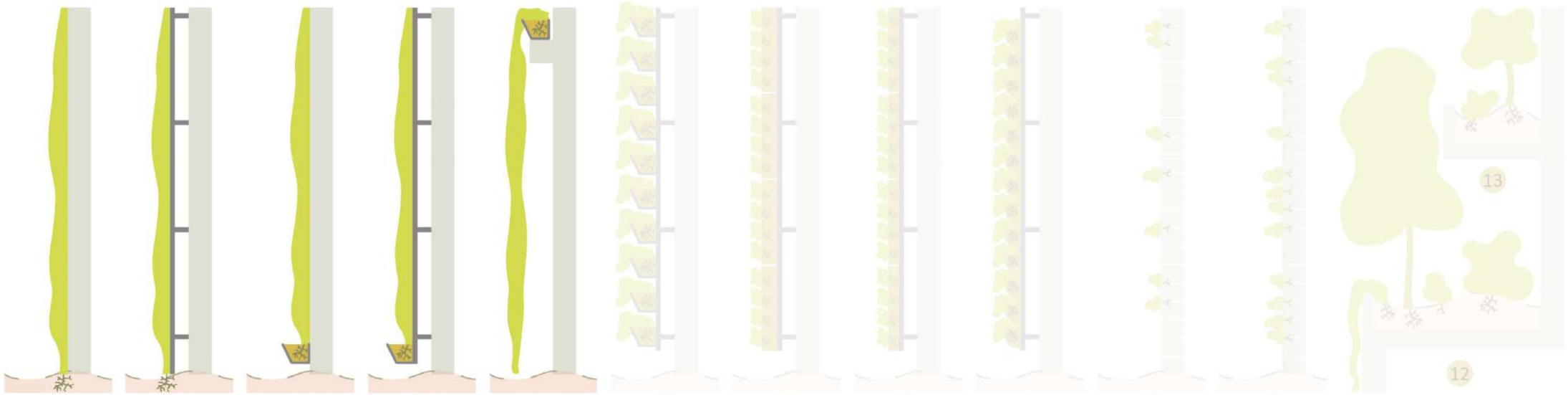
Planter box | Foams | Mineral wool | Felt

Wall vegetation

Natural | Artificial

Vertical forest

Terrace | Balcony



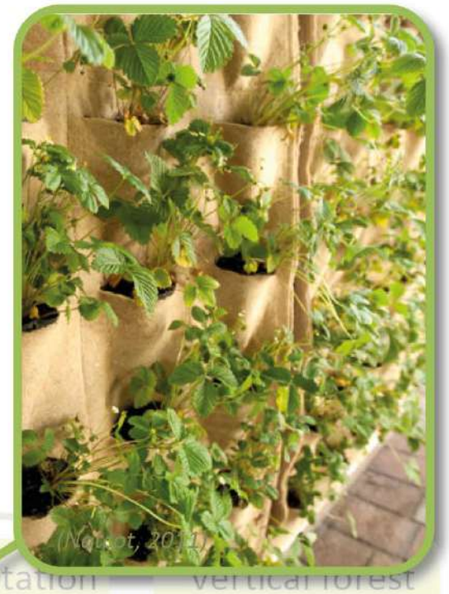
Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

(Biotecture, n.d.)

Much more material use, complex systems and high maintenance



(Nguyet, 2021)

Vertical greenery system (VGS)

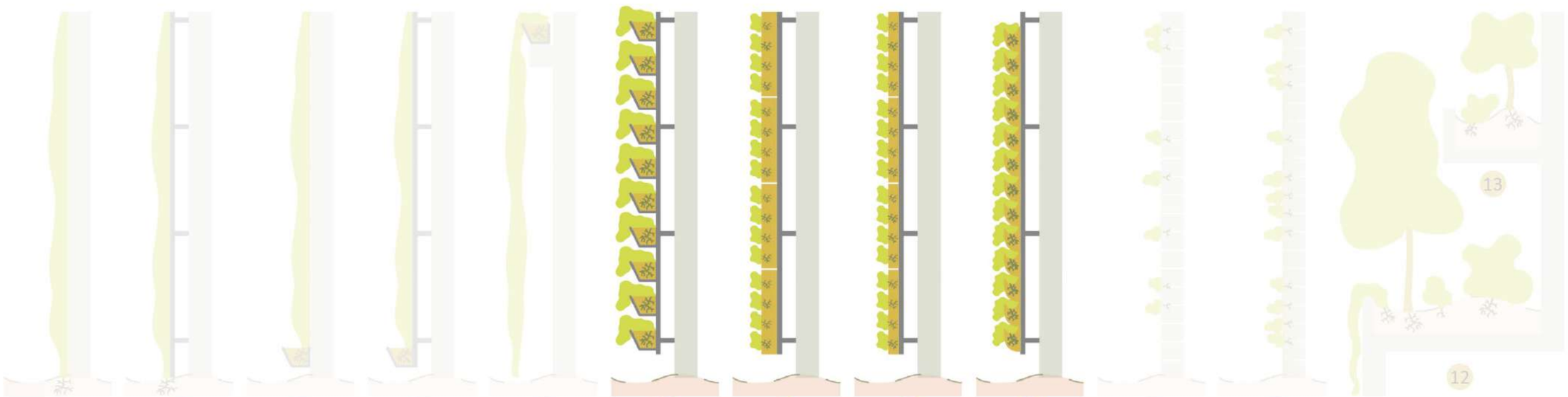
Green façades

Living Wall Systems (LWS)

Wall vegetation

Vertical forest

Direct | Indirect | Direct | Indirect | Hanging | Planter box | Foams | Mineral wool | Felt | Natural | Artificial | Terrace | Balcony



Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

(Vertical meadow, n.d.)

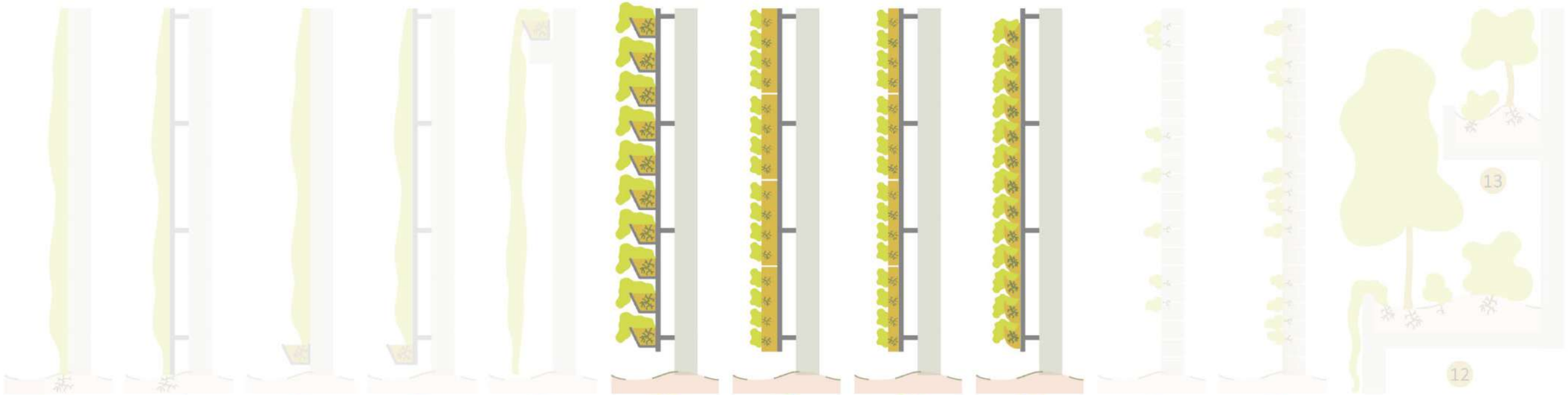
Much more material use, complex systems and high maintenance

Can be built up with incombustible materials

Living Wall Systems (LWS)

Planter box | Foams | Mineral wool | Felt

(Lawn & garden, n.d.)



Rooted into the ground

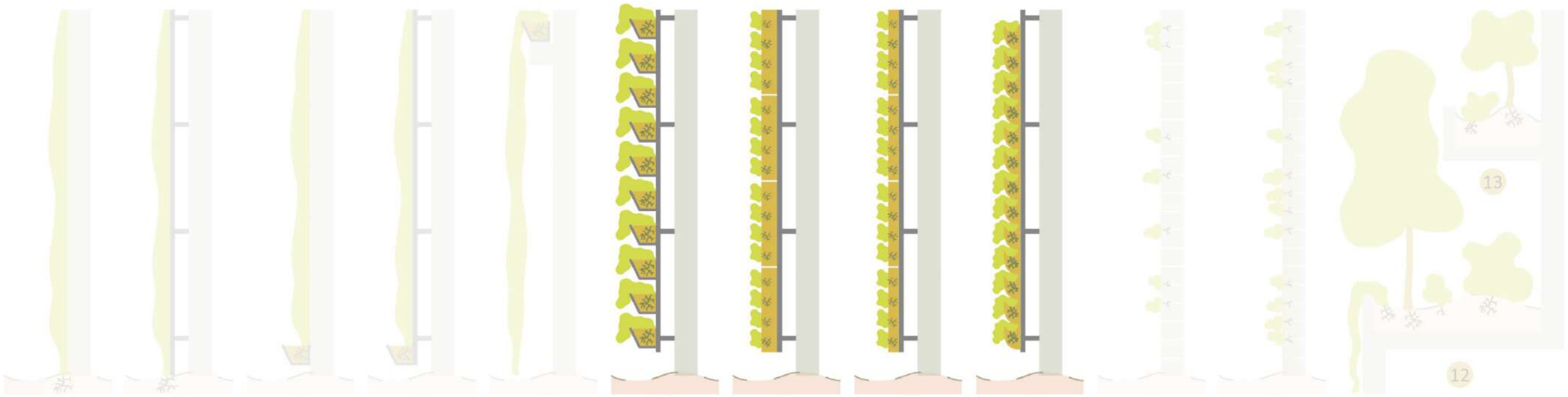
Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Creates air cavity between system and façade

Vertical greenery system (VGS)

- Green Façades
  - Direct
  - Indirect
  - Direct
  - Indirect
  - Hanging
- Living Wall Systems (LWS)
  - Planter box
  - Foams
  - Mineral wool
  - Felt
- Wall vegetation
  - Natural
  - Artificial
- Vertical forest
  - Terrace
  - Balcony



Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Minimal material use and low maintenance

Vertic

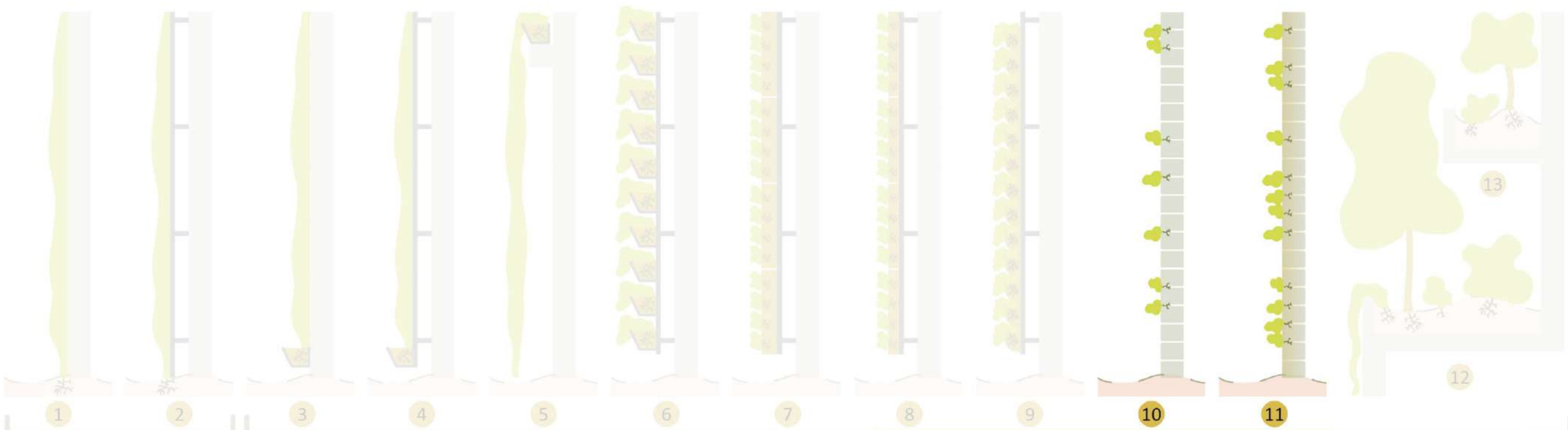
Green Façades

Living Wall Systems (LWS)

Wall vegetation

Vertical forest

Direct | Indirect | Direct | Indirect | Hanging | Planter box | Foams | Mineral wool | Felt | Natural | Artificial | Terrace | Balcony



Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Complex systems and high maintenance

Vertical greenery system (VGS)

Green Façades

Living Wall Systems (LWS)

Wall vegetation

Vertical forest

Terrace

Balcony

Direct

Indirect

Direct

Indirect

Hanging

Planter box

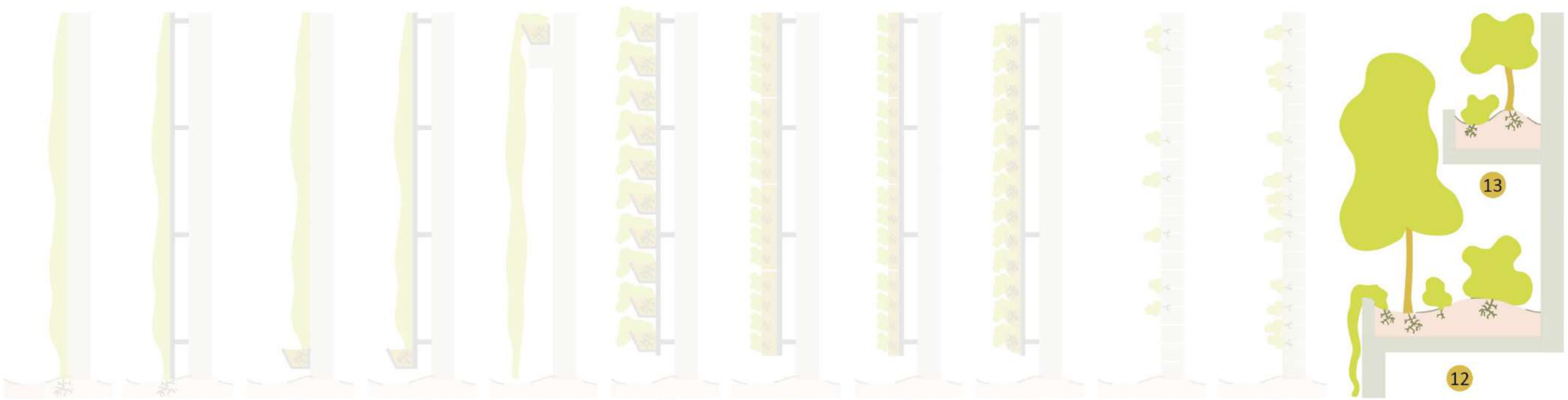
Foams

Mineral wool

Felt

Natural

Artificial



Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Vertical greenery system (V

Green Façades

Living Wall Systems (LWS)

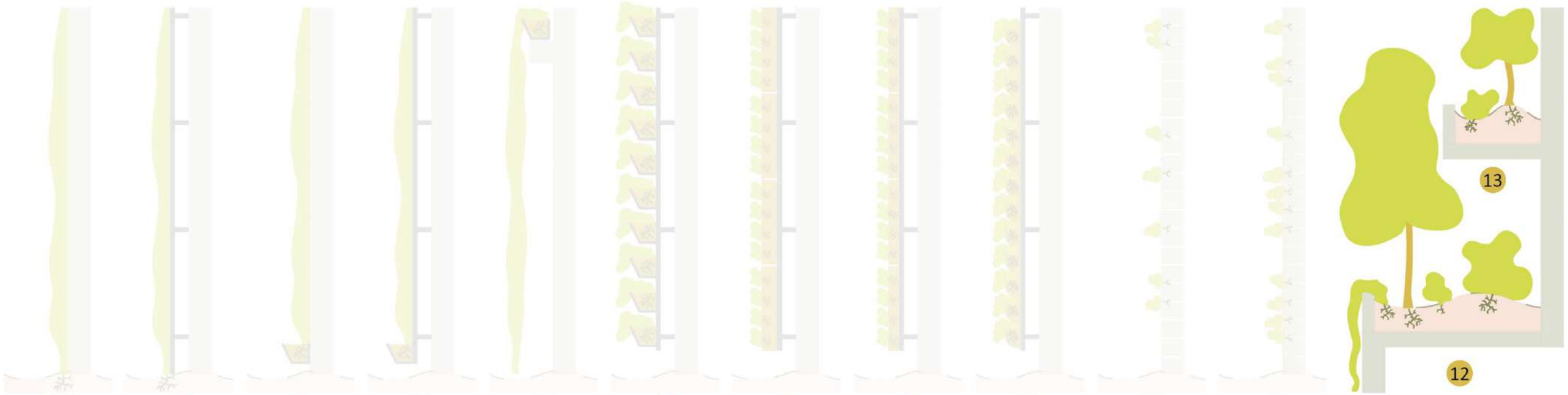
Wall vegetation

Direct | Indirect | Direct | Indirect | Hanging | Planter box | Foams | Mineral wool | Felt | Natural | Artificial

Vegetation and configuration most influential

Vertical forest

Terrace | Balcony

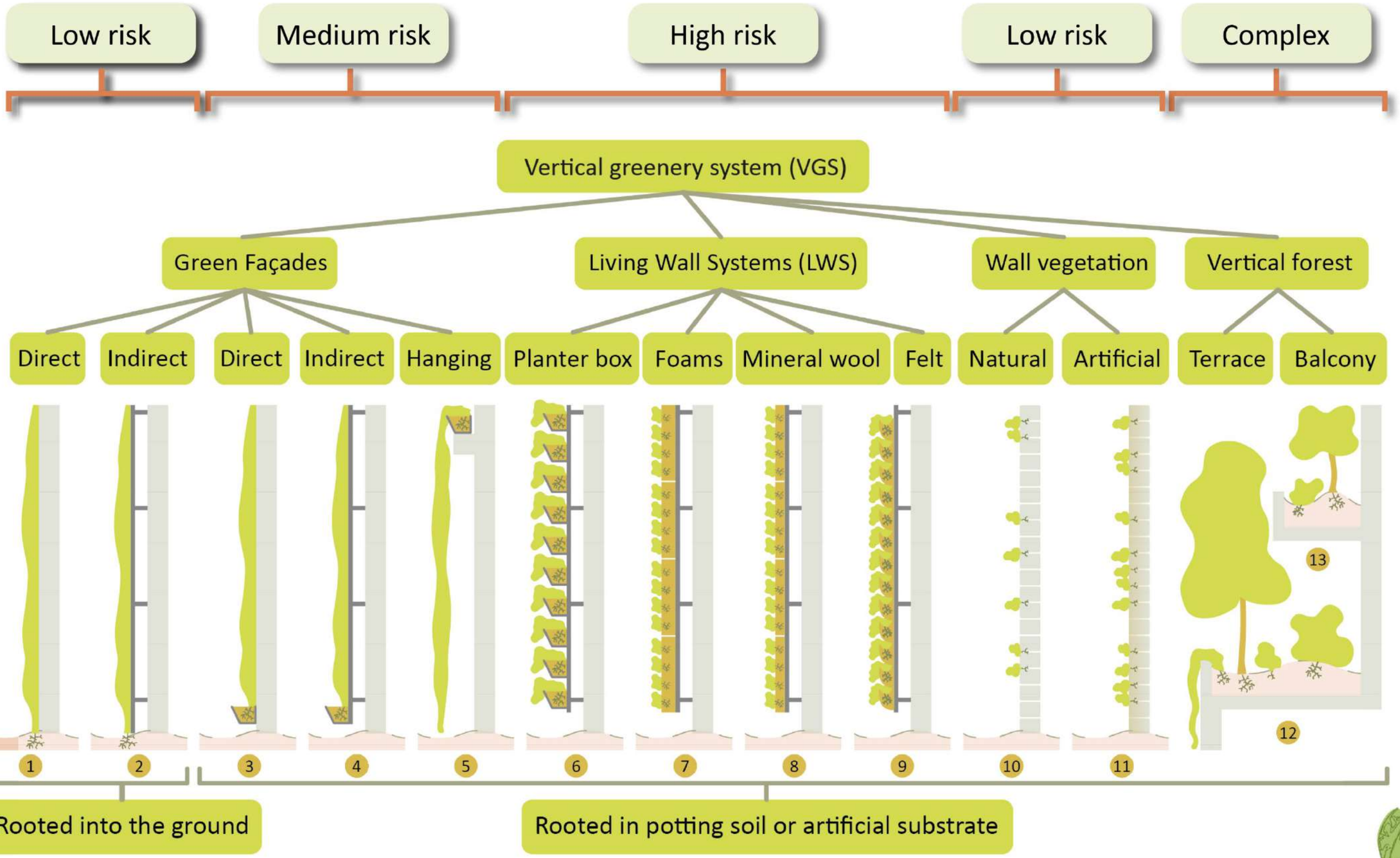


Rooted into the ground

Rooted in potting soil or artificial substrate

Vertical greenery systems (VGS)

Differences between systems

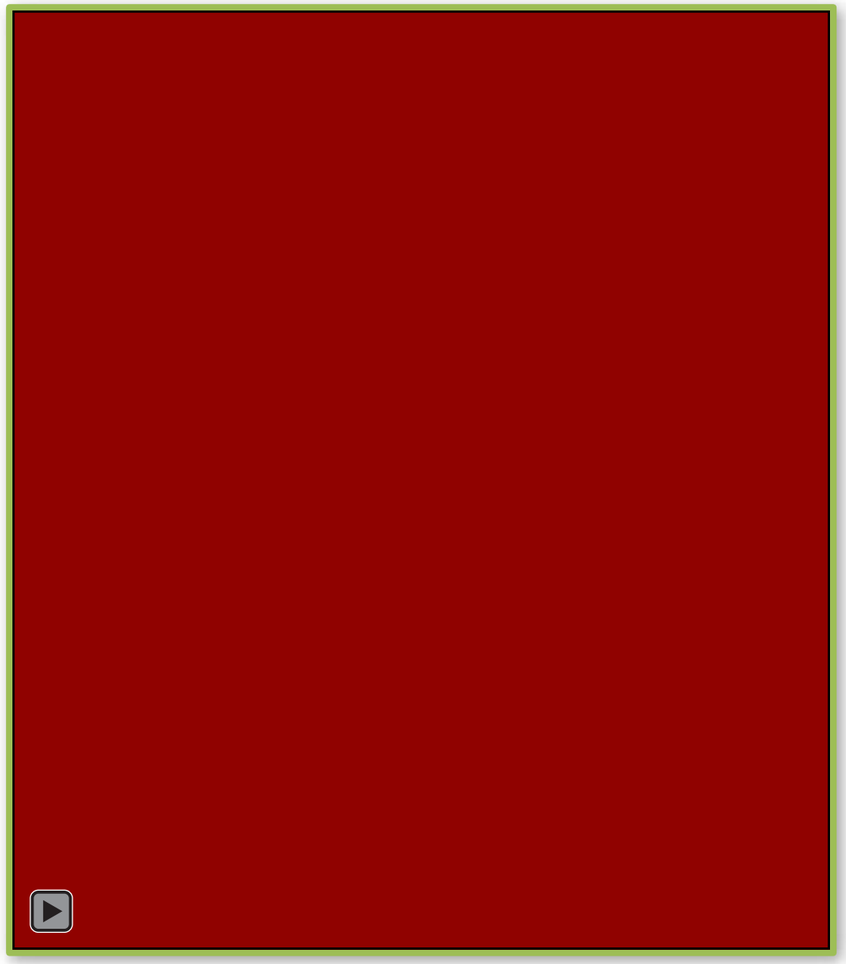


Fire safety relevant for VGS

VGS = façade system so comply with façade legislation -> Euroclassification based on tests

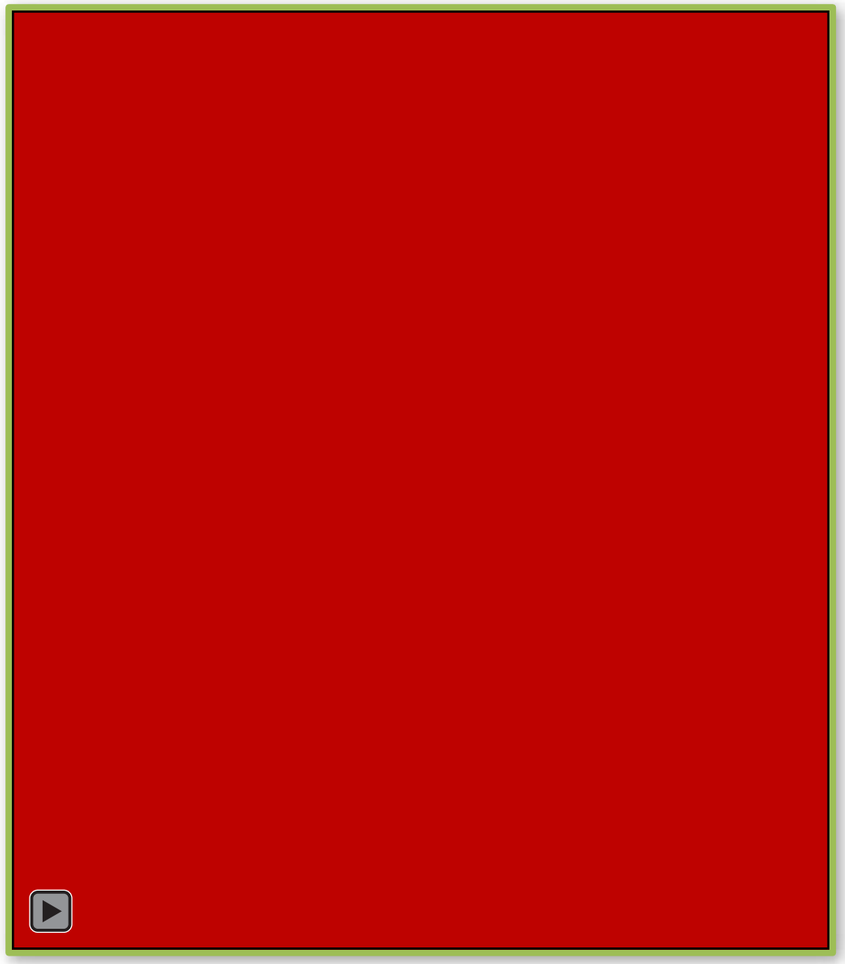
- But! Inconsistent testing and no proper documentation

Dry vegetation moisture content = ? %



(Holzbau und Baukonstruktion, 2023b)

Wet vegetation moisture content = 278 & 312 %



(Holzbau und Baukonstruktion, 2023a)

Fire safety relevant for VGS

climbing aids

- Further large-scale fire tests with climbing aids and defined distances away from fire chamber

Vegetation free zone

Ivy with fire barrier made of steel

Fire break

climbing aids in front of facade

Distance from façade

(EFB, 2022)

Inte

D n free zones

Fire breaks

(Sempergreen, n.d.)

(FuHH, 2022)

(EFB, 2022)

But! Precise dimensions are not clear. More explorative fire testing needed

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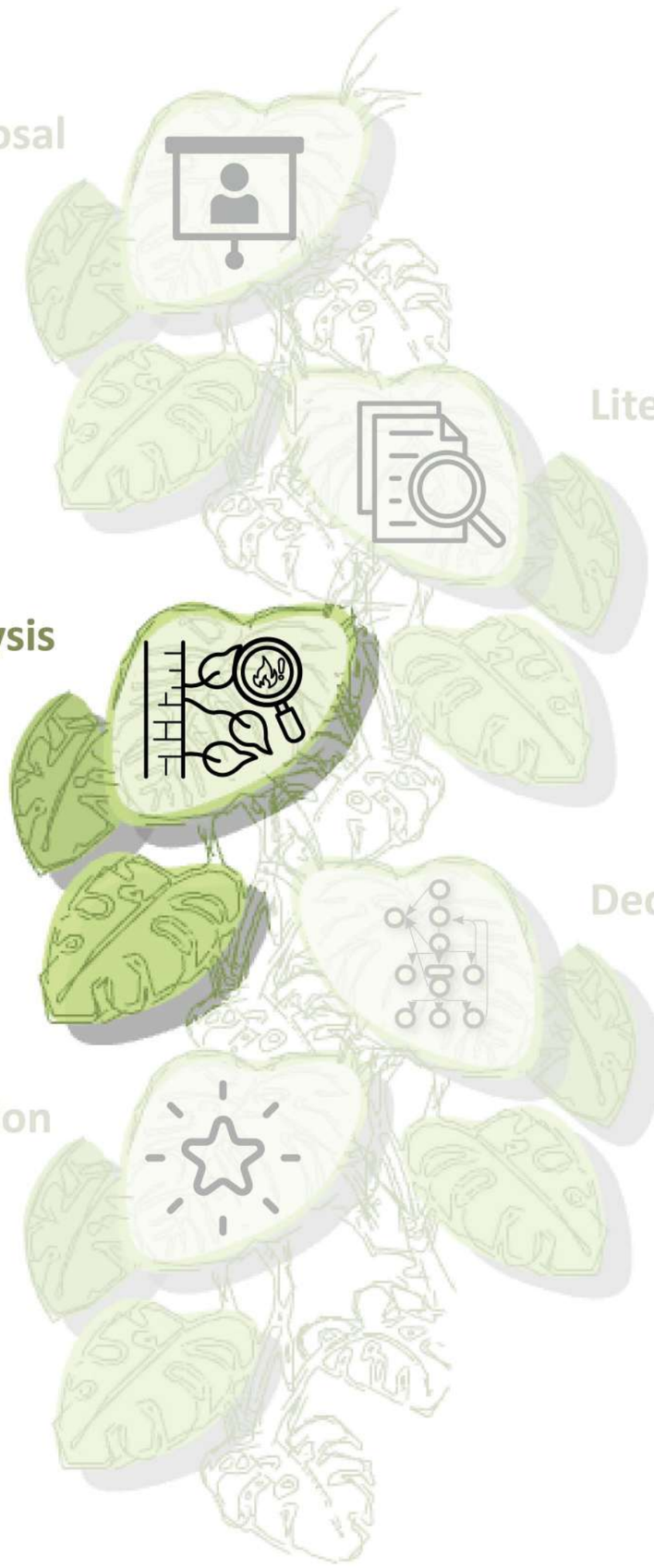

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Example case-study scenarios

'What-if' analysis on 18 case-studies with multiple scenarios

Questions:

- What could potential ignition sources be?
- If ignited how would the flames spread?
- Would the flames threaten the possibility of escaping?

Example: Gallery apartment block

LWS on blind façade

Indirect GF on balconies

Parameter overview

Relevant parameters used for decision-making framework

Detailed tool

Building scale

1	What is the building function of use?
2	What is the building height?
3	What is the location of the escape routes?
-	What is the amount of facades that need to be assessed?

Façade scale Façade

4	What is the façade typology?
5	What is the double skin façade typology?
6	Is the facade situated in front of multiple fire compartments?
7	Is the façade load-bearing?
8	Are there interruptions along the façade?
9	Are there transparent parts in the façade?
10	Is the façade accassible by firefighters?
11	Is the orientation of the facade in the prevailing wind direction?

Façade scale VGS

12	What type of VGS is used?
13	How does the system cover the façade?
14	Is the system above a transparent part in the façade?
15	Is the system below a transparent part in the façade?
16	Is the system besides a transparent part in the façade?
17	How on the façade is the system applied?
18	Is there a clear fire trajectory from the VGS to an escape route?
19	Is the system applied above an escape route?
20	Is the system easily accessible?

Product scale Façade

21	What materials are used as insulation in the façade?
22	What materials are used for the cladding?
23	Are there seams in the façade?
24	What materials are used for the cladding connection?

Product scale VGS

25	What materials are used for the support structure and substrate?
26	Is there an automatic irrigation system present?
27	What type of vegetation is used?
28	Is there lighting?

28

Simple tool

Building scale

1	What is the building function of use?
2	What is the building height?

Façade

3	Is the rear façade incombustable without open seams?
4	Is the VGS applied near openings?
5	Is the facade situated in front of multiple fire compartments?
6	What type of VGS is used?
7	Does the VGS threaten all possible escape routes in case of fire?
8	Is the façade accassible by firefighters?
9	What materials are used for the support structure and substrate?

9

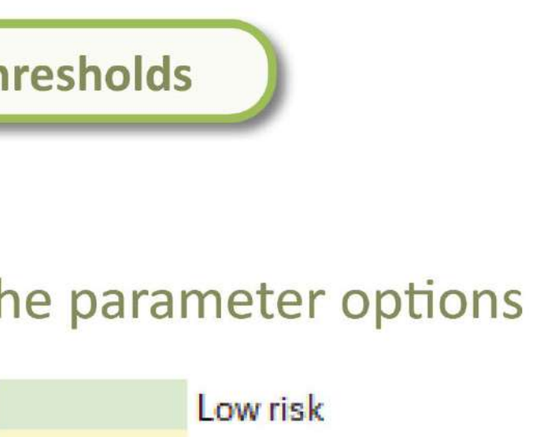
Weighing of risk factors and thresholds

Risk factors coupled to the parameter options

Higher number = higher risk

Low risk
Medium risk
High risk

(DGMR, 2019)



(Nieman & DGMR, 2022)

Basis from existing tools of Nieman and DGMR

Facade 1	Facade 2	Facade 3	Facade 4
4	64	1	16
32.0	32.0	64.0	48.0
16	12	72	27
8	5	10	8
1.25	1.25	5.625	5
2	4	6	5
Good to go	Consult fire safety expert or change design	NO-GO, change the design	NO-GO, change the design

Further determined with 18 case-studies

Thresholds for risk level

Low risk
Medium risk
High risk

Thresholds	<25	25-55	>55
Risk level	Low	Medium	High

Evaluation of risk factors and thresholds

Facade 1		Facade 2		Facade 3		Facade 4	
							
1	(1) Other building functions	1	(1) Other building functions	1	(1) Other building functions	1	(1) Other building functions
1	(1) Building height <15m	4	(4) Building height 40m-100m	2	(2) Building height 15m-40m	2	(2) Building height 15m-40m
1	(1) One staircase in residential or accomodation not in residential building or accor	1	(1) Two staircases on distance >H/2	1	(1) Two staircases on distance >H/2	1	(1) Two staircases on distance >H/2
1		4		2		2	
	Facade overview		Facade overview		Facade overview		Facade overview
2	(2) Opaque façade with air cavity	2	(2) Curtain wall	2	(2) Opaque façade with air cavity	2	(2) Opaque façade with air cavity
1.0	(1) No double skin façade	1.0	(1) No double skin façade	1.0	(1) No double skin façade	1.0	(1) No double skin façade
1	(1) No	1	(1) No	2	(2) Yes, horizontally	4	(4) Yes, vertically
1.0	(1) No	1.0	(1) No	1.0	(1) No	1.0	(1) No
2.0	(2) No	2.0	(2) No	2.0	(2) No	2.0	(2) No
2	(2) Yes	2	(2) Yes	2	(2) Yes	2	(2) Yes
1	(1) Yes	1	(1) Yes	1	(1) Yes	4	(4) No
1	(1) No	2	(2) Yes, it's perpendicular	2	(2) Yes, it's perpendicular	2	(2) Yes, it's perpendicular
8		16		32		256	
2	(2) 8. LWS with Mineral Wool	1	(1) 4. Indirect Green Façade not roote	2	(2) 9. LWS with Felt Pockets	2	(2) 6. LWS with Planter Boxes
3	(3) Whole façade	2	(2) Vertical strips	3	(3) Whole façade	3	(3) Whole façade
2	(2) Yes, <1m distance	1	(1) No	2	(2) Yes, <1m distance	2	(2) Yes, <1m distance
2	(2) Yes, <1.5m distance	1	(1) No	2	(2) Yes, <1.5m distance	2	(2) Yes, <1.5m distance
1.50	(1.5) Yes, <0.4m distance	1	(1) Yes, >1m distance	1.5	(1.5) Yes, <0.4m distance	1.5	(1.5) Yes, <0.4m distance
2	(2) Integrated in the façade	1	(1) At a distance from the façade >0.5	2	(2) Integrated in the façade	2	(2) Integrated in the façade
1	(1) No	1	(1) No	1	(1) No	1	(1) No
2	(2) Yes	1	(1) No	1	(1) No	2	(2) Yes
2	(2) Yes	1	(1) No	2	(2) Yes	2	(2) Yes
288		2		144		288	
2	(2) Combustible; class B	2	(2) Combustible; class B	2	(2) Combustible; class B	4	(4) Combustible; class C-F
2	(2 VGS is the cladding	2	(2) Combustible; class B	2	(2 VGS is the cladding	2	(2 VGS is the cladding
1	(1) No	1	(1) No	1	(1) No	2	(2) Yes, > half thickness spouwblad
1	(1) Steel or aluminium	1	(1) Steel or aluminium	1	(1) Steel or aluminium	1	(1) Steel or aluminium
4		4		4		16	
2	(2) Incombustible and combustible r	1	(1) Only incombustable materials	4	(4) Mostly combustible materials	4	(4) Mostly combustible materials
1.25	(1.25) Yes, every row of modules	1	(1) Yes, every row of plants	1.25	(1.25) Yes, every row of modules	1.25	(1.25) Yes, every row of modules
1	(1) Evergreens	2	(2) Perennials	1	(1) Evergreens	1	(1) Evergreens
1	(1) No	1.5	(1.5) Yes, not in the system	1	(1) No	1	(1) No
2.50		3.00		5		5	

Facade 1	Facade 2	Facade 3	Facade 4
1	1	1	1
8.0	16.0	32.0	256.0
288	2	144	288
4	4	4	16
2.5	3	5	5
Reset all input of facade	Reset all input of facade	Reset all input of facade	Reset all input of facade
2	0	3	7
Good to go	Good to go	Consult fire safety expert or change design	NO-GO, change the design
Facade overview	Facade overview	Facade overview	Facade overview

Evaluated with 4 (other) case-studies

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Target groups

Designers

- **Who** Architect, façade designer, sustainability consultant, manufacturer
- **When** Early design phase
- **Why** Early identification of possible problems and simple solutions

- **Who** Architect, façade designer, sustainability consultant, manufacturer
- **When** Development during design
- **Why** Check if still on track for desired level

Plan assessors

- **Who** Fire safety consultant
- **When** When consulted
- **Why** Check if personal judgement is in line with advice from tools

- **Who** Authorised supervision
- **When** When design is judged against legislation
- **Why** Supports in determining if design is safe enough

Decision-making framework in design process

The goal is to empower individuals to:

- identify easy safe designs
- gain knowledge to make informed decisions
- gain knowledge for arguments in discussions during the design process
- recognize when to consult fire safety engineer
- identify no-go situations

Tools evaluated by:

- 2 architects
- 1 landscape architect
- 1 project developer
- 1 manufacturer

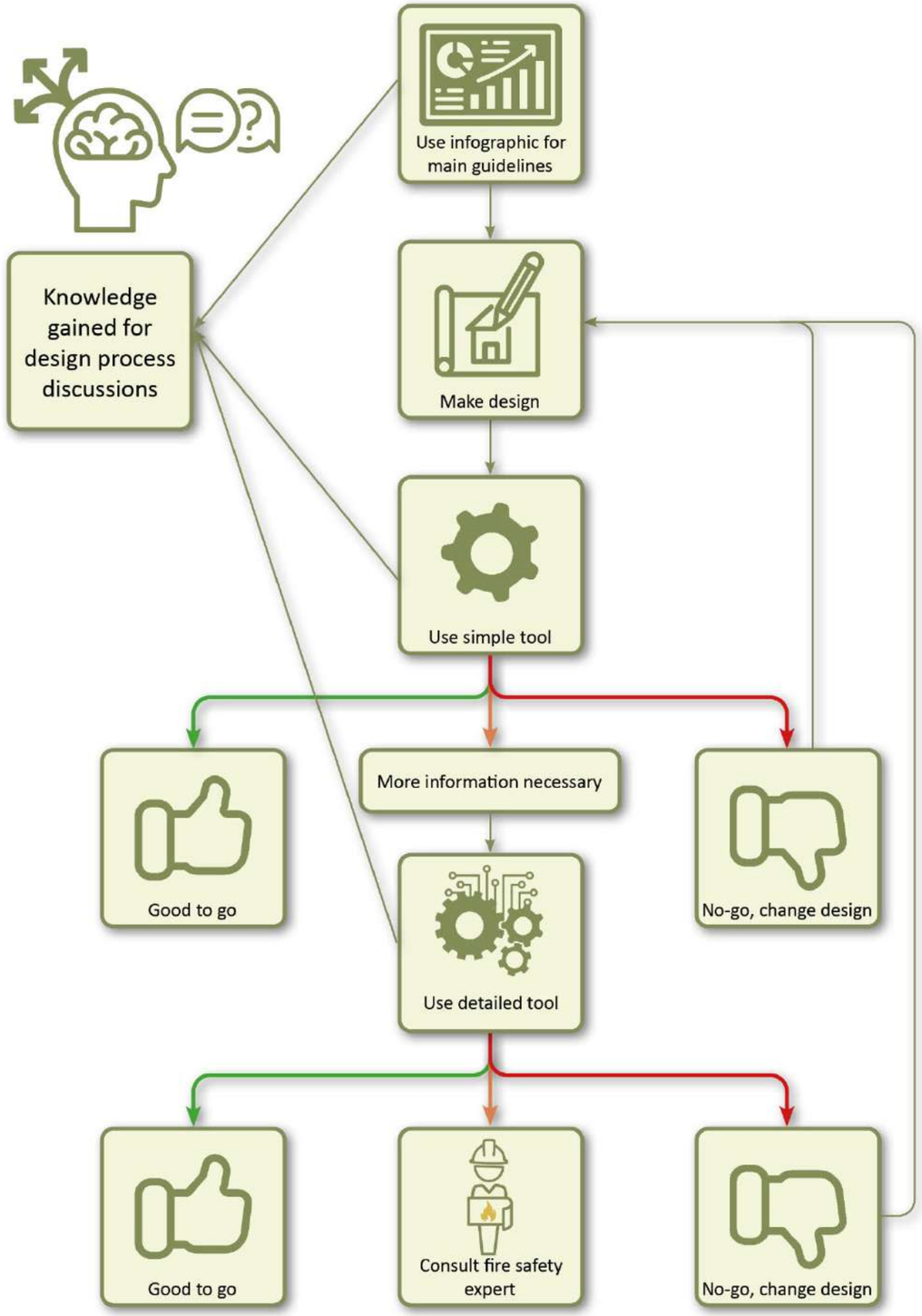
Found that tool can help in raising awareness and improve understanding

Good tool for risk mitigation

Decision-making framework in design process

Three steps:

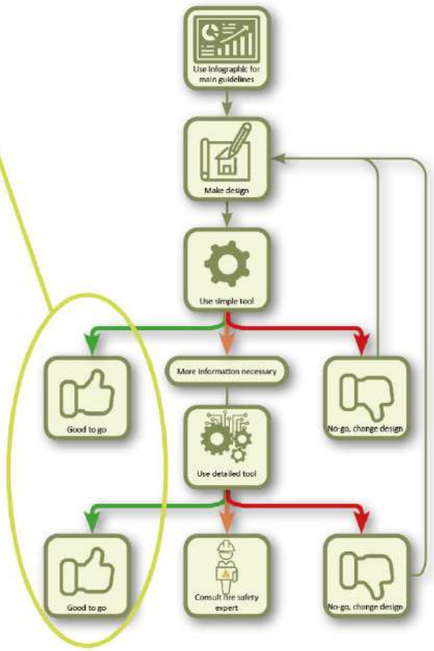
- Infographic
- Simple tool
- Detailed tool



Infographic

Quick overview of design considerations and options

Infographic should encourage to get these results



Most relevant design options

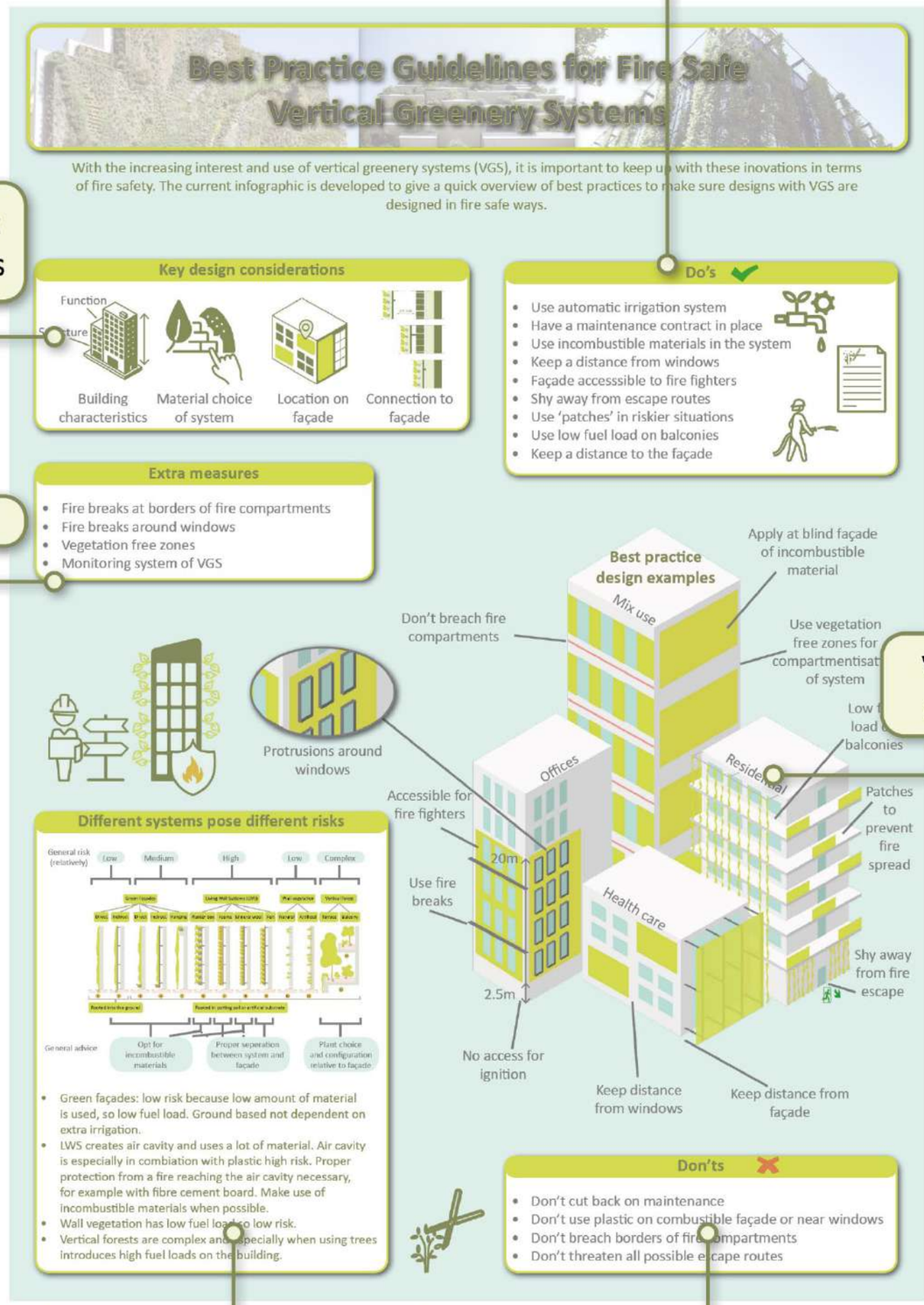
Do's

Extra measures

Visualisation of design options

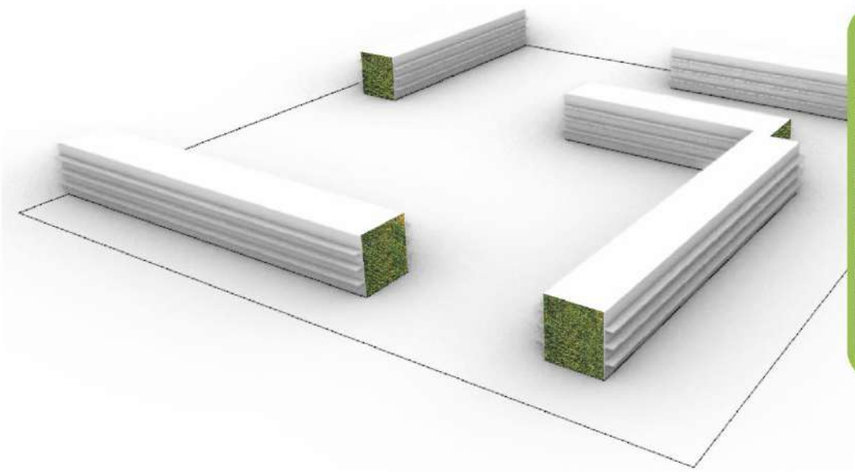
Differences between VGS

Don'ts

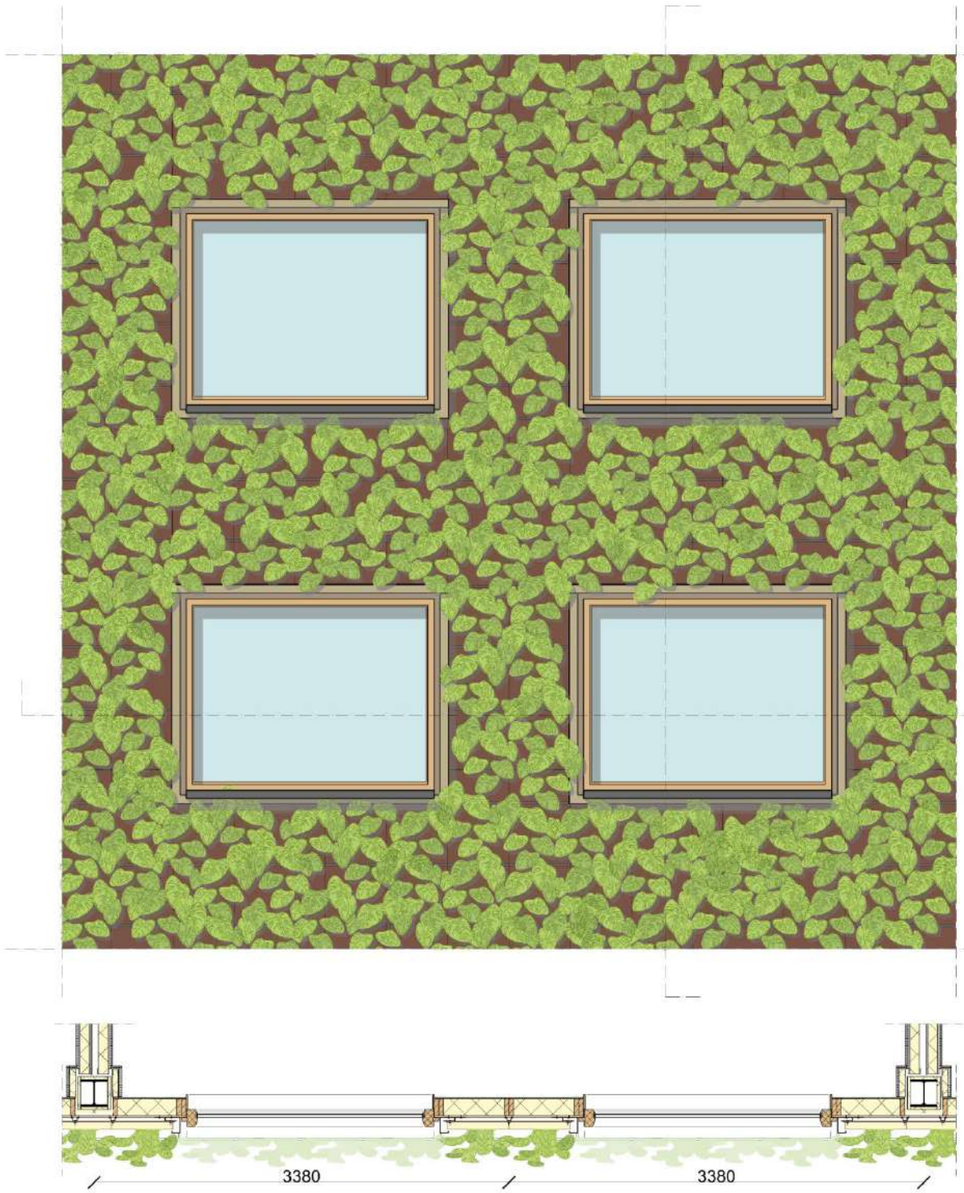


Simple tool

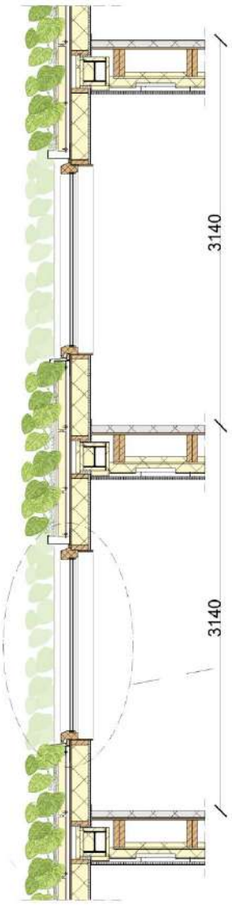
Middle high gallery appartments

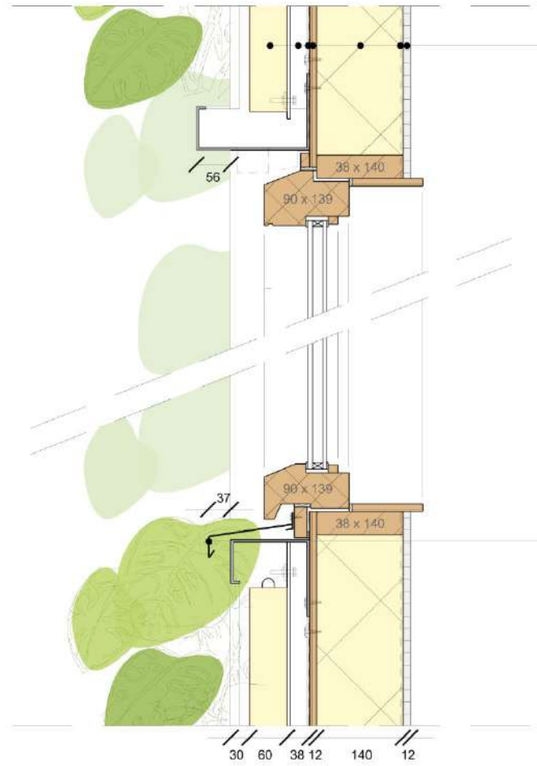


Mineral wool LWS on timber frame construction



1:20 façade view and sections





Façade build-up inside to outside
- Plasterboard 12 mm
- Vapor barrier
- Insulation 140 mm Mineral wool
- Timber beams 38 X 140 mm
- Chipboard 12 mm
- Vapour-open water barrier
- Ventilated air cavity 38 mm
- Aluminium Omega profiles
- Living Wall System

Aluminium drainage and edge
PE drip irrigation system
Mineral wool
Textile
Plants

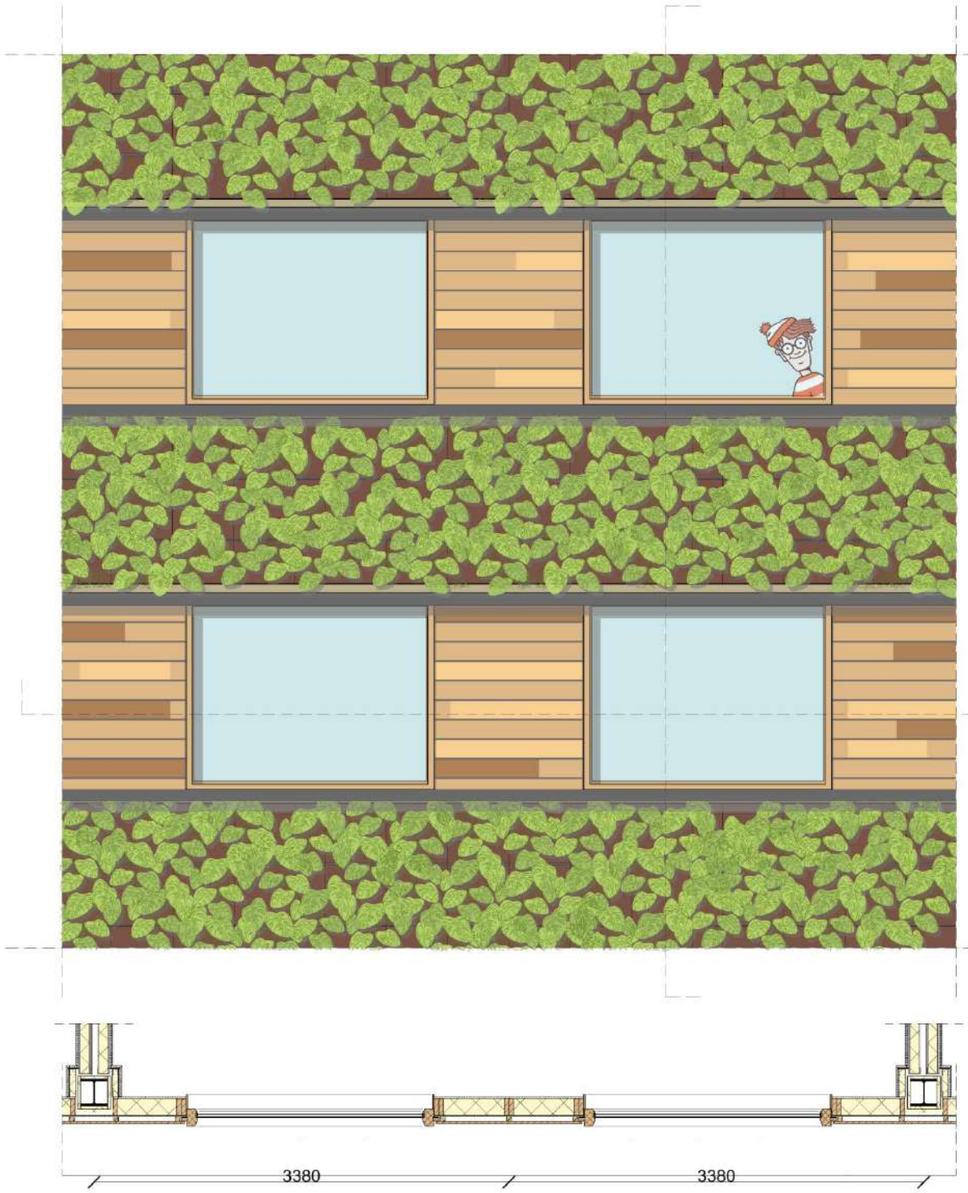
Steel sil

1:5 detail

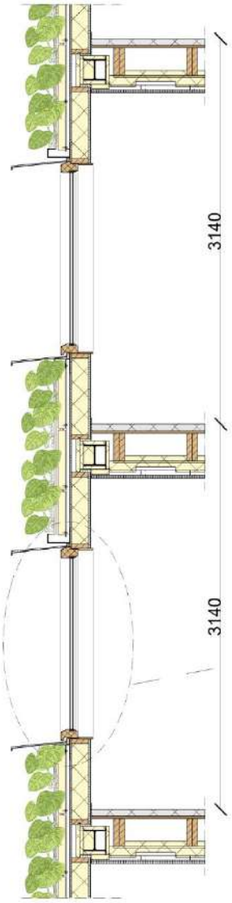
Detailed tool

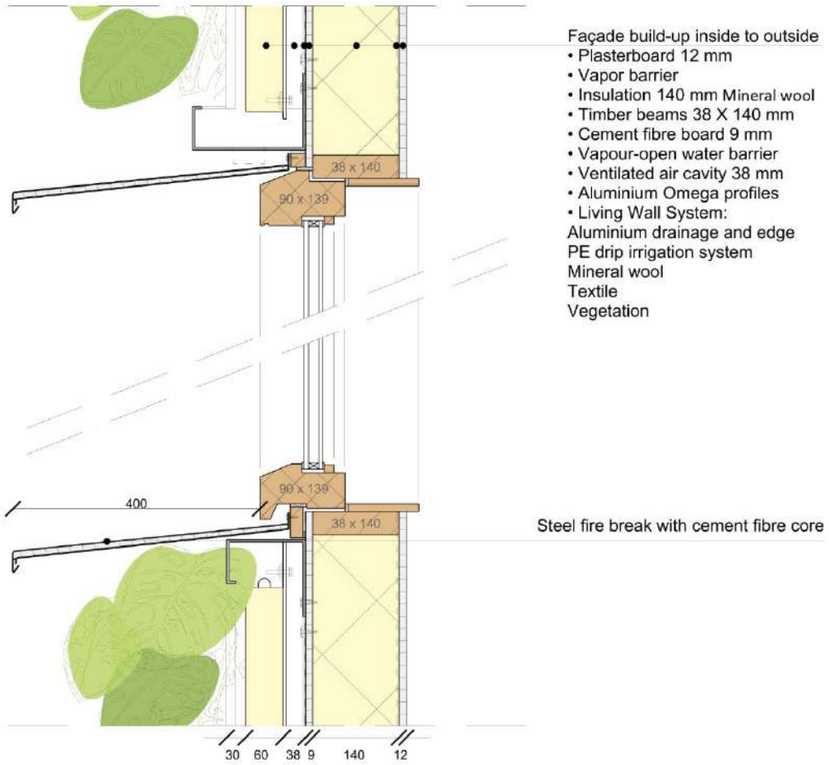
Detailed tool

Change the design using the advice in the tool



1:20 façade view and sections





Façade build-up inside to outside
- Plasterboard 12 mm
- Vapor barrier
- Insulation 140 mm Mineral wool
- Timber beams 38 X 140 mm
- Cement fibre board 9 mm
- Vapour-open water barrier
- Ventilated air cavity 38 mm
- Aluminium Omega profiles
- Living Wall System:

Aluminium drainage and edge
PE drip irrigation system
Mineral wool
Textile
Vegetation

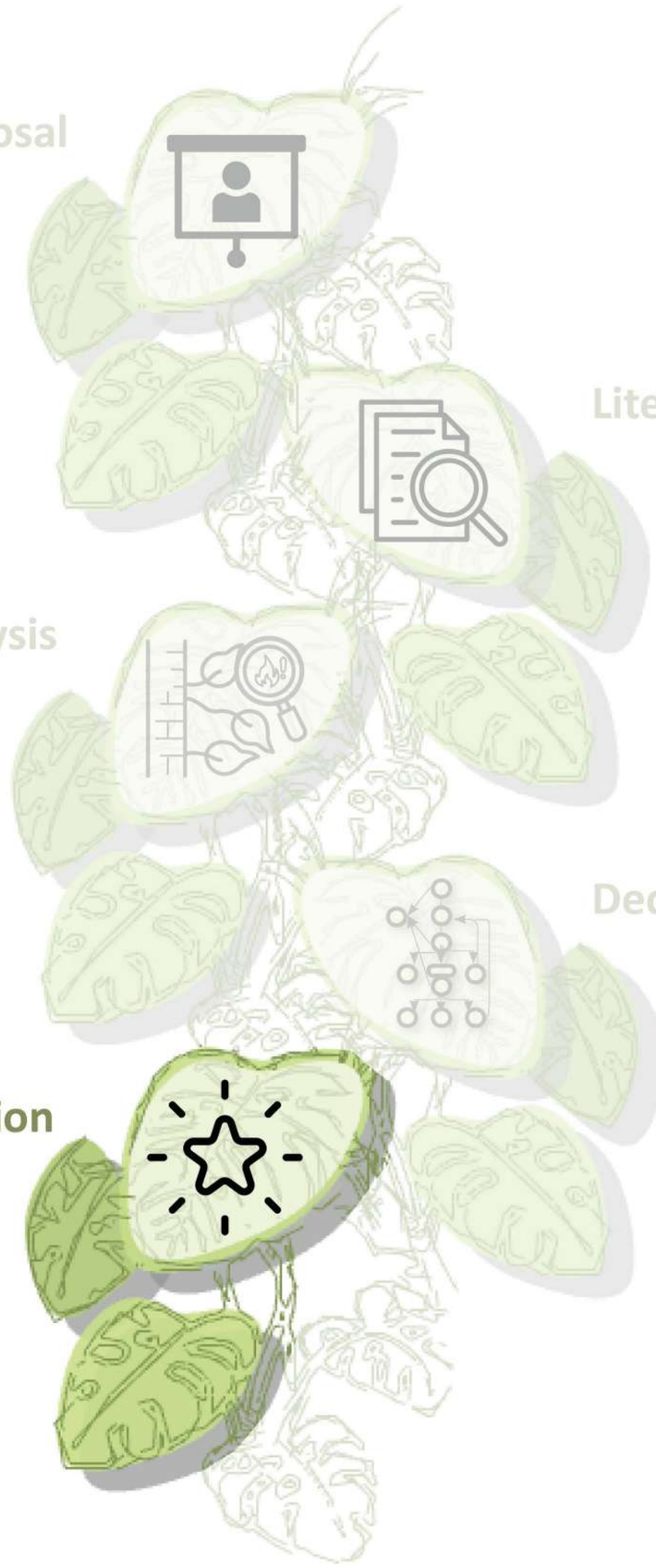
Steel fire break with cement fibre core

1:5 detail

Detailed tool

Research proposal

- Problem statement
- Research objective and question
- Research framework



Literature research

- VGS classification
- Fire safety relevant for VGS

Risk analysis

- ‘What-if’ and case-study scenarios
- Parameter overview
- Weighing & evaluation

Decision-making framework

- Use in design process
- Infographic
- Simple tool example
- Detailed tool example

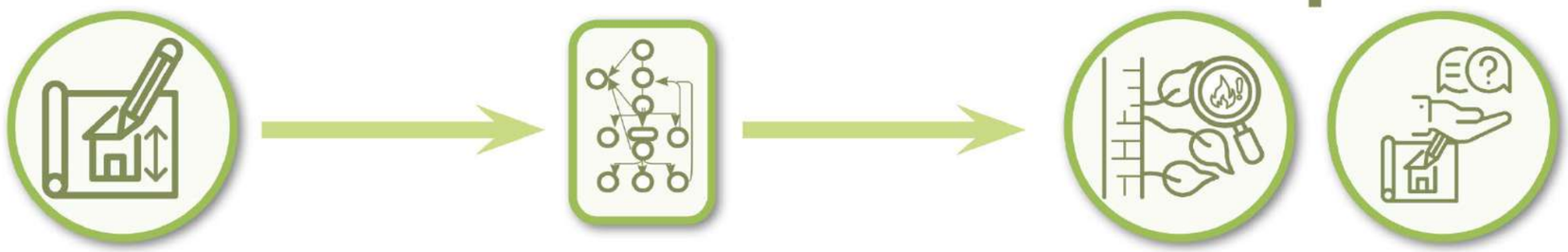
Conclusion

- Conclusions
- Discussion and limitations

Summary

*"How can a decision-making framework help guide the design process for outdoor **vertical greenery systems** which provides responsible **fire risk management** relevant to a building's characteristics?"*

Can empower individuals to analyse designs on risk by:



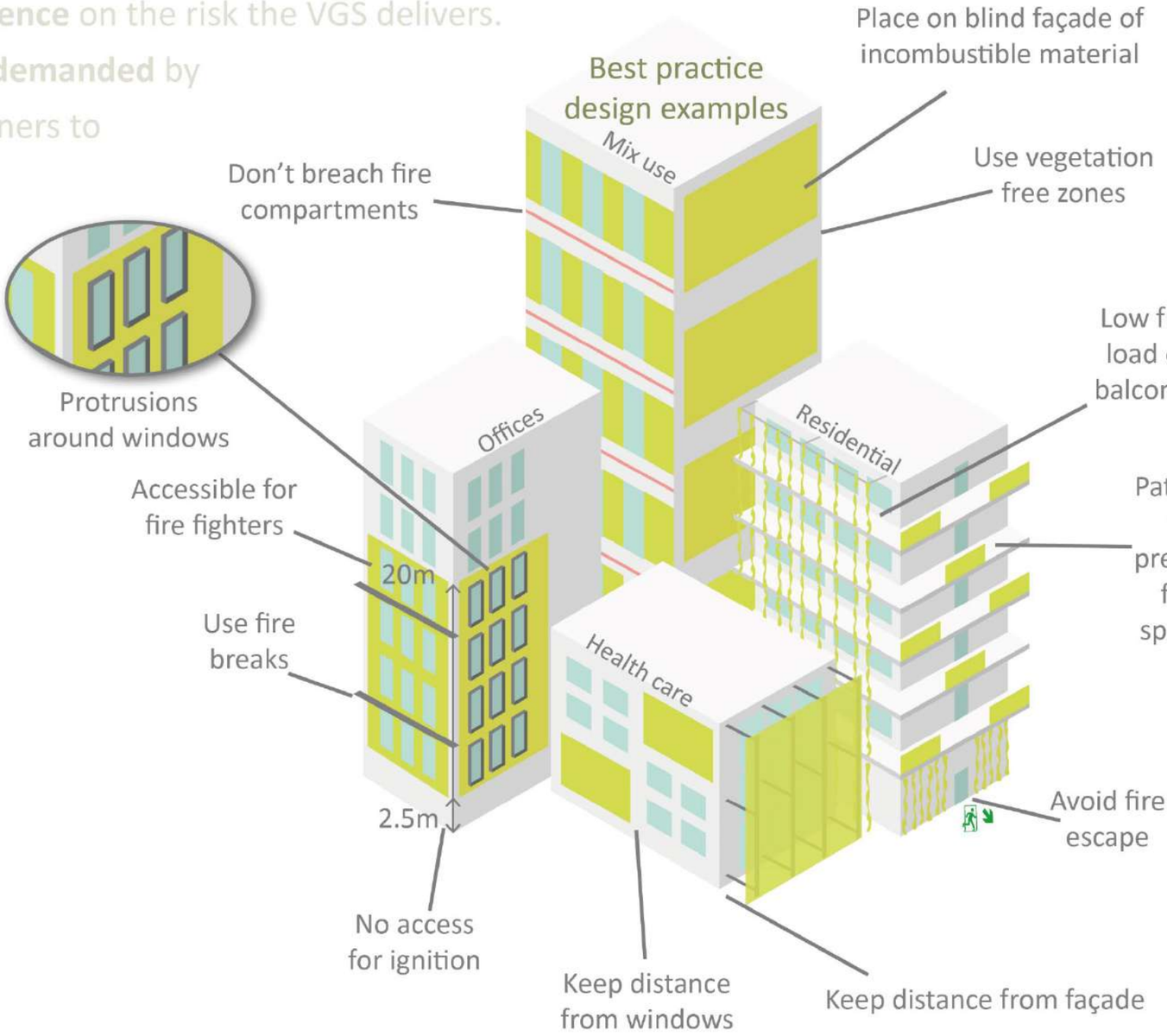
Input: design idea

Helps design process

Output: fire risk analysis and design advice

Conclusions

1. **Tests** performed to **classify VGS** are **inconsistent** and are not representative for the in practice application.
2. Further explorative testing is desired to determine when fire breaks or **vegetation free zones** work effectively.
3. The **materials** used in the systems are of **greater impact** on the fire behavior than the **vegetation**.
4. **Green façades** show significantly **lower risks** than Living Wall Systems **(LWS)**.
5. **Irrigation** does **not** guarantee **protection** from fire. Moisture slows down the fire, but does not prevent.
6. **Location** on the façade has **significant influence** on the risk the VGS delivers.
7. **Maintenance contracts** for LWS should be **demanded** by
8. A **risk analysis tool** can be **helpful** for designers to
9. **Concerns** about fire safety of VGS are **valid** but there are plenty situations and design options which minimise the risks.



Discussion and limitations

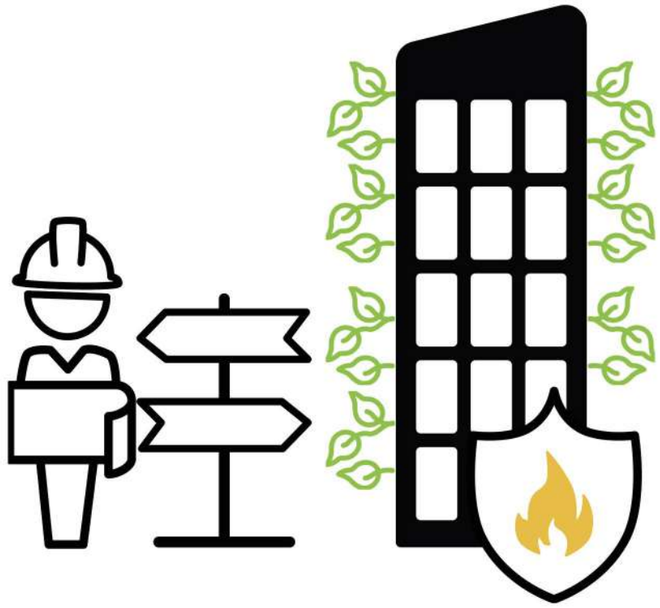
Limitations tools

- Choice of parameters
- Solutions in distances assumed
- Determining of acceptable risk
- Interdependencies between parameters

Future development tools

- User friendlier interface
- More interconnection between parameters
- Combine with sustainibility and costs
- Integrade in modeling programm, such as Rhino and Grasshoper

Thank you!



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