THERMAL COMFORT FOR MULTI-FUNCTIONAL USE IN MONUMENTAL CHURCH BUILDINGS

CASE-STUDY STEVENSKERK IN NIJMEGEN

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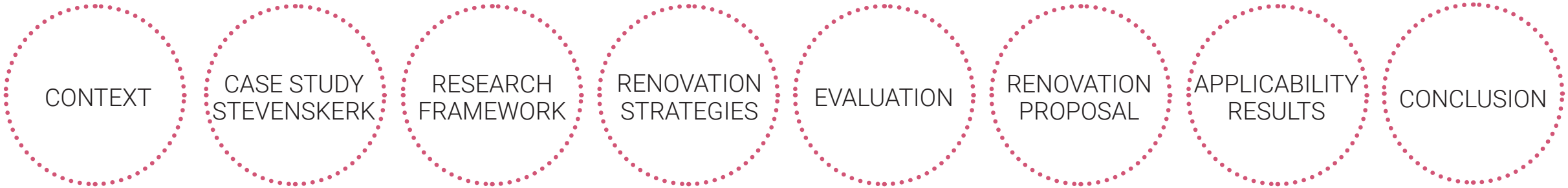
Second mentor: Dr. N. J. Clarke
Delegate: Drs. A. Mulder

Franziska Mack - 5366305

P5 Presentation
29th of June 2022
Graduation project Building Technology

OUTLINE PRESENTATION



CONTEXT

CONTEXT

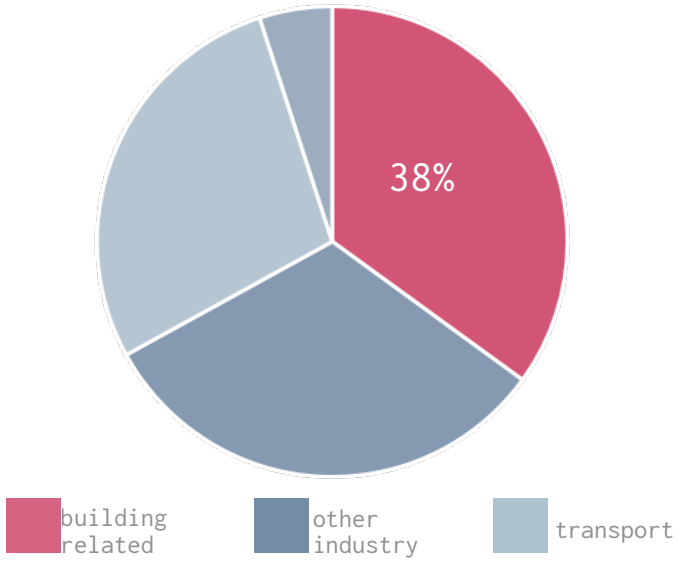
The climate and energy crisis

https://orf.at/stories/3221109/

https://www.themoscowtimes.com/2021/11/29/russias-aeroflot-posts-first-profit-since-start-of-coronavirus-a75691

CONTEXT

The role of the built environment for the climate crisis



SHARES OF WORDLWIDE CO2 EMISSIONS 2019

The greenest building is
...one that is already built

(Carl Elefante)

source: Global Alliance for Buildings and Construction. (2020). 2020 global status report for buildings and construction (Report).
source: Elefante, Carl. (2012). The Greenest Building Is... One That Is Already Built. Forum Journal. 27. 62-72.

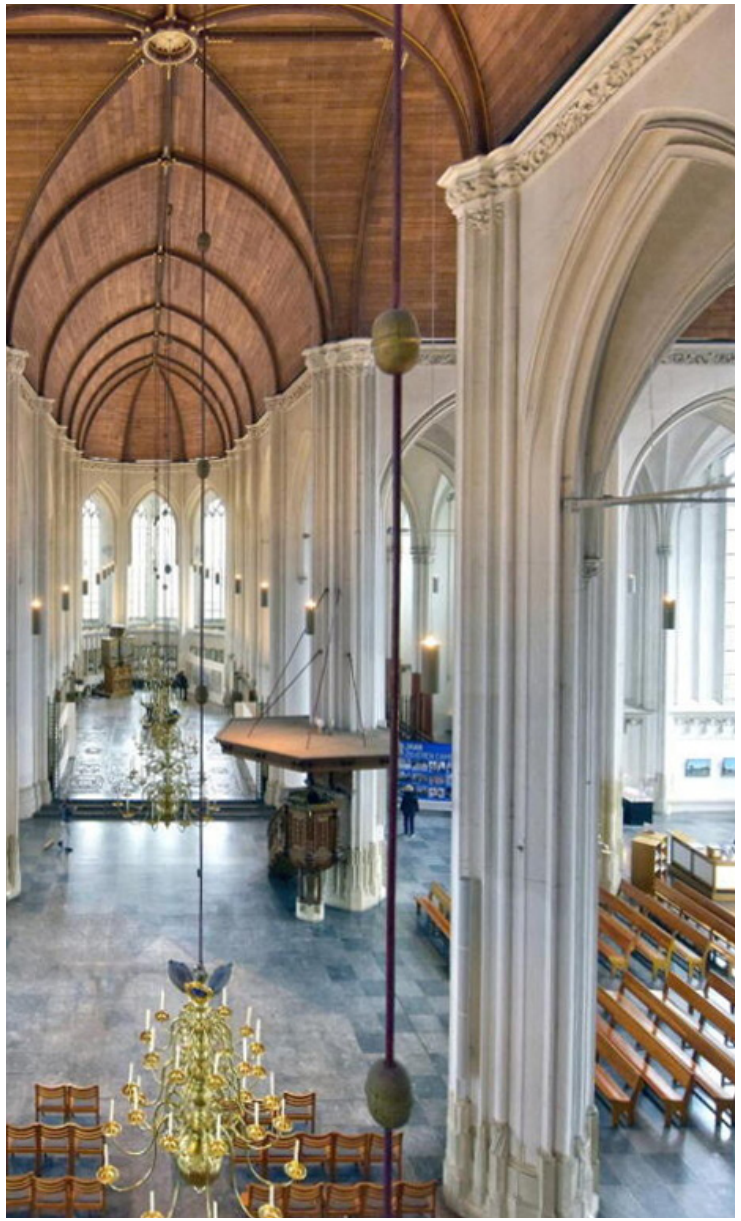
STEVENSKERK NIJMEGEN

STEVENSKERK

https://www.gelderlander.nl/nijmegen/toren-dicht-door-betonrot~adcafdfa/

https://www.intonijmegen.com/blijf-op-de-hoogte/verhaal/canon-van-nijmegen-de-stevenskerk

Instagram Stevenskerk



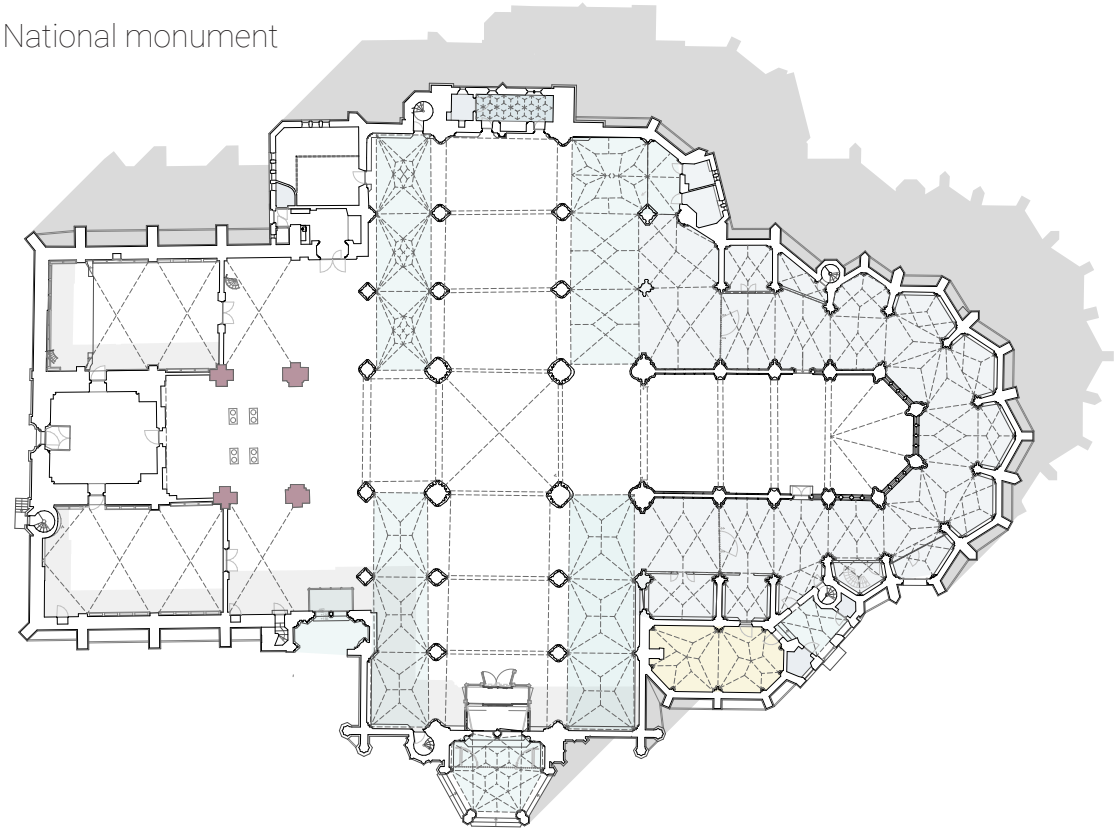
https://www.stevenskerk.nl/

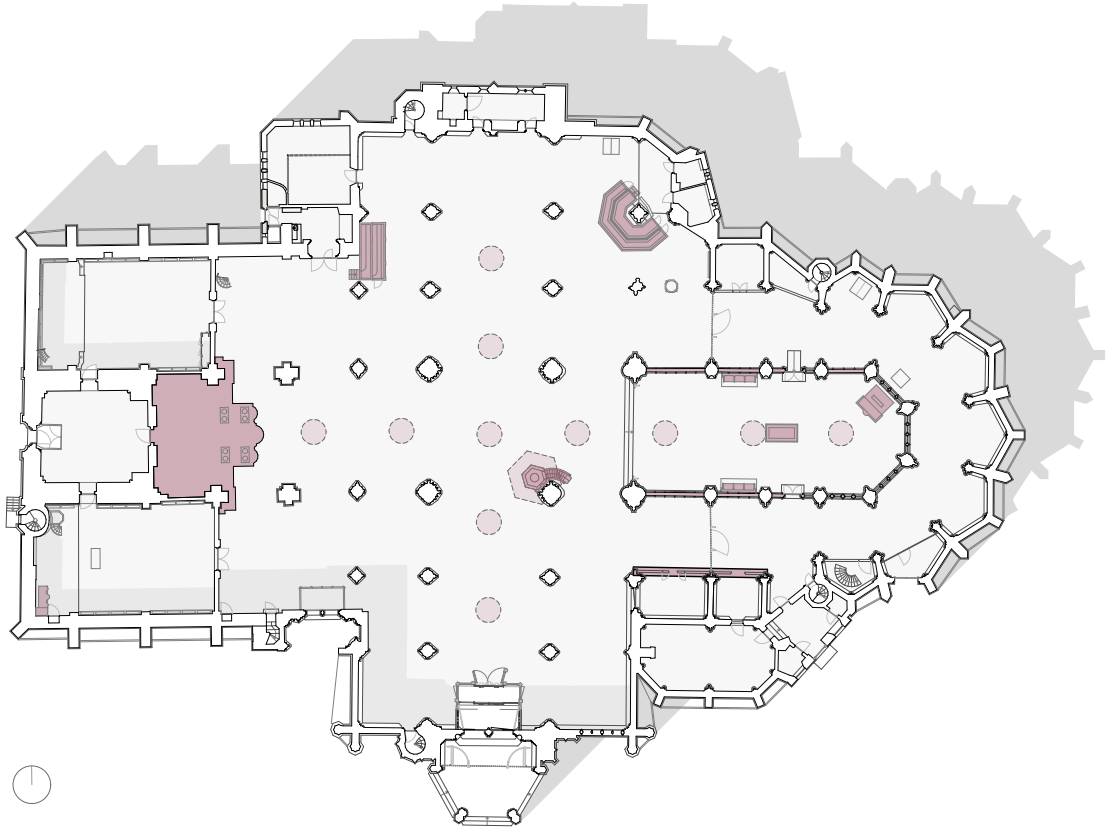
https://www.gelderlander.nl/nijmegen/rennen-door-de-kerk-toch-nog-een-stevens-stadscross-dit-jaar-de-inschrijving-is-gestart

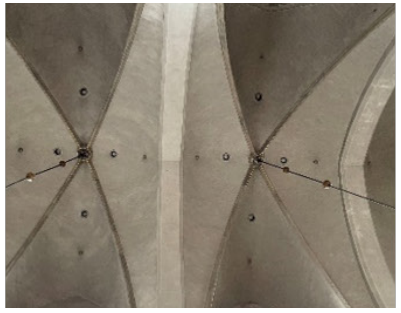
THERMAL DISCOMFORT

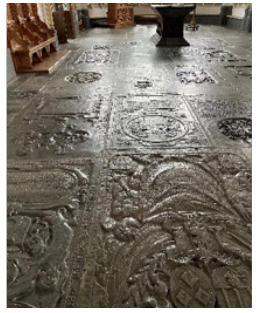
STEVENSKERK

National monument





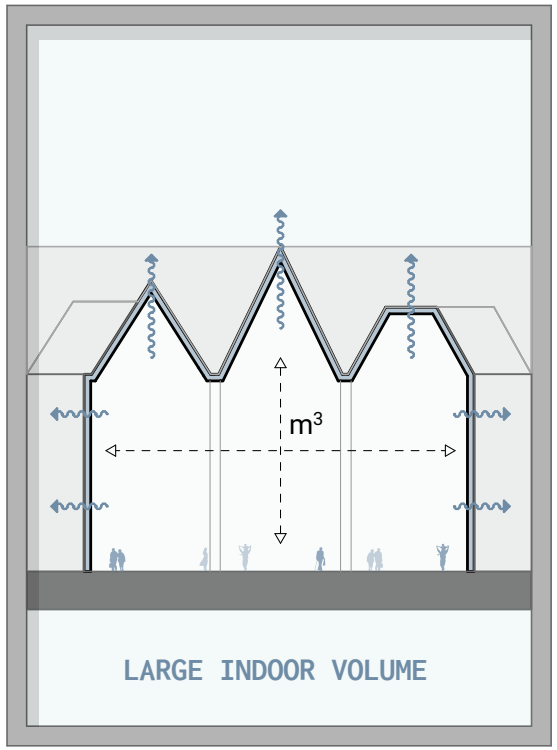


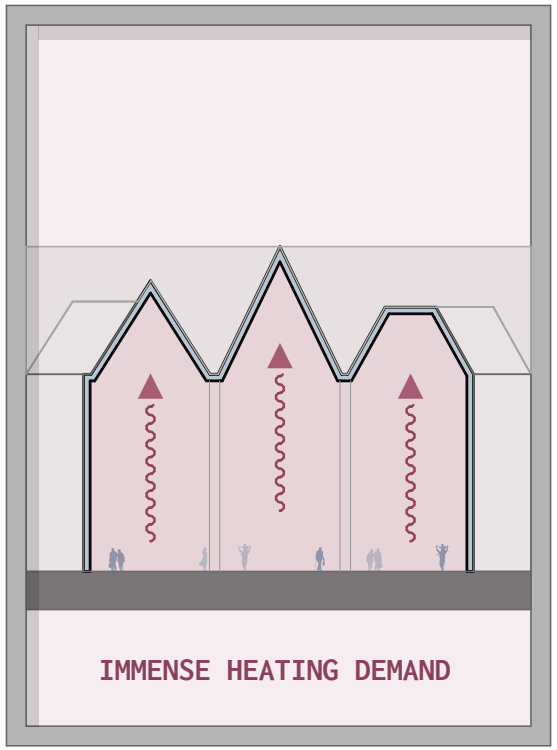


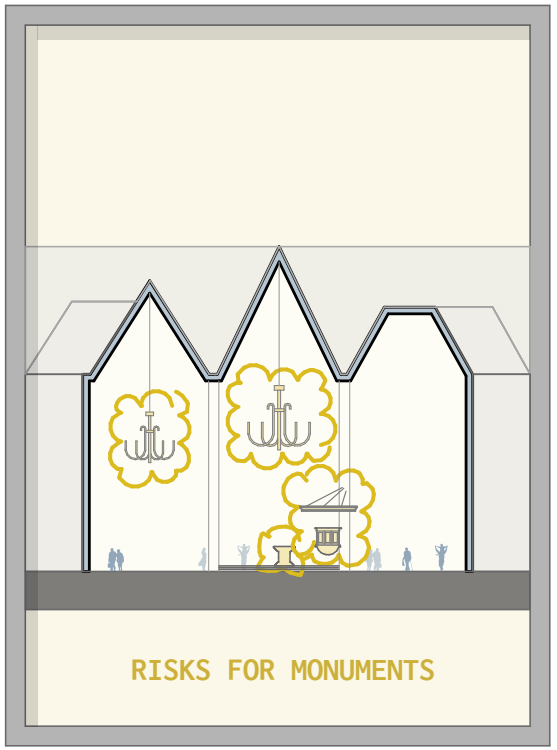
RESEARCH FRAMEWORK

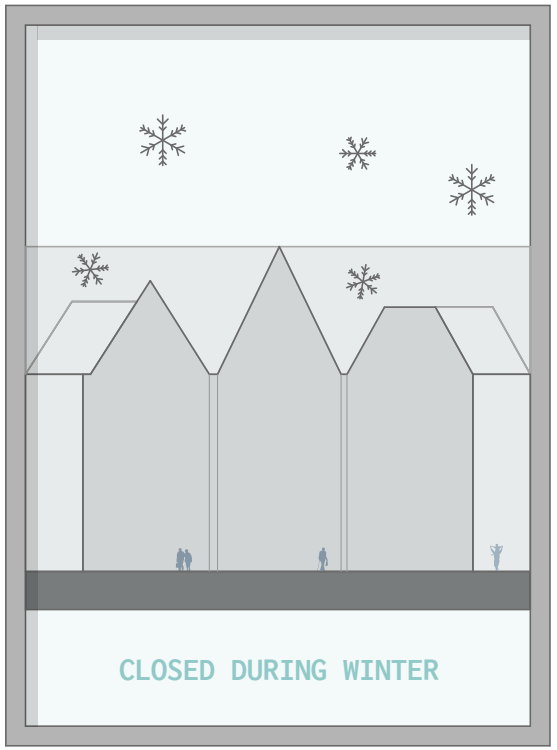
RESEARCH FRAMEWORK

Problem statement





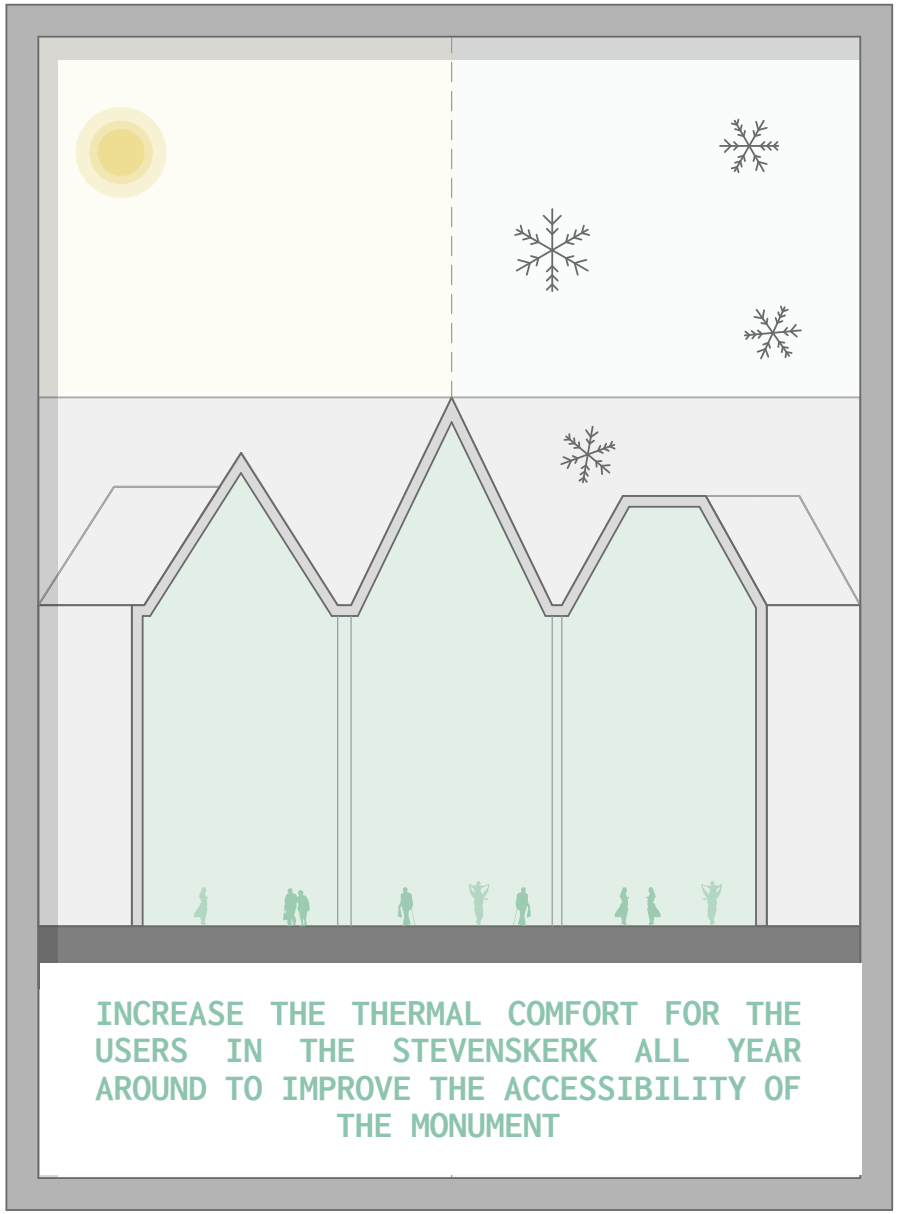




Thermal discomfort in the Stevenskerk due to heat losses and a large indoor volume resulting in a high heating demand, a harmful environment for monuments and a closed church during the winter.

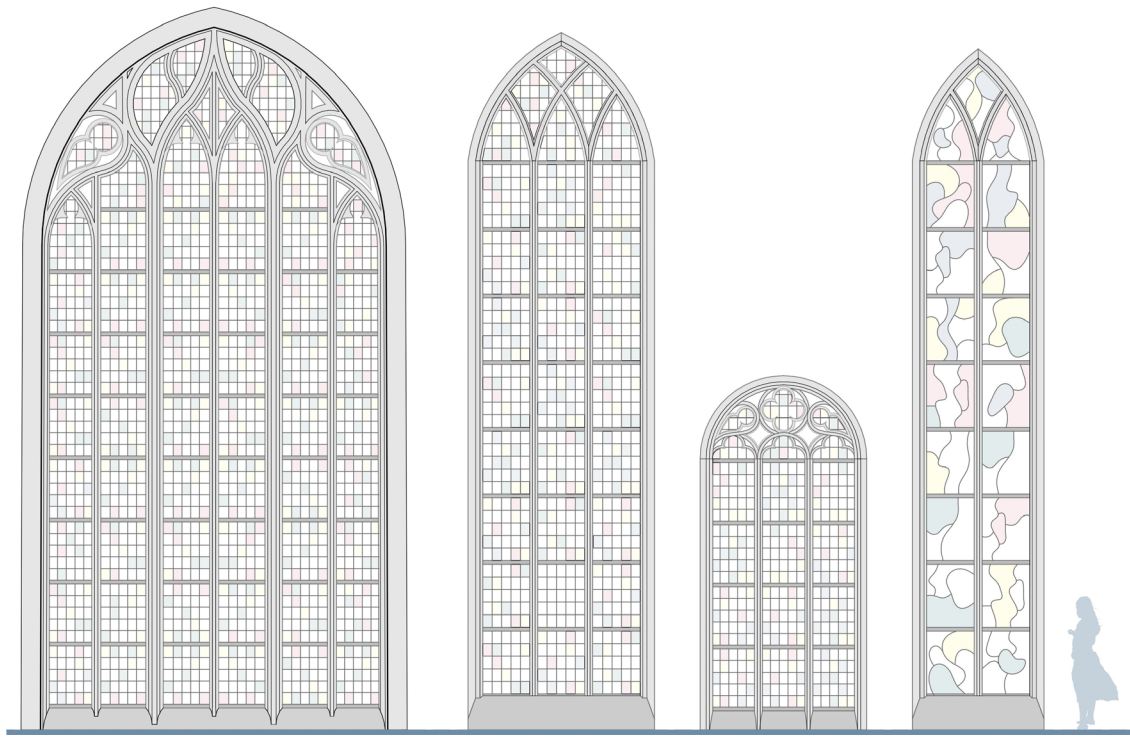
RESEARCH FRAMEWORK

Main research objective

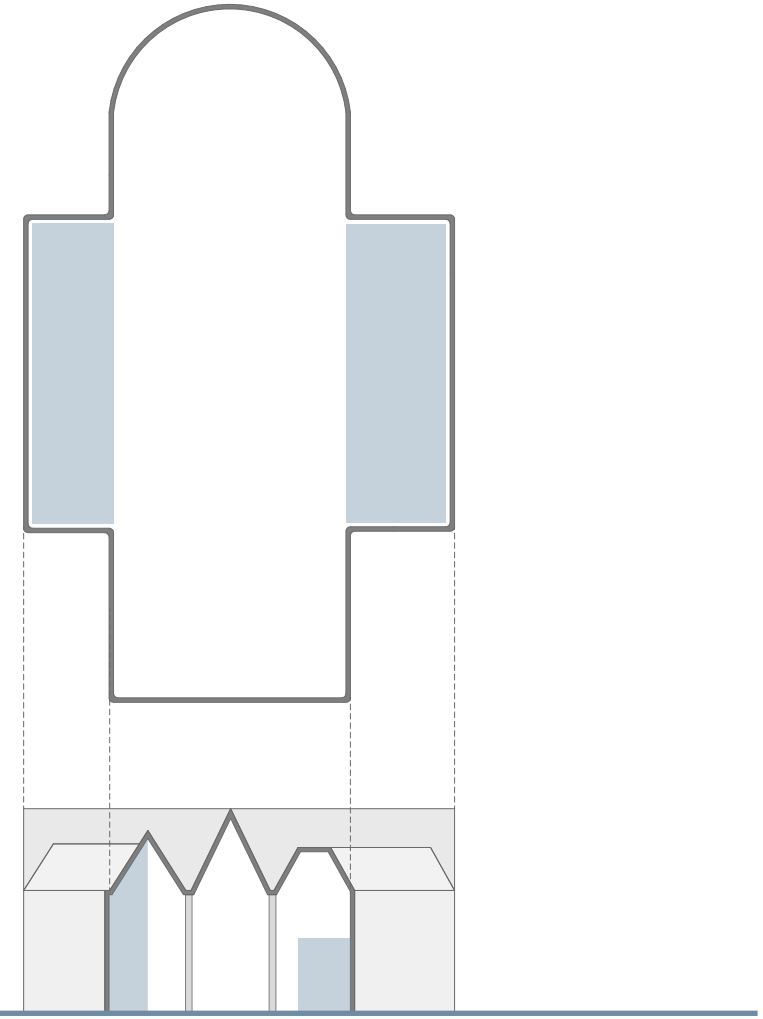


RESEARCH FRAMEWORK

Focus and restrictions



STAINED GLASS WINDOW RENOVATION



SPATIAL INDOOR ADAPTATIONS

RESEARCH FRAMEWORK

Main research question

«How can the renovation of the stained glass windows in combination with indoor space adaptations increase the thermal comfort in the multi-functional Stevenskerk in order to improve the accessibility of the monument all year around?»

RESEARCH FRAMEWORK

Process

LITERATURE STUDY &
VISIT STEVENSKERK

DEFINE PROBLEM STATEMENT
& RESEARCH QUESTION

LITERATURE REVIEW &
CASE-STUDIES &
RESEARCH BY DESIGN

OVERVIEW & DEVELOPMENT
RENOVATION STRATEGIES

RESEARCH FRAMEWORK

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MEASUREMENTS STEVENSKERK
CALCULATION MODELS
THERMAL SIMULATIONS

DATA COLLECTION &
ASSESSMENT STRATEGIES

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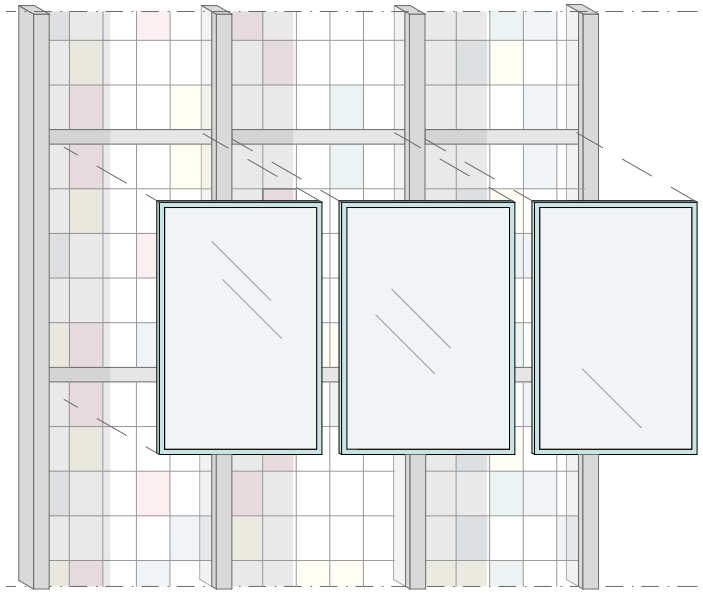
FINAL OUTCOME

COMPARATIVE OVERVIEW
RENOVATION PROPOSAL

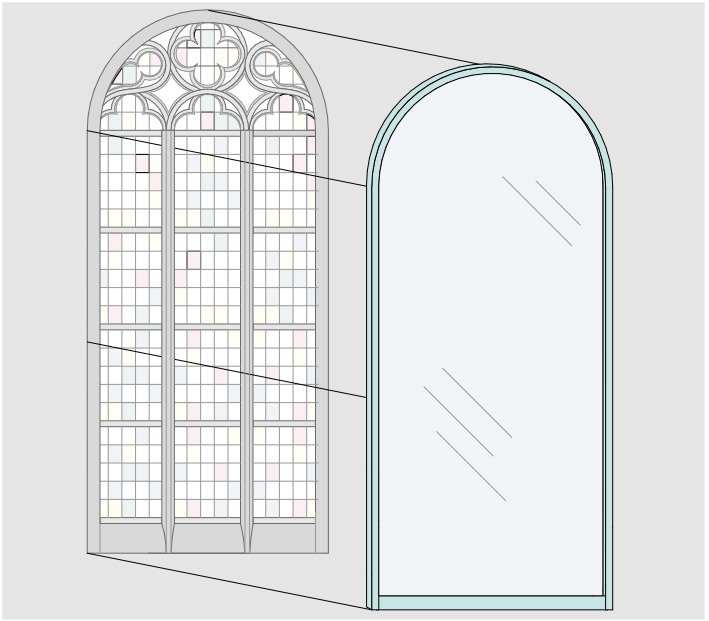
RENOVATION STRATEGIES

RENOVATION STRATEGIES

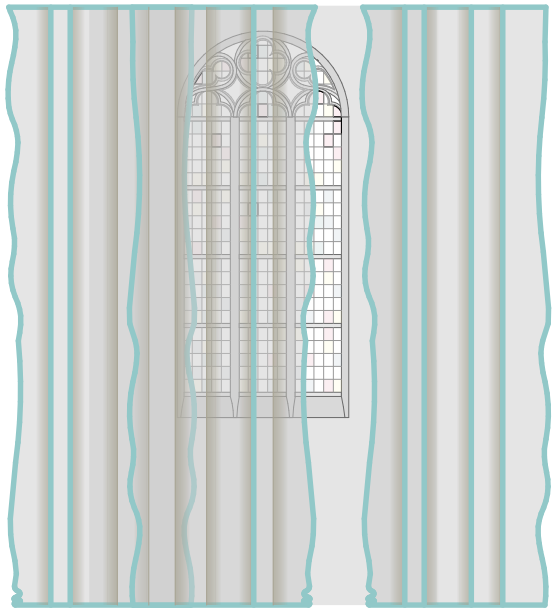
Window renovation



PROTECTIVE GLAZING VARIATIONS



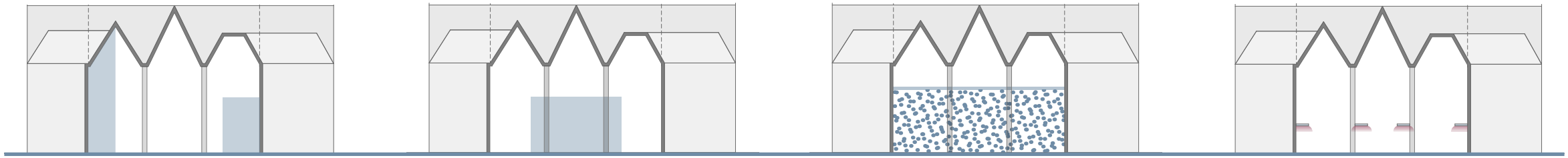
INTERNAL SECONDARY WINDOW



TEXTILE APPLICATION - CURTAIN

RENOVATION STRATEGIES

Spatial adaptation



FLOORPLAN ADAPTATION

BOX IN BOX

INDOOR VOLUME DIVISION

LOCAL HEATING

ASSESSMENT OF THE RENOVATION STRATEGIES

RENOVATION STRATEGY ASSESSMENT

Performance criteria

1 - Functionality
Flexible & Multi-functional
Café / Shop
Office
Church

2 - Floor area
Very large (>200 m2)
Limited (60 - 200 m2)
Very limited (<60 m2)

3 - Use cycle
Irregular use
Regular use
Frequent use

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THERMAL COMFORT & HEATING DEMAND

WINDOW RENOVATION
1 - Window insulation
2 - Scenario performance
3 - Facade insulation
4 - Airtightness facade

SPATIAL ADAPTATION
1 - Air velocity
2 - MRT
3 - PMV
4 - Heating demand

RENOVATION STRATEGY ASSESSMENT

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SPATIAL ADAPTATION
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HERITAGE VALUES

1 - Inventory
2 - Stained glass
3 - Exterior values
4 - Interior values
5 - Reversibility

LIFE-CYLCLE & DURABILITY

1 - Lifespan
2 - Maintenance
3 - Embodied Carbon
4 - Circularity

FINANCE

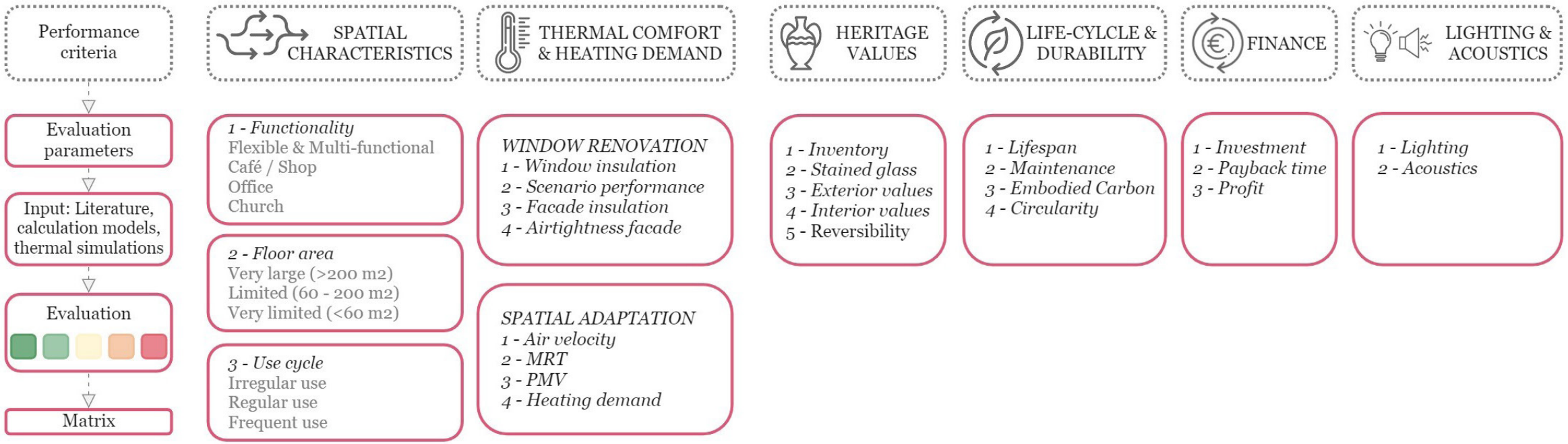
1 - Investment
2 - Payback time
3 - Profit

LIGHTING & ACOUSTICS

1 - Lighting
2 - Acoustics

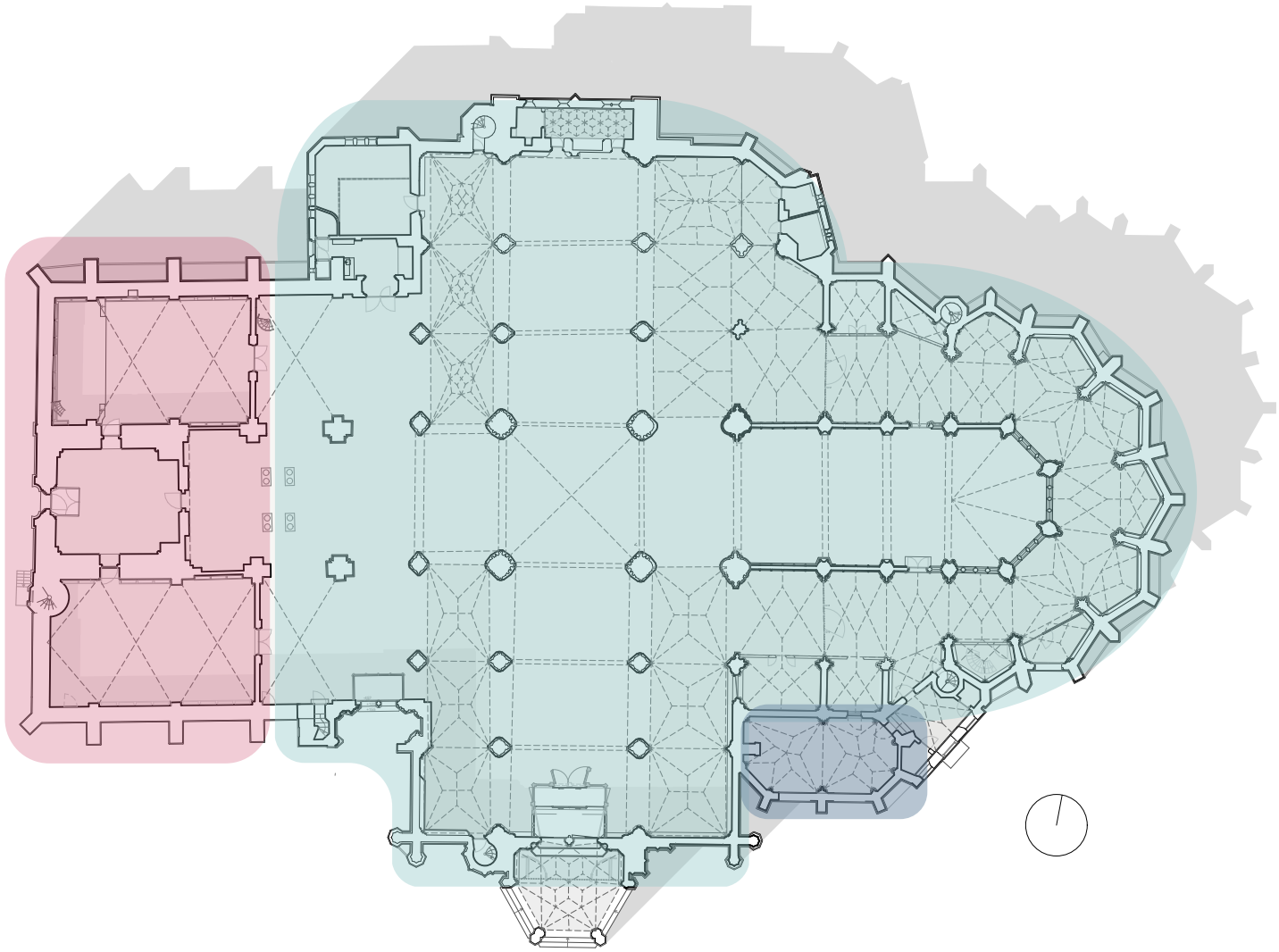
RENOVATION STRATEGY ASSESSMENT

Performance criteria



RENOVATION PROPOSAL STEVENSKERK

STEVENSKERK NIJMEGEN

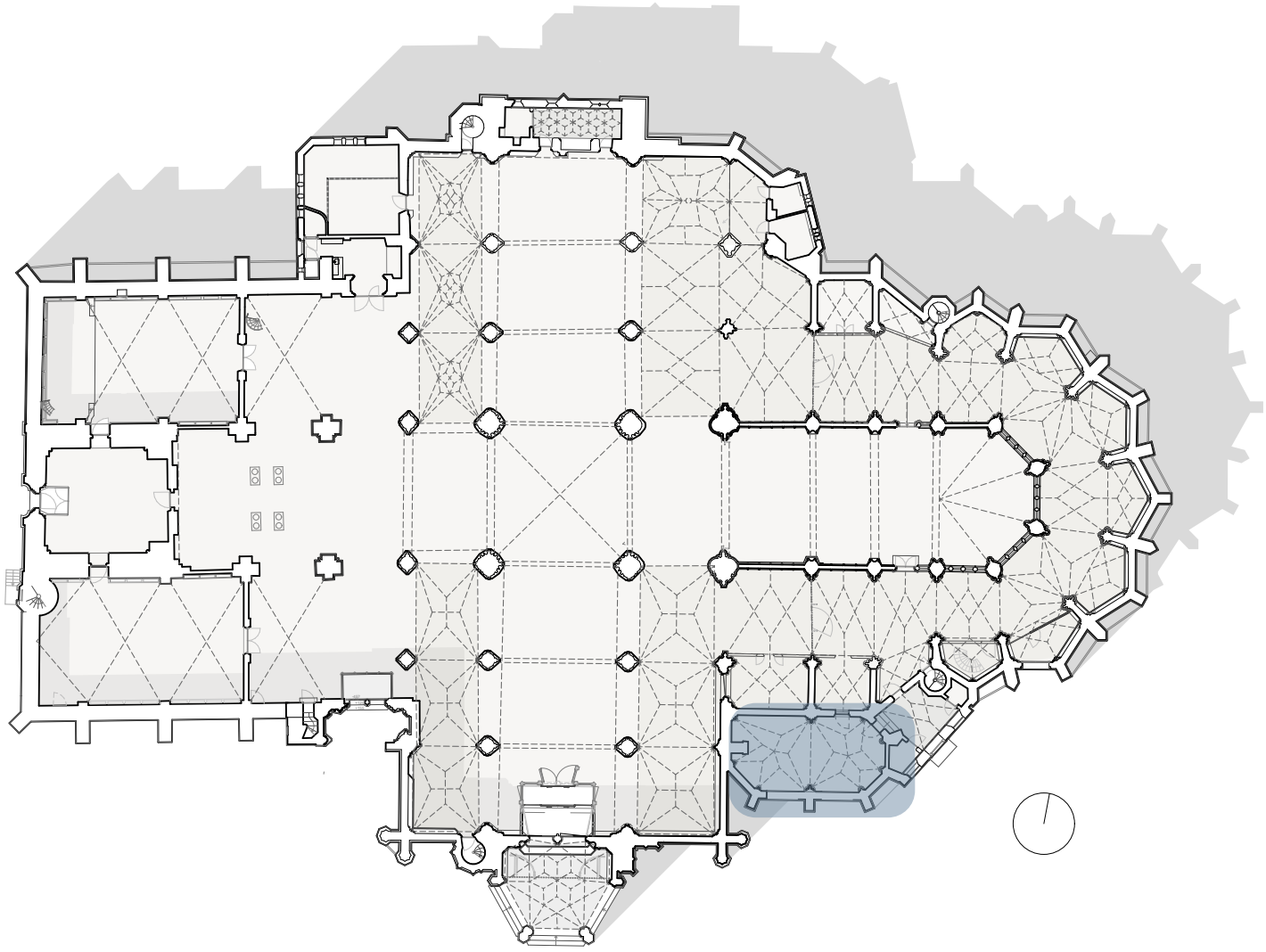


LARGE CHURCH SPACE

SIDE CHAPELS

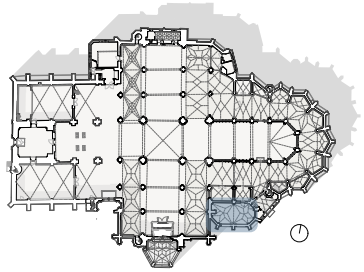
GERFKAMER

GERFKAMER



GERFKAMER

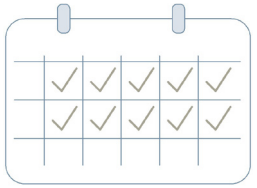
Spatial characteristics

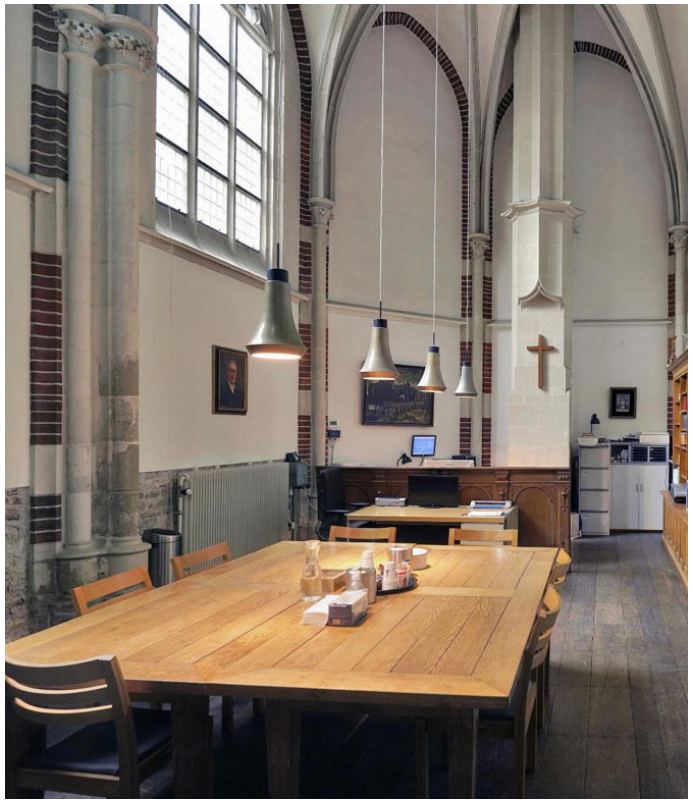


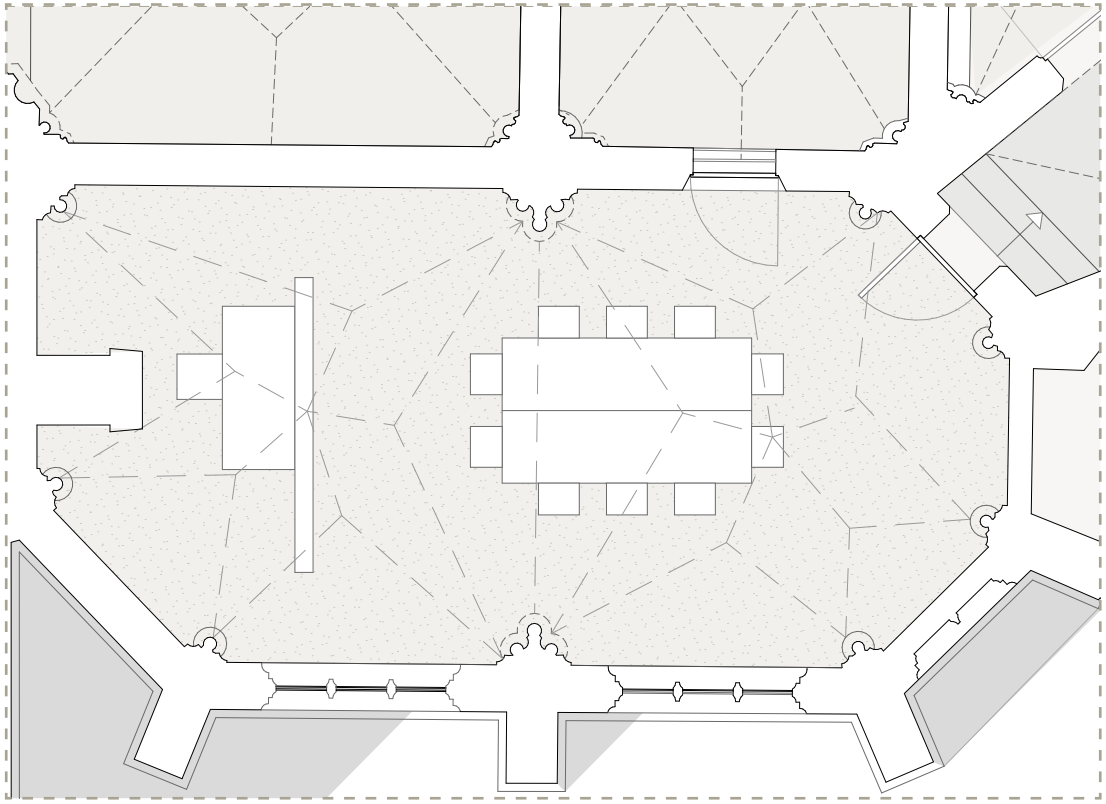
OFFICE USE

LIMITED FLOOR AREA

REGULAR USE-CYCLE

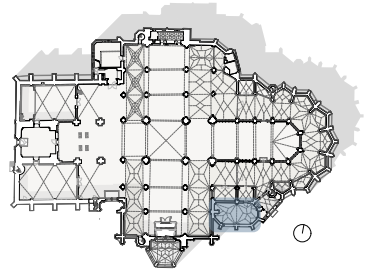




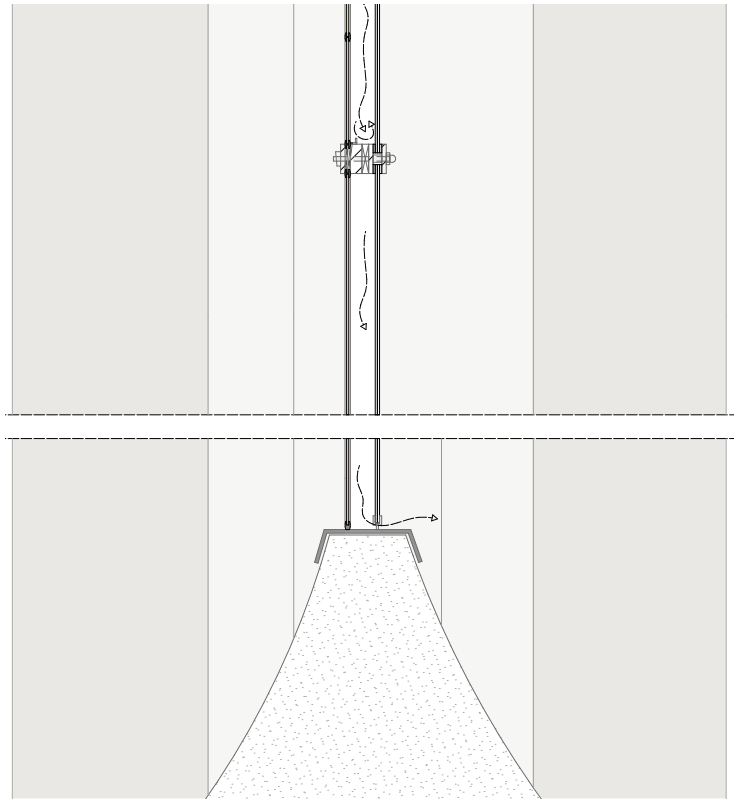


GERFKAMER

Windows with protective glazing



GERFKAMER SOUTH FACADE

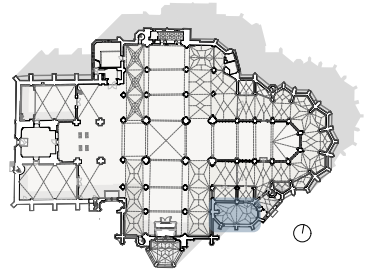


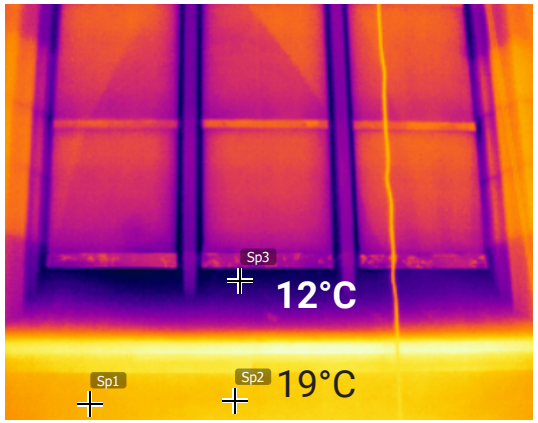
DETAIL PROTECTIVE GLAZING

VISUAL INTEGRATION PG

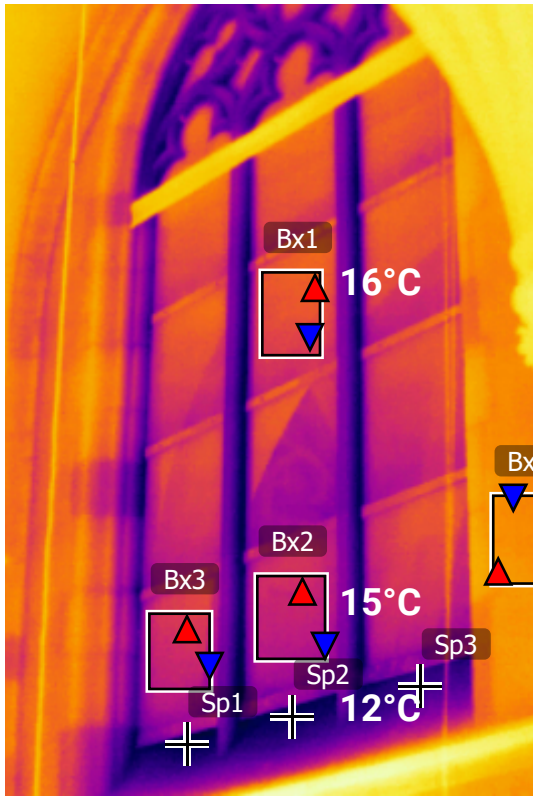
GERFKAMER

Window assessment





10°C 22°C

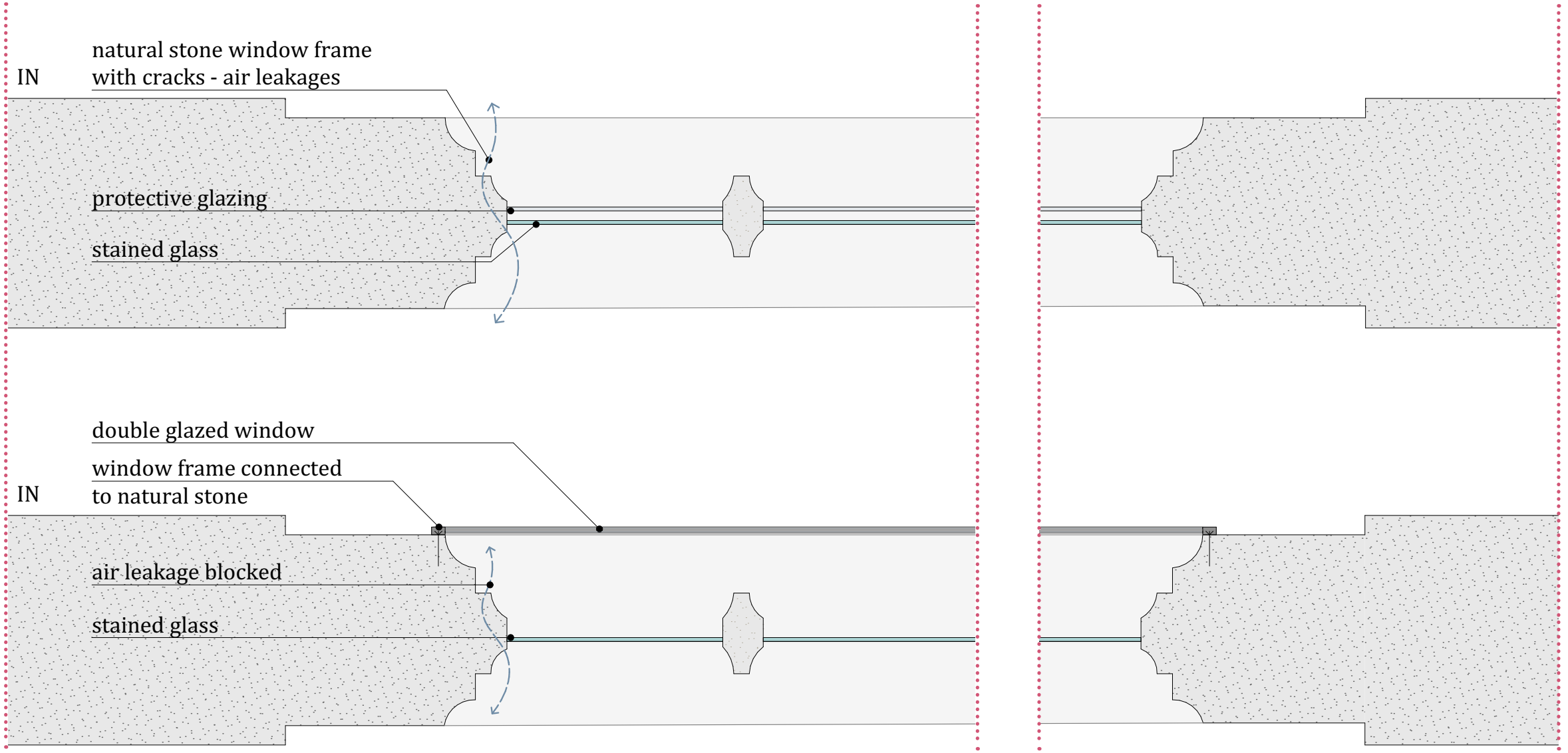


THERMOGRAPHY
ANALYSIS PROTECTIVE GLAZING GERFKAMER

THERMAL BRIDGE
REDUCED WALL THICKNESS

OUTSIDE AIR INFILTRATION
THROUGH CRACKS

INTERNAL SECONDARY WINDOW



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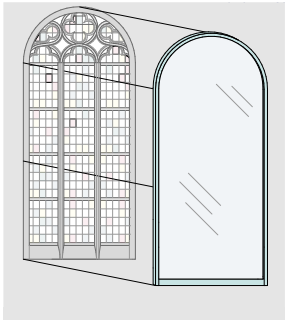
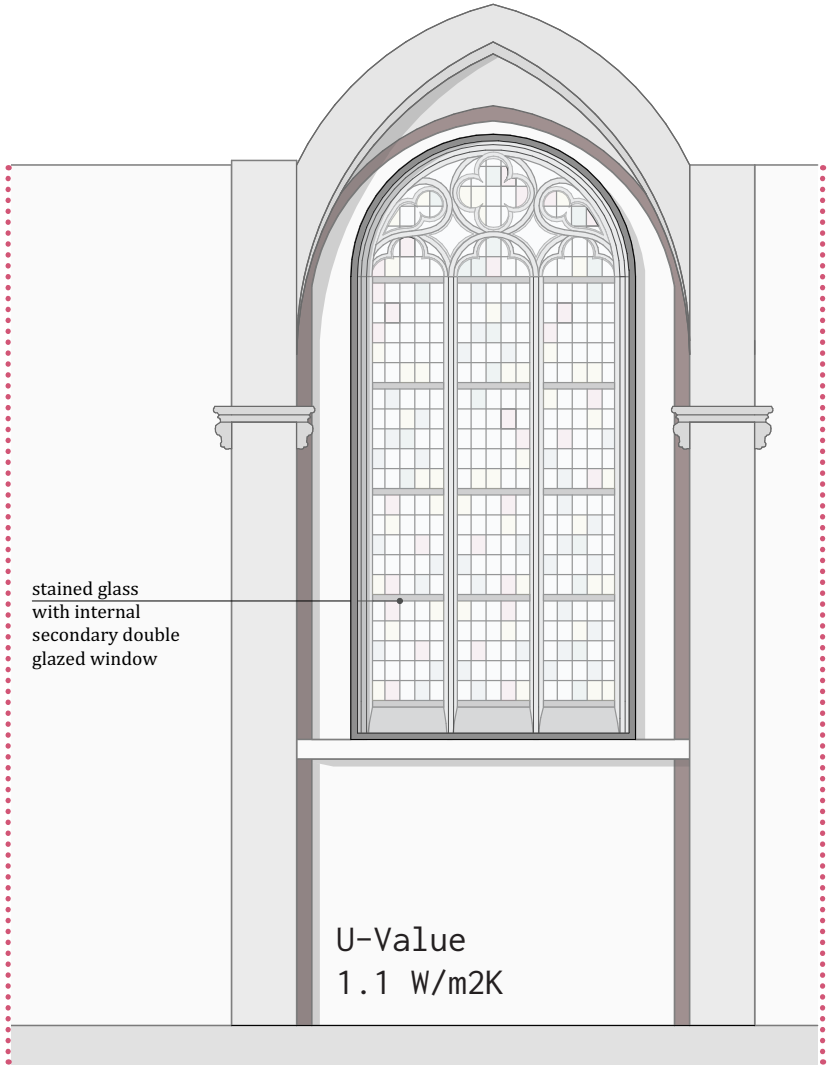
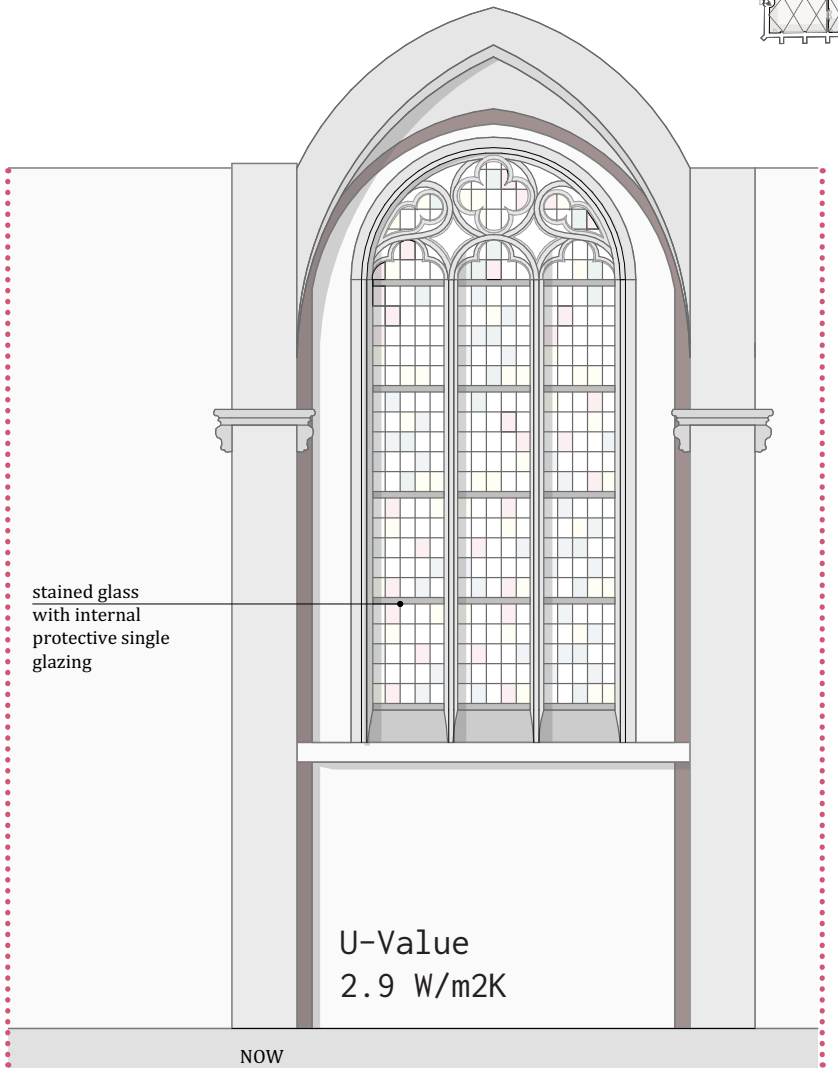
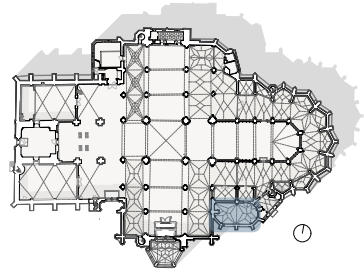
Internal secondary window

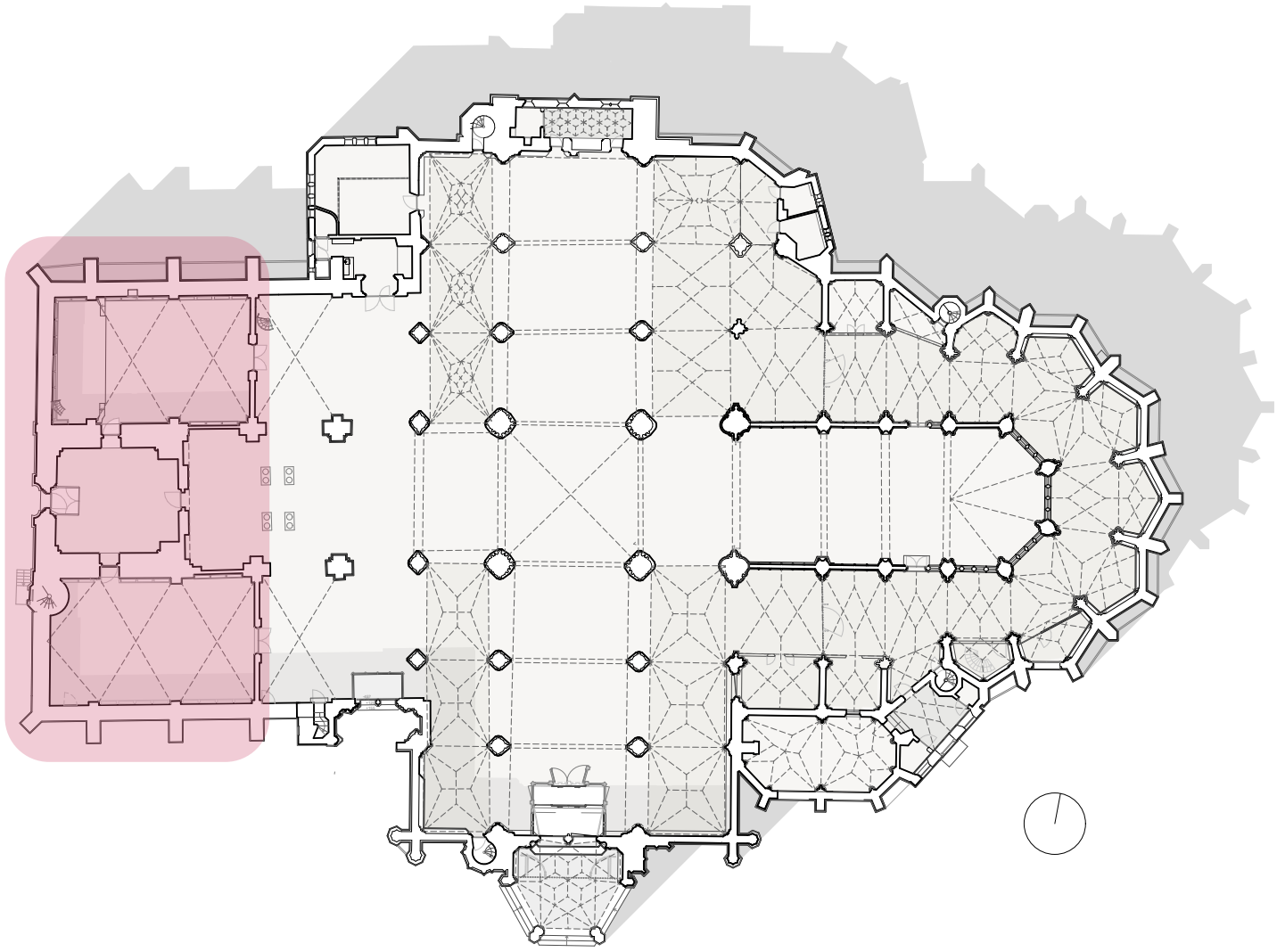






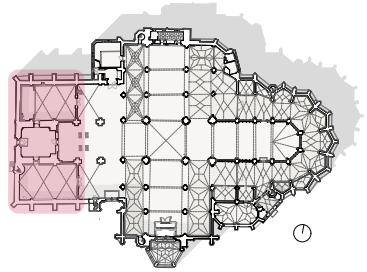


SIDE CHAPELS



SIDE CHAPELS

Spatial characteristics

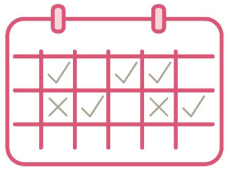


South chapel

MULTI-FUNCTIONAL

LIMITED FLOOR AREA

IRREGULAR USE-CYCLE

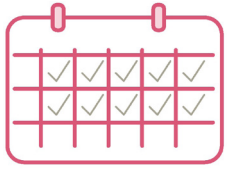


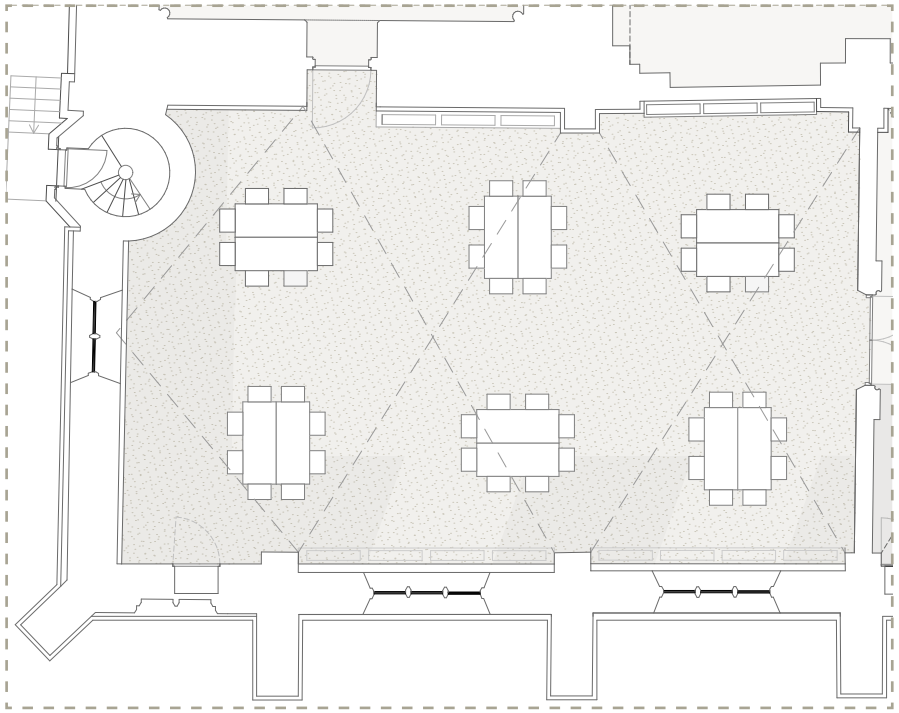
North chapel

CAFE & SHOP

LIMITED FLOOR AREA

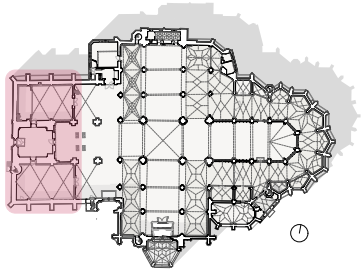
REGULAR USE-CYCLE

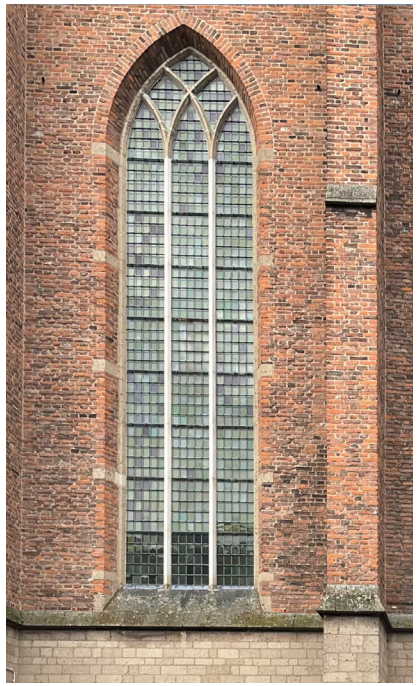




SIDE CHAPELS

Assessment protective glazing





WINDOW SIDE CHAPELS

INTERNAL PG

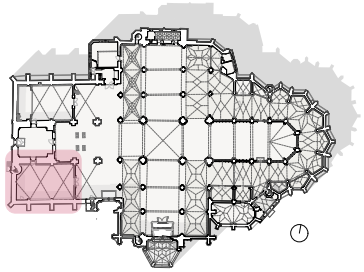
SMOKE TEST - DRAFT

VENTILATED CAVITY

CLOSED CAVITY

SOUTH CHAPEL

Experimental measurements

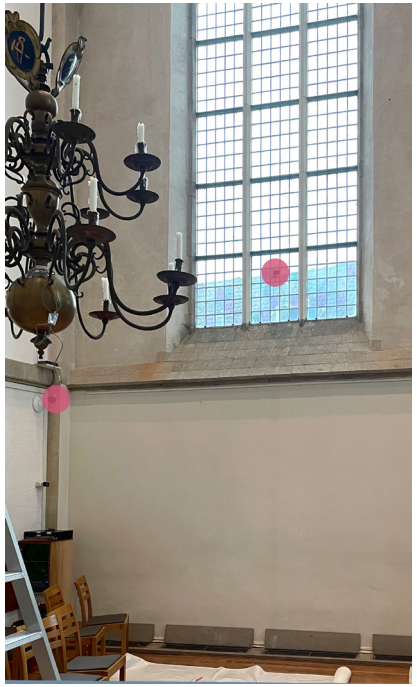


Data loggers

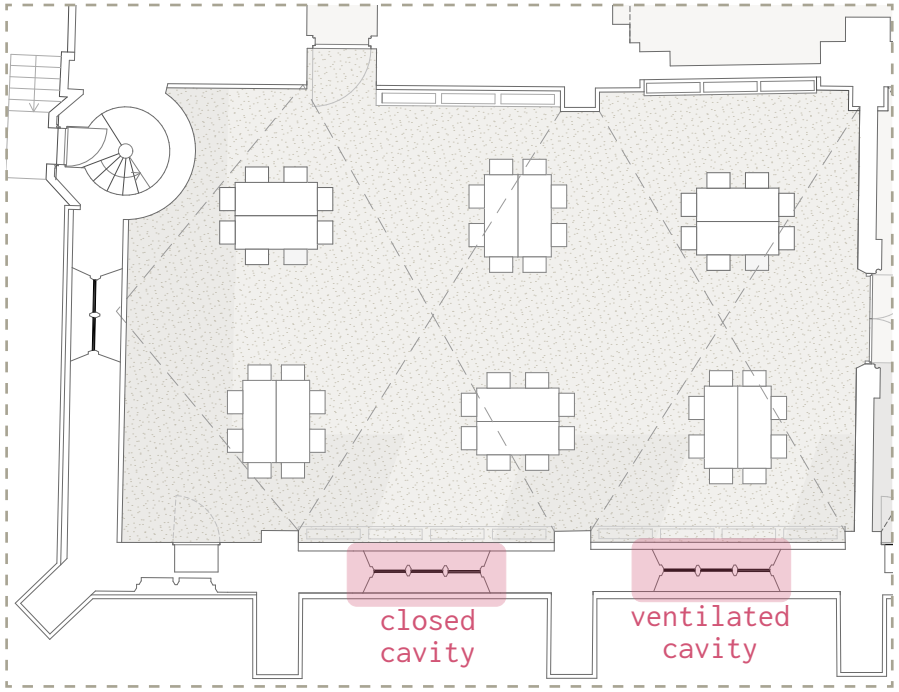
closed cavity

ventilated cavity

PLACEMENT LOGGERS CLOSED CAVITY WINDOW
TEMPERATURE GLASS OUTSIDE & INSIDE & CAVITY

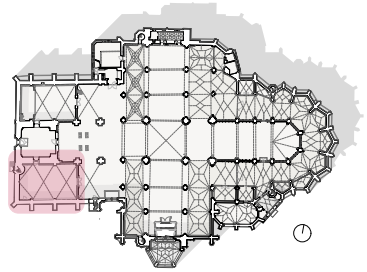


PLACEMENT LOGGERS
MRT & OPEN CAVITY



SOUTH CHAPEL

Experimental measurements



closed cavity

MEASURED

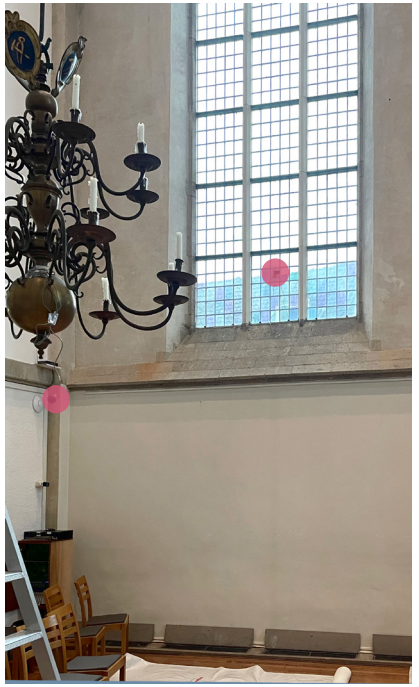
AVERAGE RH: 74 %

PLACEMENT LOGGERS CLOSED CAVITY WINDOW
TEMPERATURE GLASS OUTSIDE & INSIDE & CAVITY

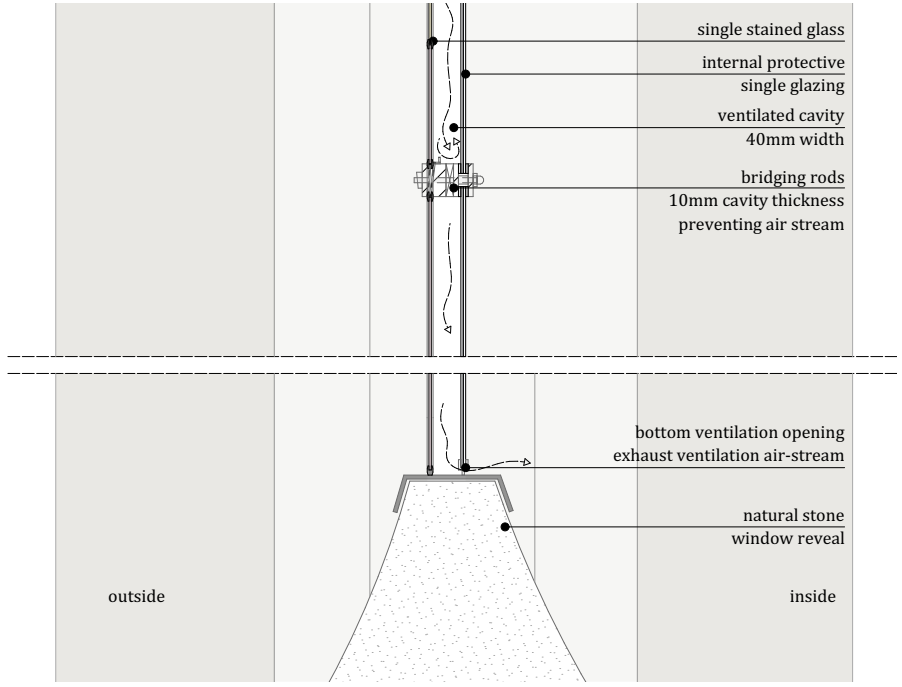
ventilated cavity

MEASURED

AVERAGE RH: 71 %



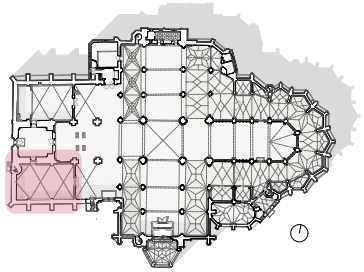
PLACEMENT LOGGERS
MRT & OPEN CAVITY



DETAIL INTERNAL PROTECTIVE GLAZING
CAVITY VENTILATED WITH INDOOR AIR

SOUTH CHAPEL

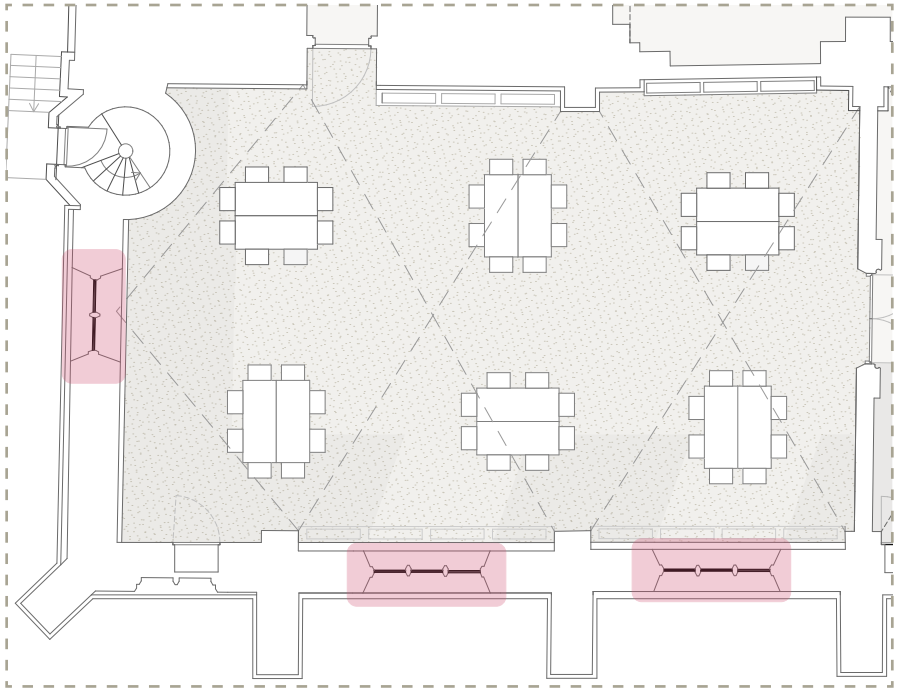
Experimental measurements - conclusion / recommendation



CLOSED CAVITY

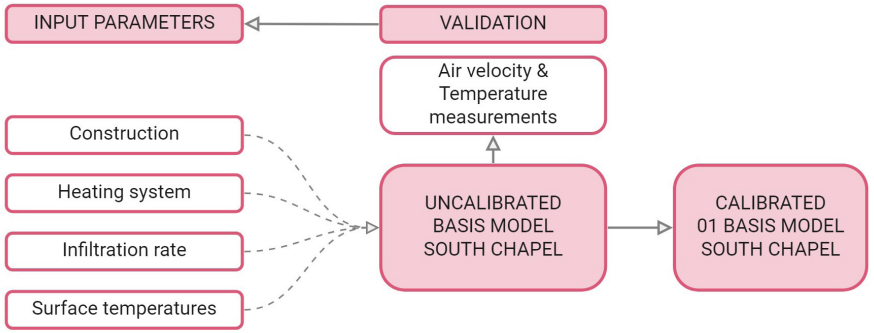
improved thermal performance

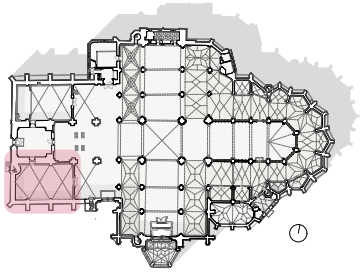
FURTHER OBSERVATION & CONDENSATION RISK ASSESSMENT

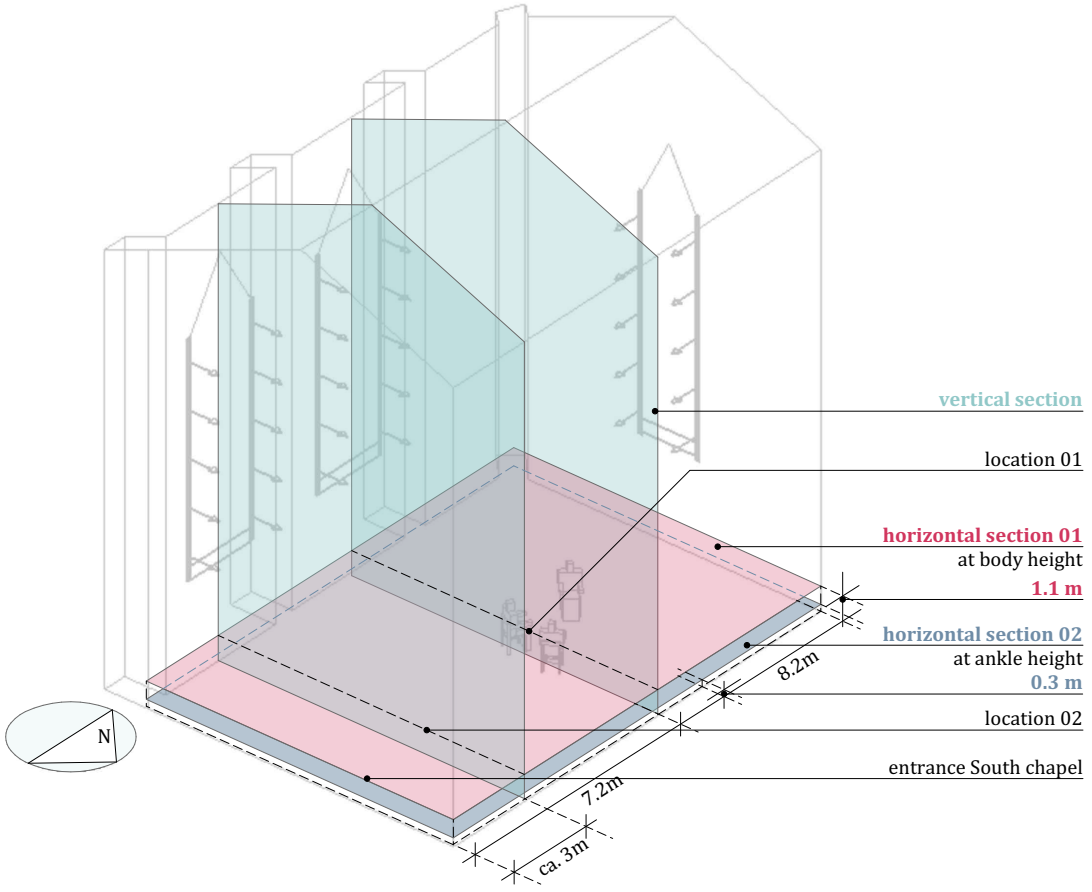


SOUTH CHAPEL

Design Builder simulations for thermal comfort assessment

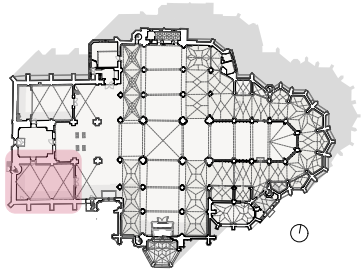


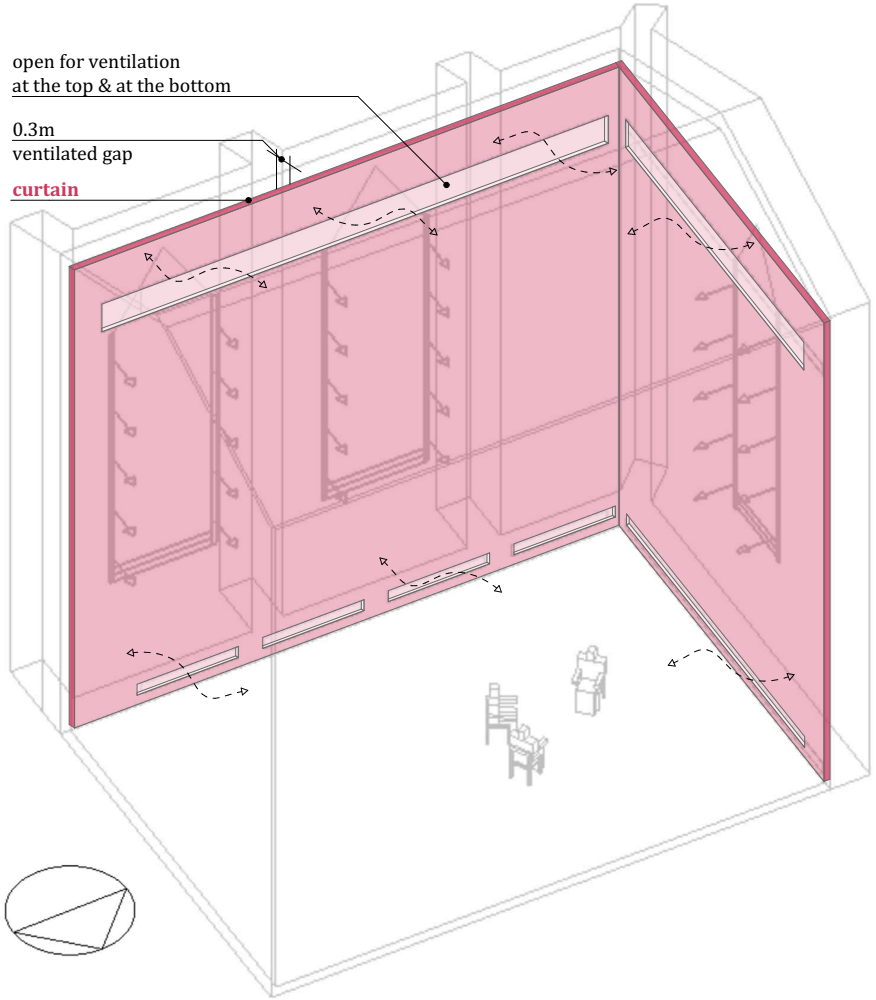


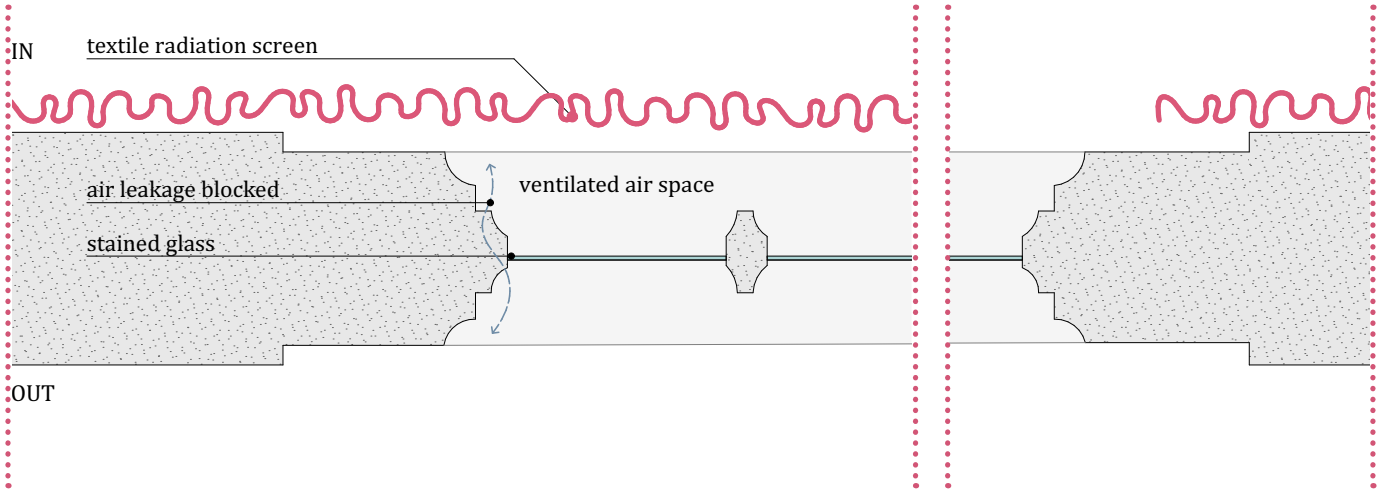


SOUTH CHAPEL

Design Builder simulations curtain as radiation screen

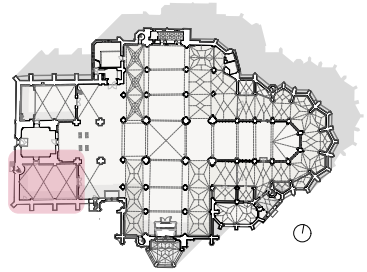




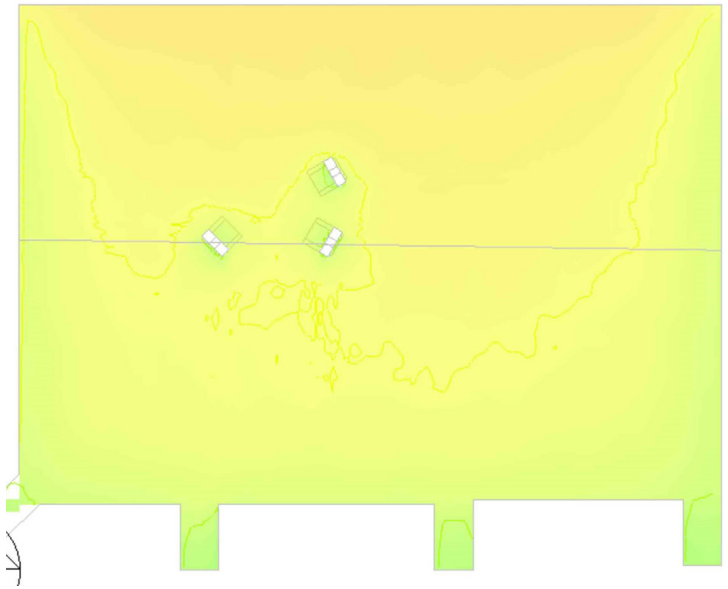


SOUTH CHAPEL

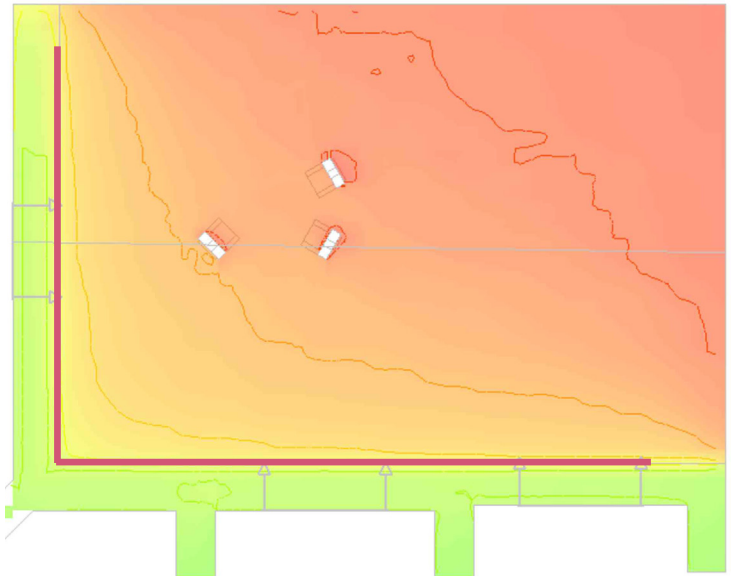
Simulation Mean Radiant Temperature with curtain as radiation screen
Horizontal section diagram at 1 m height



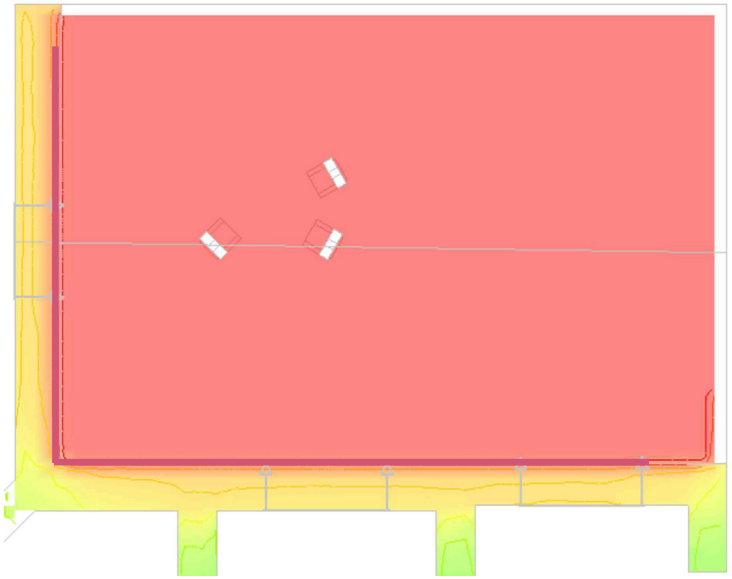
BASIS MODEL - SITUATION NOW



TRANSLUCENT FABRIC AS RADIATION SCREEN



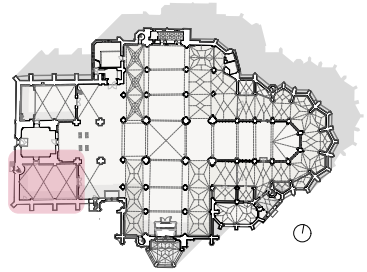
OPAQUE FELT FABRIC AS RADIATION SCREEN



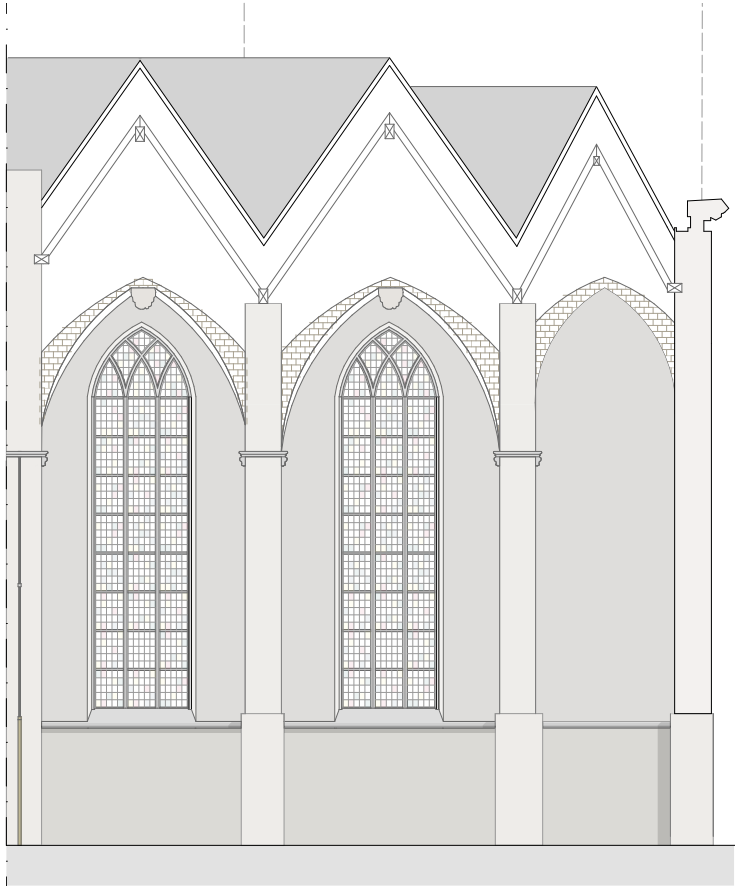
MRT °C

SOUTH CHAPEL

Curtain - Adaptability space



SOUTH CHAPEL NOW

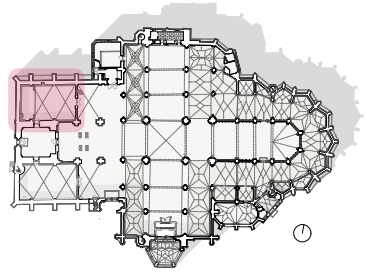


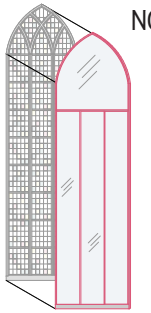
SOUTH CHAPEL WITH CURTAIN - EXHIBITION

SOUTH CHAPEL WITH CURTAIN - CALM SPACE

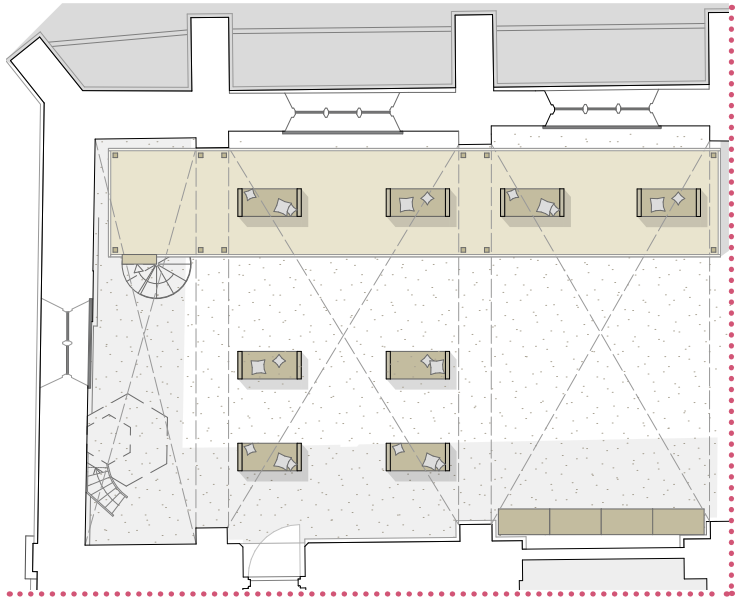
NORTH CHAPEL

Regular use as cafe and shop

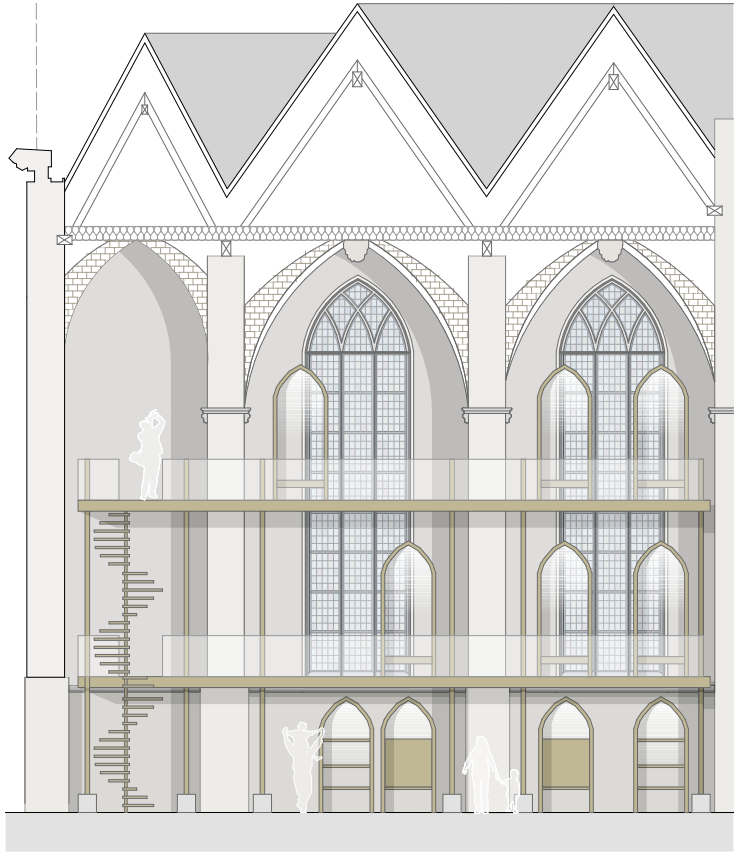




NORTH CHAPEL FLOORPLAN WITH WALKWAY & SECONDARY INTERNAL WINDOWS

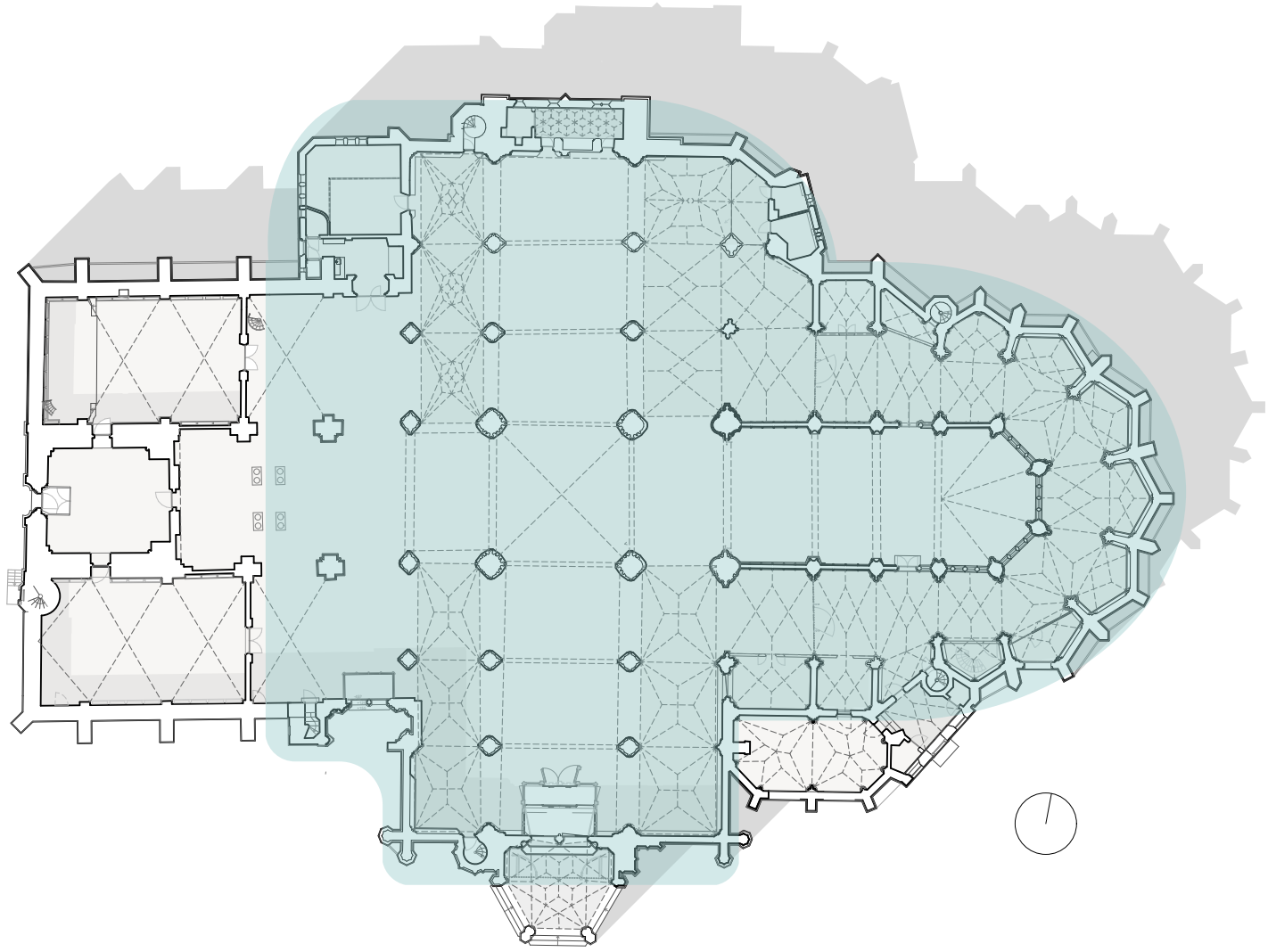


NORTH CHAPEL WITH WALKWAY



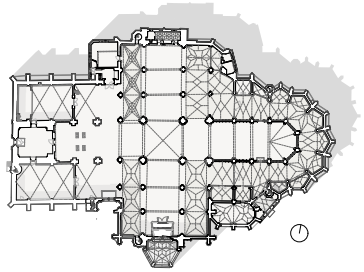
NORTH CHAPEL WITH WALKWAY

LARGE CHURCH SPACE



GERFKAMER

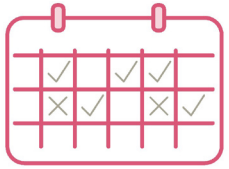
Spatial characteristics



MULTI FUNCTIONAL

VERY LARGE AREA

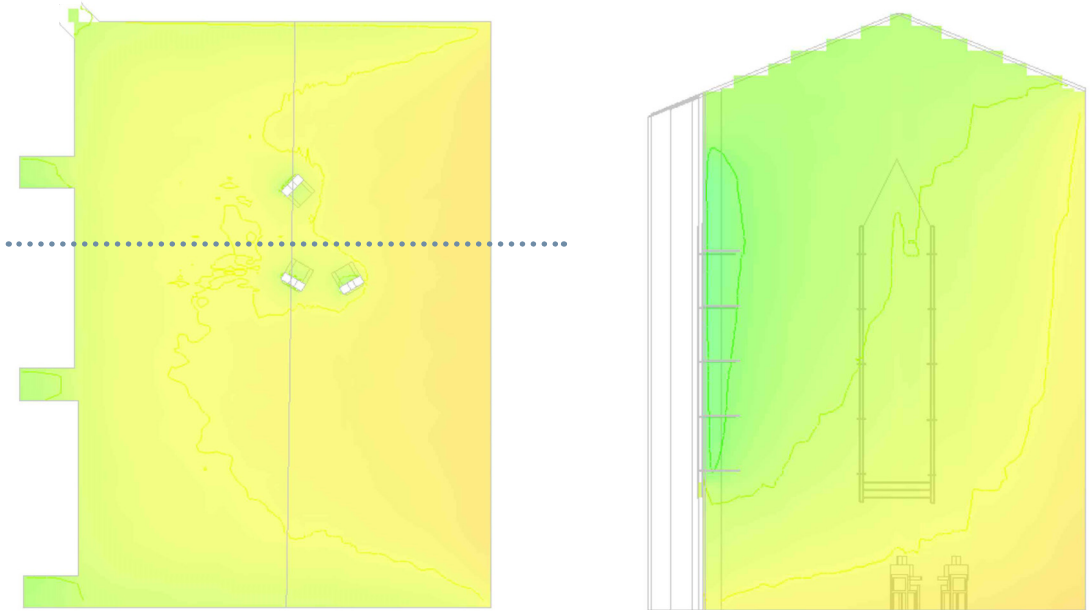
IRREGULAR USE-CYCLE



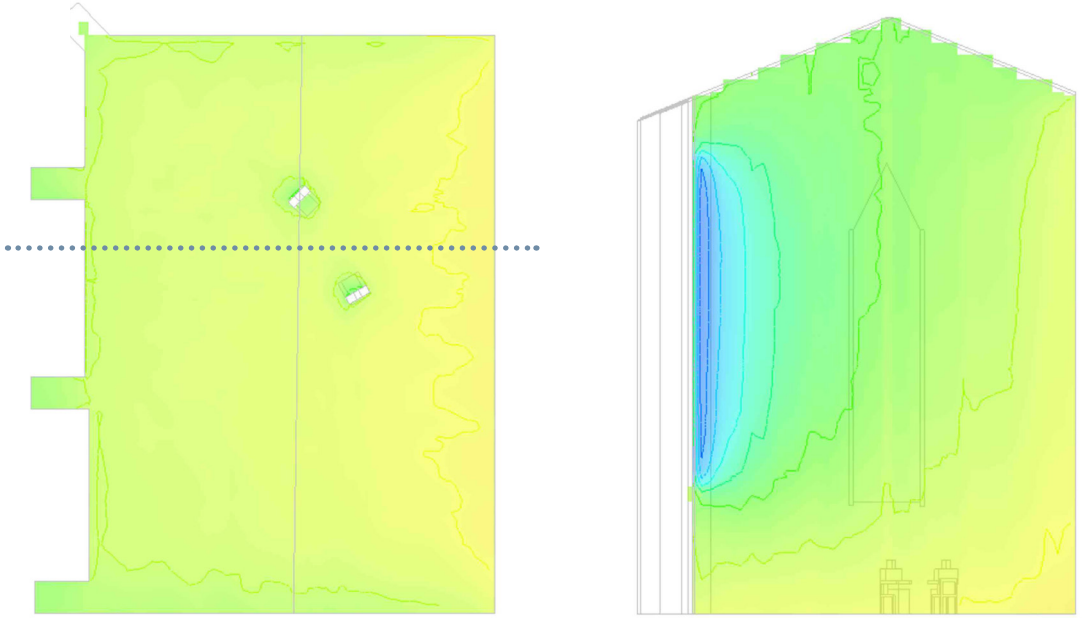
THERMAL SIMULATION MRT

Horizontal section diagrams at 1 m height and vertical section at location 1

BASIS MODEL – STAINED GLASS WITH INTERNAL PG

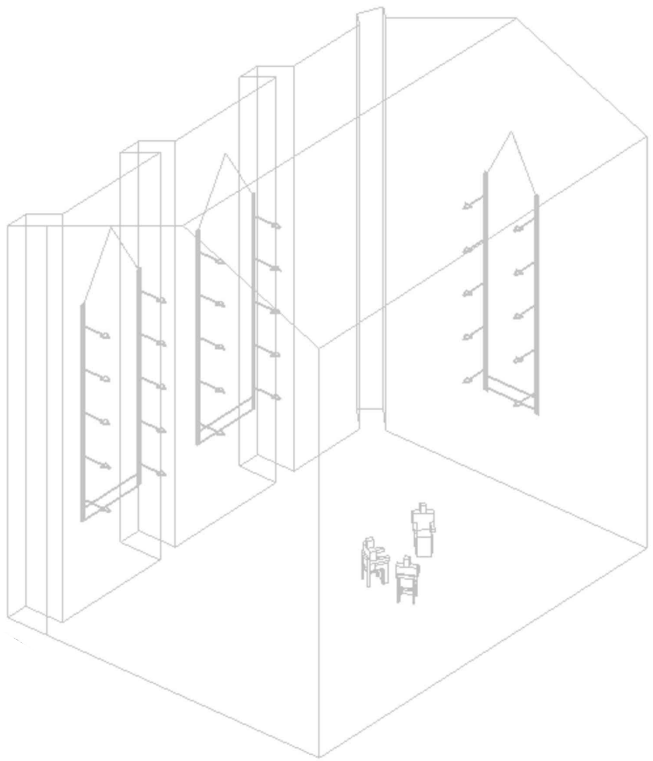


SINGLE STAINED GLASS WINDOWS

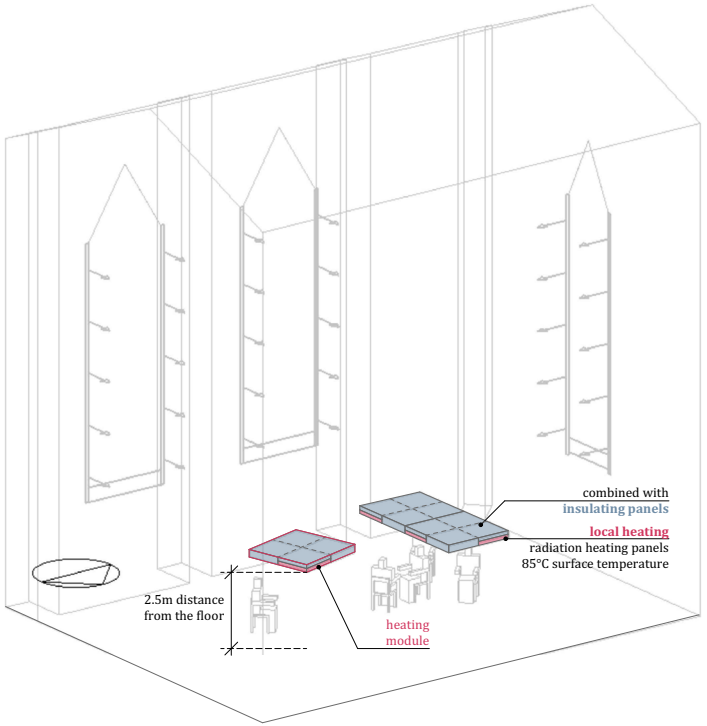


THERMAL SIMULATIONS

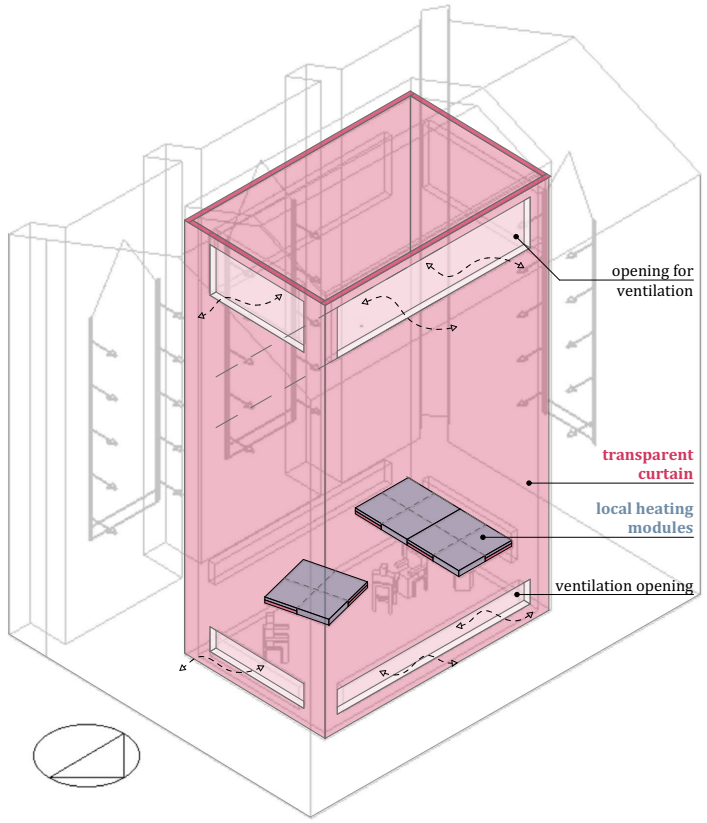
Local heating strategy - *heating people not spaces*



BASIS MODEL(CURRENT SITUATION)



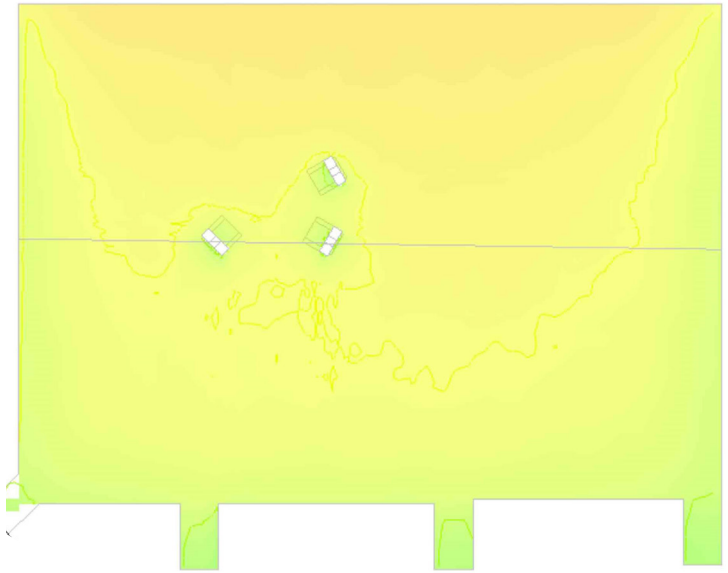
LOCAL HEATING MODULES



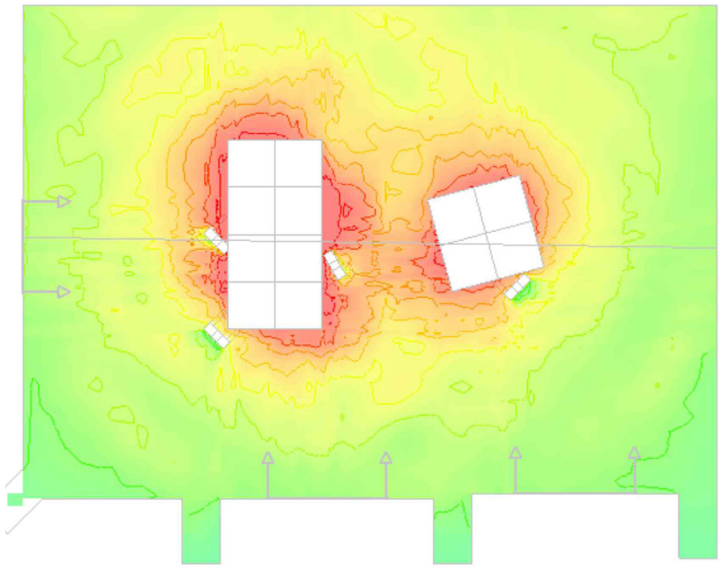
LOCAL HEATING MODULES & TEXTILE ROOM DIVISION

THERMAL SIMULATIONS

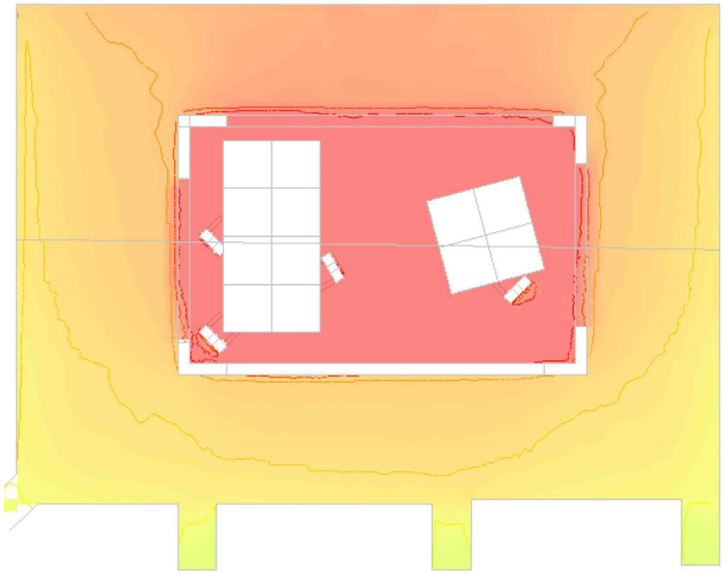
Horizontal section diagrams at 1 m height MRT



BASIS MODEL(CURRENT SITUATION)



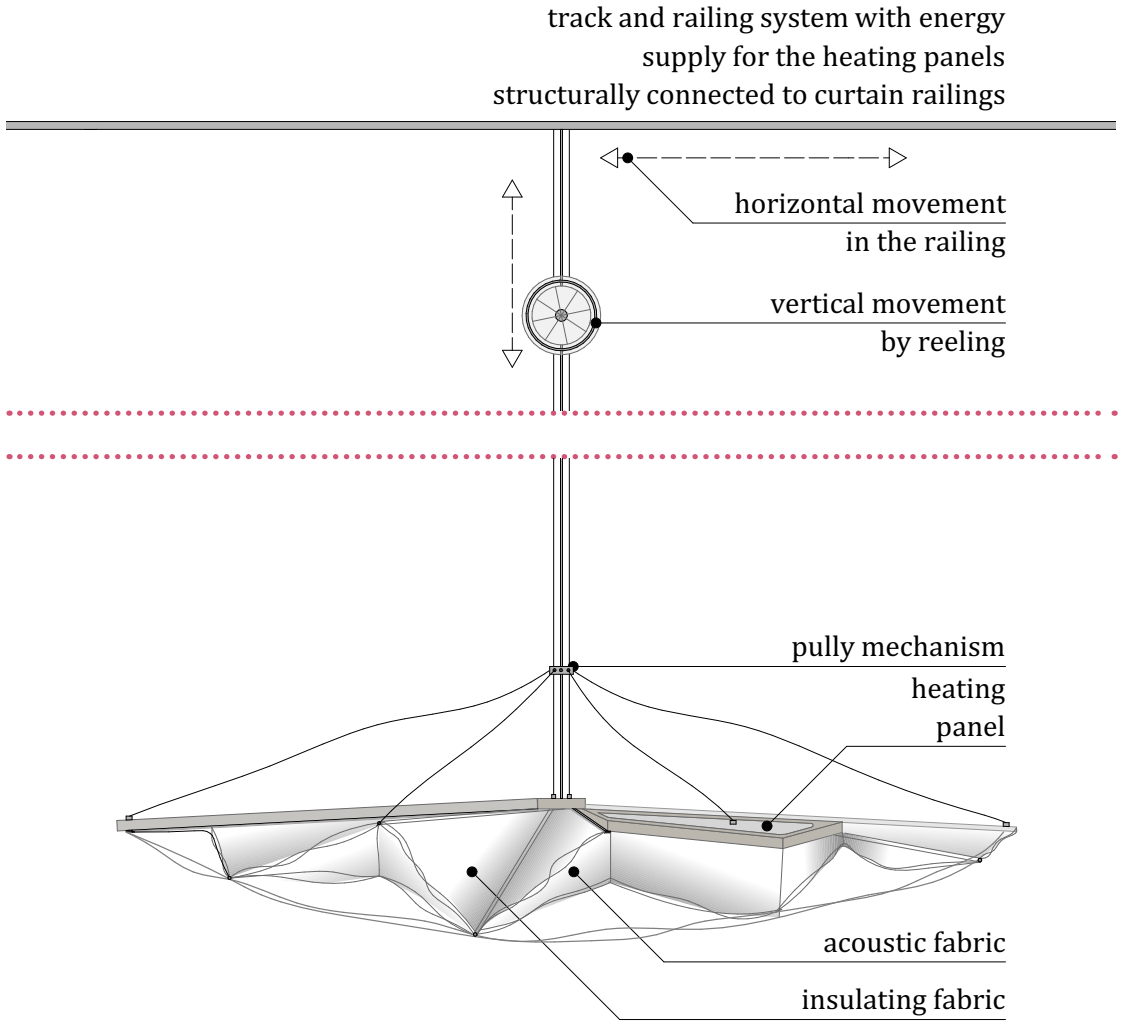
LOCAL HEATING MODULES

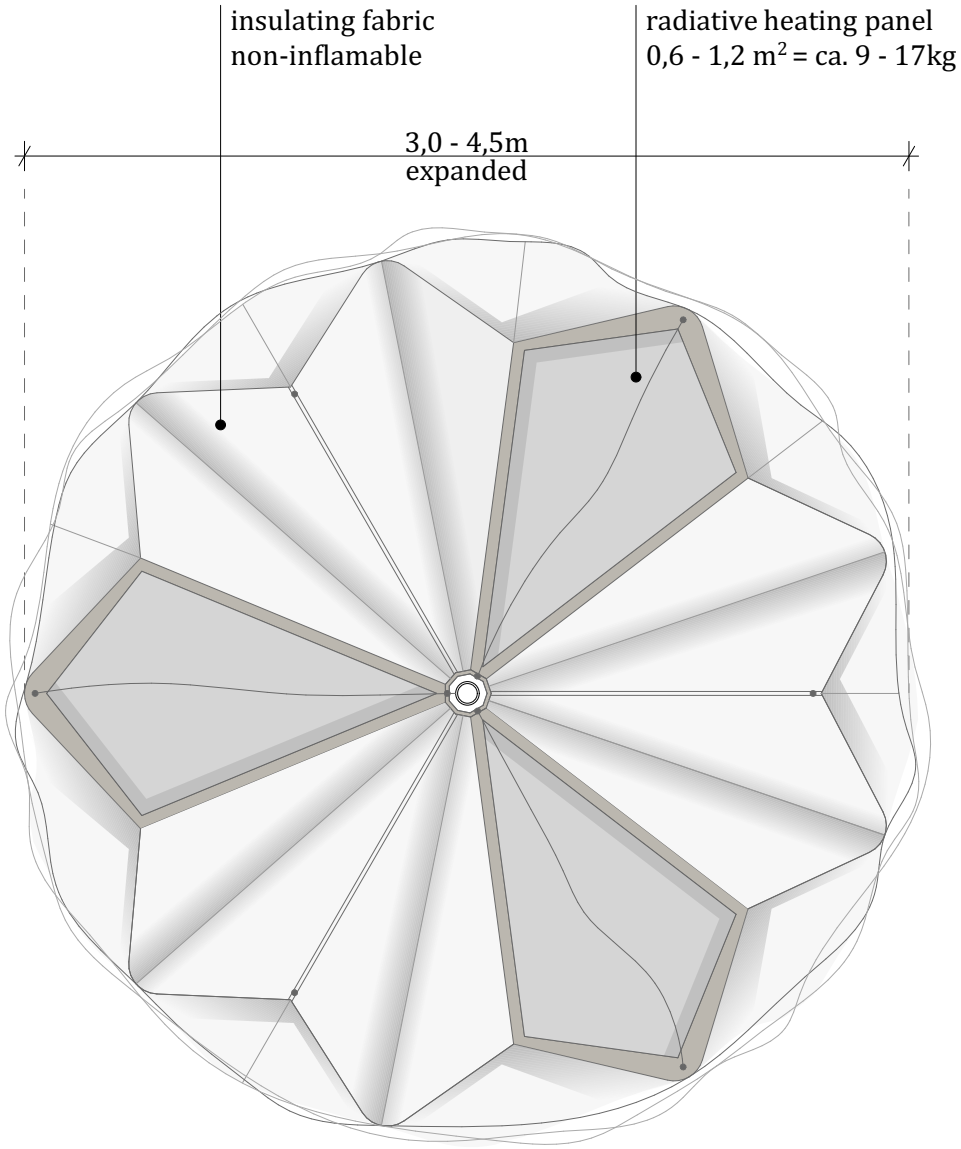


LOCAL HEATING MODULES & TEXTILE ROOM DIVISION

DESIGN LOCAL HEATING MODULES

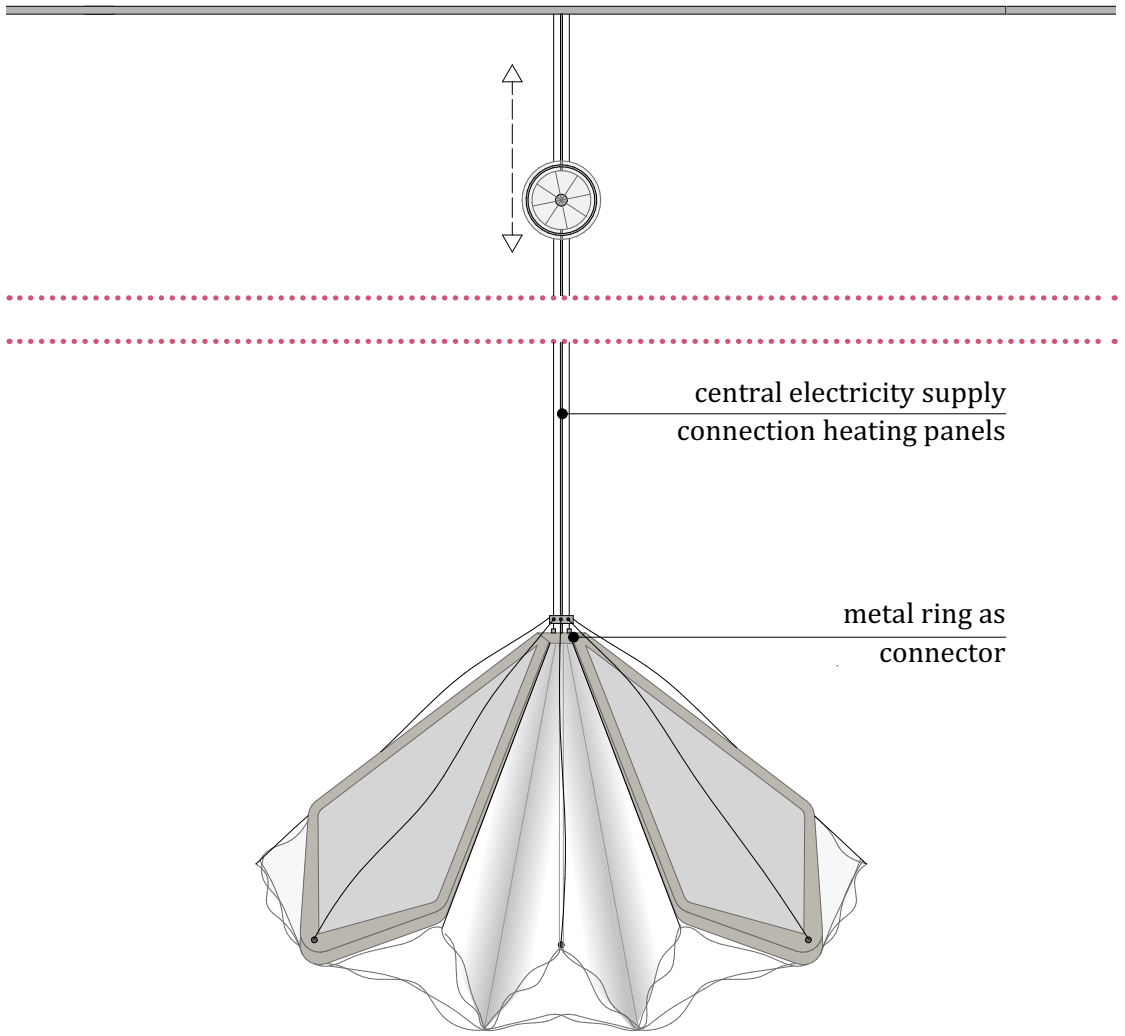
Open

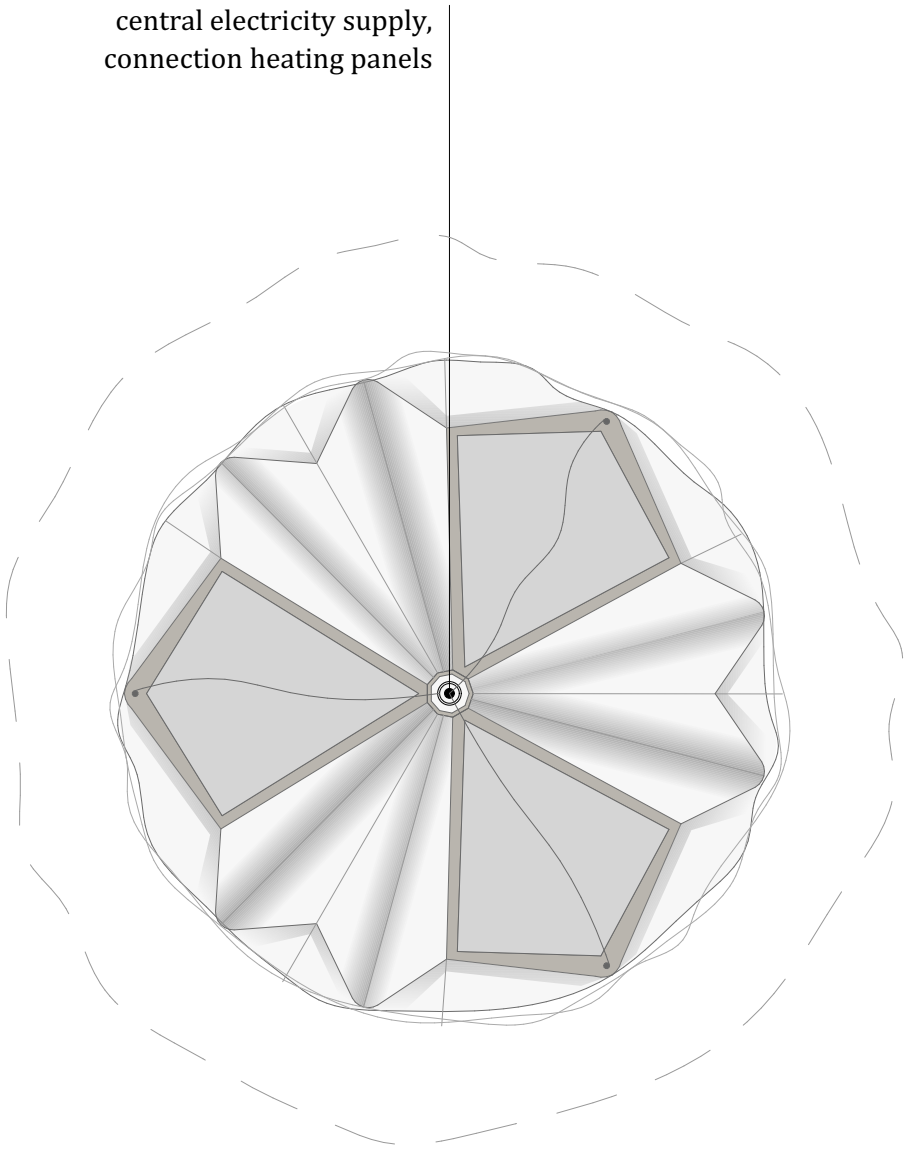




DESIGN LOCAL HEATING MODULES

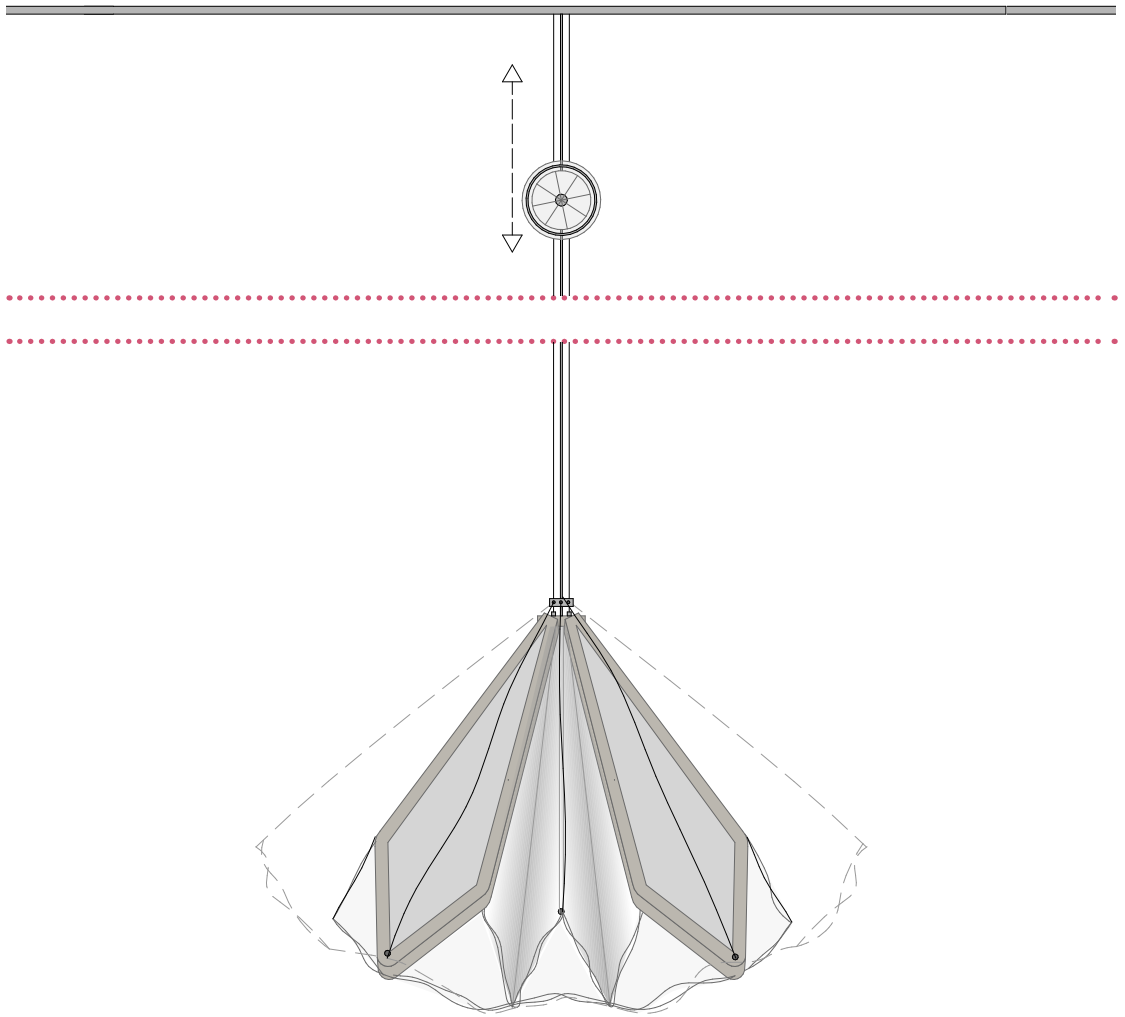
Collapsed

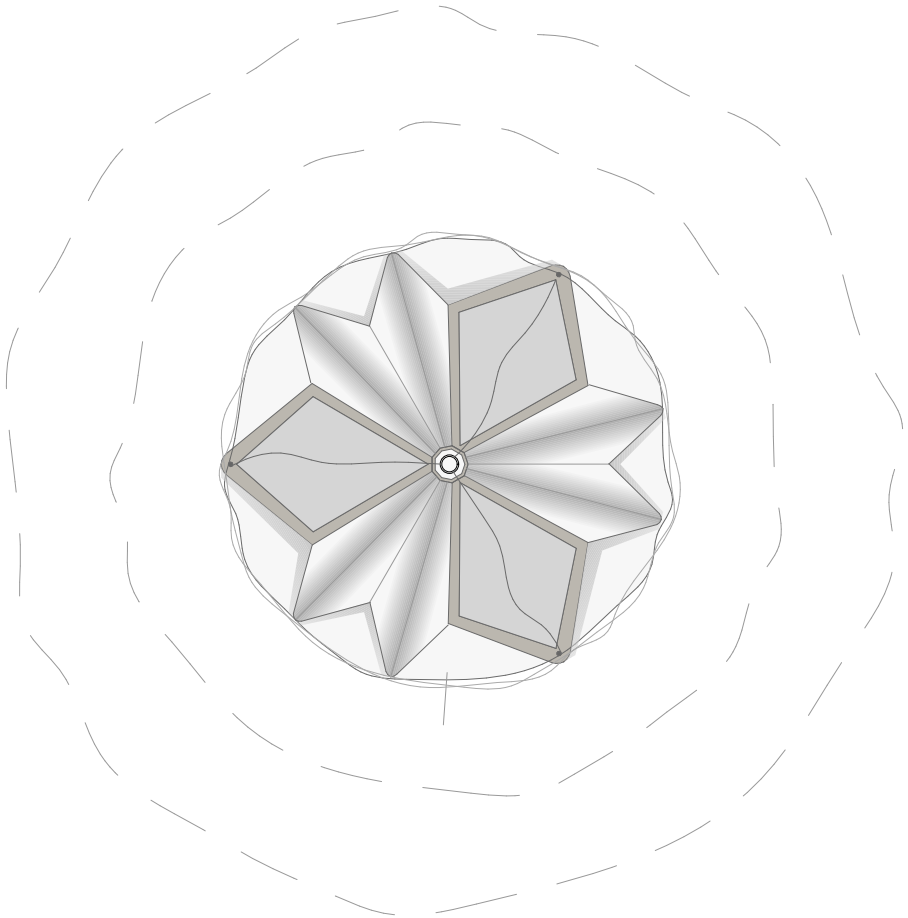




DESIGN LOCAL HEATING MODULES

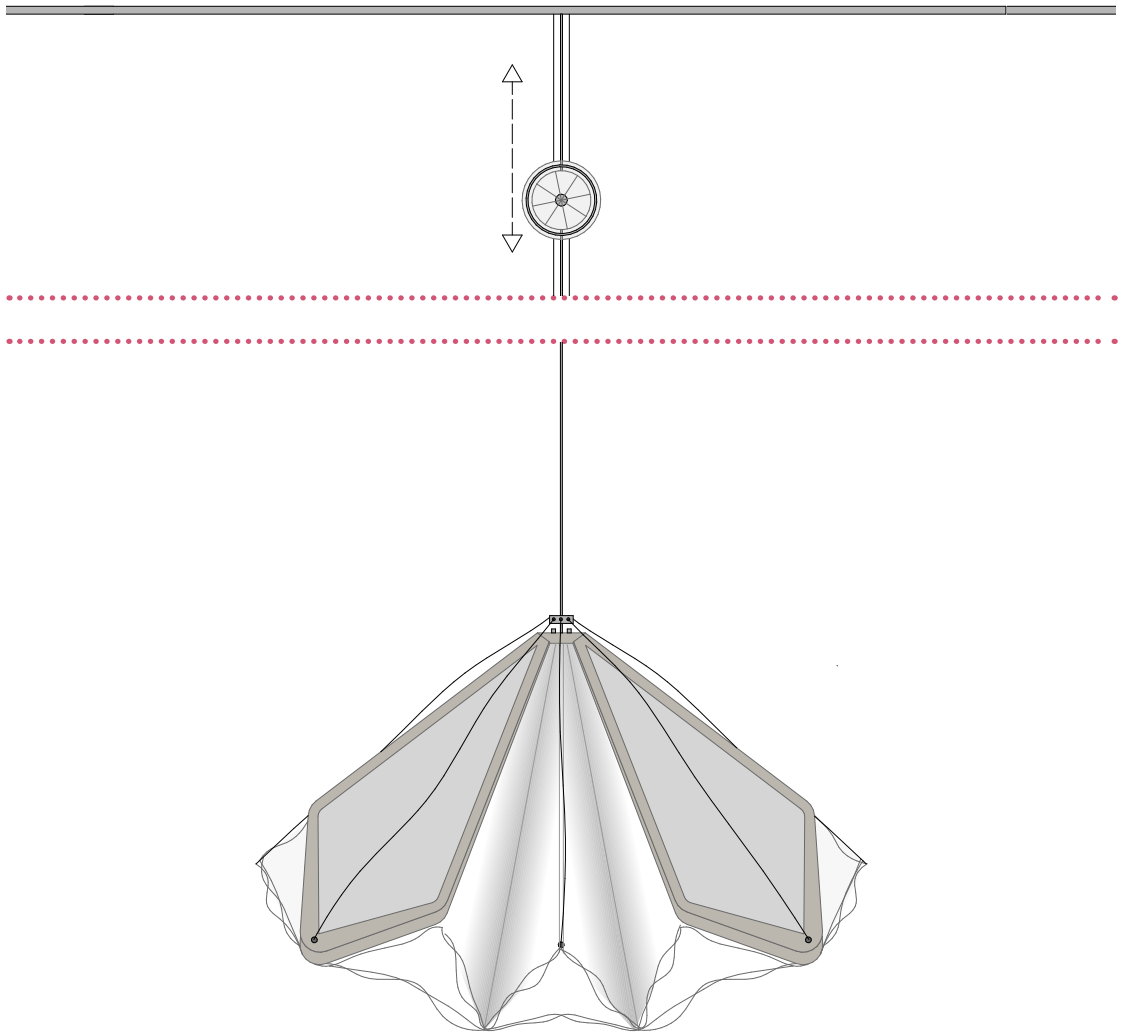
Closed

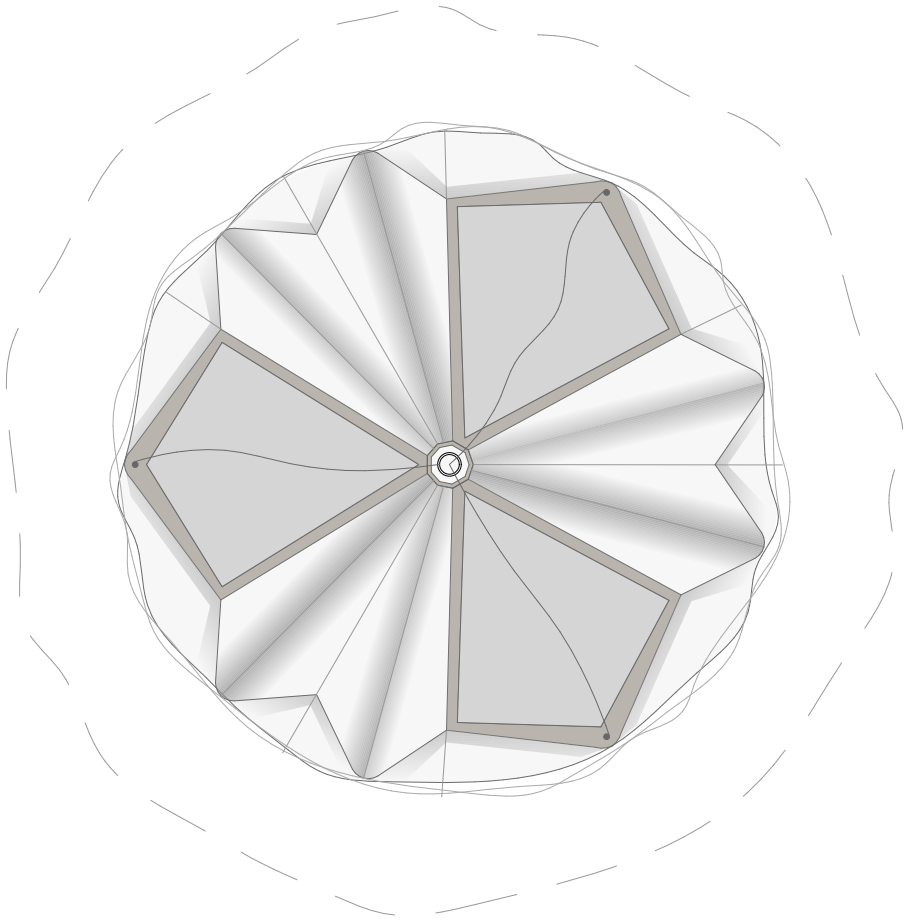




DESIGN LOCAL HEATING MODULES

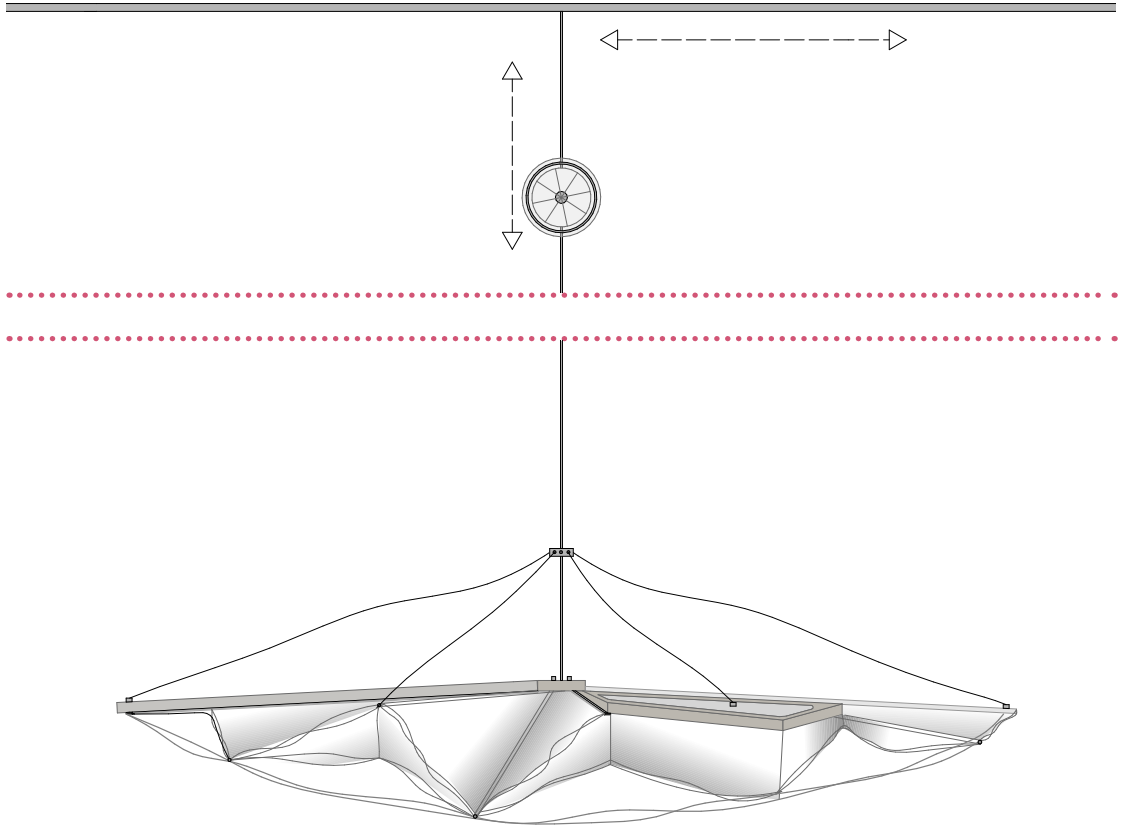
Collapsed

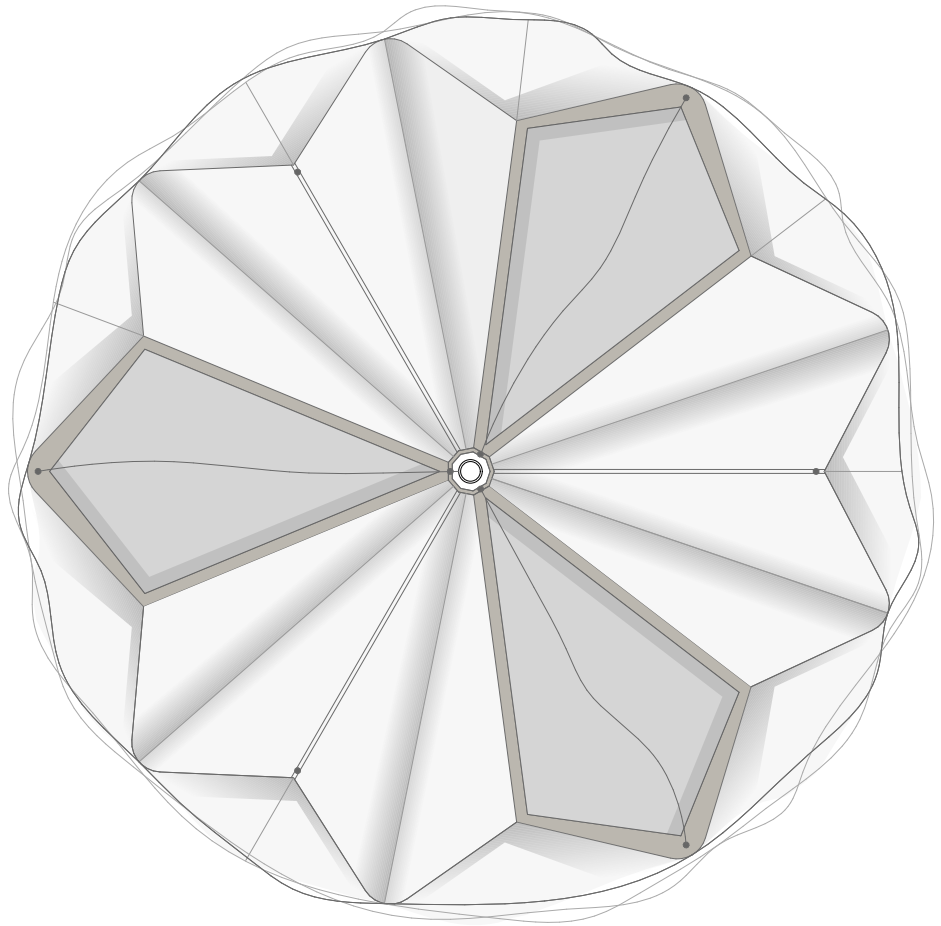




DESIGN LOCAL HEATING MODULES

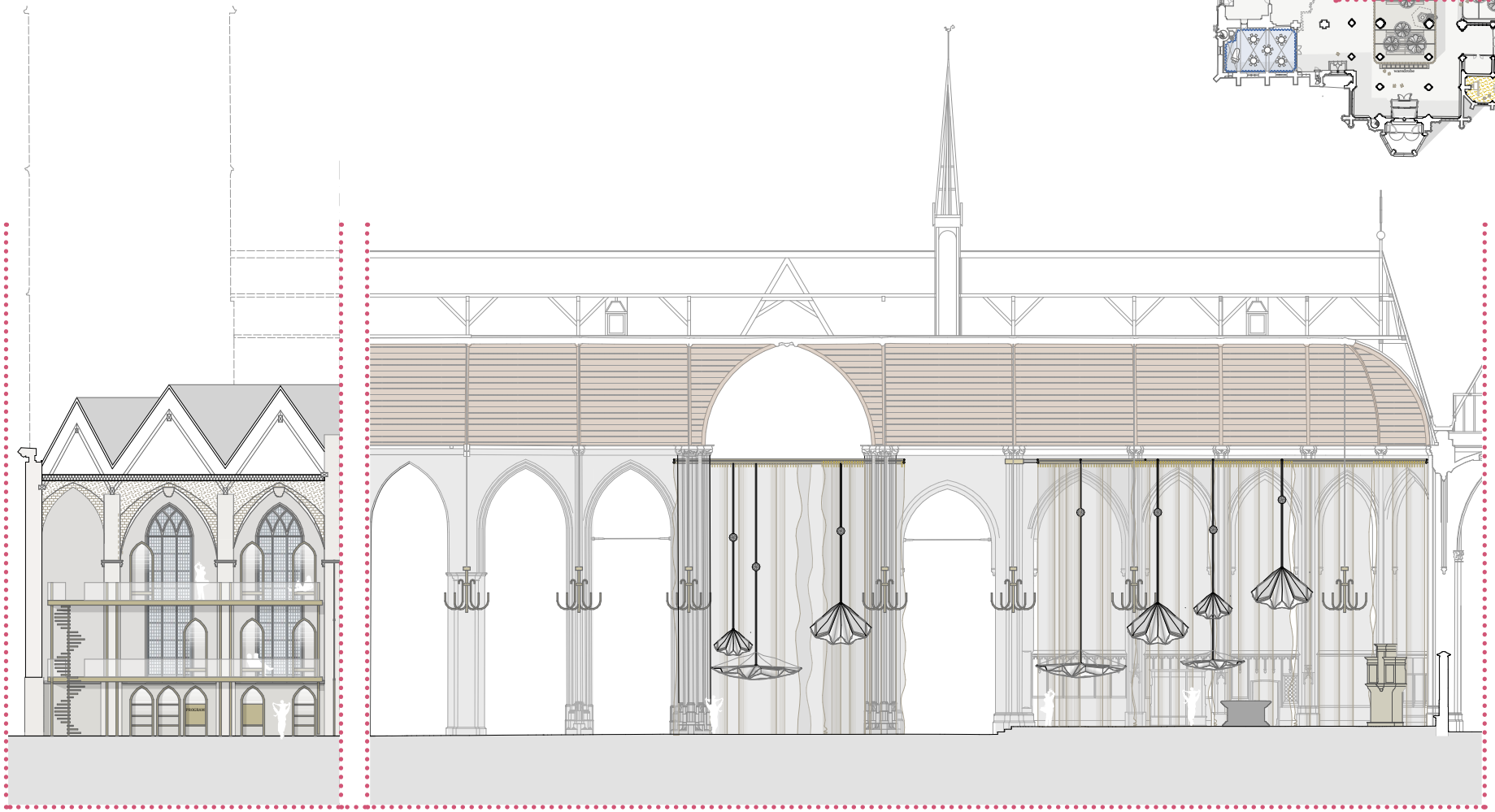
Open





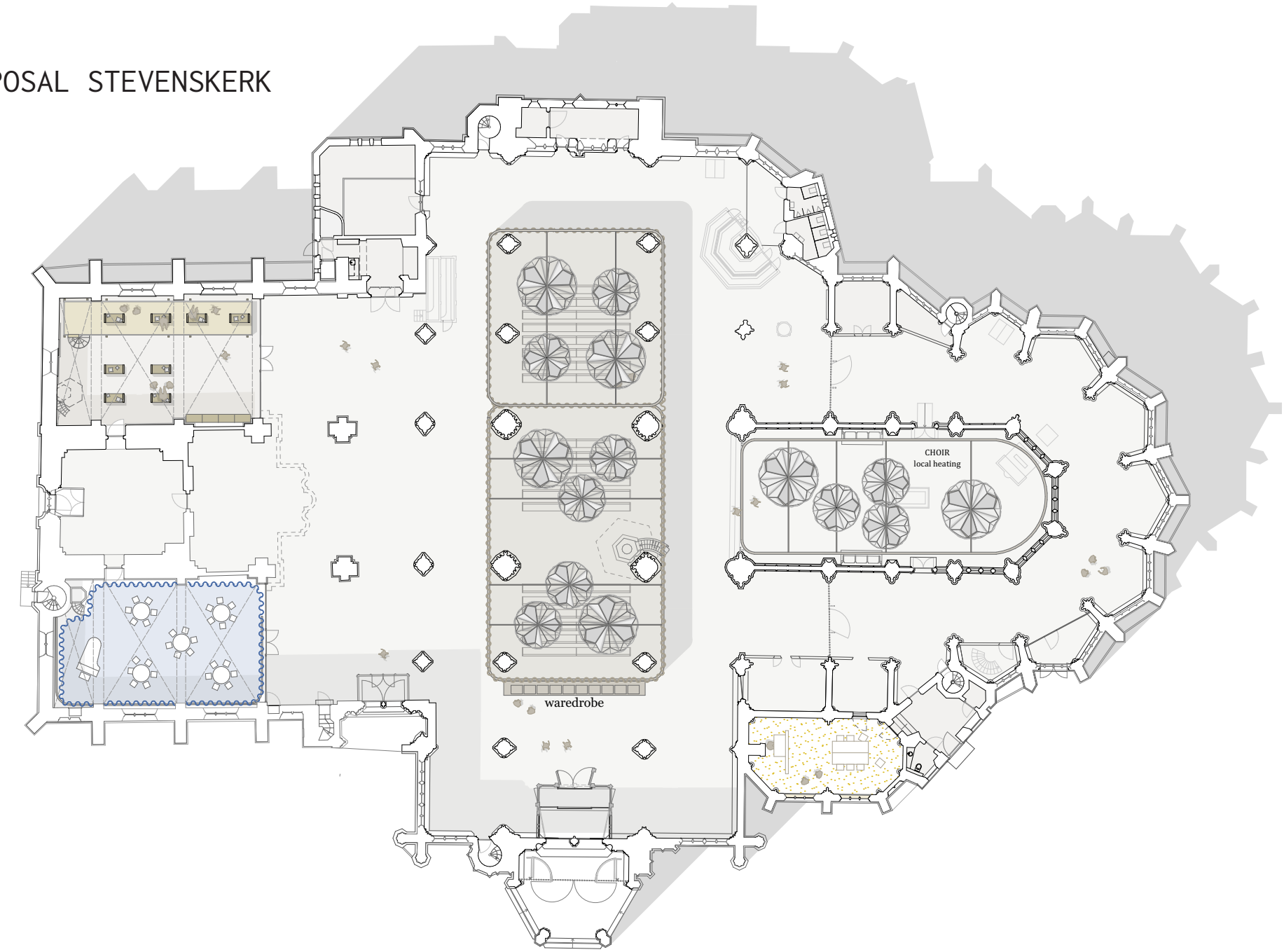
RENOVATION PROPOSAL STEVENSKERK

Section



RENOVATION PROPOSAL STEVENSKERK

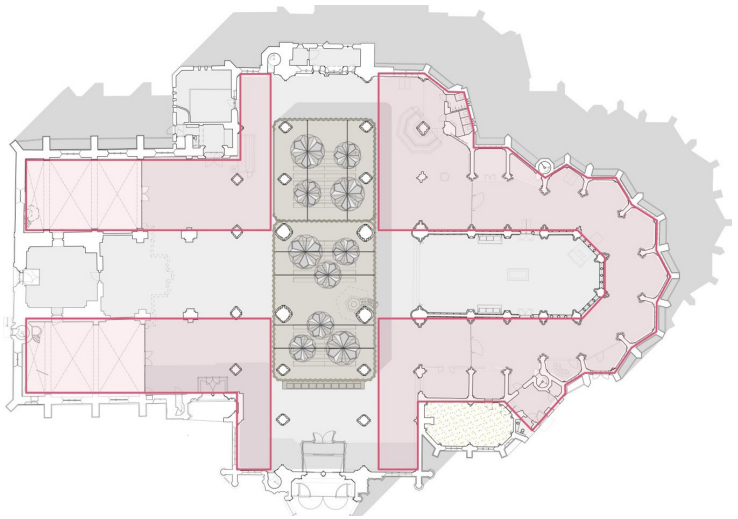
Floorplan

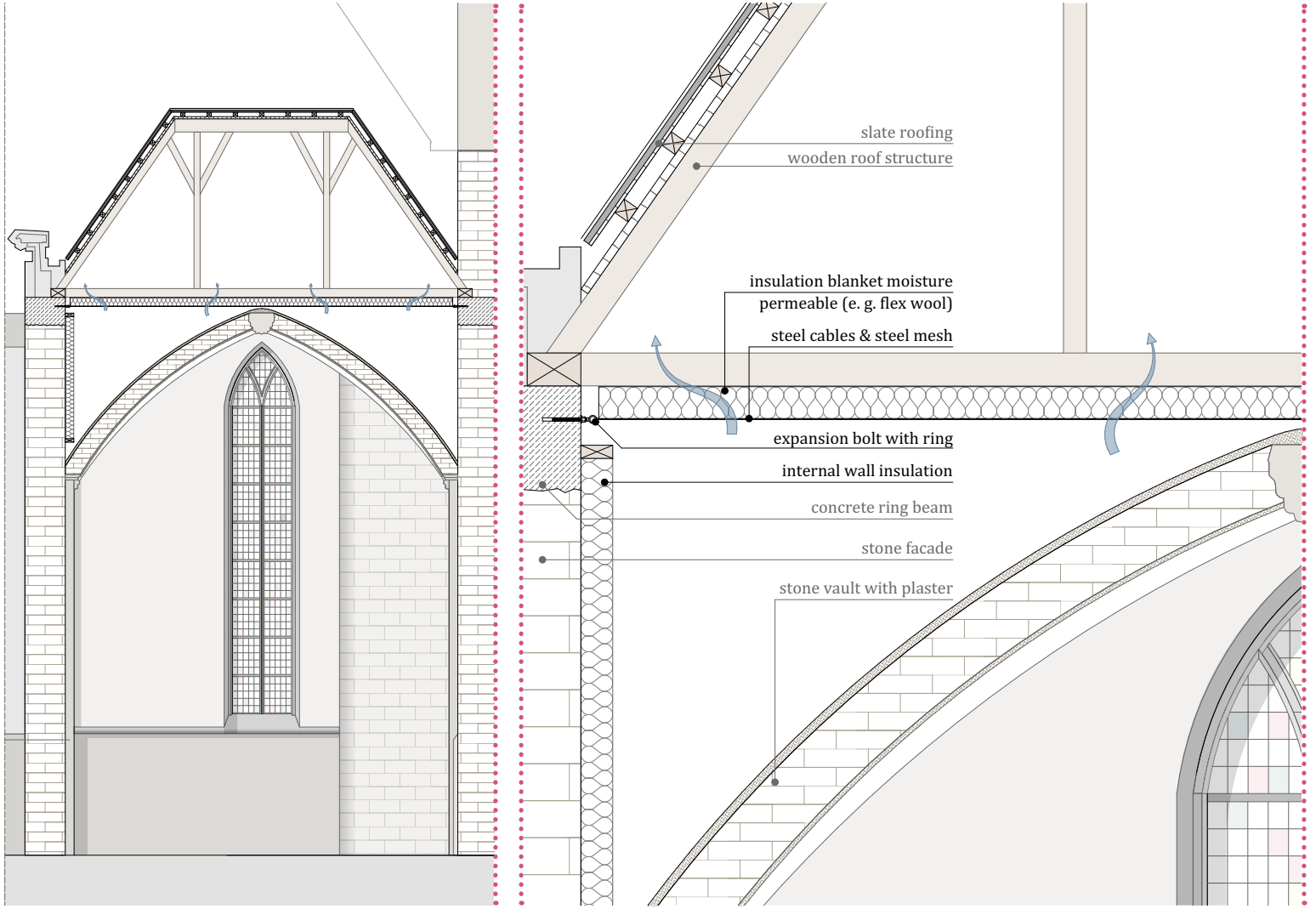


INDOOR
SPACE
IMPRESSION

VAULT INSULATION

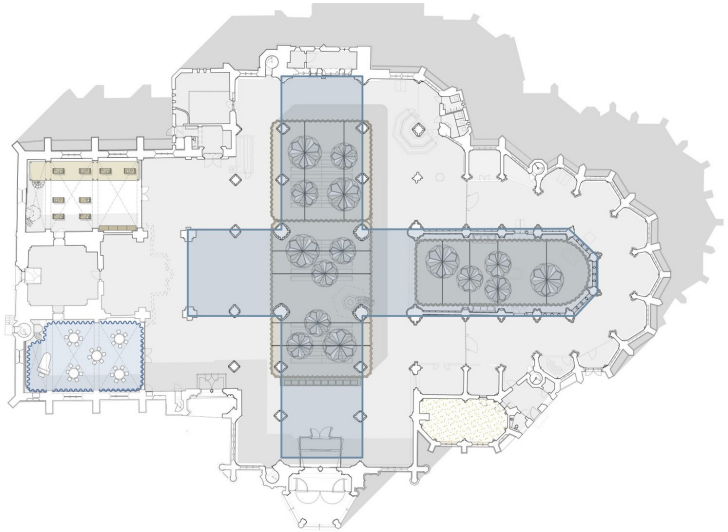
Stone vault

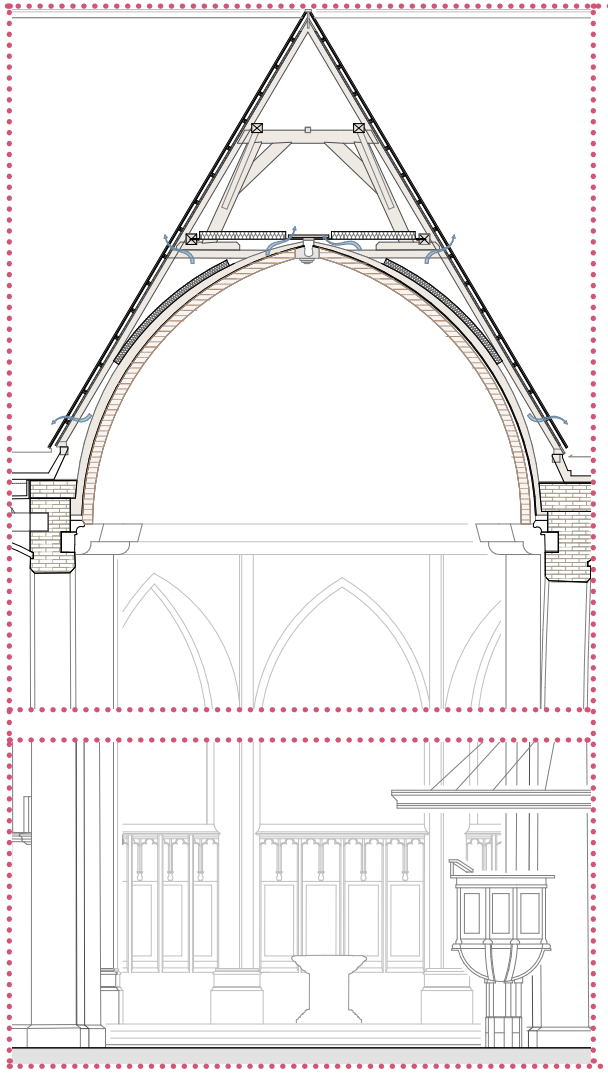


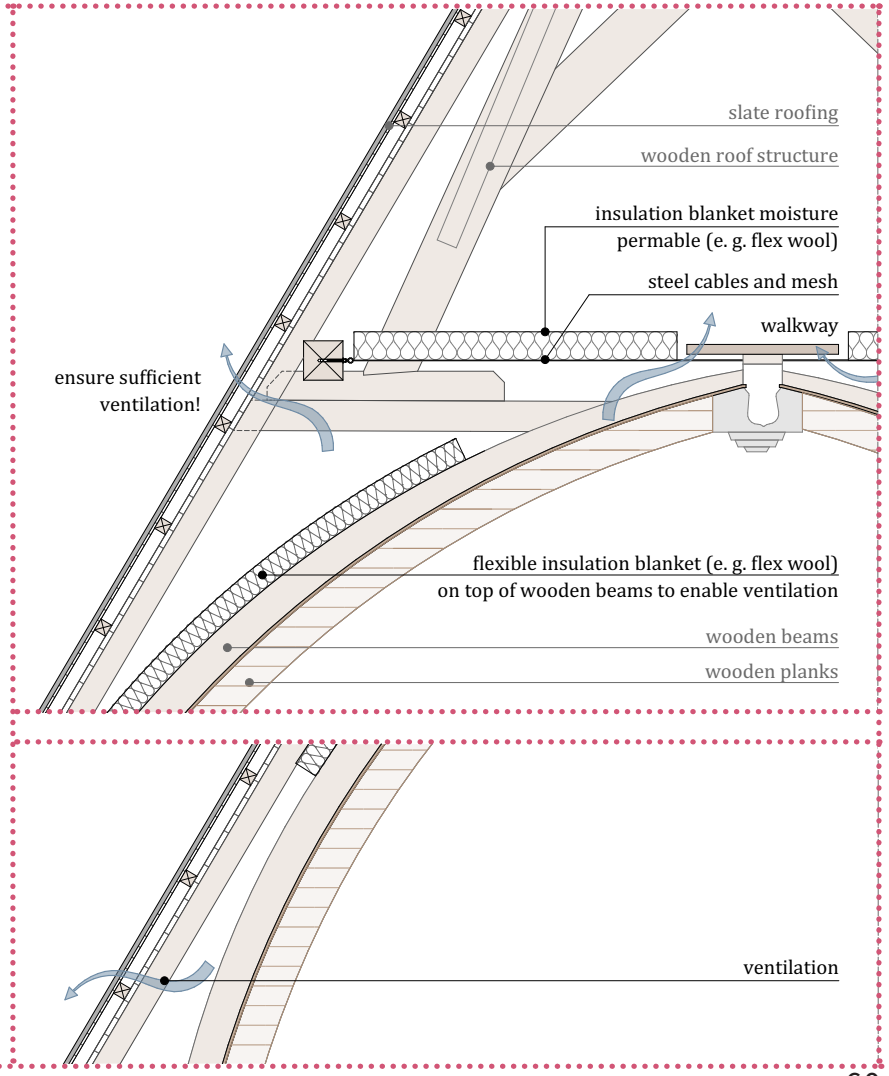


VAULT INSULATION

Wooden vault



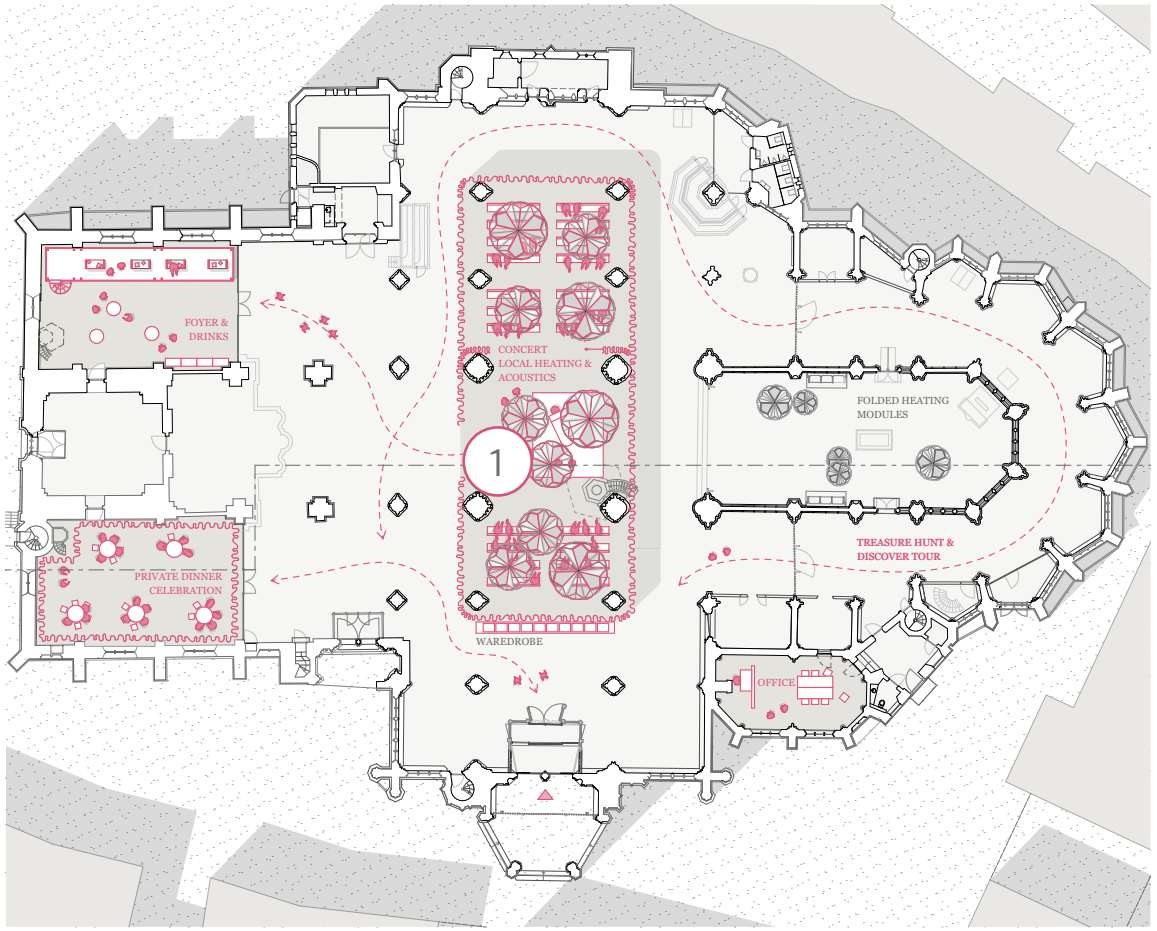




USE-CASE SCENARIOS

SIMULTANEOUS EVENTS

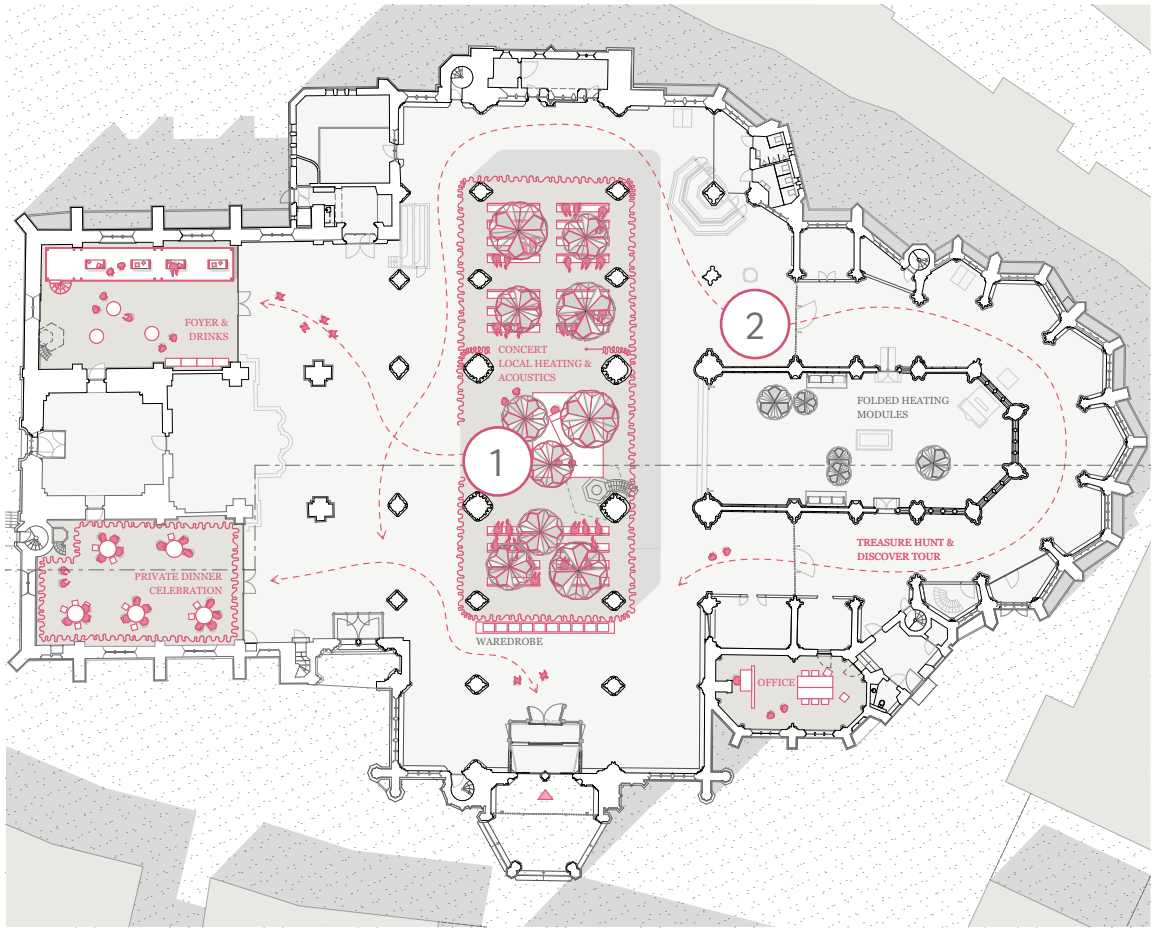
1



SIMULTANEOUS EVENTS

1

2

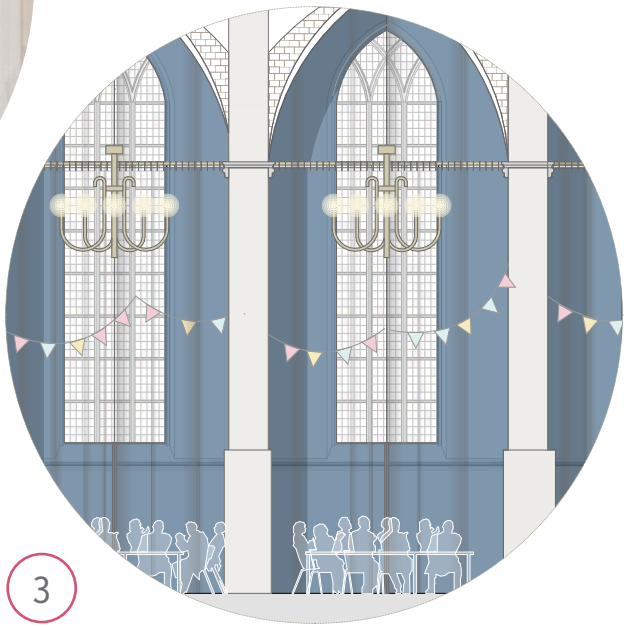


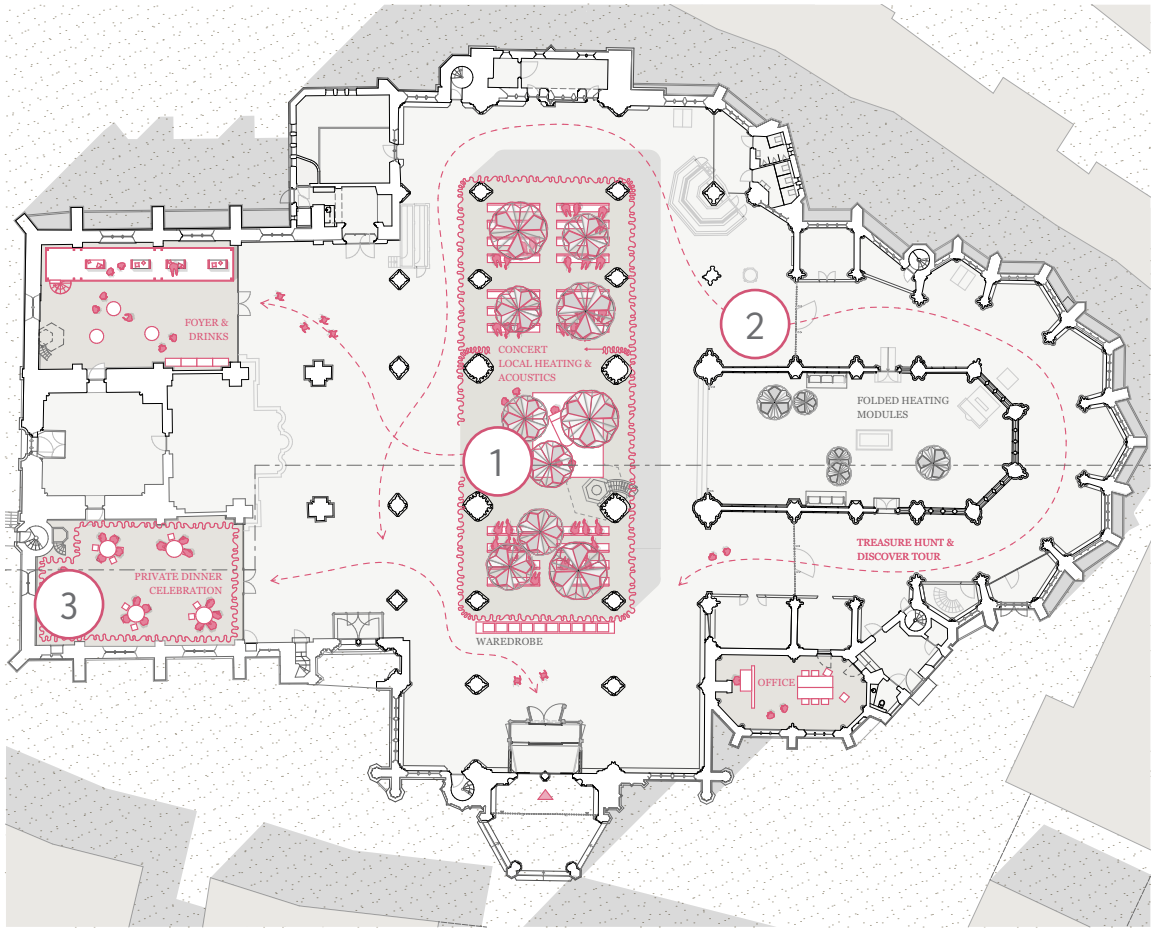
SIMULTANEOUS EVENTS

1

2

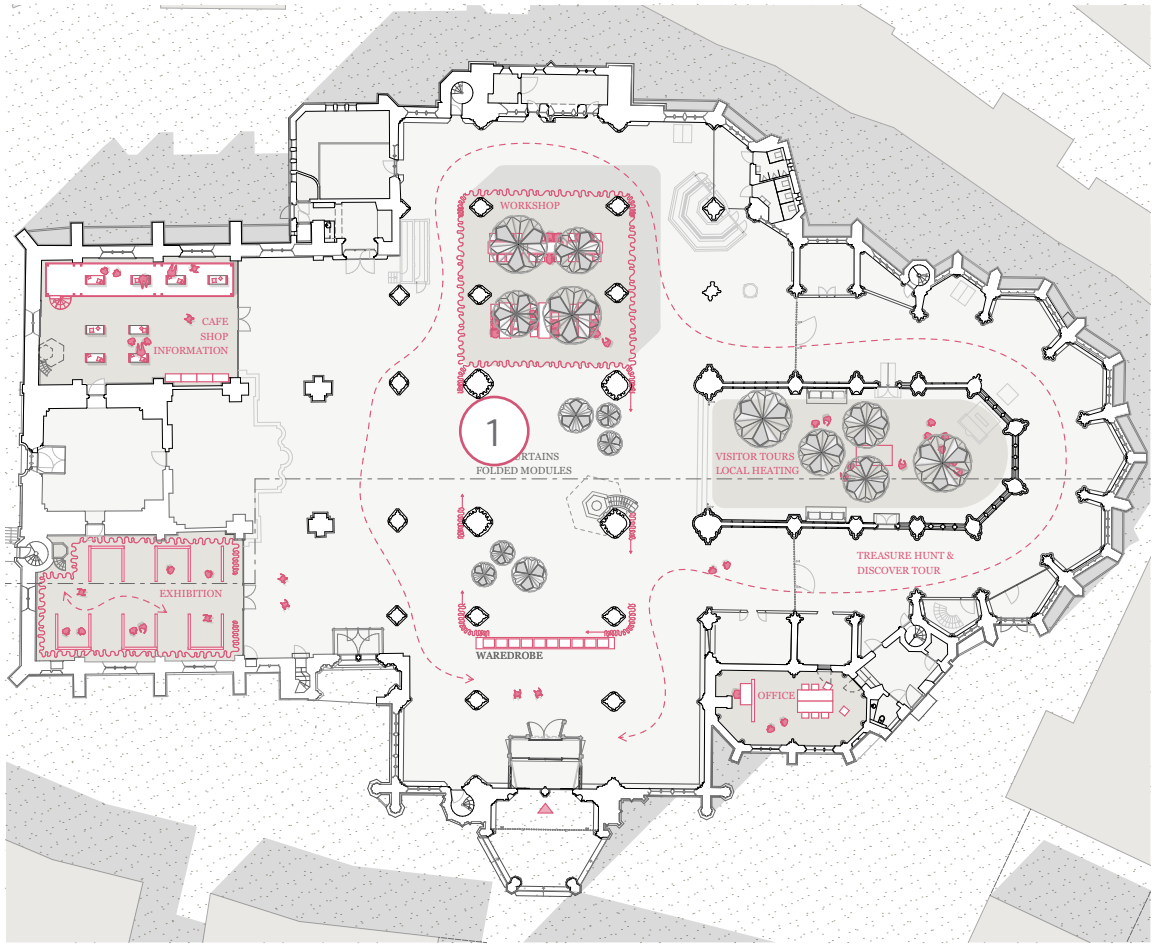
3





CULTURAL EVENTS

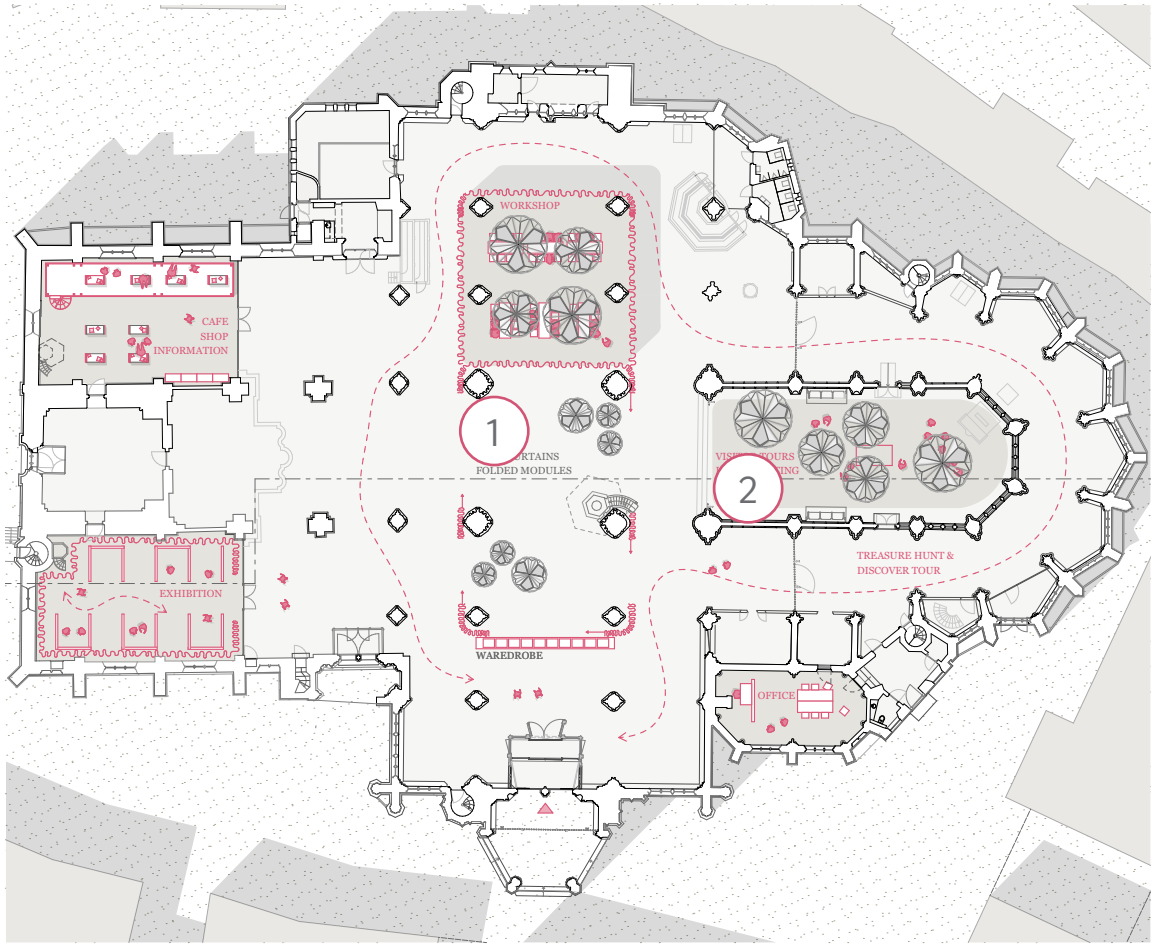
1



CULTURAL EVENTS

1

2

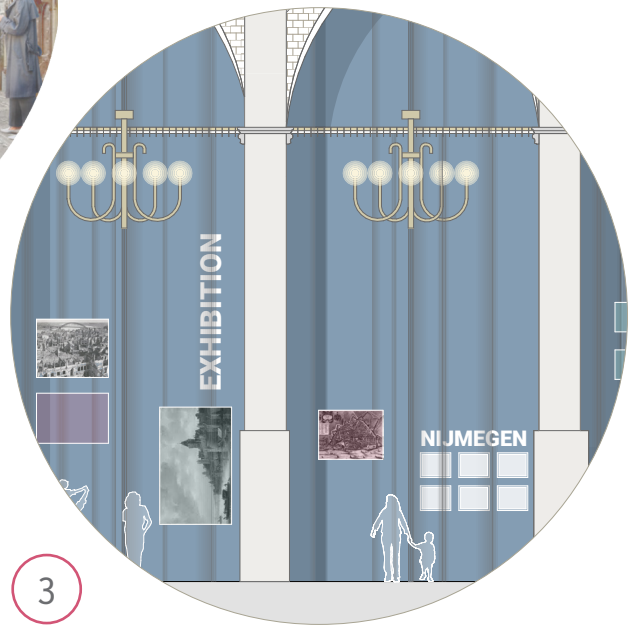


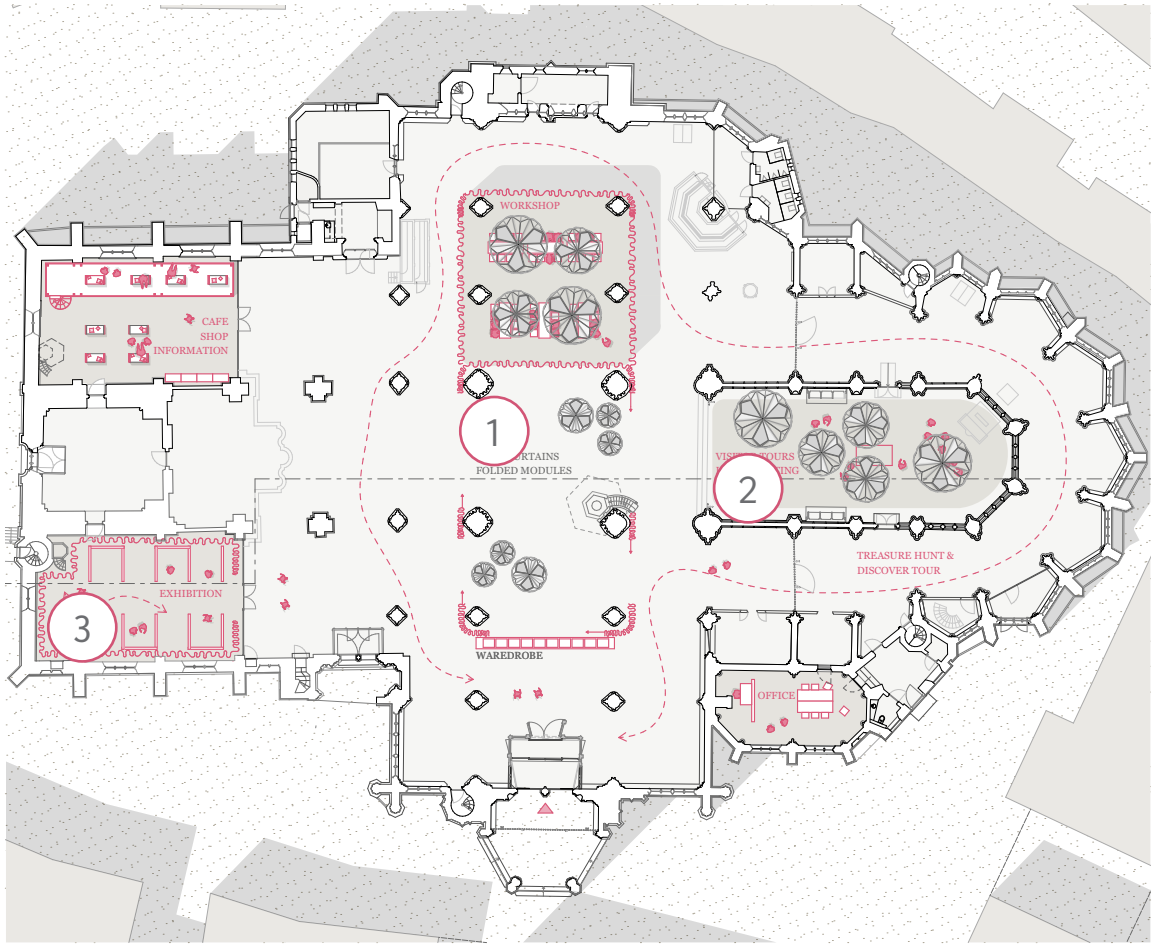
CULTURAL EVENTS

1

2

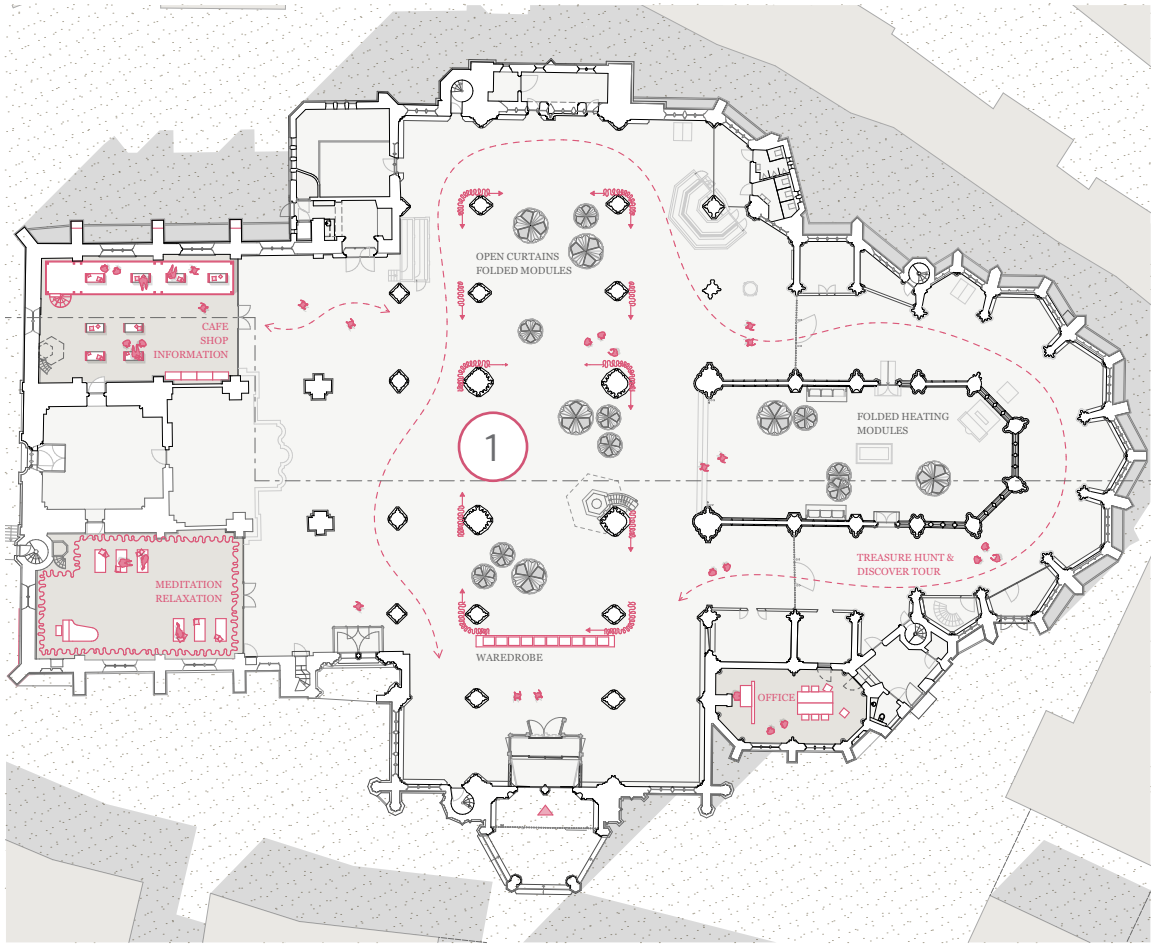
3





OPEN CHURCH

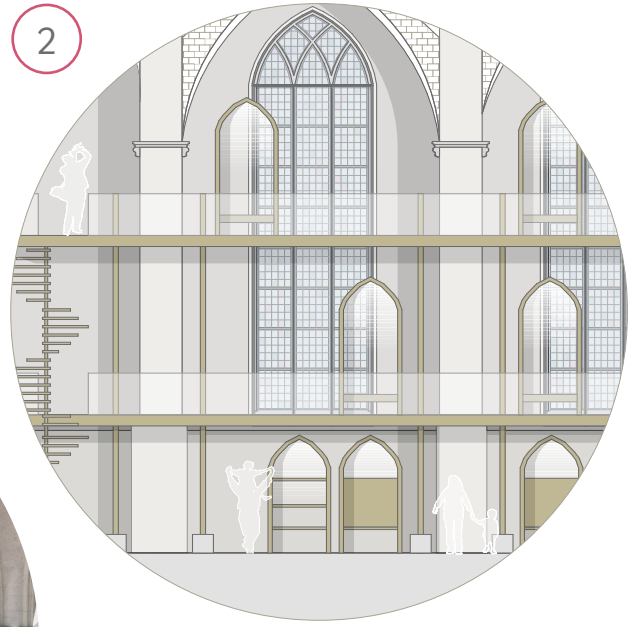
1

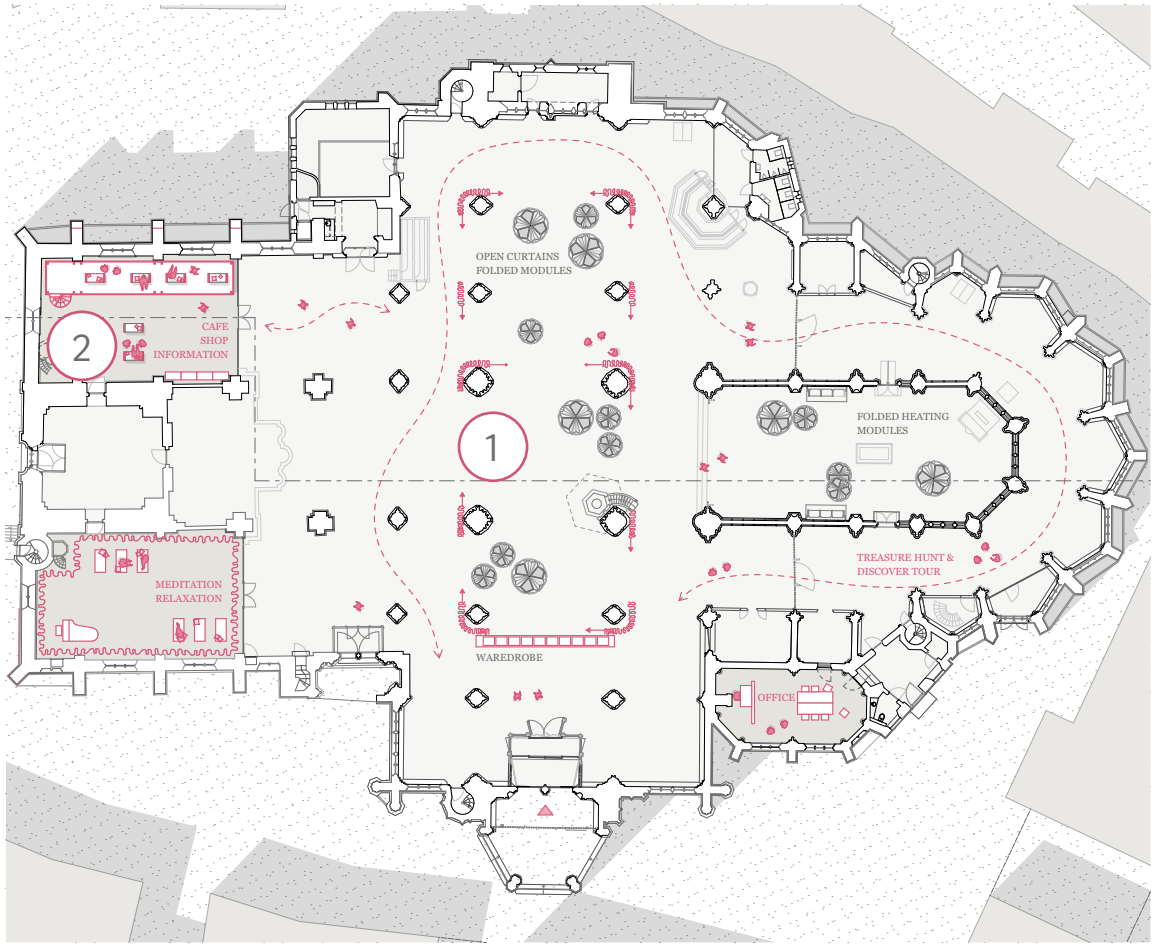


OPEN CHURCH

1

2

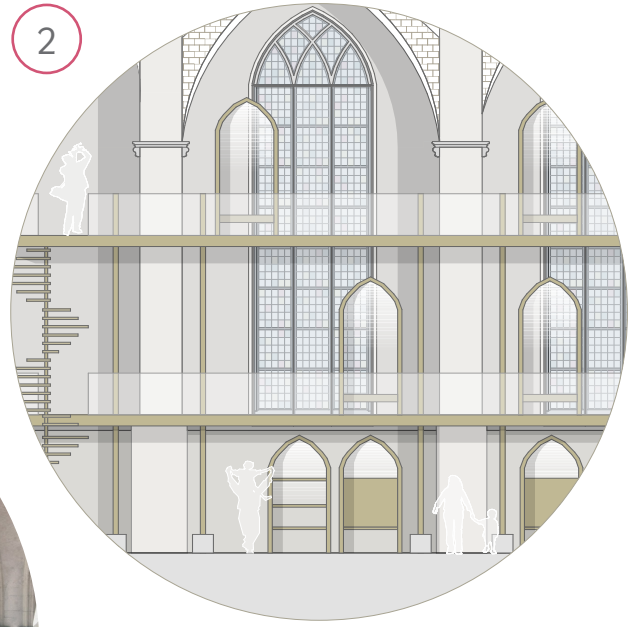




OPEN CHURCH

1

2



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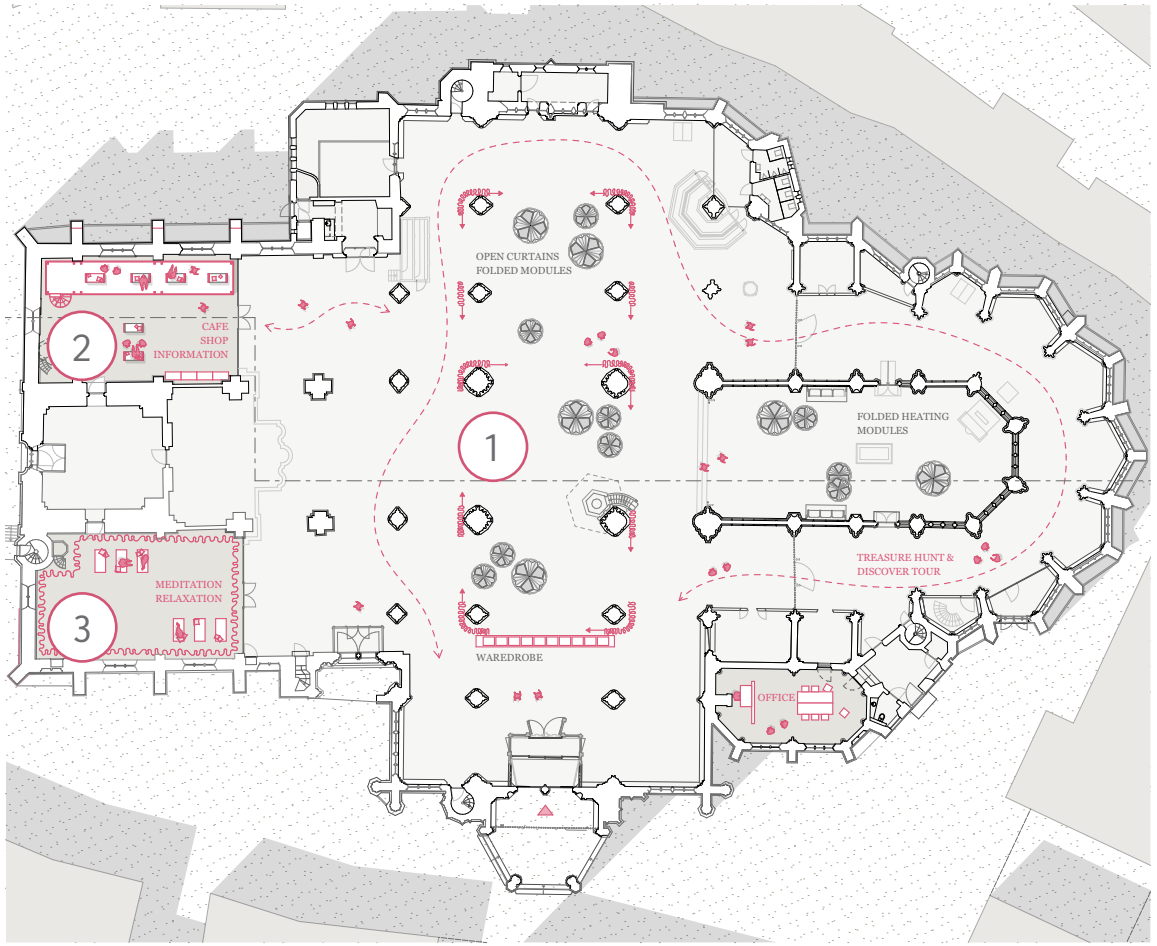


APPLICABILITY ON OTHER CHURCHES

APPLICABILITY ON OTHER CHURCHES

Matrix as evaluation overview

				1. SPATIAL CHARACTERISTICS										2. THERMAL COMFORT & HEATING DEMAND							THERMAL COMFORT & ENERGY DEMAND	3. HERITAGE VALUES							HERITAGE VALUES	4. LIFE CYCLE & DURABILITY				DURABILITY	5. FINANCE			ECONOMIC EFFICIENCY	6. LIGHT & ACOUSTICS		LIGHT & ACOUSTICS
	NOW	Single stained glass window *current situation large church space*	*Single stained glass*	1.1 Functionality				1.2 Floor area			1.3 Use cycle			5,76	8,3	0,42	2,78	Cracks / Thermal bridges																								
			Structure *(outside to inside)*	Multi-functional	Café / Shop	Office	Church	Very large	Limited	Very limited	Irregular use	Regular use	Very regular	2.1 Window insulation		2.2 Performance winter scenario		2.3 Facade insulation		2.4 Airtightness facade		3.1 Conservation risks	3.2 Conservation risks lead glass windows			3.3 Exterior values	3.4 Interior values	3.5 Reversibility		4.1 Lifespan	4.2 Maintenance	4.3 Embodied Carbon	4.4 Circularity		5.1 Costs	5.2 Payback	5.3 Profit		6.1 Lighting	6.2 Acoustics	
														U [W/m²K]	ΔU	T_{glass} [°C]	v_{winkle} [m/s]	$U_{combined}$	ΔU			Building Level	Outside degradation	Condensation risk	Other risks					EC [kgCO2/m² or kg]											
A. INTERNAL SECONDARY GLAZING	**A.1**	Secondary single glass cavity ventilated with indoor air *Gerfkamer & Side chapels*	*stained glass* 10mm ventilated cavity 3mm*safety foil*3mm glass											3,98	1,78	14,3	0,26	2,25	0,53	unchanged		unchanged	unchanged	condensation risk	-	no change	small intervention	possible		40 - 100	difficult	21,6/m² 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
	A.2	Secondary single glass closed cavity *tested in the Gerfkamer & Side chapels*	*stained glass* cavity 3mm*safety foil*3mm glass											3,69	2,07	16,1	0,19	2,16	0,62	unchanged		slightly improved	unchanged	condensation risk	-	no change	small intervention	possible		40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
	A.3	Secondary double glazing	*stained glass* 10mm unventilated cavity 4mm glass 6mm closed cavity with gas											1,01	4,75	16,7	0,16	1,36	1,42	unchanged		improved	unchanged	*ext. ventilation* *int. ventilation*	-	no change	small intervention	possible		20 -40	difficult	32,5/m2 8mm double glazing, ex cavity & frame	difficult		high	long-term	limited		unchanged	-	
B. INTERNAL WINDOW	**B.1**	Single glazed window	stained glass 200mm unventilated space thin glass window											3,02	2,74	14,1	0,27	1,96	0,82	improved		slightly improved	unchanged	*ext. ventilation* *int. ventilation*	-	no change	reasonable intervention	possible		40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		high	long-term	limited		unchanged	-	
	B.2	Double glazed window	*stained glass* 200mm unventilated space double glazed window											1,01	4,75	16,7	0,16	1,36	1,42	improved		improved	unchanged	*ext. ventilation* *int. ventilation*	-	no change	reasonable intervention	possible		20 - 40	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		high	long-term	limited		unchanged	-	
C. EXTERNAL SECONDARY GLAZING	**C.1**	External secondary single glazing *covering the lead connections,* *fitted between the natural stone frame*	3mm*safety foil*3mm glass 200mm unventilated space *stained glass*											3,69	2,07	16,1	0,19	2,16	0,62	unchanged		slightly improved	improved	*ext. ventilation* *int. ventilation*	-	intervention	no change	possible		40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
	C.2	External secondary double glazing *covering the lead connections,* *fitted between the natural stone frame*	3mm*safety foil*3mm glass 150mm unventilated space *stained glass*											1,01	4,75	16,7	0,16	1,36	1,42	unchanged		improved	improved	*ext. ventilation* *int. ventilation*	-	intervention	no change	possible		20 - 40	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		high	long-term	limited		unchanged	-	
	C.3	Museum arrangement	Double glazing 10mm ventilated cavity *stained glass*											1,49	4,26			1,51	1,28	unchanged		improved	improved	*single glazing* *double glazing*	removal glass	intervention	no change	not possible		40 - 100	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	limited		unchanged	-	
	C.4	Bonded glazing	Double glazing with *stained* glass integrated in the cavity											2,78	2,98			1,89	0,89	unchanged		slightly improved	improved	condensation risk	cutting thermal breakage	intervention	no change	not possible		40 - 100	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	limited		unchanged	-	
D. OTHERS	**D.1**	Curtain as radiation screen	*stained glass* 300mm cavity low emissivity fabric											4,88	0,88	13,2	0,29	2,52	0,26	largely improved		slightly improved	unchanged	no risk	-	no change	reasonable intervention	very good		< 20	possible		possible		low	mid-term	good		temporary reduction	> 1m²/m²	
	D.2	Curtain as textile wall insulation	*stained glass* 50mm cavity insulating fabric (felt)											2,51	3,25	13,8	0,28	1,81	0,97	largely improved		slightly improved	unchanged	low risk	-	no change	reasonable intervention	very good		< 20	possible	11/m² wool	possible		low	mid-term	good		temporary reduction	> 1m²/m²	
	D.3	Internal glass box	stained glass 300mm unventilated space (possibly outside infiltration) 10mm structural glazing box											1,01	4,75	16,7	0,16	1,36	1,42	improved		improved *option to integrate control*	unchanged	low risk	-	no change	reasonable intervention	challenging		20 - 40	difficult	32,5 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	high potential		limited reduction	-	
	NOW	*South chapel basis model simulation* *DesignBuilder*		1.1 Functionality				1.2 Floor area			1.3 Use cycle			0,25 - 0,30	16	-1	20 - 28	basis																								
				Multi-functional	Café / Shop	Office	Church	Very large	Limited	Very limited	Irregular use	Regular use	Very regular use	2.1 Air velocity [m/s]		2.2 MRT [°C]	2.3 PMV *(-3 to +3)*	2.4 PPD [%]	2.5 Heating demand			3.1 Conservation risks		3.3 Exterior values		3.4 Interior values	3.5 Reversibility		4.1 Lifespan	4.2 Maintenance		4.4 Circularity		5.1 Costs		5.3 Profit		6.1 Lighting	6.2 Acoustics	
E. INDOOR SPACE ADAPTATION	**E.1**	Floorplan adaptation or Zoning the indoor space	permanent internal division(s) and/or built in new storeys and spaces											*no thermal comfort simulations performed*								unchanged		no change		intervention	not possible		40 - 100	possible		difficult		very high		high potential		adjustable	1m²/m²	
	E.2	Box in Box temporary *(Design Builder simulation 04)*	flexible, temporary tent or box in box structure											0,15		19	0	11		unchanged		unchanged		no change		reasonable intervention	very good		< 20	possible		possible		low		good		unchanged	-	
	E.3	Box in Box permament	permanent box in box structure											*no thermal comfort simulations performed*								unchanged		no change		reasonable intervention	not possible		40- 100	possible		possible		very high		high potential		adjustable	1m²/m²	
	E.4	Vertical division	vertical divison (e. g. textile or glass material) for compartmentalization of the occupied space											*no thermal comfort simulations performed*								unchanged		no change		reasonable intervention	good		20 - 40	possible		possible		low		limited		limited reduction	-	
	E.5	Horizontal division	horizontal transparent disivison (e. g. textile or glass material)											*no thermal comfort simulations performed*								slightly improved		no change		reasonable intervention	good		20 - 40	difficult		possible		high		limited		limited reduction	-	
	E.6	Local heating modules *(Design Builder simulation 05.A)*	radiative heating panels above the occupied space for localized heating											0,25		19,5	-0,3	12		locally increased		unchanged		no change		reasonable intervention	very good		20 - 40	possible		possible		high		high potential		controllable	> 1m²/m²	
	E.7	Local heating modules in combination with textile vertical division *(Design Builder simulation 05.B)*	Local heating modules in combination with textile vertical division											0,10		19,5	0	7		locally increased		unchanged		no change		reasonable intervention	very good		20 - 40	possible		possible		high		high potential		controllable	> 1m²/m²	

APPLICABILITY ON OTHER CHURCHES

Matrix as evaluation overview

EVALUATION CRITERIA

WINDOW RENOVATION STRATEGIES

Group	ID	Strategy	Structure (outside to inside)
	NOW	Single stained glass window *current situation large church space*	*Single stained glass*
A. INTERNAL SECONDARY GLAZING	A.1	Secondary single glass cavity ventilated with indoor air *Gerfkamer & Side chapels*	*stained glass* 10mm ventilated cavity 3mm*safety foil*3mm glass
A. INTERNAL SECONDARY GLAZING	A.2	Secondary single glass closed cavity *tested in the Gerfkamer & Side chapels*	*stained glass* cavity 3mm*safety foil*3mm glass
A. INTERNAL SECONDARY GLAZING	A.3	Secondary double glazing	*stained glass* 10mm unventilated cavity 4mm glass 6mm closed cavity with gas
B. INTERNAL WINDOW	B.1	Single glazed window	stained glass 200mm unventilated space thin glass window
B. INTERNAL WINDOW	B.2	Double glazed window	*stained glass* 200mm unventilated space double glazed window
C. EXTERNAL SECONDARY GLAZING	C.1	External secondary single glazing *covering the lead connections,* *fitted between the natural stone frame*	3mm*safety foil*3mm glass 200mm unventilated space *stained glass*
C. EXTERNAL SECONDARY GLAZING	C.2	External secondary double glazing *covering the lead connections,* *fitted between the natural stone frame*	3mm*safety foil*3mm glass 150mm unventilated space *stained glass*
C. EXTERNAL SECONDARY GLAZING	C.3	Museum arrangement	Double glazing 10mm ventilated cavity *stained glass*
C. EXTERNAL SECONDARY GLAZING	C.4	Bonded glazing	Double glazing with *stained* glass integrated in the cavity
D. OTHERS	D.1	Curtain as radiation screen	*stained glass* 300mm cavity low emissivity fabric
D. OTHERS	D.2	Curtain as textile wall insulation	*stained glass* 50mm cavity insulating fabric (felt)
D. OTHERS	D.3	Internal glass box	stained glass 300mm unventilated space (possibly outside infiltration) 10mm structural glazing box

ID	1. SPATIAL CHARACTERISTICS – 1.1 Functionality: Multi-functional	Café / Shop	Office	Church	1.2 Floor area: Very large	Limited	Very limited	1.3 Use cycle: Irregular use	Regular use	Very regular
A.1										
A.2										
A.3										
B.1										
B.2										
C.1										
C.2										
C.3										
C.4										
D.1										
D.2										
D.3										

ID	2. THERMAL COMFORT & HEATING DEMAND – 2.1 Window insulation U [W/m²K]	ΔU	2.2 Performance winter scenario T_{glass}[°C]	v_{ankle} [m/s]	2.3 Facade insulation $U_{combined}$	ΔU	2.4 Airtightness facade	THERMAL COMFORT & ENERGY DEMAND
NOW	5,76		8,3	0,42	2,78		Cracks / Thermal bridges	
A.1	3,98	1,78	14,3	0,26	2,25	0,53	unchanged	
A.2	3,69	2,07	16,1	0,19	2,16	0,62	unchanged	
A.3	1,01	4,75	16,7	0,16	1,36	1,42	unchanged	
B.1	3,02	2,74	14,1	0,27	1,96	0,82	improved	
B.2	1,01	4,75	16,7	0,16	1,36	1,42	improved	
C.1	3,69	2,07	16,1	0,19	2,16	0,62	unchanged	
C.2	1,01	4,75	16,7	0,16	1,36	1,42	unchanged	
C.3	1,49	4,26			1,51	1,28	unchanged	
C.4	2,78	2,98			1,89	0,89	unchanged	
D.1	4,88	0,88	13,2	0,29	2,52	0,26	largely improved	
D.2	2,51	3,25	13,8	0,28	1,81	0,97	largely improved	
D.3	1,01	4,75	16,7	0,16	1,36	1,42	improved	

ID	3. HERITAGE VALUES – 3.1 Conservation risks: Building Level	3.2 Conservation risks lead glass windows: Outside degradation	Condensation risk	Other risks	3.3 Exterior values	3.4 Interior values	3.5 Reversibility	HERITAGE VALUES
A.1	unchanged	unchanged	condensation risk	-	no change	small intervention	possible	
A.2	slightly improved	unchanged	condensation risk	-	no change	small intervention	possible	
A.3	improved	unchanged	*ext. ventilation* / *int. ventilation*	-	no change	small intervention	possible	
B.1	slightly improved	unchanged	*ext. ventilation* / *int. ventilation*	-	no change	reasonable intervention	possible	
B.2	improved	unchanged	*ext. ventilation* / *int. ventilation*	-	no change	reasonable intervention	possible	
C.1	slightly improved	improved	*ext. ventilation* / *int. ventilation*	-	intervention	no change	possible	
C.2	improved	improved	*ext. ventilation* / *int. ventilation*	-	intervention	no change	possible	
C.3	improved	improved	*single glazing* / *double glazing*	removal glass	intervention	no change	not possible	
C.4	slightly improved	improved	condensation risk	cutting thermal breakage	intervention	no change	not possible	
D.1	slightly improved	unchanged	no risk	-	no change	reasonable intervention	very good	
D.2	slightly improved	unchanged	low risk	-	no change	reasonable intervention	very good	
D.3	improved *option to integrate control*	unchanged	low risk	-	no change	reasonable intervention	challenging	

ID	4. LIFE CYCLE & DURABILITY – 4.1 Lifespan	4.2 Maintenance	4.3 Embodied Carbon EC [kgCO2/m² or kg]	4.4 Circularity	DURABILITY	5. FINANCE – 5.1 Costs	5.2 Payback	5.3 Profit	ECONOMIC EFFICIENCY	6. LIGHT & ACOUSTICS – 6.1 Lighting	6.2 Acoustics	LIGHT & ACOUSTICS
A.1	40 - 100	difficult	21,6/m² 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
A.2	40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
A.3	20 -40	difficult	32,5/m2 8mm double glazing, ex cavity & frame	difficult		high	long-term	limited		unchanged	-	
B.1	40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		high	long-term	limited		unchanged	-	
B.2	20 - 40	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		high	long-term	limited		unchanged	-	
C.1	40 - 100	difficult	21,6/m2 6mm single glazing, ex frame	possible		basis	long-term	limited		unchanged	-	
C.2	20 - 40	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		high	long-term	limited		unchanged	-	
C.3	40 - 100	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	limited		unchanged	-	
C.4	40 - 100	difficult	32,5/m2 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	limited		unchanged	-	
D.1	< 20	possible		possible		low	mid-term	good		temporary reduction	> 1m²/m²	
D.2	< 20	possible	11/m² wool	possible		low	mid-term	good		temporary reduction	> 1m²/m²	
D.3	20 - 40	difficult	32,5 8mm double glazing, ex cavity, ex frame	difficult		very high	long-term	high potential		limited reduction	-	

SPATIAL ADAPTATION STRATEGIES

Group	ID	Strategy	Structure
	NOW	*South chapel basis model simulation DesignBuilder*	
E. INDOOR SPACE ADAPTATION	E.1	Floorplan adaptation or Zoning the indoor space	permanent internal division(s) and/or built in new storeys and spaces
E. INDOOR SPACE ADAPTATION	E.2	Box in Box temporary *(Design Builder simulation 04)*	flexible, temporary tent or box in box structure
E. INDOOR SPACE ADAPTATION	E.3	Box in Box permament	permanent box in box structure
E. INDOOR SPACE ADAPTATION	E.4	Vertical division	vertical divison (e. g. textile or glass material) for compartmentalization of the occupied space
E. INDOOR SPACE ADAPTATION	E.5	Horizontal division	horizontal transparent disivison (e. g. textile or glass material)
E. INDOOR SPACE ADAPTATION	E.6	Local heating modules *(Design Builder simulation 05.A)*	radiative heating panels above the occupied space for localized heating
E. INDOOR SPACE ADAPTATION	E.7	Local heating modules in combination with textile vertical division *(Design Builder simulation 05.B)*	Local heating modules in combination with textile vertical division

ID	1. SPATIAL CHARACTERISTICS – 1.1 Functionality: Multi-functional	Café / Shop	Office	Church	1.2 Floor area: Very large	Limited	Very limited	1.3 Use cycle: Irregular use	Regular use	Very regular use
E.1										
E.2										
E.3										
E.4										
E.5										
E.6										
E.7										

ID	2. THERMAL COMFORT & HEATING DEMAND – 2.1 Air velocity [m/s]	2.2 MRT [°C]	2.3 PMV *(-3 to +3)*	2.4 PPD [%]	2.5 Heating demand	THERMAL COMFORT & ENERGY DEMAND
NOW	0,25 - 0,30	16	-1	20 - 28	basis	
E.1	*no thermal comfort simulations performed*					
E.2	0,15	19	0	11	unchanged	
E.3	*no thermal comfort simulations performed*					
E.4	*no thermal comfort simulations performed*					
E.5	*no thermal comfort simulations performed*					
E.6	0,25	19,5	-0,3	12	locally increased	
E.7	0,10	19,5	0	7	locally increased	

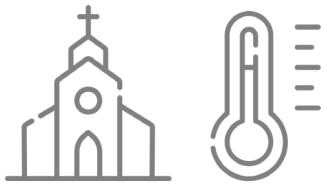
ID	3. HERITAGE VALUES – 3.1 Conservation risks	3.3 Exterior values	3.4 Interior values	3.5 Reversibility	HERITAGE VALUES
E.1	unchanged	no change	intervention	not possible	
E.2	unchanged	no change	reasonable intervention	very good	
E.3	unchanged	no change	reasonable intervention	not possible	
E.4	unchanged	no change	reasonable intervention	good	
E.5	slightly improved	no change	reasonable intervention	good	
E.6	unchanged	no change	reasonable intervention	very good	
E.7	unchanged	no change	reasonable intervention	very good	

ID	4. LIFE CYCLE & DURABILITY – 4.1 Lifespan	4.2 Maintenance		4.4 Circularity	DURABILITY	5. FINANCE – 5.1 Costs		5.3 Profit	ECONOMIC EFFICIENCY	6. LIGHT & ACOUSTICS – 6.1 Lighting	6.2 Acoustics	LIGHT & ACOUSTICS
E.1	40 - 100	possible		difficult		very high		high potential		adjustable	1m²/m²	
E.2	< 20	possible		possible		low		good		unchanged	-	
E.3	40- 100	possible		possible		very high		high potential		adjustable	1m²/m²	
E.4	20 - 40	possible		possible		low		limited		limited reduction	-	
E.5	20 - 40	difficult		possible		high		limited		limited reduction	-	
E.6	20 - 40	possible		possible		high		high potential		controllable	> 1m²/m²	
E.7	20 - 40	possible		possible		high		high potential		controllable	> 1m²/m²	

APPLICABILITY ON OTHER CHURCHES

Stepped approach towards identifying suitable renovation strategies

1 Relevance & applicability evaluation matrix



building characteristics & thermal comfort challenge

APPLICABILITY ON OTHER CHURCHES

Example case-study Walburgiskerk Zutphen

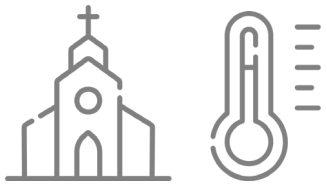
source: https://www.gelderlander.nl/zutphen/langs-verborgen-schatten-in-walburgis-kerk-in-zutphen~a88635c6/217208480/

source: https://fotografie.gerritveldman.nl/image/546/walburgiskerk-zutphen

APPLICABILITY ON OTHER CHURCHES

Stepped approach towards identifying suitable renovation strategies

1 Relevance & applicability evaluation matrix



building characteristics & thermal comfort challenge

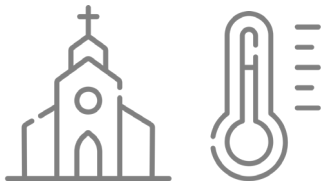
2 Identify requirements

building & user needs

APPLICABILITY ON OTHER CHURCHES

Stepped approach towards identifying suitable renovation strategies

1 Relevance & applicability evaluation matrix



building characteristics & thermal comfort challenge

2 Identify requirements

building & user needs

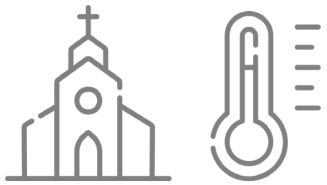
3 Define renovation objective(s)

building vision

APPLICABILITY ON OTHER CHURCHES

Stepped approach towards identifying suitable renovation strategies

1 Relevance & applicability evaluation matrix



building characteristics & thermal comfort challenge

2 Identify requirements

building & user needs

3 Define renovation objective(s)

building vision

4 Select renovation strategies

identify & combine with the matrix

APPLICABILITY ON OTHER CHURCHES

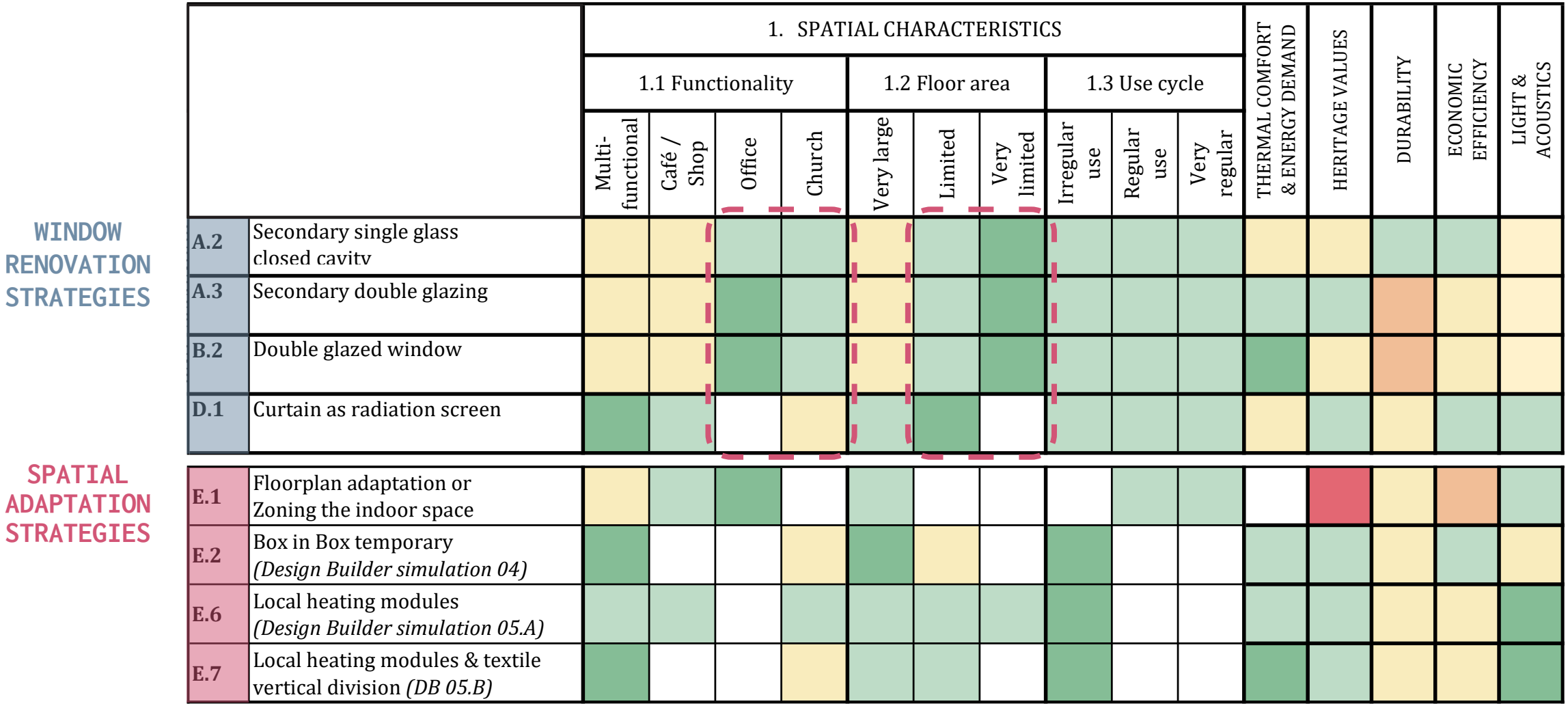
How the evaluation matrix can support the selection of renovation strategies

		1. SPATIAL CHARACTERISTICS										THERMAL COMFORT & ENERGY DEMAND	HERITAGE VALUES	DURABILITY	ECONOMIC EFFICIENCY	LIGHT & ACOUSTICS
		1.1 Functionality				1.2 Floor area			1.3 Use cycle							
		Multi-functional	Café / Shop	Office	Church	Very large	Limited	Very limited	Irregular use	Regular use	Very regular					
WINDOW RENOVATION STRATEGIES	A.2 Secondary single glass closed cavity															
	A.3 Secondary double glazing															
	B.2 Double glazed window															
	D.1 Curtain as radiation screen															
SPATIAL ADAPTATION STRATEGIES	E.1 Floorplan adaptation or Zoning the indoor space															
	E.2 Box in Box temporary *(Design Builder simulation 04)*															
	E.6 Local heating modules *(Design Builder simulation 05.A)*															
	E.7 Local heating modules & textile vertical division *(DB 05.B)*															

zoom-in abbreviated matrix

APPLICABILITY ON OTHER CHURCHES

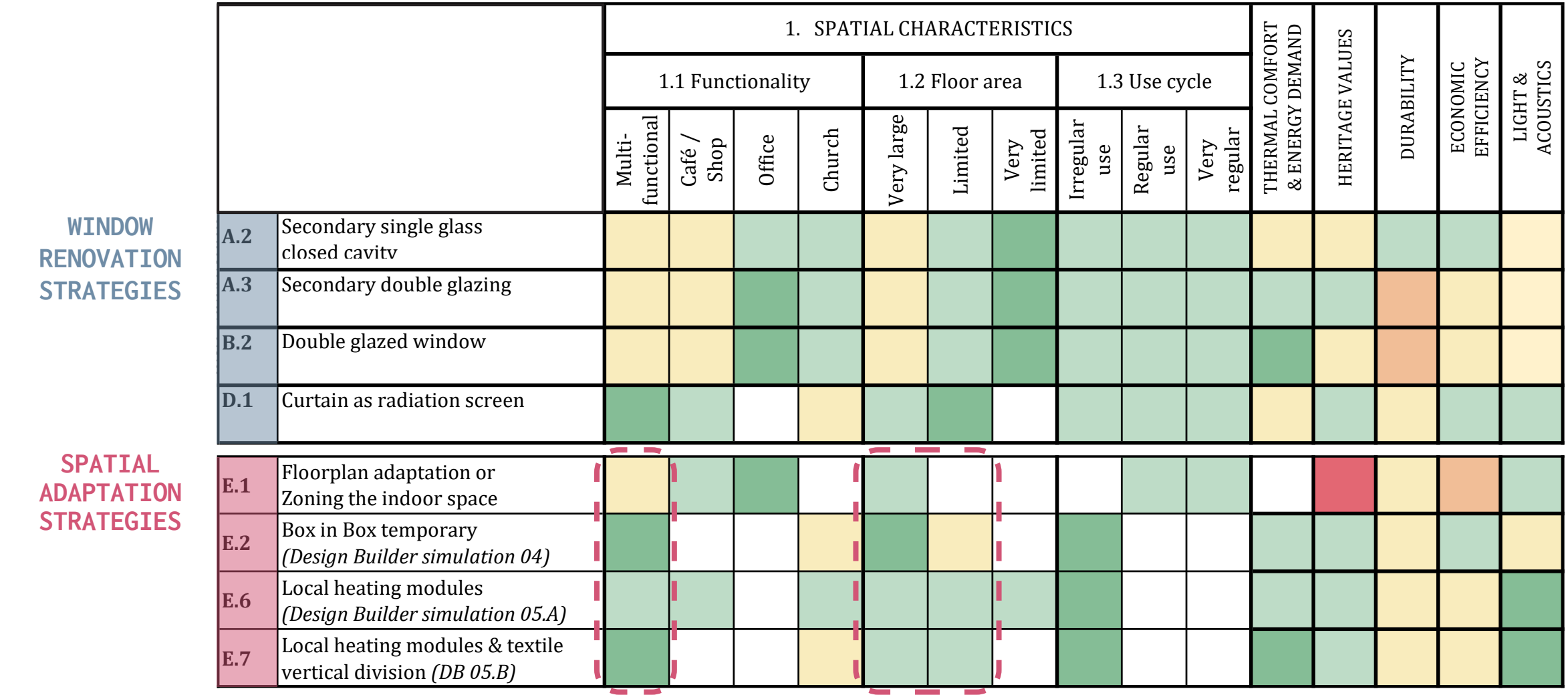
How the evaluation matrix can support the selection of renovation strategies



zoom-in abbreviated matrix

APPLICABILITY ON OTHER CHURCHES

How the evaluation matrix can support the selection of renovation strategies



zoom-in abbreviated matrix

APPLICABILITY ON OTHER CHURCHES

How the evaluation matrix can support the selection of renovation strategies

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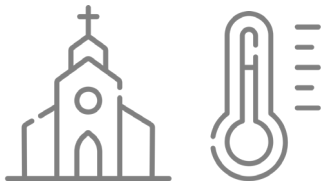
	E.7 Local heating modules & textile vertical division *(DB 05.B)*															

zoom-in abbreviated matrix

APPLICABILITY ON OTHER CHURCHES

Stepped approach towards identifying suitable renovation strategies

1 Relevance & applicability evaluation matrix



building characteristics & thermal comfort challenge

2 Identify requirements

building & user needs

3 Define renovation objective(s)

building vision

4 Select renovation strategies

identify & combine with the matrix

5 Adapt renovation strategies

building specific design

CONCLUSION

«How can the renovation of the stained glass windows in combination with indoor space adaptations increase the thermal comfort in the multi-functional Stevenskerk in order to improve the accessibility of the monument all year around?»

CONCLUSION

Research question

«How can the renovation of the stained glass windows in combination with indoor space adaptations increase the thermal comfort in the multi-functional Stevenskerk in order to improve the accessibility of the monument all year around?»

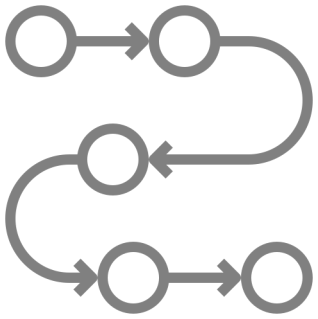
COMPARATIVE OVERVIEW
RENOVATION STRATEGIES

CONCLUSION

Research question

«How can the renovation of the stained glass windows in combination with indoor space adaptations increase the thermal comfort in the multi-functional Stevenskerk in order to improve the accessibility of the monument all year around?»

COMPARATIVE OVERVIEW
RENOVATION STRATEGIES



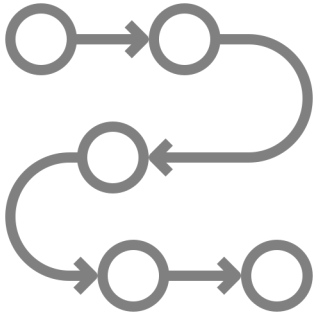
STEPPED APPROACH HOW TO IDENTIFY
SUITABLE RENOVATION STRATEGIES

CONCLUSION

Research question

«How can the renovation of the stained glass windows in combination with indoor space adaptations increase the thermal comfort in the multi-functional Stevenskerk in order to improve the accessibility of the monument all year around?»

COMPARATIVE OVERVIEW
RENOVATION STRATEGIES



STEPPED APPROACH HOW TO IDENTIFY
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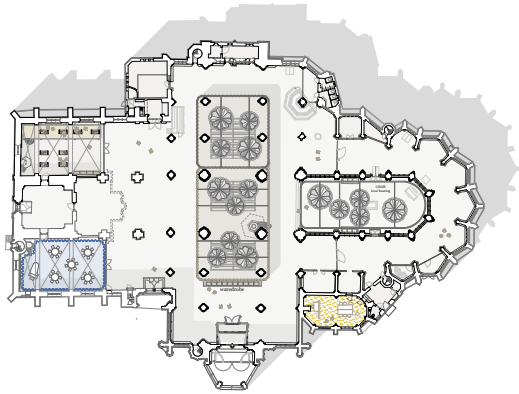


RENOVATION PROPOSAL
FOR THE CASE-STUDY STEVENSKERK

EVALUATION MATRIX

Expand evaluation matrix with more evaluation criteria and more diverse renovation strategies such as vault insulation, heat recovery and renewable energy production potentials

CONCLUSION

Further research

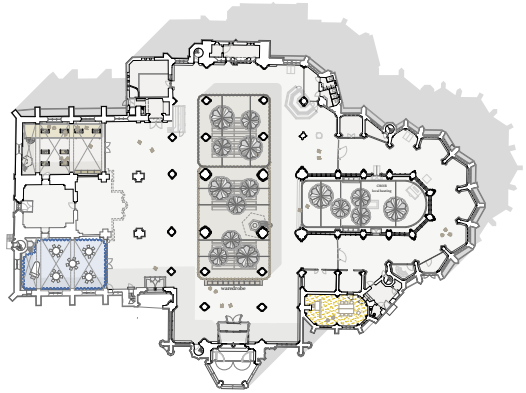
EVALUATION MATRIX

Expand evaluation matrix with more evaluation criteria and more diverse renovation strategies such as
vault insulation, heat recovery and renewable energy production potentials

RENOVATION STEVENSKERK

Renovation proposal – Detailed planning regarding the connections/materiality etc. as the next step

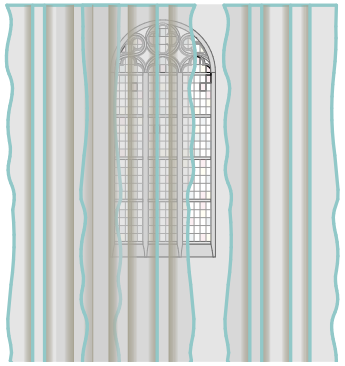
Research other renovation strategies:
Vault insulation / Ventilation etc.



CONCLUSION

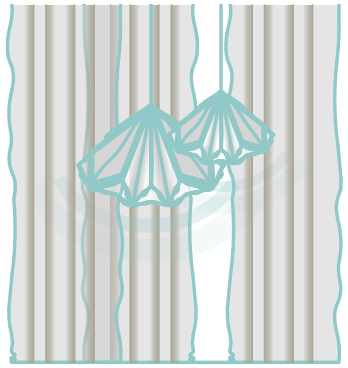
Reflection

LEARNING FROM THE PAST
HISTORICAL ORIGIN OF PROPOSED RENOVATION STRATEGIES



curtain as
radiation screen

1. https://mymodernmet.com/famous-tapestries/



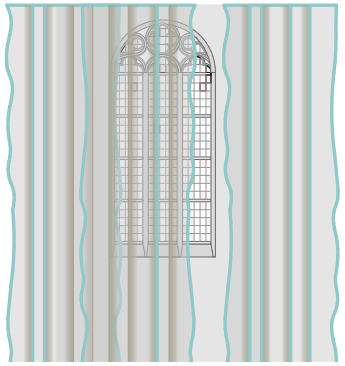
local heating &
box in box

1. https://de.wikipedia.org/wiki/Himmelbett
2. https://heavenly-holland.com/stoves/

CONCLUSION

Reflection

LEARNING FROM THE PAST
HISTORICAL ORIGIN OF PROPOSED RENOVATION STRATEGIES



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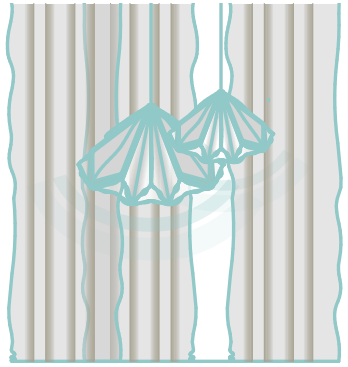

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COMBINE CURRENT USER &
MONUMENTAL CONSERVATION REQUIREMENTS

THANK YOU

QUESTIONS?

First mentor: Ing. E. R. van den Ham
Second mentor: Dr. N. J. Clarke
Delegate: Drs. A. Mulder

Franziska Mack - 5366305
P5 Presentation
29th of June 2022
Graduation project Building Technology

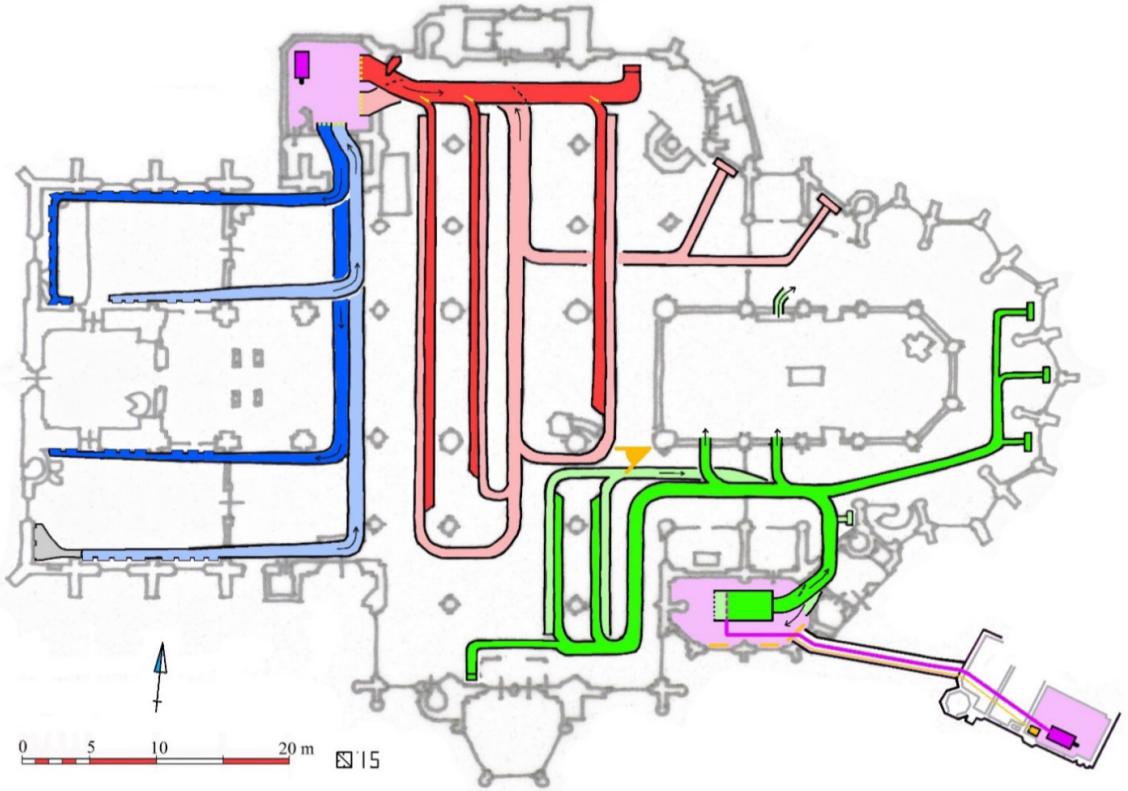
APPENDIX

HYPOCAUST AIR-HEATING SYSTEM STEVENSKERK

Dating from the renovation 1953-1969

AIR DUCTS BELOW THE FLOOR

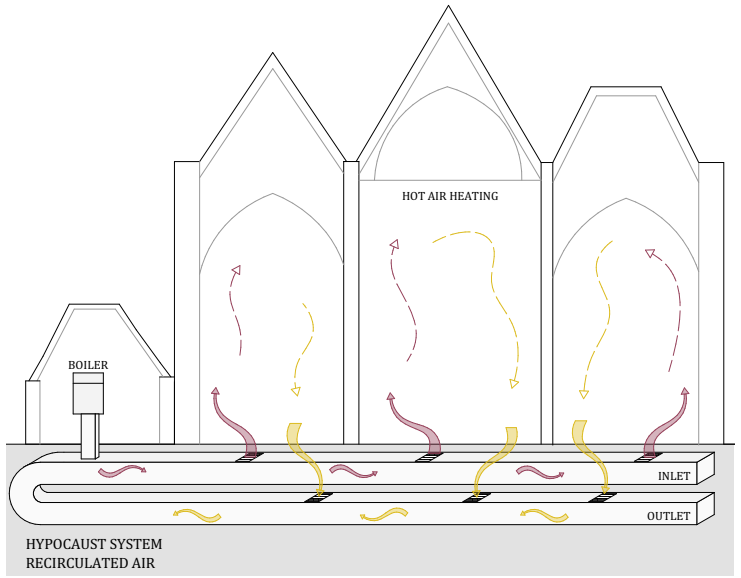
FLOORPLAN SUPPLY AND RETURN DUCTS STEVENSKERK



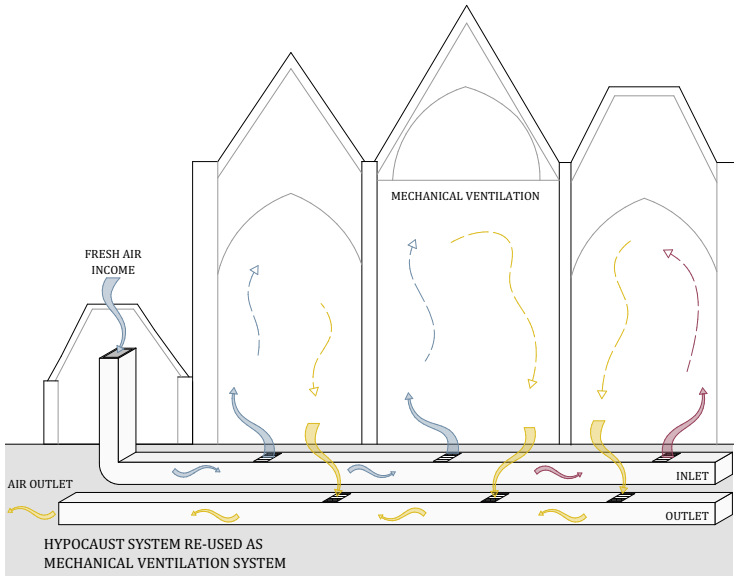
MECHANICAL VENTILATION SYSTEM

Concepts for the integration

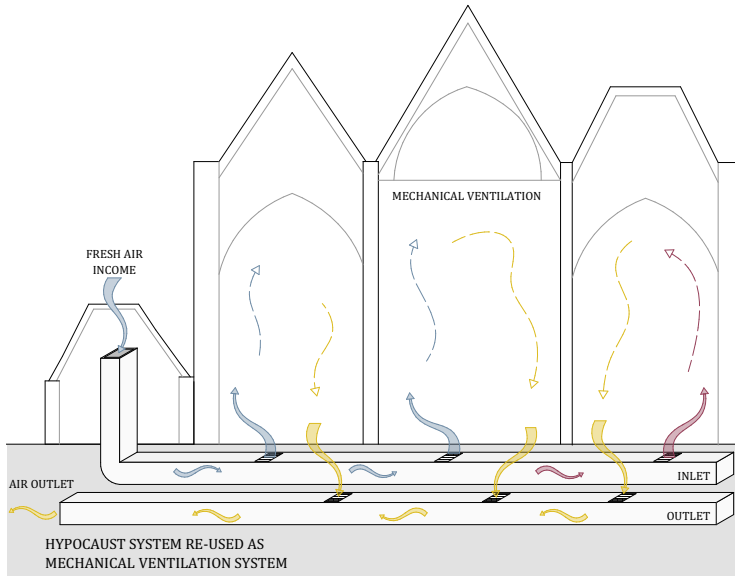
HYPOCAUST AIR HEATING SYSTEM



INTEGRATED VENTILATION CONCEPT 1

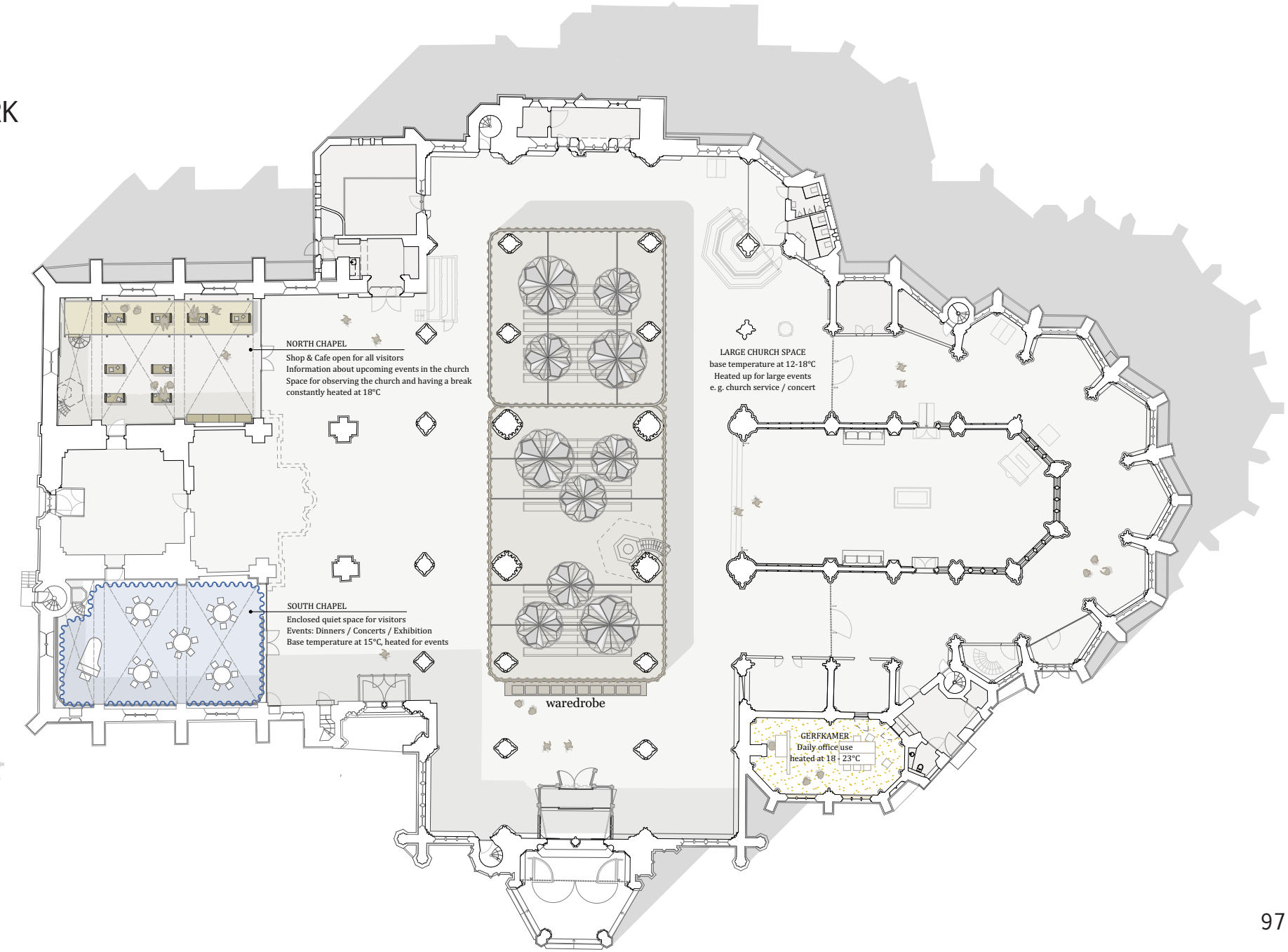


INTEGRATED VENTILATION CONCEPT 2

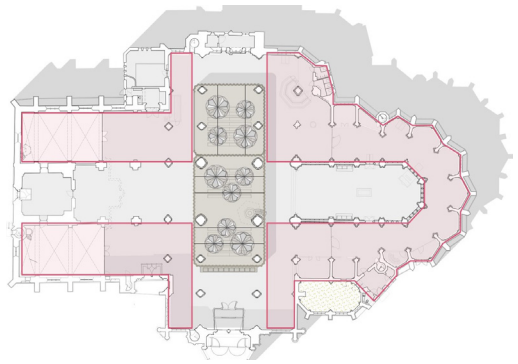


STEP-BY-STEP PLAN
RENOVATION STEVENSKERK

Step 1
short term 2 to 5 years

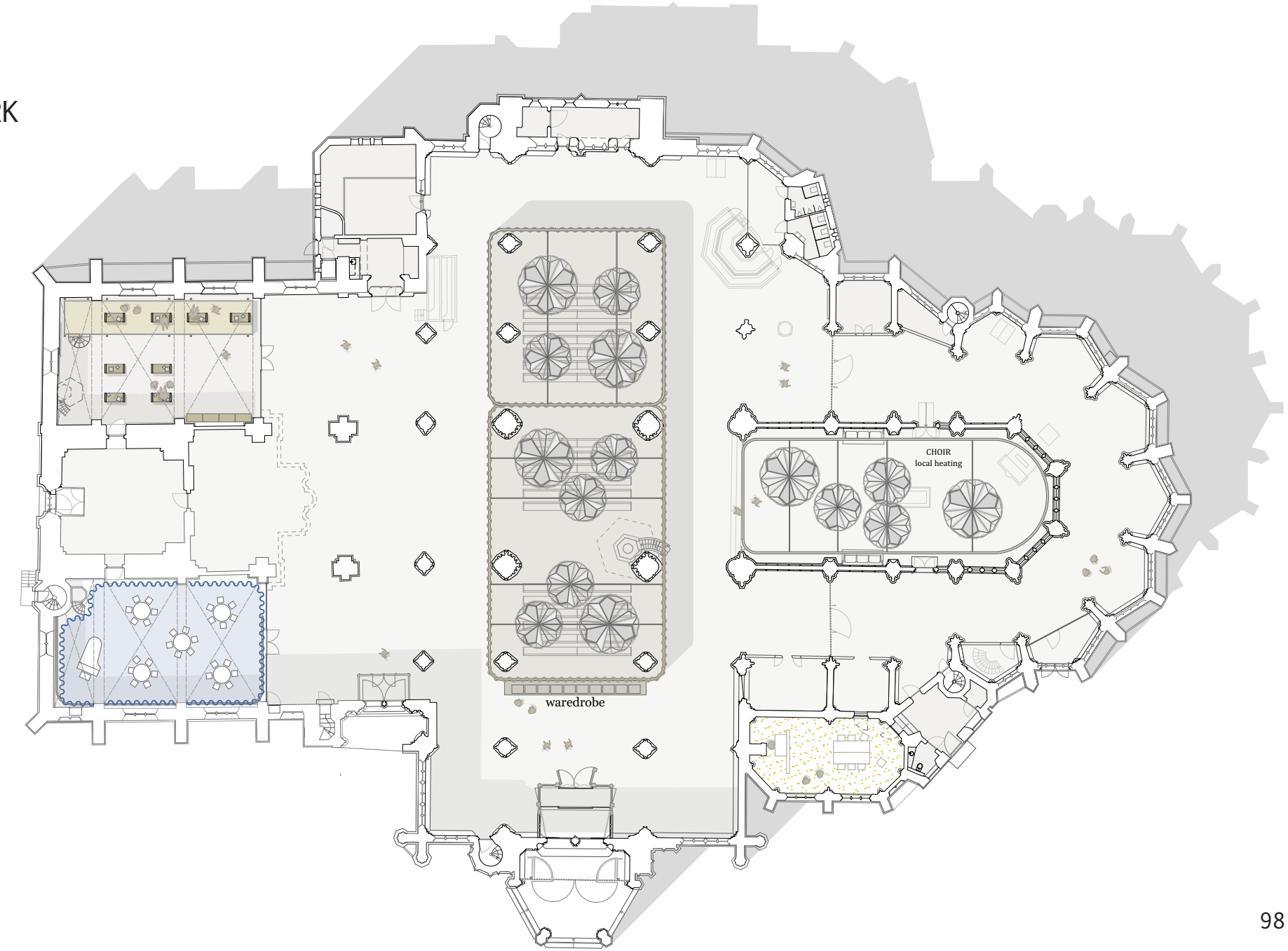


Stone vault insulation

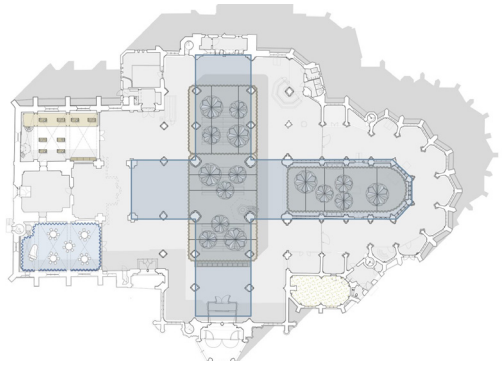


STEP-BY-STEP PLAN
RENOVATION STEVENSKERK

Step 2
5 to 10 years

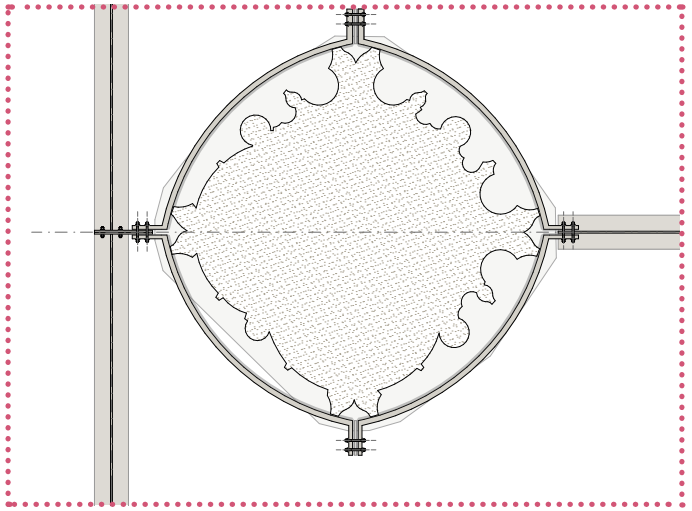


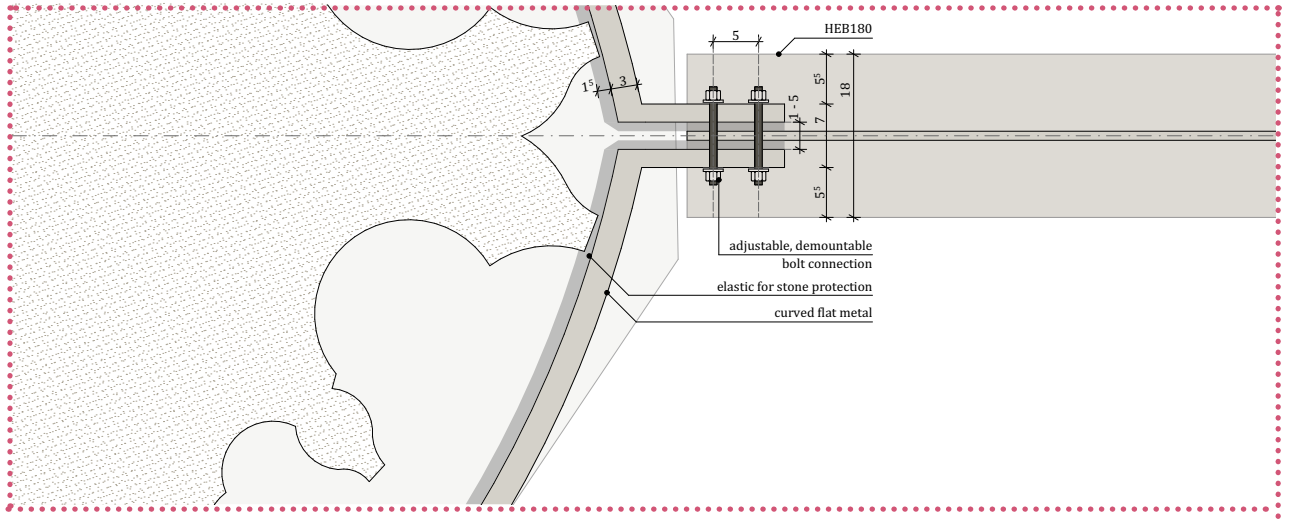
Wooden vault insulation

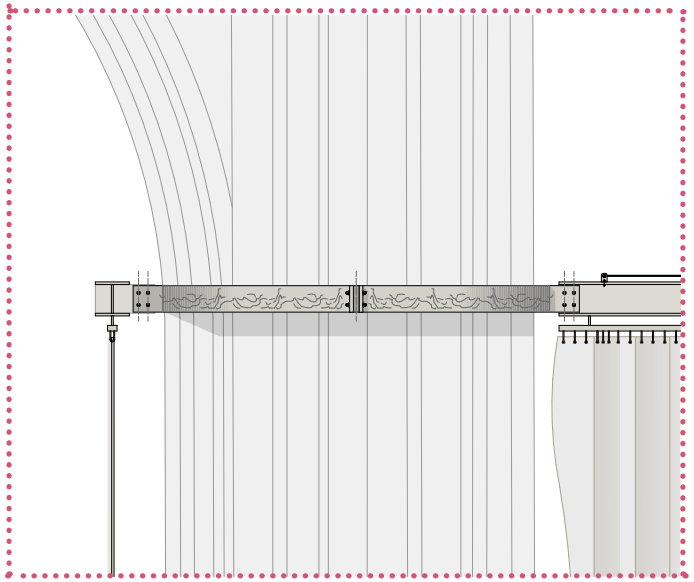


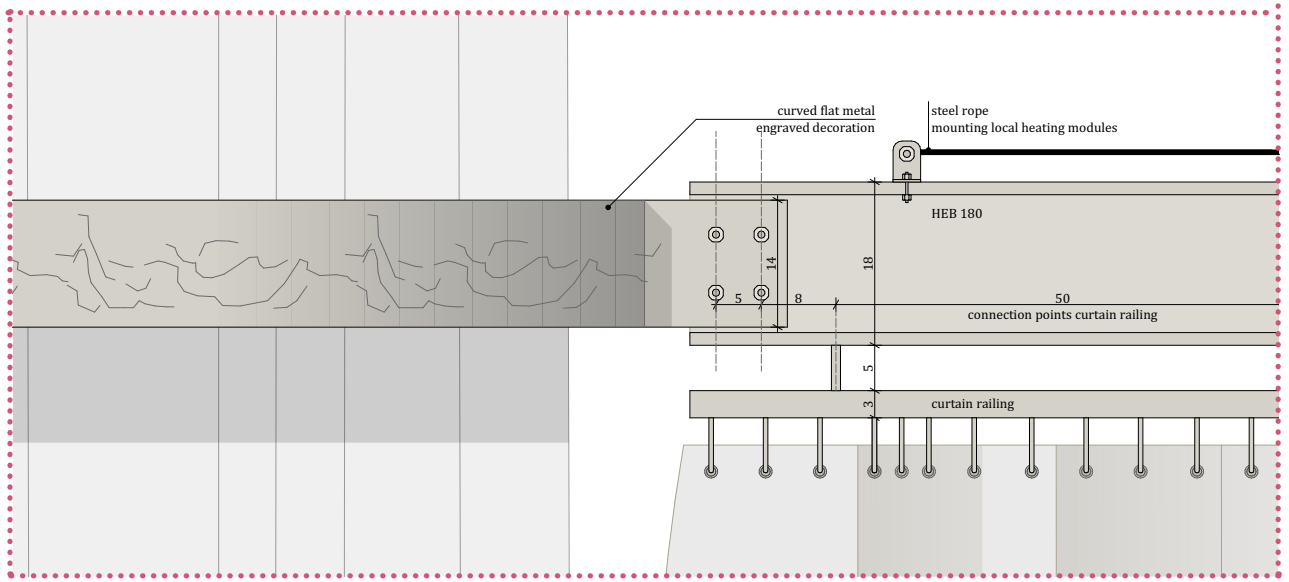
LARGE SPACE STEVENSKERK

Detailing example curtain connection points



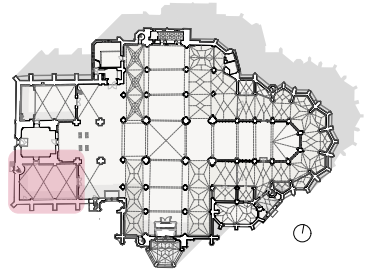




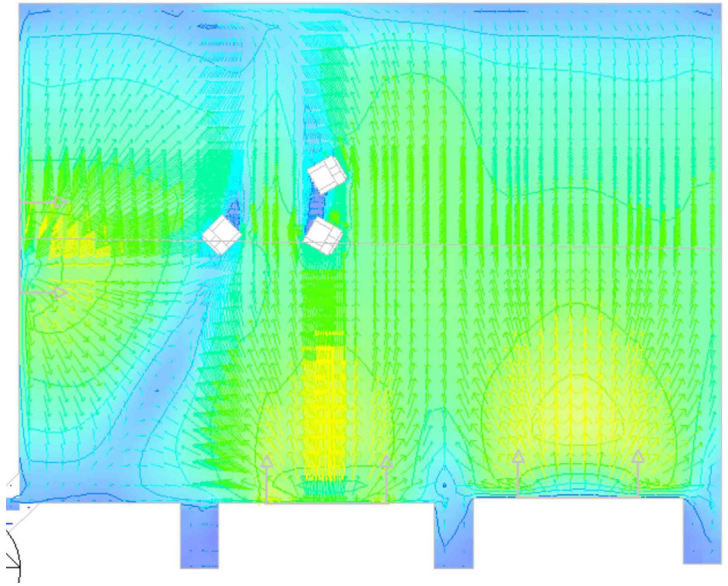


SOUTH CHAPEL

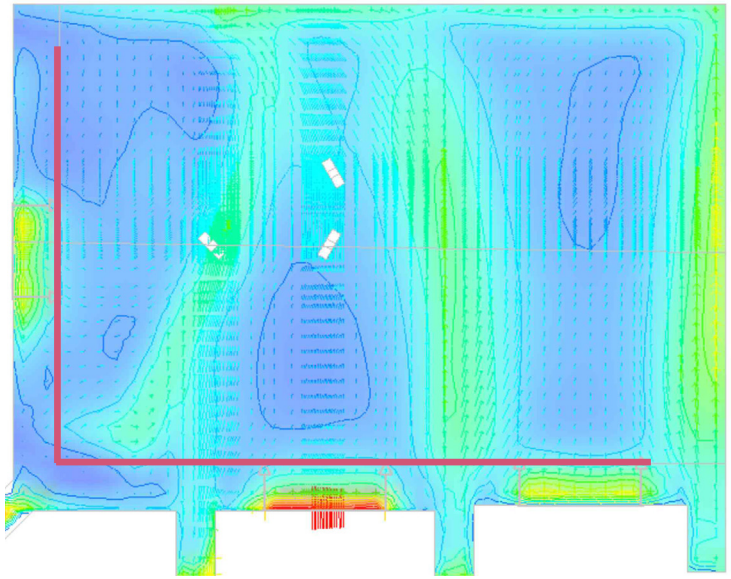
Simulation air stream velocity with curtain as radiation screen
Horizontal section diagram at 1 m height



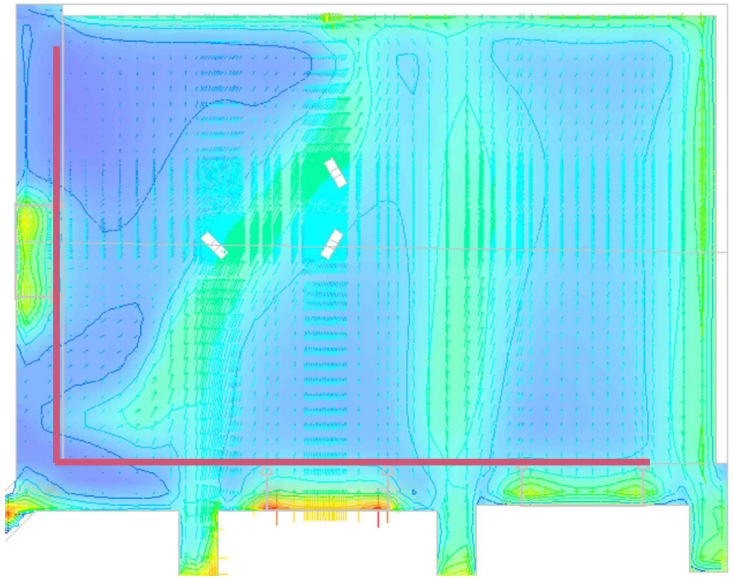
BASIS MODEL – SITUATION NOW



TRANSLUCENT FABRIC AS RADIATION SCREEN



OPAQUE FELT FABRIC AS RADIATION SCREEN



VELOCITY m/s