Building Technology Graduation Topic

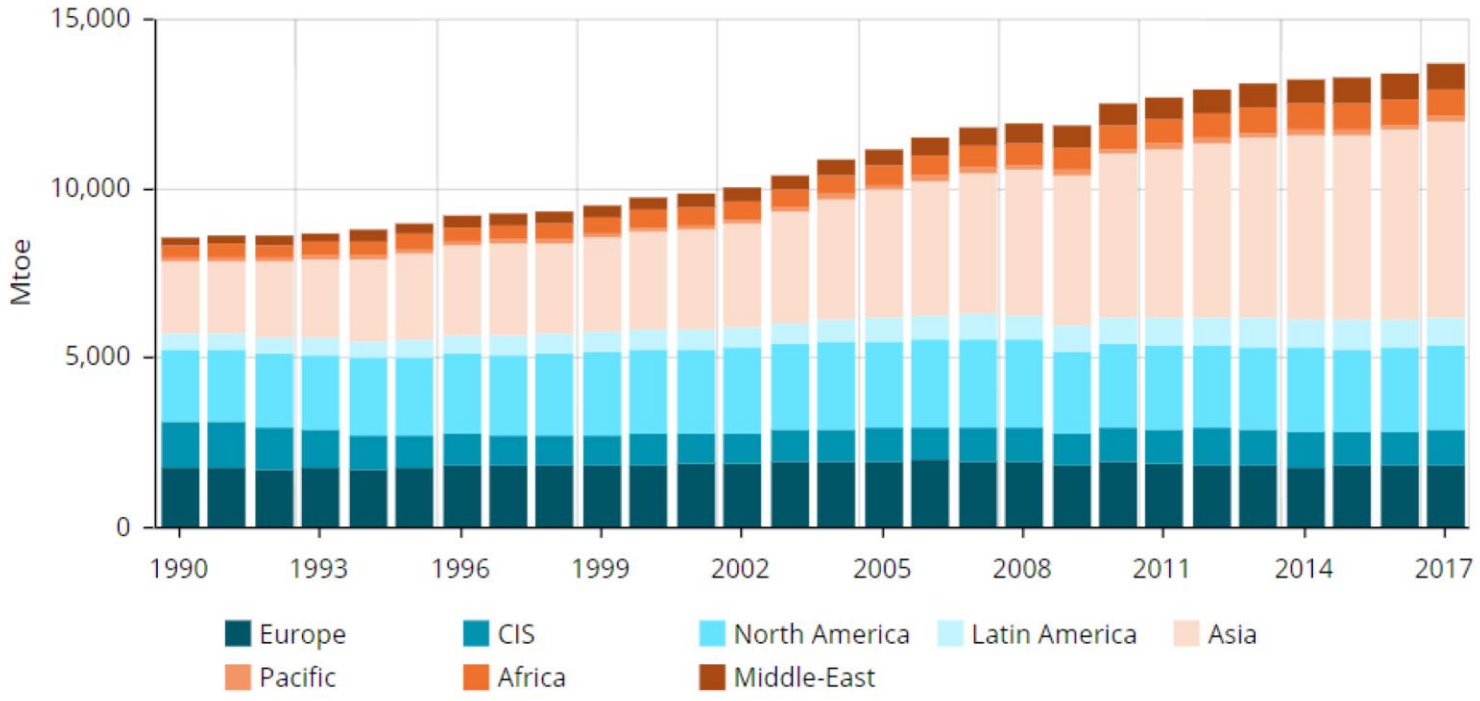
Photovoltaic Technology and Heritage :
Towards a zero energy building environment

Student : Ioanna Tzetzi
Student Number :4744527

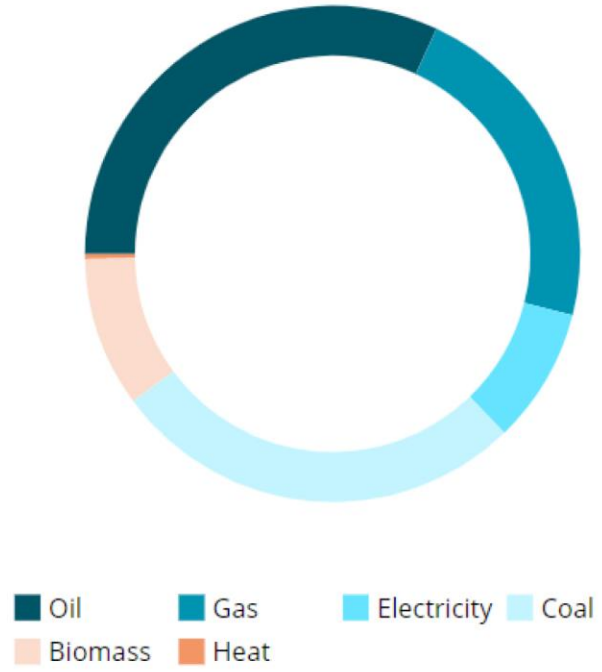
Mentor Team : Andy van den Dobbelsteen
Wido Quist
Zoheir Haghighi

External Examiner: F.L. Hooimeijer

Global Energy Consumption Trend
1990- 2017



Global Energy Consumption by Continent



Global Energy Consumption by Material

Enerdata : Global Energy Statistical Yearbook 2018 _ https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

The building environment is the cause of...

40 %

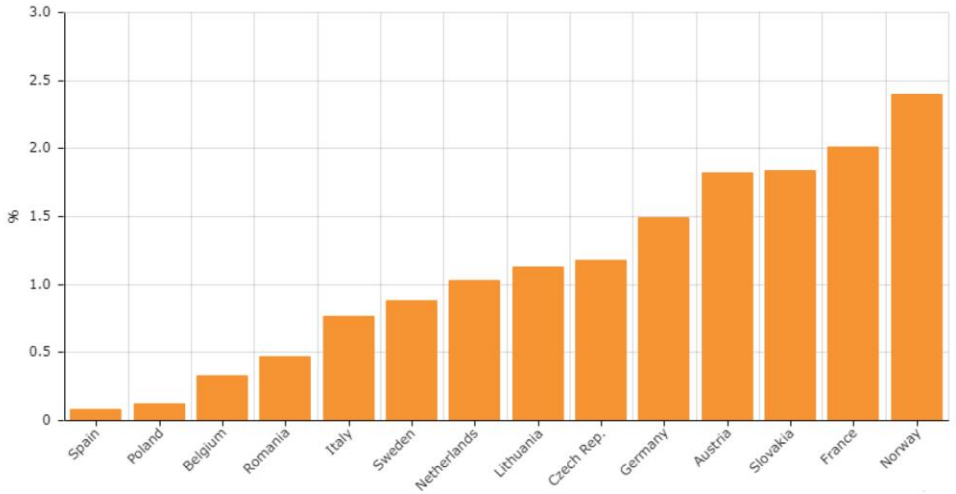
energy consumption

&

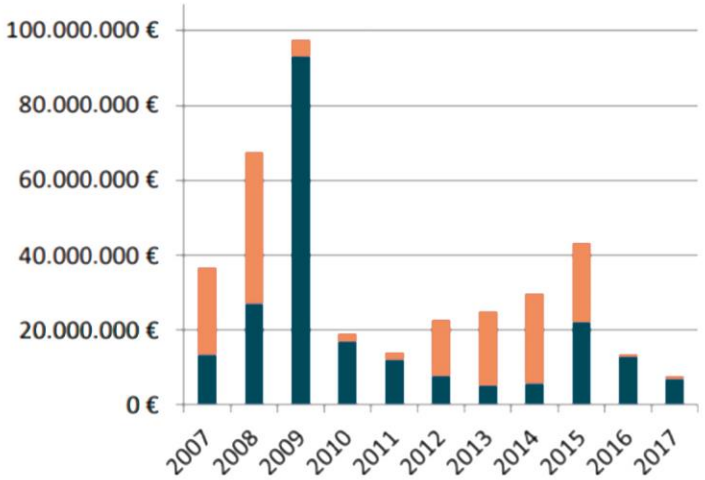
36 %

the total CO_2 emissions

Renovation & Construction Rate



Percentage of annual non-residential stock renovated by level of renovation



Greece: Project costs on Museum and Monuments

Project costs in progress Project costs being done

6,5 %

The Netherlands

0,8 %

Italy

-14.6 %

Greece

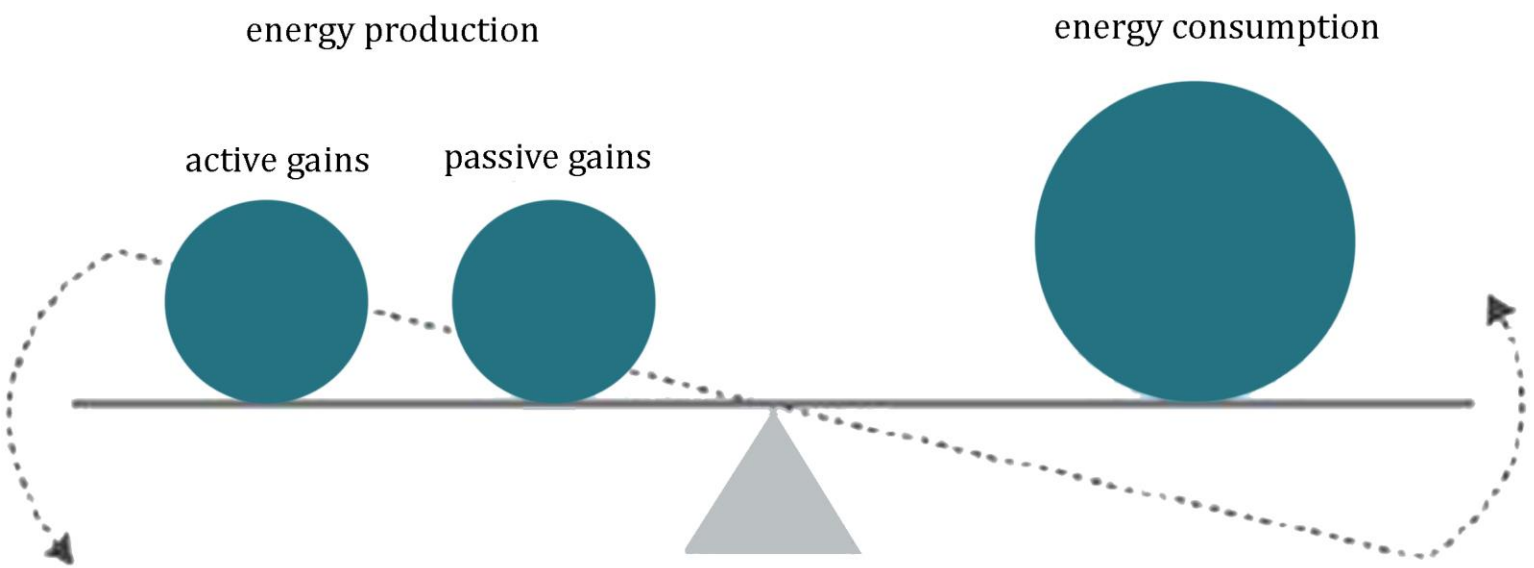
4,3%

EU

Annual change in the production indicator in the construction sector (2017)

Enerdata : Global Energy Statistical Yearbook 2018 _ https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

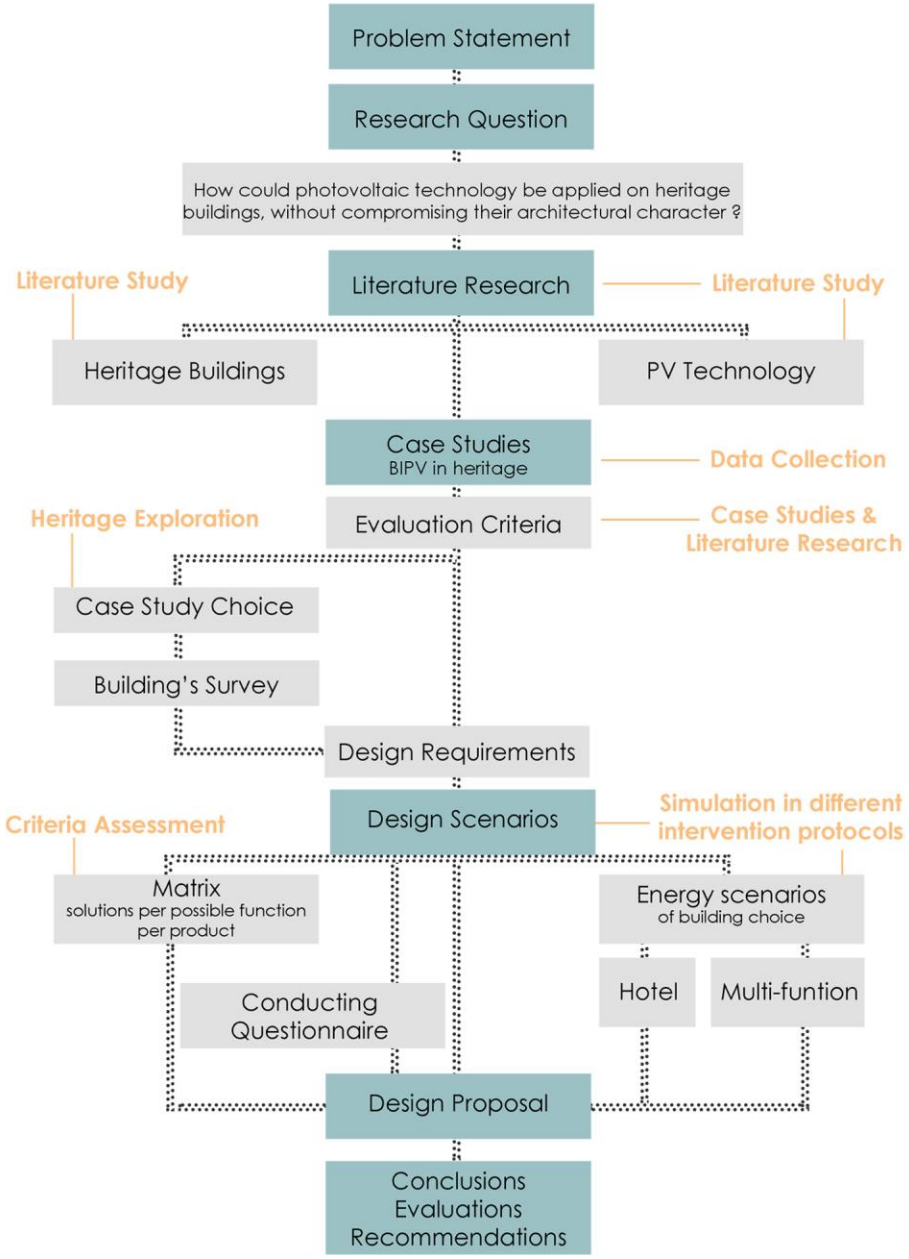
Energy Balance



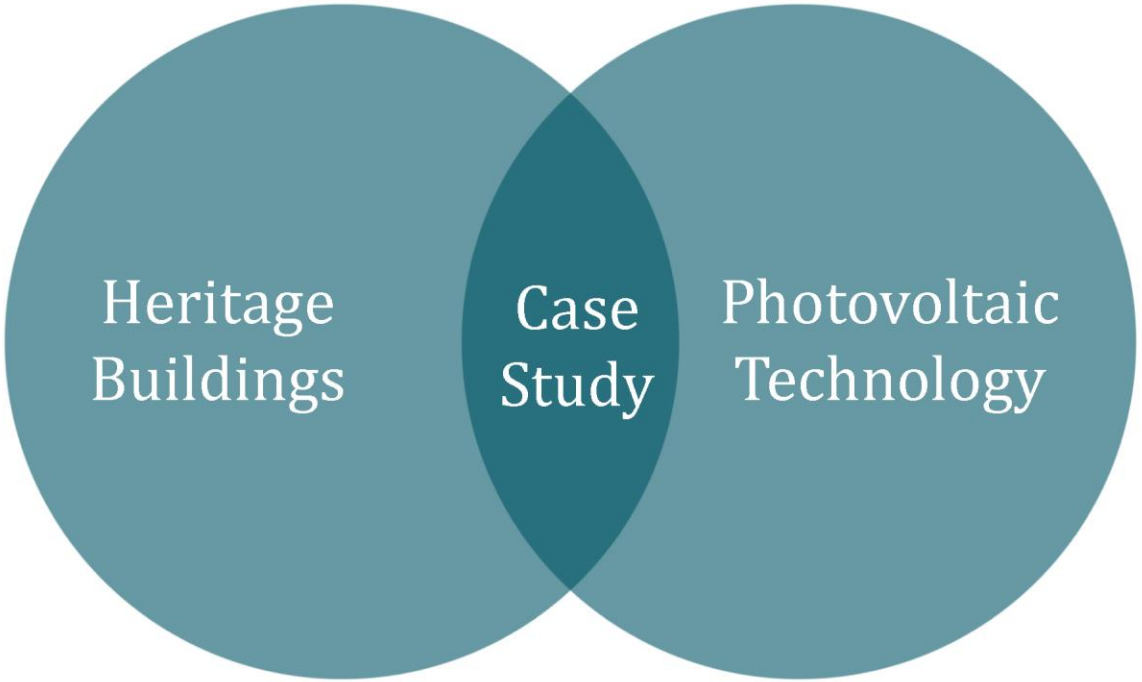
Main Research Question :

How could photovoltaic technology be applied on heritage buildings,

without compromising their architectural character?


Problem Statement
Research Question
How could photovoltaic technology be applied on heritage buildings, without compromising their architectural character ?
Literature Study
Literature Research
Literature Study
Heritage Buildings
PV Technology
Case Studies
BIPV in heritage
Data Collection
Heritage Exploration
Evaluation Criteria
Case Studies & Literature Research
Case Study Choice
Building's Survey
Design Requirements
Criteria Assessment
Design Scenarios
Simulation in different intervention protocols
Matrix
solutions per possible function per product
Energy scenarios
of building choice
Hotel
Multi-funtion
Conducting Questionnaire
Design Proposal
Conclusions
Evaluations
Recommendations

Literature Research



Legislation Framework

Cultural Heritage is considered the monuments, group of buildings and sites, which have a universal invaluable estimation from historical, ethnological, antropological, artistic, aethetical and scientific point of view.

https://en.unesco.org/

"...authenticity and preservation of every heritage, safeguarding history in a globalized world. "
(Nara Document, 1994)

"... intergrated conservation of heritage in a modern urban planning ."
(Amsterdam Declaration, 1975)

" ...applying the guidelines through the countries' own culture and traditions."
(Charter of Venice, 1964)

Guidelines for Heritage Interventions

Wateringsevest Street, Delft, Netherlands

High-risk values by PV integration on heritage

High risk of damage by winning solar energy	*Risk depends on the specific motivation*	*Without the risk of damage by winning solar energy*
Architectural value	Archaeological value	Cultural value
Artistic value	Industrial-archaeological value	Social value
Aesthetic value	Urban planning value	Folklore value
Historical value	Technical value	
Spatial-structuring value	Scientific value	
	Common interest	
	National importance	
	Values to be reinterpreted	

Criteria for better integration from Flemish Goverment

- built-in installations
- resembling traditional materials
- grouping and alighnment
- integration level
- experience value

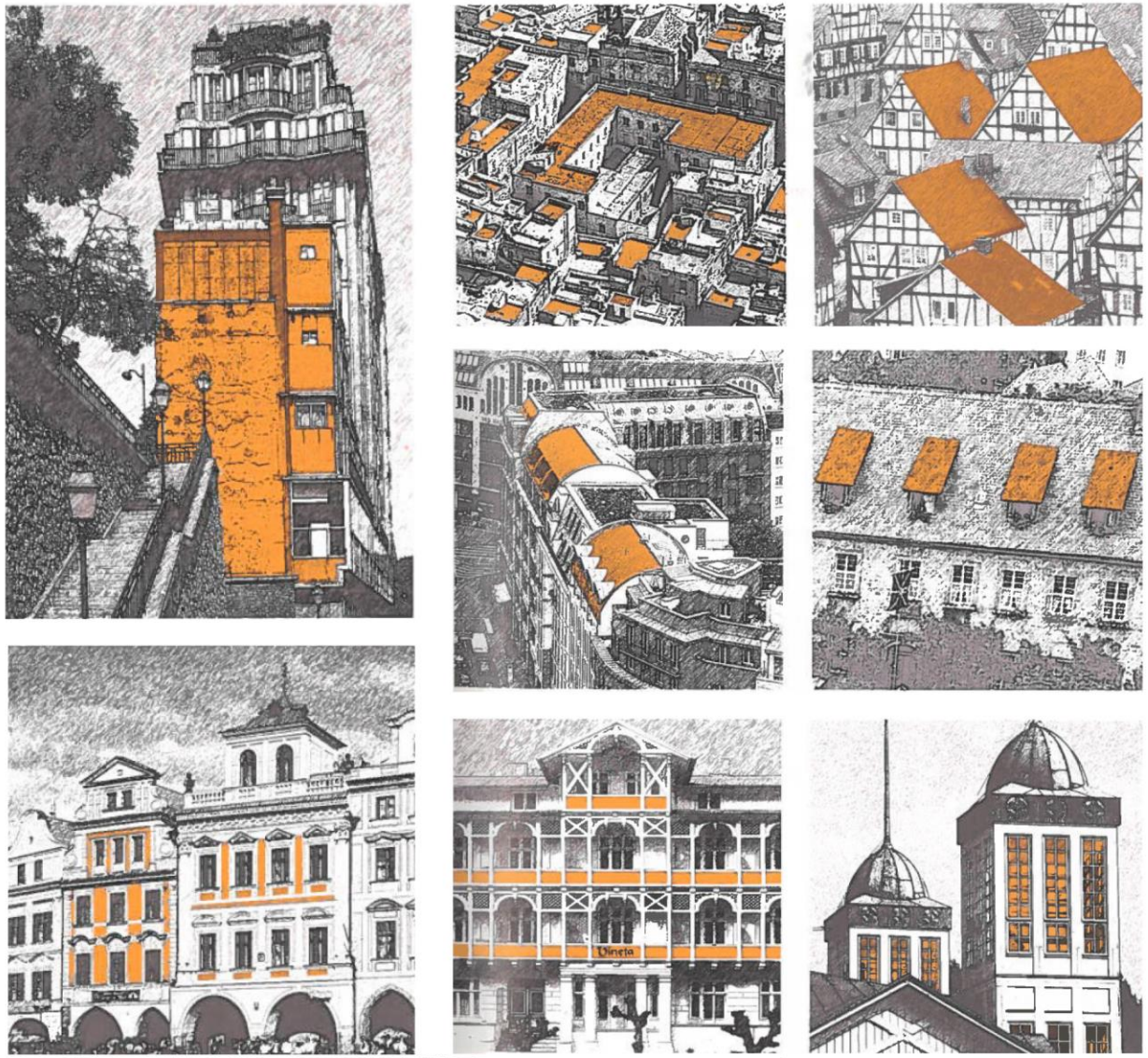
Visibility interpretation by goverment

St. Trudo, Belgium

St. Silas, England

Reference Case Studies

Solar Design _ Range of applictaion



Roof Application

- Connected surface areas, orientation and inclination could be optimized according to the technological requirements.
- The installation and maintenance are possible without he need for scaffolding.
- Smaller surfaces could also be usable.

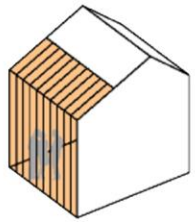
Facade Application

- Vertical installation of solar panels is less energy efficient that on inclined surfaces.
- Appliying photovoltaics to the facade is a difficult process due to specific style.
- Semi-transparent modules are recommended in this context.

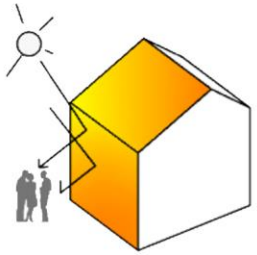
Hermannsdorfer I., Rub Ch. (2015) Solar Design : Photovoltaics for Old Buildings, Urban Space, Landscapes, jovis Verlag, Berlin

Color

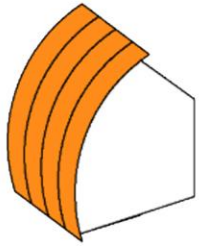
Pattern



Transparency



Optical reflection



Flexibility

Characteristics of PV application

generic

- **location** of the case

- construction **age**

- **use** of land

- hiring an architect or a consultant company for the application

architectural

- **area** of application

- **typology** of the building

- **color** of the PV

- respecting the **lines** (building rythm)

- **shape** of the modules

visual

- **visibility** from:

  * important viewports
  * street view
  * neighbour buildings
  * higher roof or landscape

- color adaptability (difference in color **shade**)

- **surface structure** (reflectivity)

- percentage of **coverage**

technical

- **orientation** requirements

- **technology** (generation)

- **efficiency** of the colored PV

- mountaining application

- **degree** of integration

Characteristics of PV application

generic

- **location** of the case
- construction **age**
- **use** of land
- hiring an architect or a consultant company for the application

architectural

- **area** of application
- **typology** of the building
- **color** of the PV
- respecting the **lines** (building rythm)
- **shape** of the modules

visual

- **visibility** from:
  * important viewports
  * street view
  * neighbour buildings
  * higher roof or landscape
- color adaptability (difference in color **shade**)
- **surface structure** (reflectivity)
- percentage of **coverage**

technical

- **orientation** requirements
- **technology** (generation)
- **efficiency** of the colored PV
- mountaining application
- **degree** of integration

Characteristics of PV application

generic

- **location** of the case
- construction **age**
- **use** of land
- hiring an architect or a consultant company for the application

architectural

- **area** of application
- **typology** of the building
- **color** of the PV
- respecting the **lines** (building rythm)
- **shape** of the modules

visual

- **visibility** from:
  * important viewports
  * street view
  * neighbour buildings
  * higher roof or landscape
- color adaptability (difference in color **shade**)
- **surface structure** (reflectivity)
- percentage of **coverage**

technical

- **orientation** requirements
- **technology** (generation)
- **efficiency** of the colored PV
- mountaining application
- **degree** of integration

Characteristics of PV application

generic

- **location** of the case
- construction **age**
- **use** of land
- hiring an architect or a consultant company for the application

architectural

- **area** of application
- **typology** of the building
- **color** of the PV
- respecting the **lines** (building rythm)
- **shape** of the modules

visual

- **visibility** from:
  * important viewports
  * street view
  * neighbour buildings
  * higher roof or landscape
- color adaptability (difference in color **shade**)
- **surface structure** (reflectivity)
- percentage of **coverage**

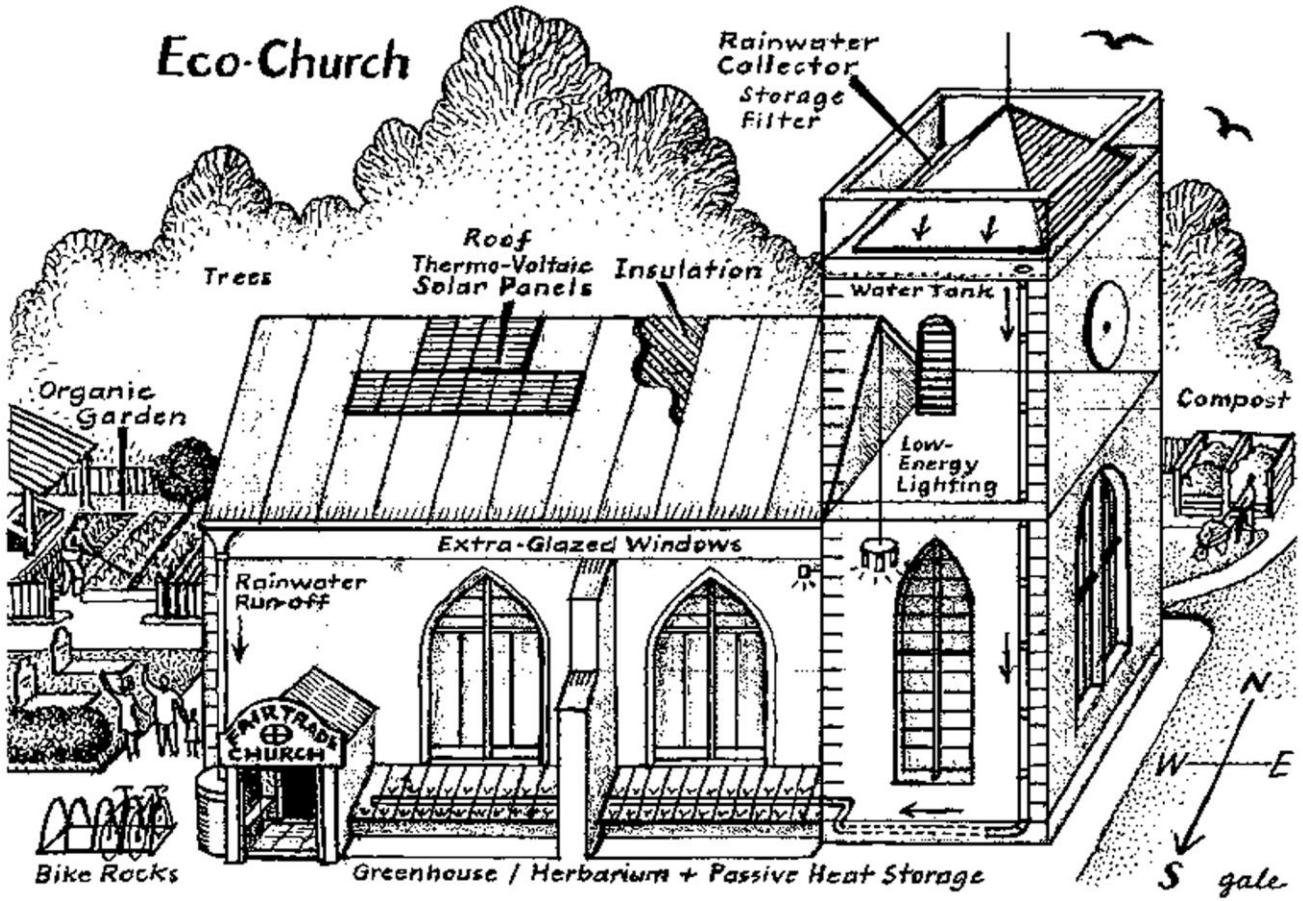
technical

- **orientation** requirements
- **technology** (generation)
- **efficiency** of the colored PV
- mountaining application
- **degree** of integration

Architectural aspect : Building Typology

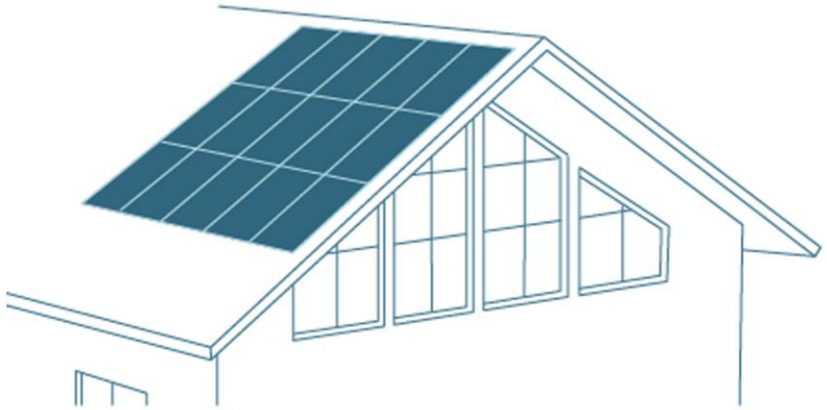
Building Typology : Church

- Driven by an ethical commitment to reduce carbon use, but the potential revenue from energy fed back into the electricity grid.
- Large north-facing roof slopes, which can appear to be ideal for generating energy from solar PV cells.
- PV installation requires planning approval as well as listed building consent.

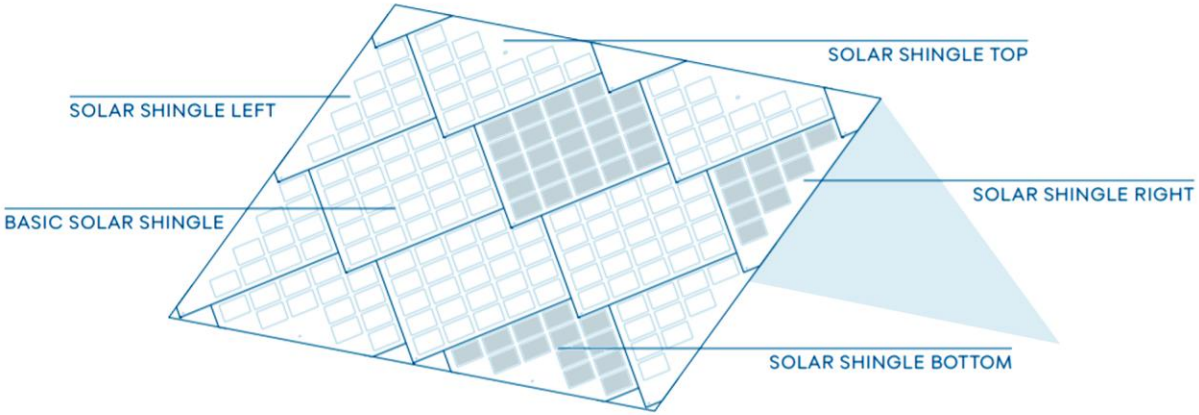


Eco-Church
https://ecochurchsouthwest.org.uk
https://arcuatearchitecture.com.au

Architectural aspect : Shape of module



(Panasonic, www.panasonic.com)



(SUNSTYLE, www.sunstyle.com)

Visual aspect: Visibility in the urban landscape

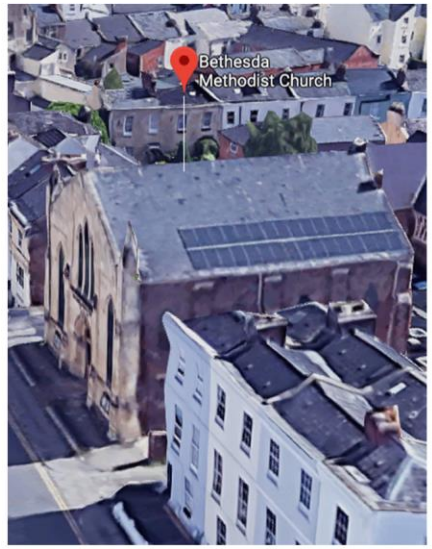
In both cases PV modules are hidden from ...

- important urban viewport
- street view

Ca' S. Orsola, Treviso
http://www.cazzarocostruzioni.it/

In both cases PV modules are visible from ...

- neighbour buildings
- higher roof or lanscape



Bethesda Methodist Church, Cheltenham, England
https://commons.wikimedia.org

Visual aspect : Color Adaptability

Case : St. Silas

- The first of heritage buildings in England that embraces the photovoltaic.
- 362 panels used specially designed to match the colour of the slate. (grey, opaque and frameless)

St. Silas Church , England
(https://www.saint-silas.org.uk)

Case : St. Peter

- creating a full PV roof without modify the global image and perception of the church within the landscape.
- 382 m^2 made of PV monocrystalline , black opaque and frameless modules was installed, replacing the old roof tiling.

Roman Catholic Parish St Peter and Paul, Switzerland
(Institute of Applied Sustainability to the Built Environment (ISAAC), www.bipv.ch)

Visual aspect : Surface Structure

Cases : Chalet (BE) and Church in (NW)

- Mimicing the slate- design (fish-scale pattern)
- High reflectivity of the suroundings. Perfect for remote districts. Not recomended in high density urban areas.

Chalet in Innerkirchen, Belgium
(https://www.sunstyle.com)

Church in the Strand Municipality
(https://www.sunstyle.com)

Cases : Rural House (FR) and Church in (CH)

- Mimicing roof tiles (shape, proportion, grouping, high percentage of coverage)
- Low reflectivity in order not to modify the global image and perception of the cases within the landscape.

Rural House, France
(Prix Solaire Suisse 2018)

Roman Catholic Parish St Peter and Paul
(SUPSI, www.bipv.ch)

Visual aspect : Percentage of Coverage

Cases : Reformative Kirche, (AU)

- One of the pioneers in the PV application with no resistance fprm the church community.
- Low percentage of coverage makes the application visible from a higher building.
- No visibility from the street view, due to narowness of the street.

Reformierte Kirche, Vienna
(http://www.pvdatabase.org)

Cases : Solar Church (CH)

- In the south, the old roof has been replaced by a system with higher thermal insulation and with monocrystalline high efficiency PV cells in blue color.
- High percentage of coverage and grouping the modules provides the sence of unity in the eye.

Roman Catholic Parish St Peter and Paul
(SUPSI, www.bipv.ch)

Technical aspect : Integration Degree

Case : Academy Building "Alter Kiosterhof" (DE)

- They are installed at an 8° angle and provide both light and shade for the stairwell below.
- They were grouped in three lots of eight modules each, making the installation, which looks like an additional roof, appear very light.

Academy Building " Alter Kiosterhof", Germany
(I.Hermannsdofer, C.Rub, 2005, Solar Design)

Case : Dormer Roof (DE)

- The roofs of the two dormers, having an inclination of 20 degrees, oriented south-west, were equipped with PV.
- 27 frameless multicrystalline photovoltaic modules were installed on each dormer using an all-purpose tixing system replacing the roof tiling.

Dormer Roof, Germany
(I.Hermannsdofer, C.Rub, 2005, Solar Design)

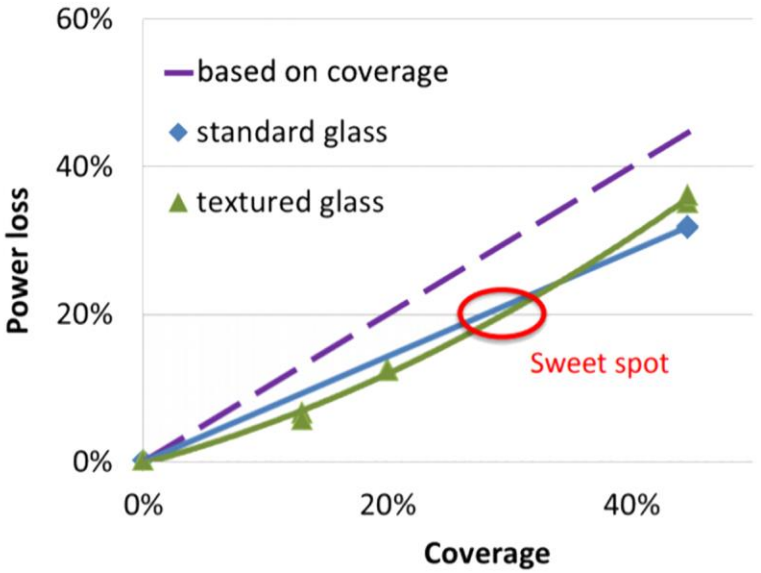
Technical aspect : Efficiency of the ceramic-patterned-PV

Advantages :

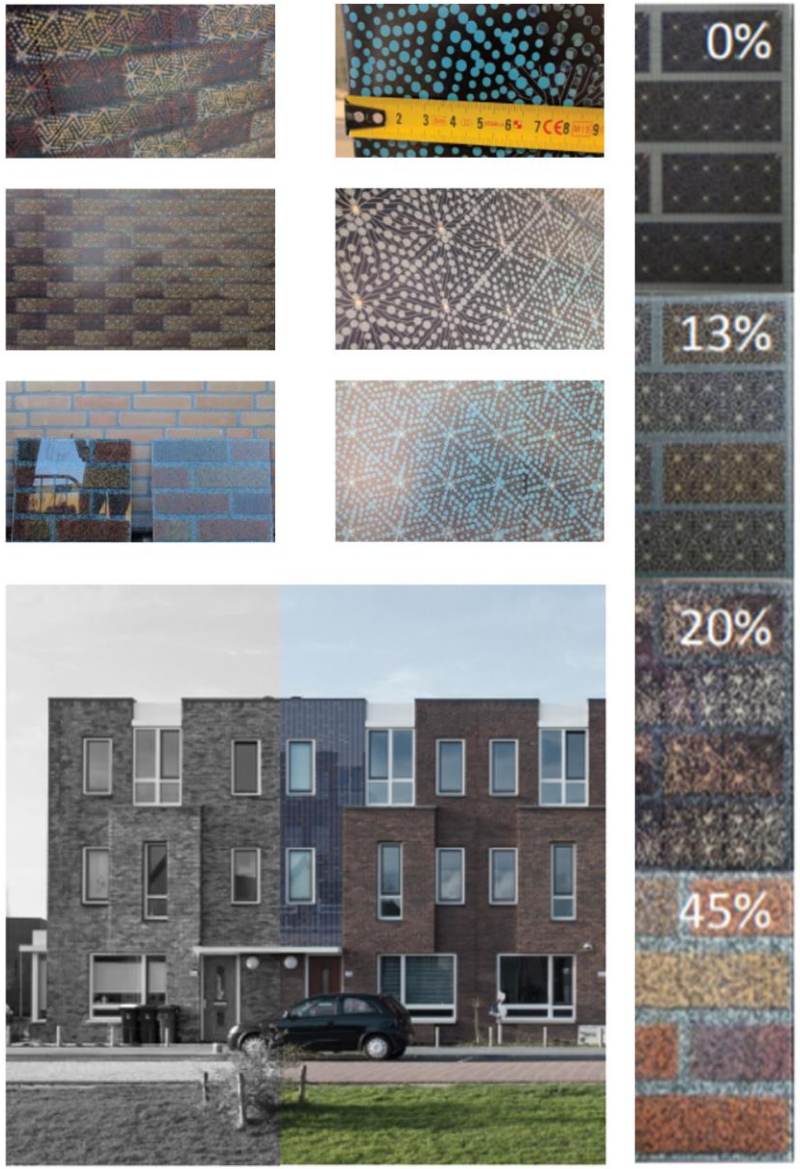
- individually designed modules as part of a larger (building) canvas
- blending in with surroundings
- freedom of architectural design
- outer surface treatment provides diffused reflection
- high light transmittance
- **80-150 Wp / m²**

Disadvantages :

- coverage dependent outcome



Full colored PV : Performance



source of all figures : http://www.dsd-pv.nl/

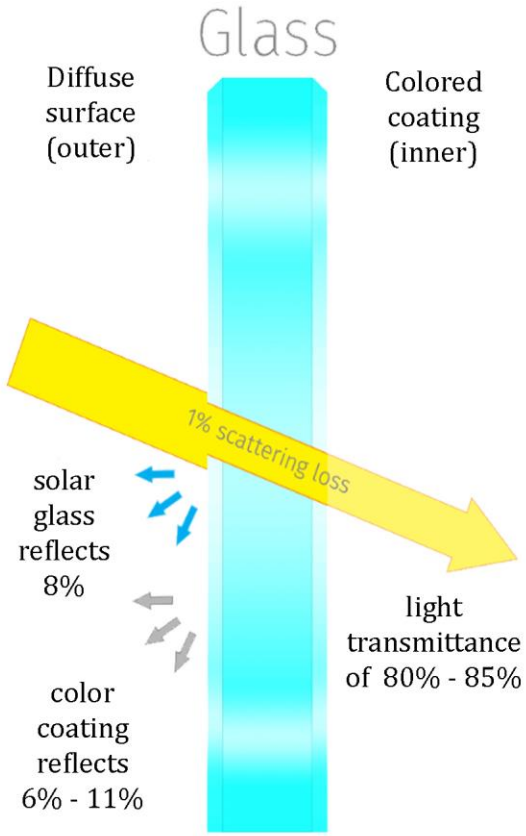
Technical aspect : Efficiency of the colored-glass-PV

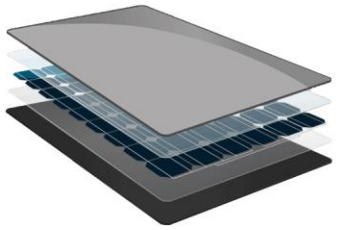
Advantages :

- high solar transmittance
- minimal absorption
- high durability
- outer surface treatment provides diffused reflection
- **75% - 90%** of the standard module
- **90-150 Wp / m²**

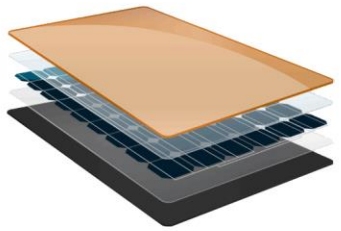
Disadvantages:

- change appearance by changing angle of light and view.

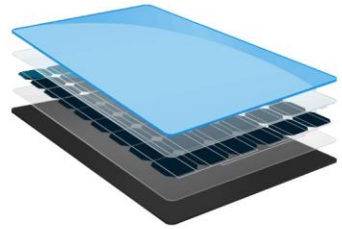




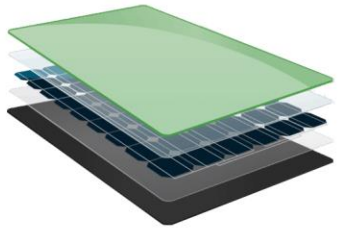
Grey
90% transmittance



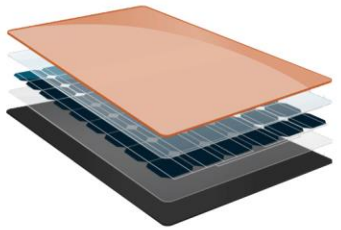
Bronze
89% transmittance



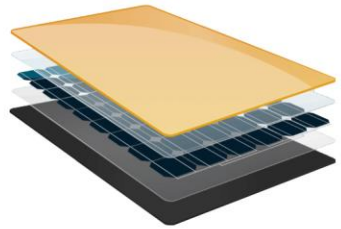
Blue
88% transmittance



Green
88% transmittance



Terracotta
87% transmittance



Gold
86% transmittance

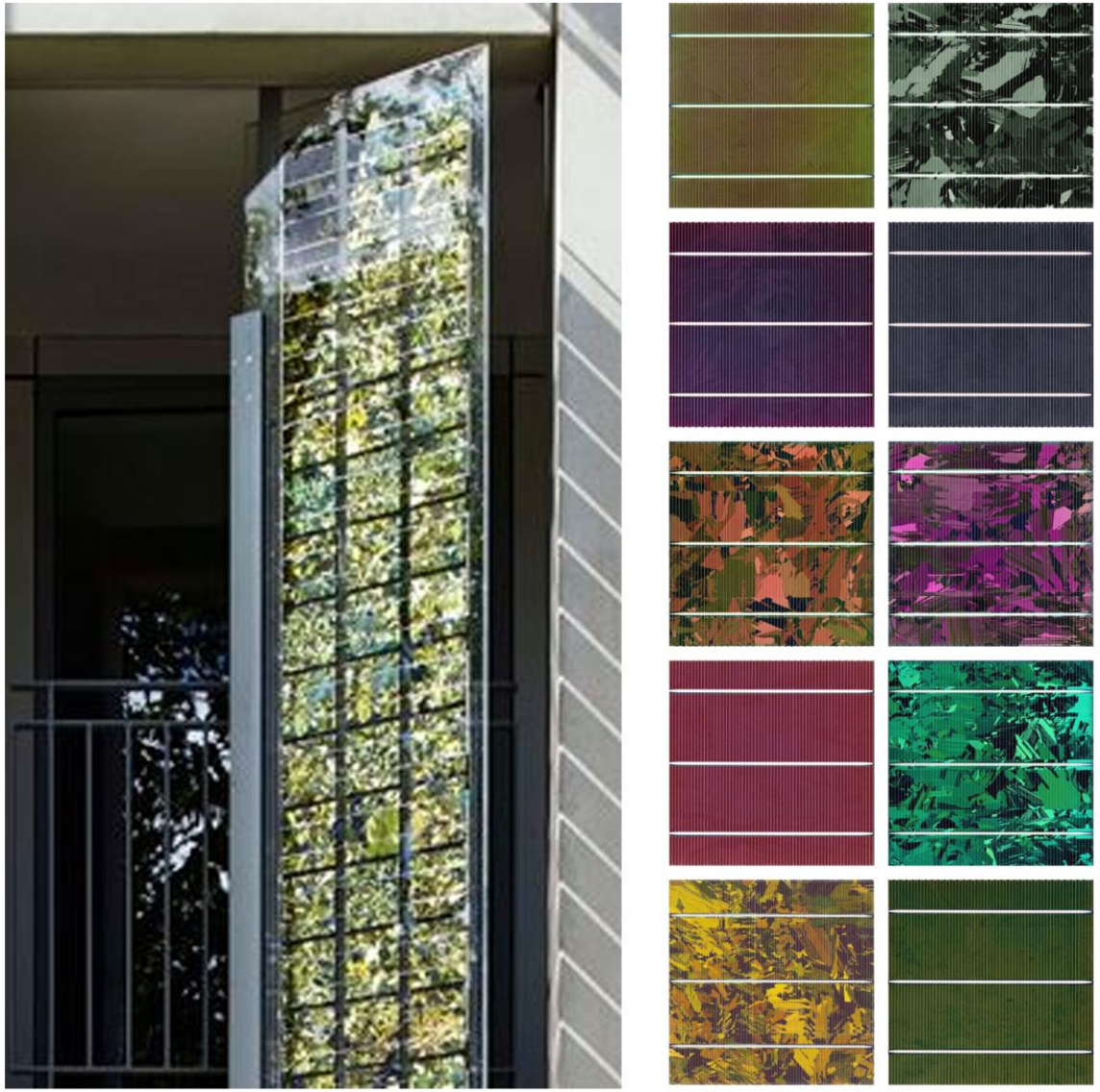
Technical Aspect : Efficiency of Colored-PV

Advantages :

- High conversion efficiency
- Positive power gain rate after lamination
- Optimized design for good solderability and long-term stability
- Customized design

Disadvantages :

- By changing the color, changes the efficiency by definition.
- Marbel effect is visible from a closer look.



Colored PV by LOF Solar (http://www.lofsolar.com/)

Evaluation Criteria of a PV Application

Objective

- being **parallel** with the building 's surfaces of application
- **respecting the lines**, shaping with the proportions to avoid uneven solar installation
- **grouping** for optimum integration
- **precision** of connecting elements
- **visibility** or not from other buildings or from street viewports

Subjective

- **percentage of covering** the construction surface
- **multifunctionality** of modules
- **aesthetics**

Conlusions derived from literature & reference cases

DO….

- be parallel with the building surface application
- respect the architectural form (lines)
- shape with proportions to avoid uneven outcome
- group for optimal integration
- apply precise connections
- adapt in color and reflectance (imitation of material)
- visibility with a scope
- replace with caution
- get approval from qualified authorities
- inform the public about the application

DON'T …

- exceed coverage without reason
- create new surfaces other than the existing ones
- differ too much in color from original
- use reflective surfaces
- use always standard panels (i.e. when visible)
- (i.e. main elevations) be visible from important city viewports

Case Study : Hotel “Diethnes” (International)

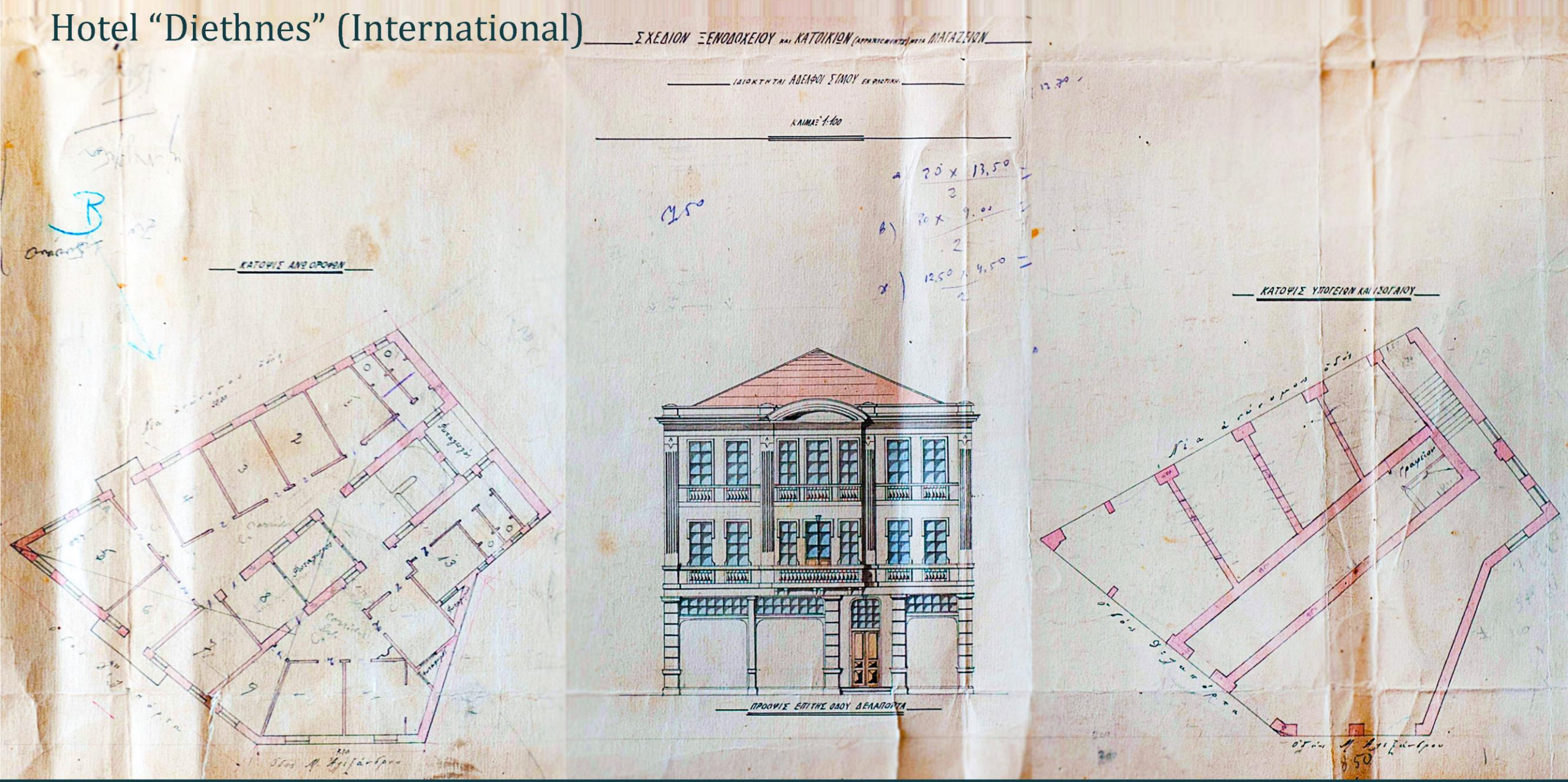
Hotel “Diethnes”

- Built in 1924
- In the city Florina, North-western Macedonia, Greece
- Representative of neoclassic movement

- Preserved by law as a work of art
- Any changes should be authorized
- High energy demand (weather & deterioration)

- Original use : Hotel
- Current use : Multi-functional

Hotel “Diethnes” (International)



Hotel “Diethnes” (International) _ Surveying the building

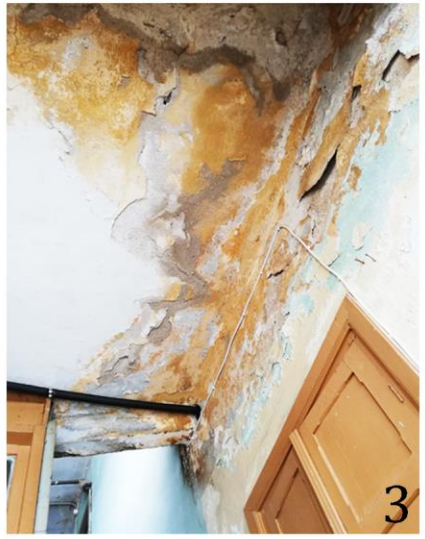
Hotel “Diethnes” (International) _ Surveying the building

Deteriorated Facade_ Bottom view (Survey Product)

Damage registration (Survey Product)

Deteriorated Facade Details (Survey Product)

Hotel “Diethnes” (“International”) _ Energy Scenarios



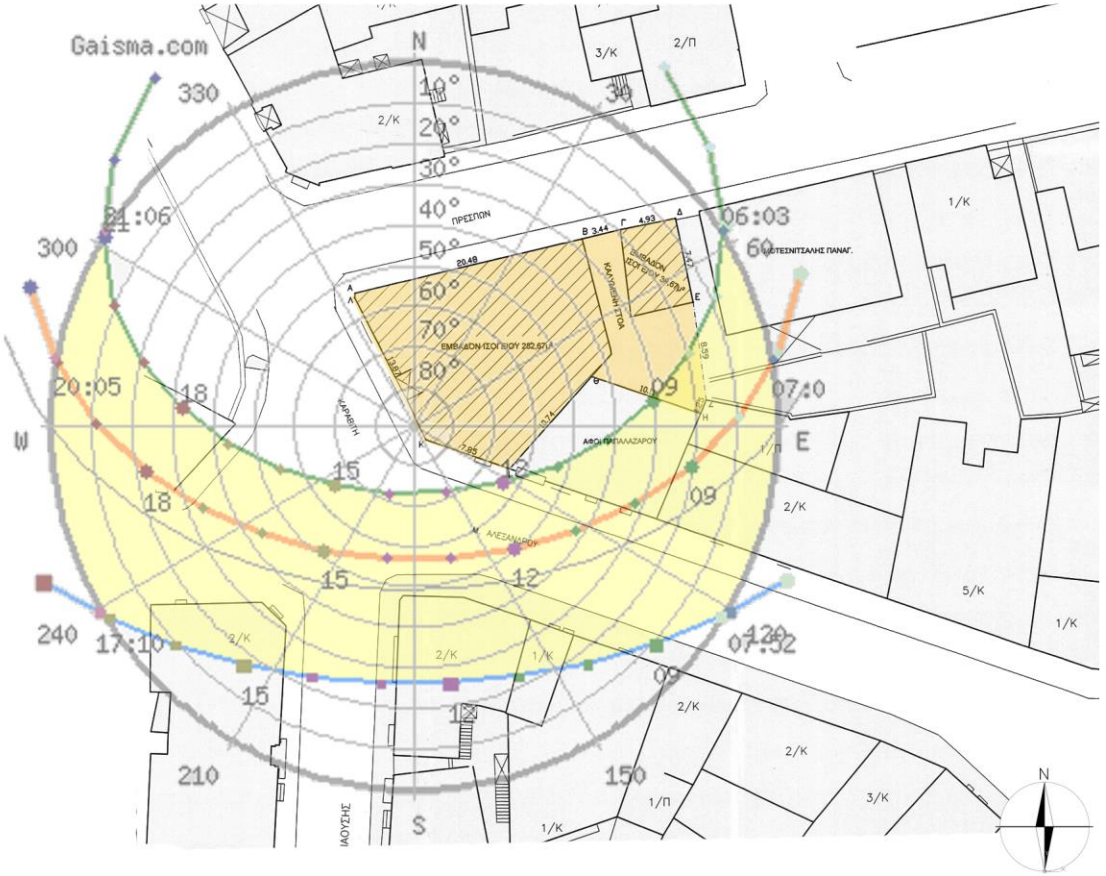
Roof_ Internal bottom view (Survey Product)

Building Layouts (Survey Product)

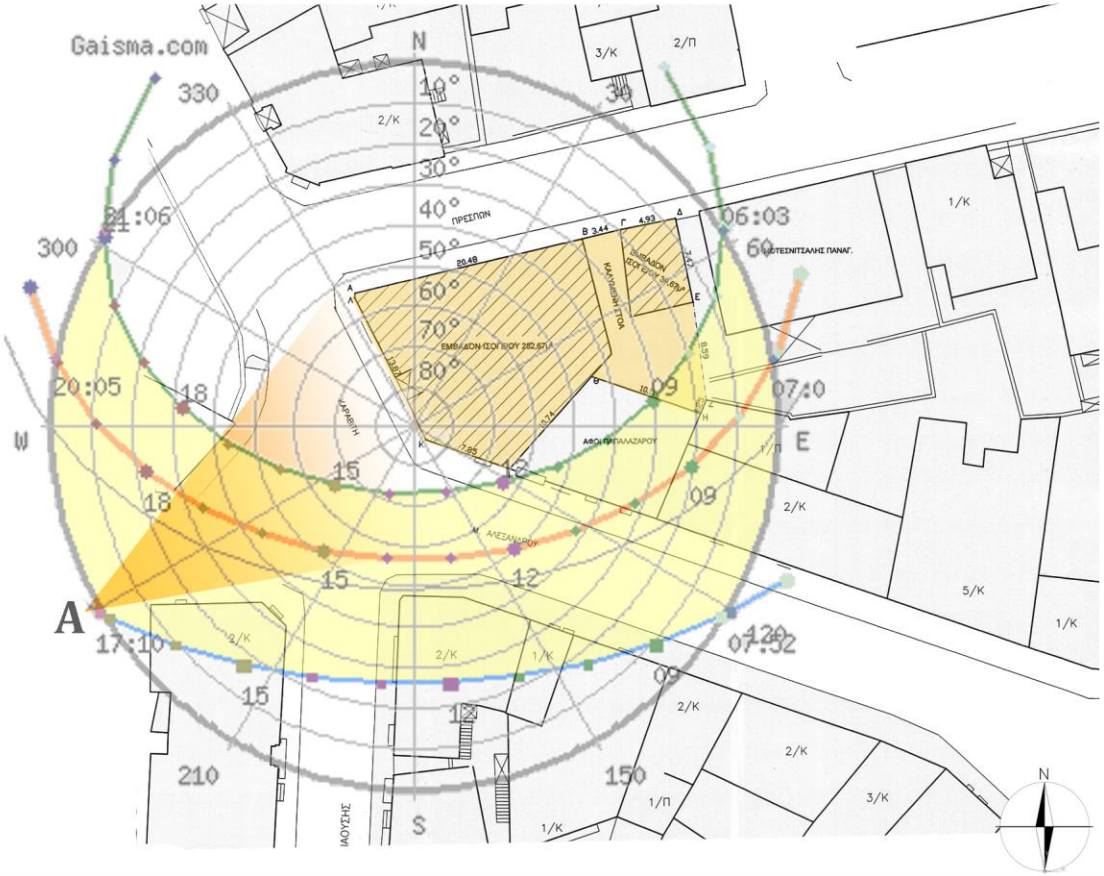
Internal building views & deteriorating details (Survey Product)

Solar Analysis

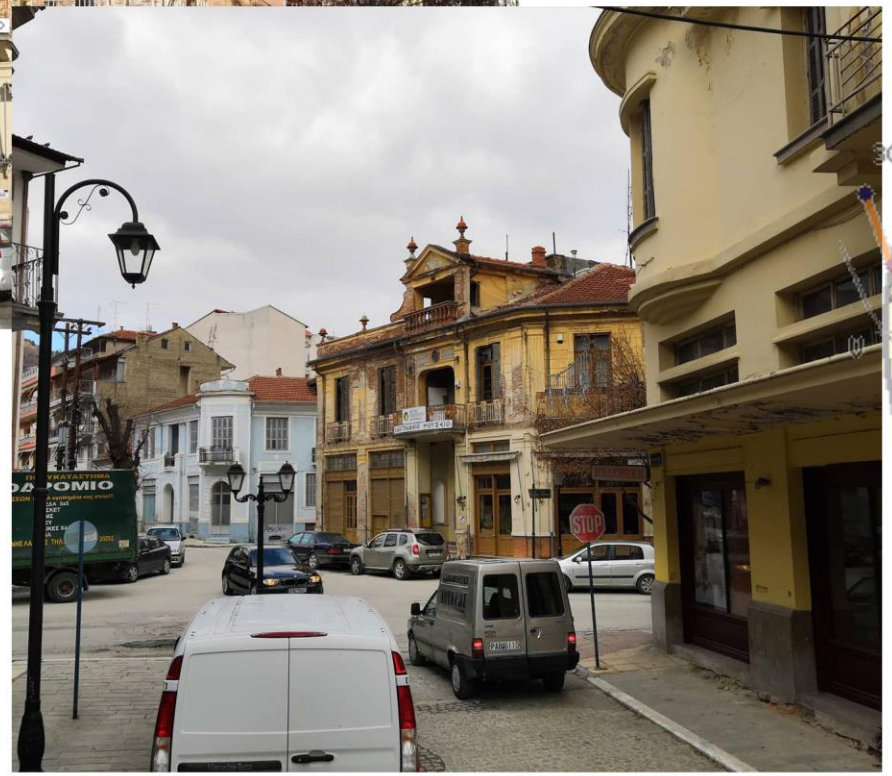
Hotel “Diethnes” (International)_Important urban viewports

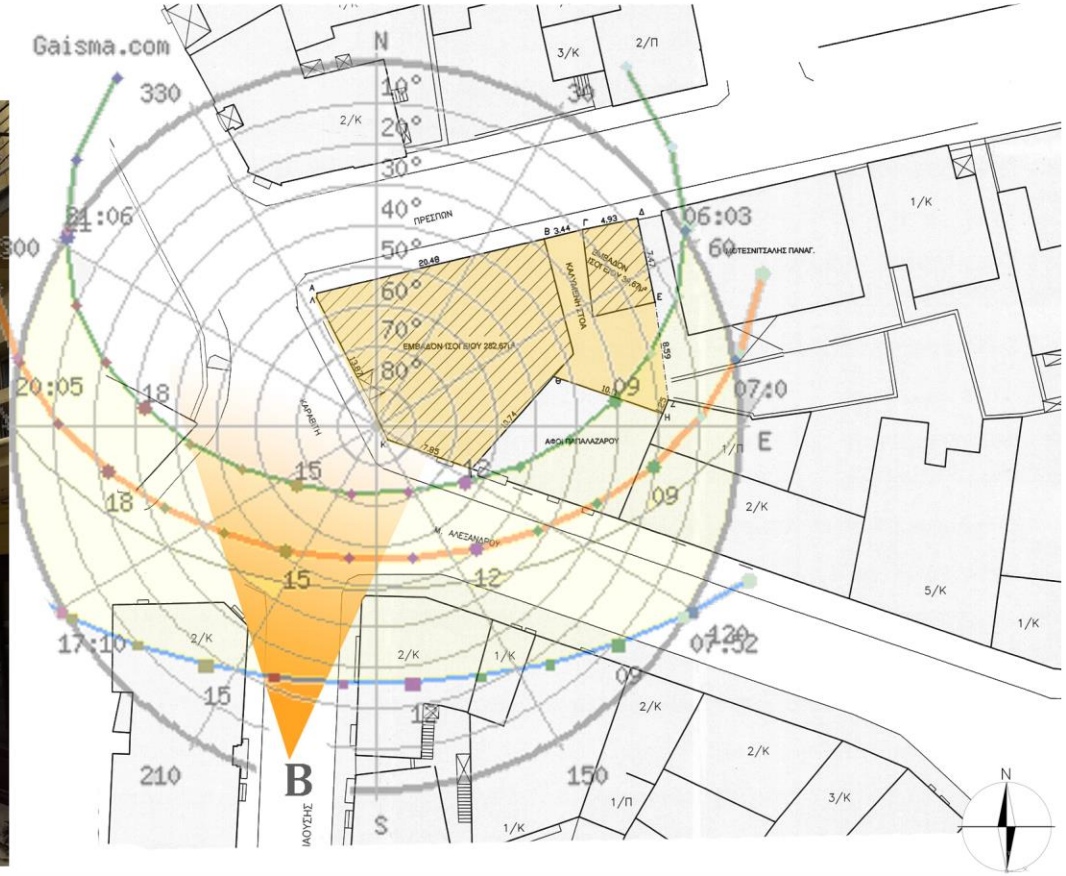


Hotel “Diethnes” (International)_Important urban viewports

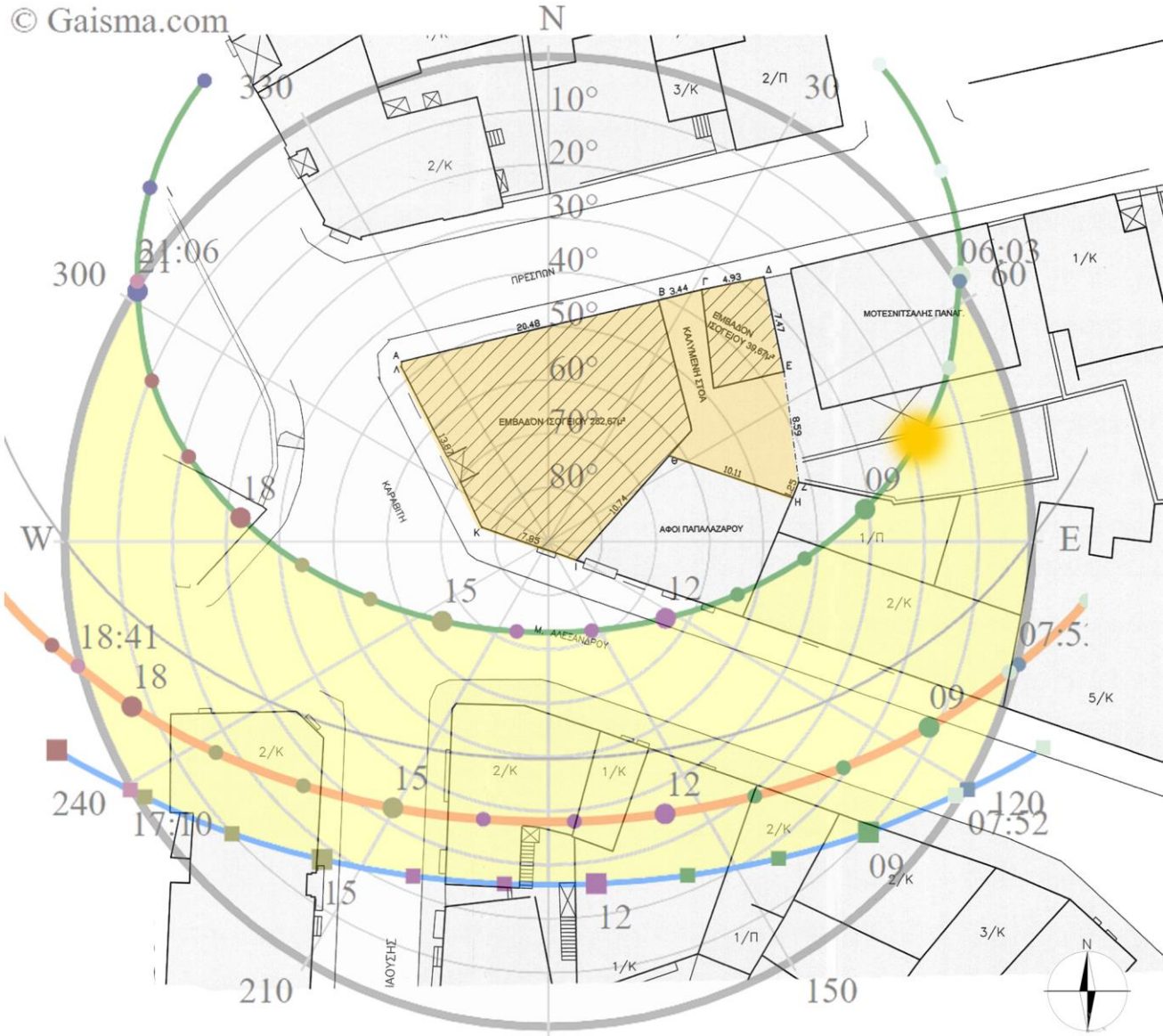


Hotel “Diethnes” (International)_Important urban viewports

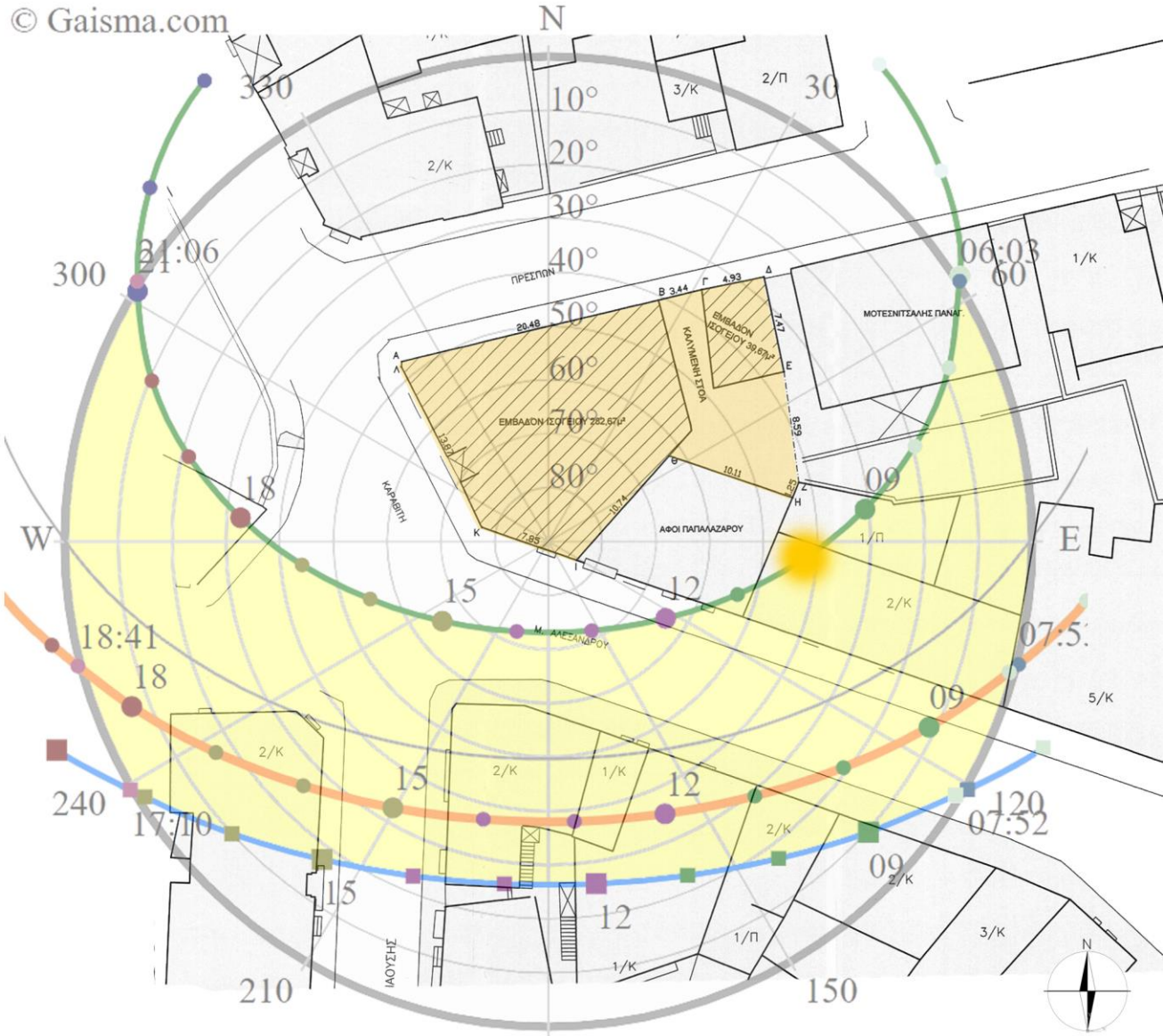




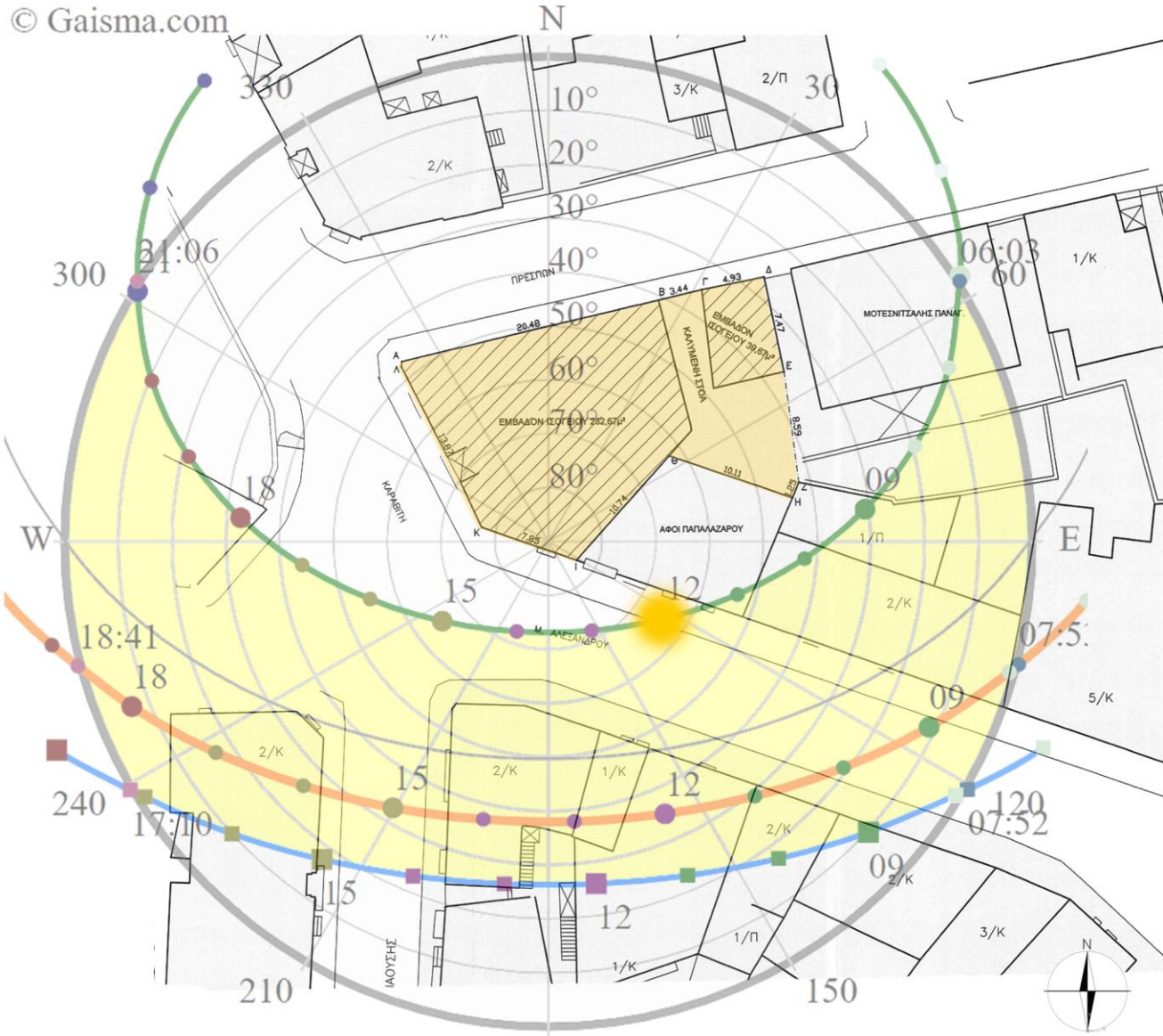
Hotel “Diethnes” (International) _Solar Gains



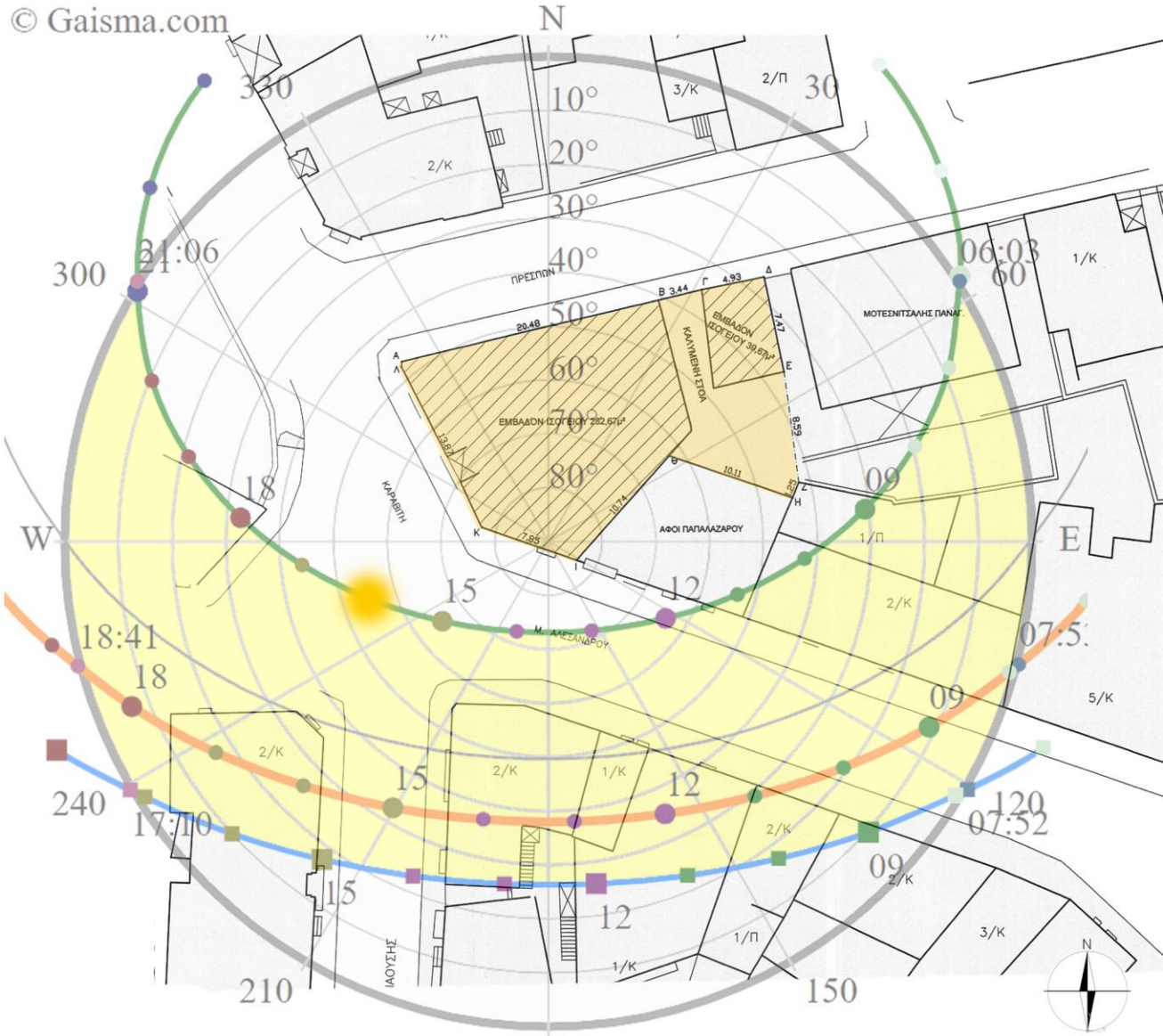
Hotel “Diethnes” (International) _Solar Gains



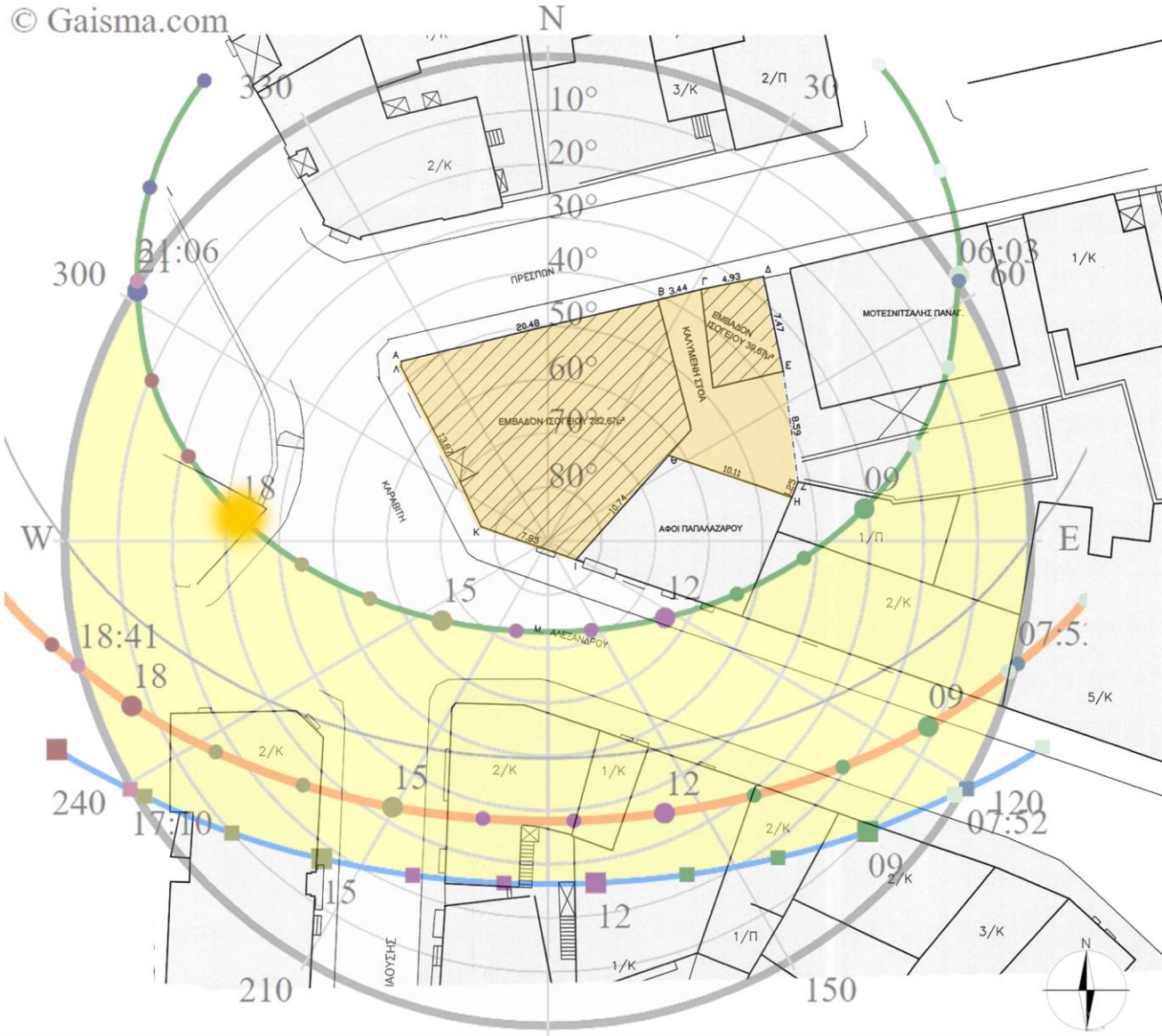
Hotel “Diethnes” (International) _Solar Gains



Hotel “Diethnes” (International) _Solar Gains



Hotel “Diethnes” (International) _Solar Gains



Solar Simulation

Rhinoceros

GEOMETRY

Grasshopper

INPUT DATA

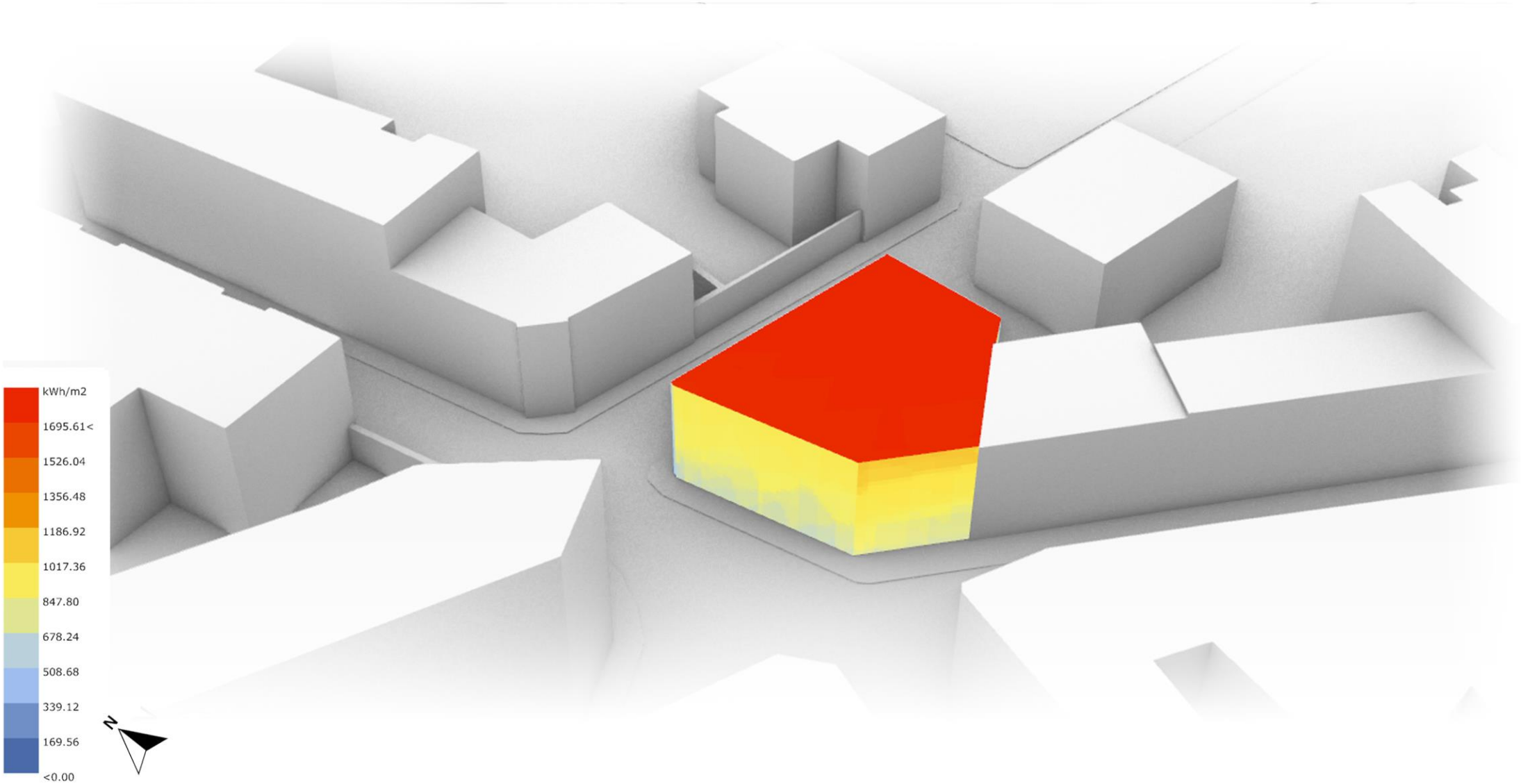
Ladybug & Honeybee

SIMULATIONS

Microsoft Excel

RESULTS

Hotel “Diethnes” (International) _Solar Radiation Analysis

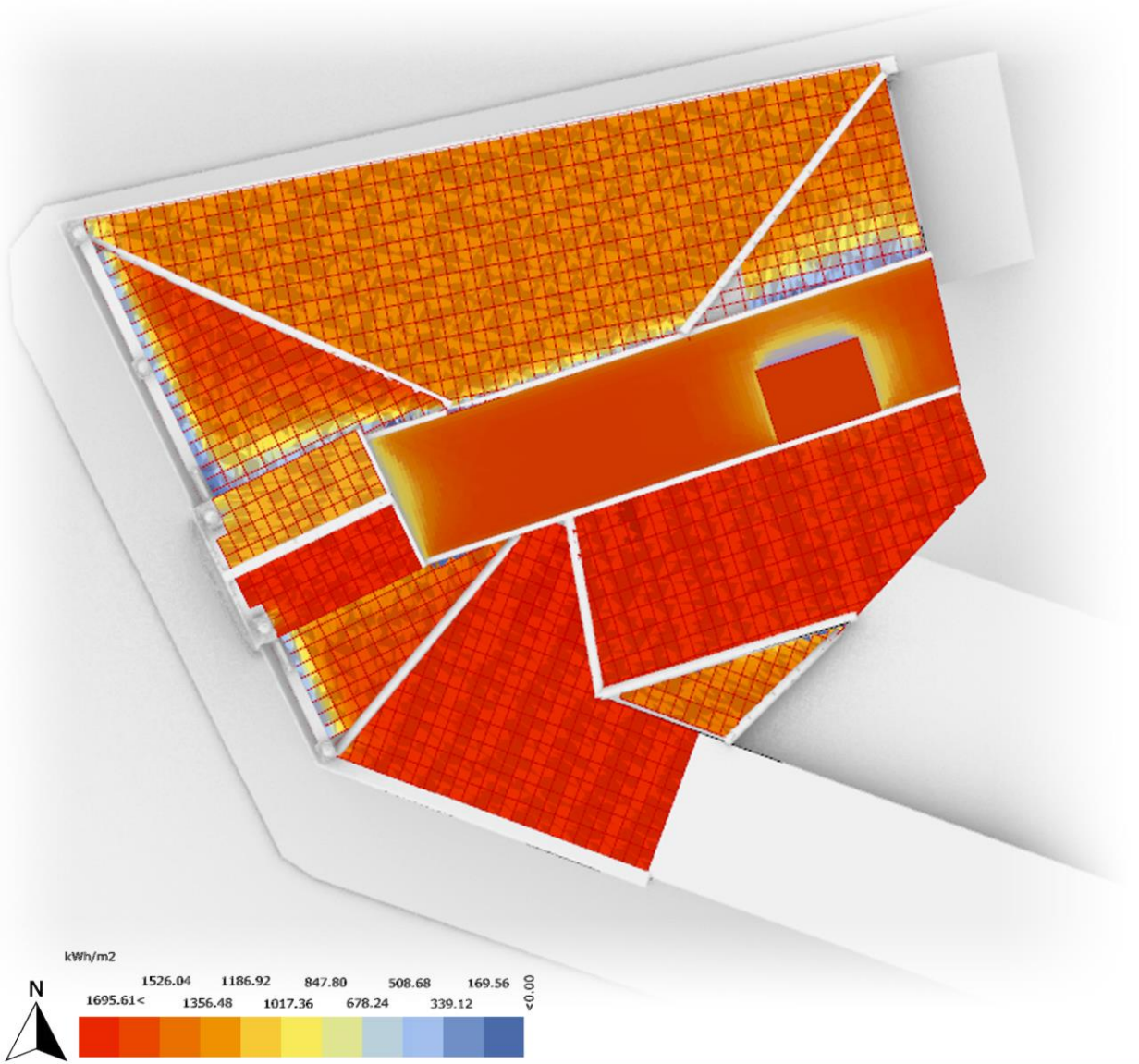


Solar radiation analysis _ annual gains in footprint volume

Hotel “Diethnes” (International) _Solar Radiation Map _ Facade

Solar radiation analysis _ annual gains_ Elevations : south-west (left) and south-east (right)

Hotel “Diethnes” (International) _Solar Radiation Map _ Roof



Hotel “Diethnes” (International) _Energy Scenarios

Building’s Surface

Ground Floor : 257 m^2
First Floor : 234 m^2
Attic : 38 m^2

TOTAL : 528 m^2

Hotel

- original purpose of construction
- high energy demand option
- appealing to possible investors
- energy demand (366.63 kWh/m2)

193 GWh annually

Multi-functional

- hosting variant functions
- educational and cultural use on the first floor (119.9 kWh/m2)
- commericial function on the ground floor (249.7 kWh/m2)
- a low energy demand option

96 GWh annually

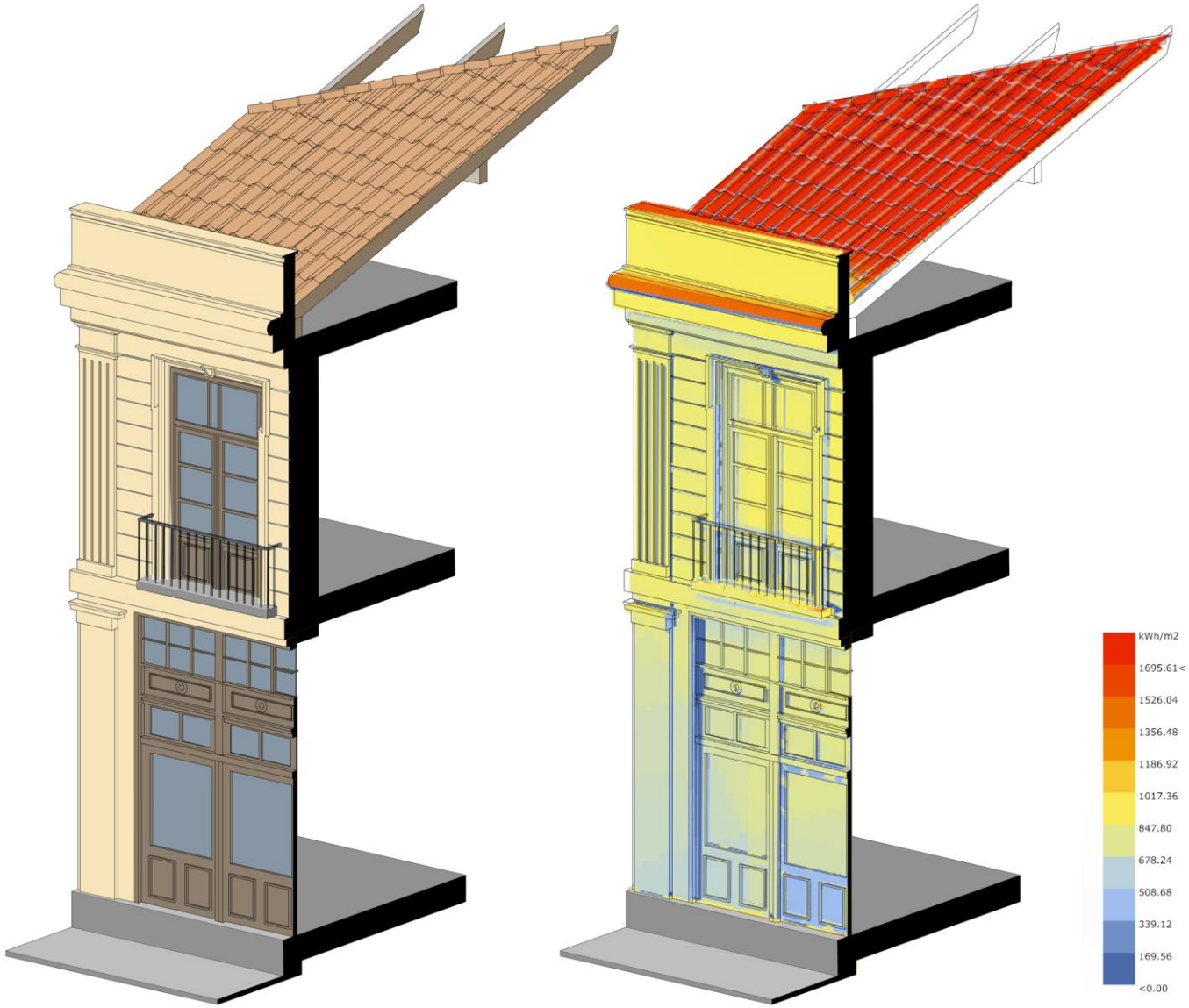
Source: https://ec.europa.eu

Hotel “Diethnes” (International) _ Concept Proposal _ PV Placement

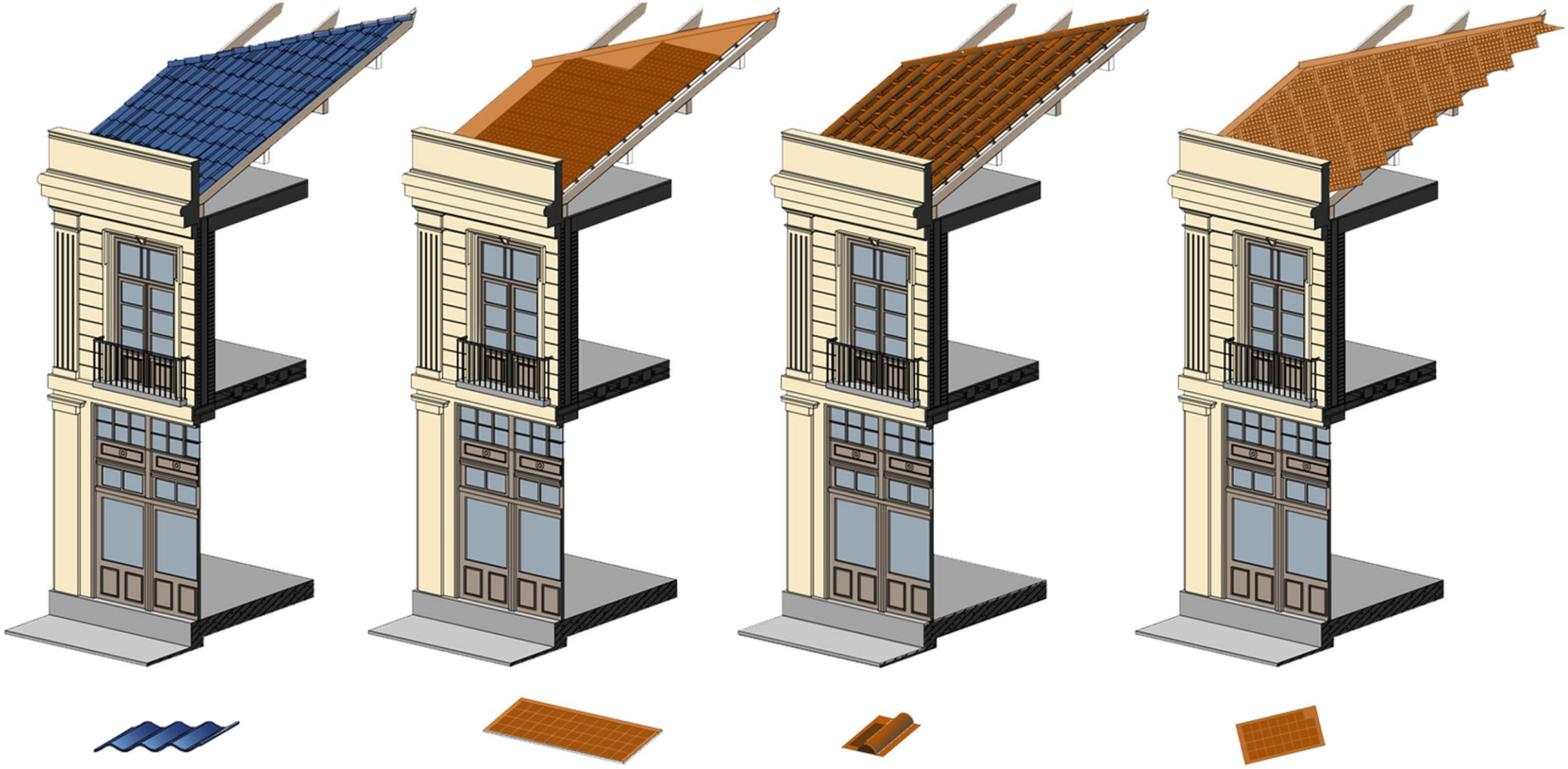
Plaster | 70% transparency windows | 10% transparency windows | wooden tamplet | sign board | roof tiles

Matrix

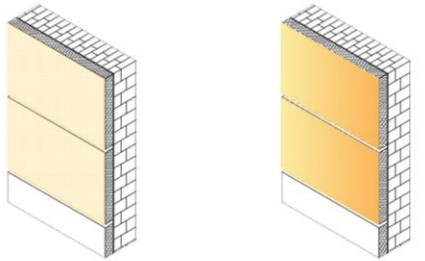
Hotel “Diethnes” (International) _ Matrix Base

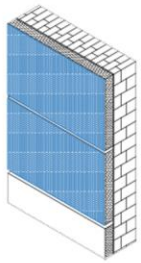


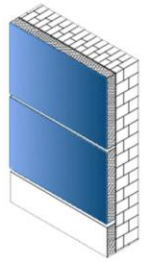
Hotel “Diethnes” (International) _ Application Options :Roof



Hotel “Diethnes” (International) _Aplication Options : Facade _ Plaster



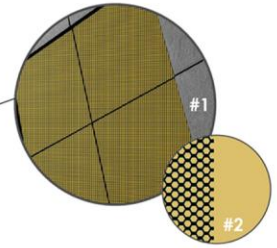


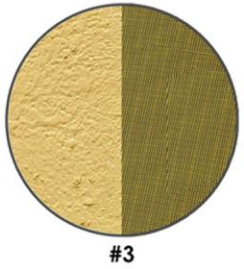


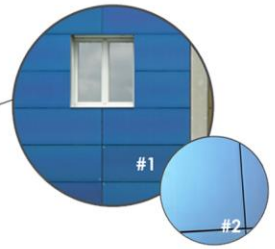
printing pattern

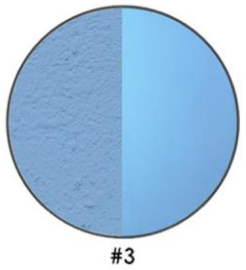
coat application

Variants in color shade and material immression









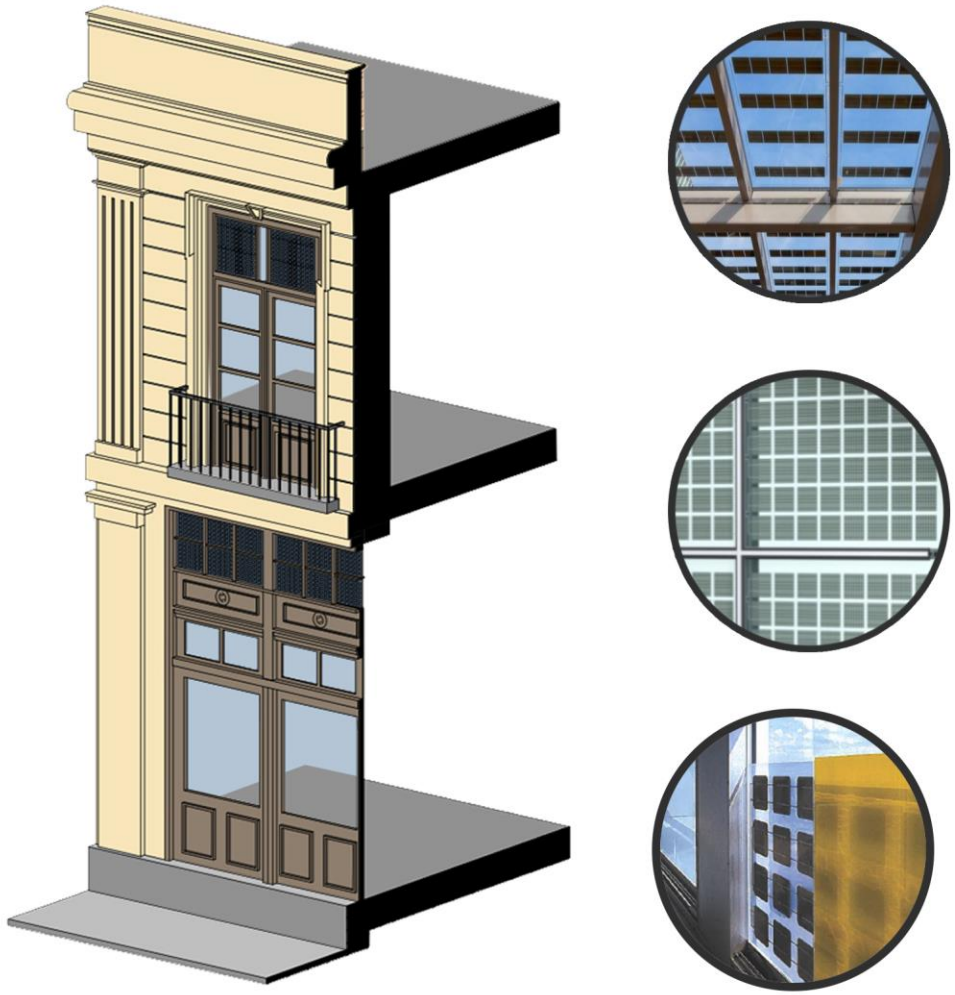
material immression

pv panels_custom size

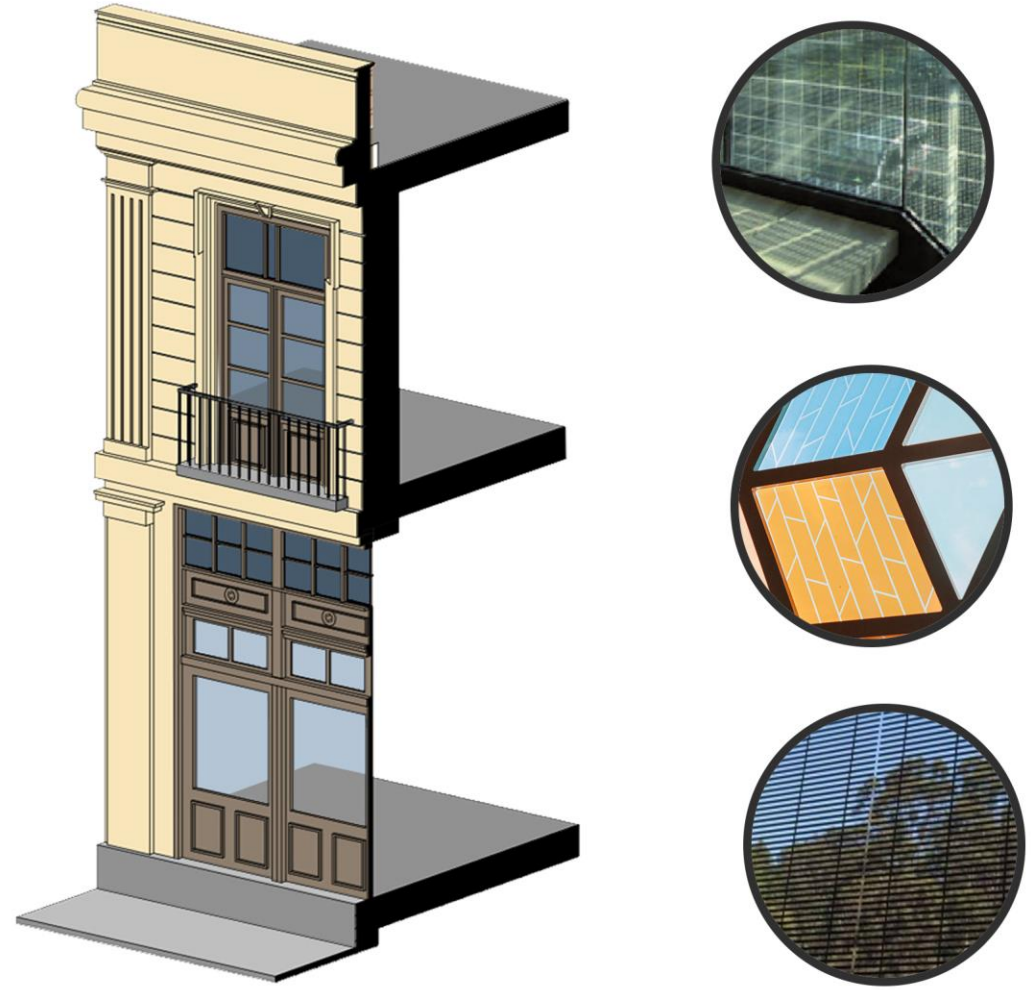
pv panel (one piece)_custom size

Variants in manner of application

Hotel “Diethnes” (International) _ Application Options :Facade _Window Glazing

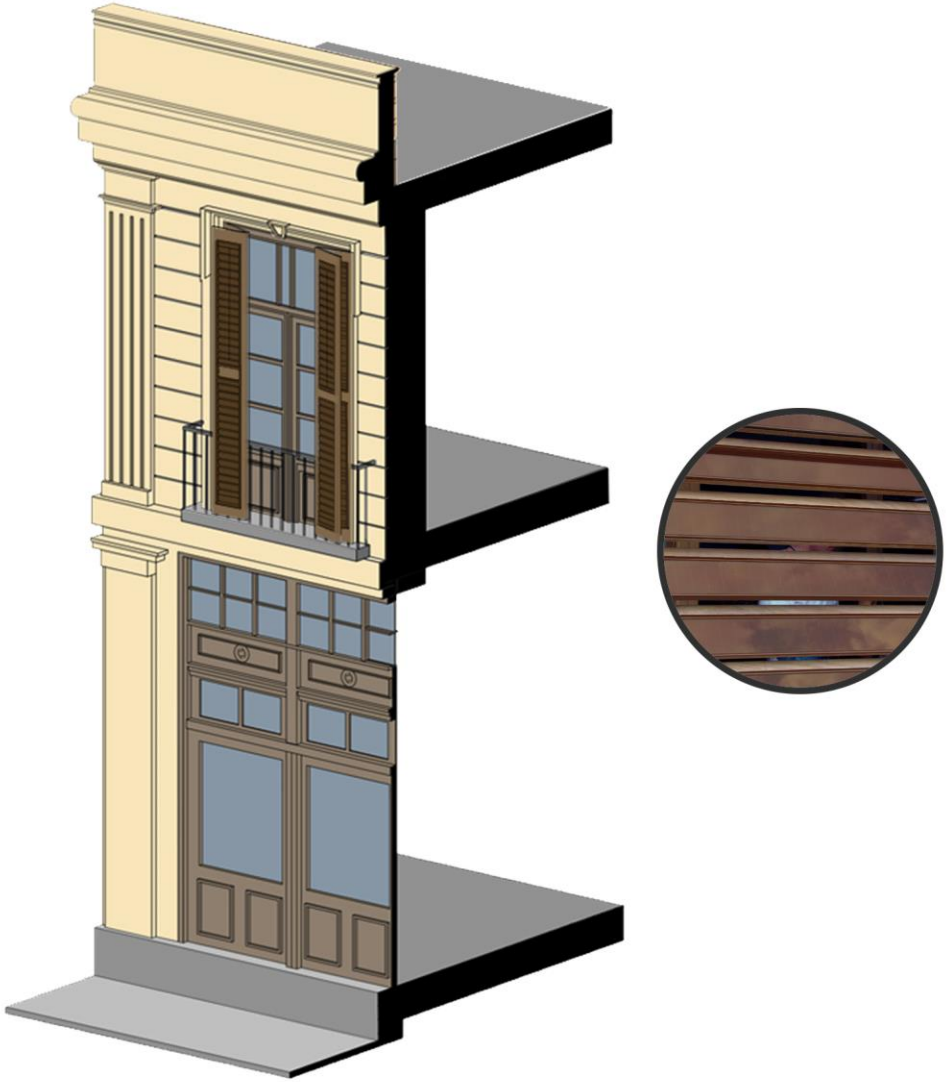


pv cells inside glass

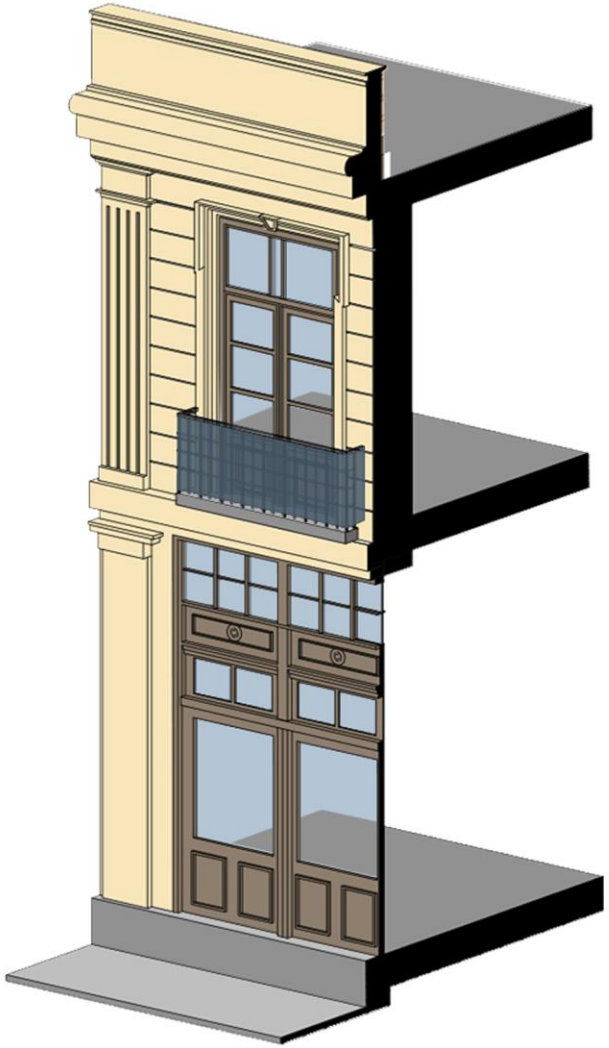


semi-transparent pv

Hotel “Diethnes” (International) _ Application Options :Facade _Additional Elements



Shutter Option



Balcony Option

Hotel “Diethnes” (International) _ Matrix

roof

shape			"respecting" the lines	"following" the shape	visibility from... street views	visibility from... height	color difference	installing in ... renovated structure	installing in ... added structure	efficiency(Wp/m²)	energy scenarios #1c	#1p	#2c	#2p
slate	color	grey				●	●	●		112-160		●		●
		blue				●	●	●		112-160		●		●
		terracotta-like				●		●		106-120	●			●
tile with cell	color	grey	●	●			●	●		90				●
		blue	●	●			●	●		90				●
		terracotta-like	●	●				●		80			●	●
diamond tile monocristalline silicon cells	color	grey				●	●	●		162		●		●
		blue				●	●	●		142				●
		terracotta-like				●		●		140				●
hantile roof tile monocristalline silicon cells	color	grey	●	●			●	●						
		blue	●	●			●	●		105				●
		terracotta-like	●	●				●						

plaster

production technique			"respecting" the lines	"following" the shape	visibility from... street views	visibility from... height	color difference	installing in ... renovated structure	installing in ... added structure	efficiency(Wp/m²)	energy scenarios #1c	#1p	#2c	#2p
pattern	color	indigo blue	●	●	●		●		●	150		●		●
		yellow ochre	●	●	●		●		●	80	●		●	●
		terracotta-like	●	●	●		●		●	146	●		●	●
dye encapsulant	color	indigo blue	●	●	●				●	147		●		●
		yellow ochre	●	●	●				●	144	●		●	●
		terracotta-like	●	●	●				●	145	●		●	●
		white(if needed)	●	●	●				●	90		●		●

glass

type			"respecting" the lines	"following" the shape	visibility from... street views	visibility from... height	color difference	installing in ... renovated structure	installing in ... added structure	efficiency(Wp/m²)	energy scenarios #1c	#1p	#2c	#2p
pv-glass amorphus silicon cells	color	blue	●	●	●		●		●	28		●		●
		yellow	●	●	●		●		●	28		●		●
		red	●	●	●		●		●	28		●		●
		green	●	●	●		●		●	28		●		●
		0% transparency	●	●	●		●		●	57.6				
		10% transparency	●	●					●	40		●		
		20% transparency	●	●					●	34		●		●
		30% transparency	●	●					●	28	●	●	●	●
glass encapsulant crystalline silicon cells	color	low solar cell density (38% tr.)			●		●		●	35.8				●
		high solar cell density (15% tr.)			●		●		●	48.9		●		

shutters

type			"respecting" the lines	"following" the shape	visibility from... street views	visibility from... height	color difference	installing in ... renovated structure	installing in ... added structure	efficiency(Wp/m²)	energy scenarios #1c	#1p	#2c	#2p
thin-film pv	color	grey	●	●	●		●		●	120		●		●
		golden brown	●	●	●				●	120	●	●	●	●
bifacial thin-film pv	color	grey	●	●	●		●		●	156		●		●
		brown	●	●	●				●	156	●	●		●

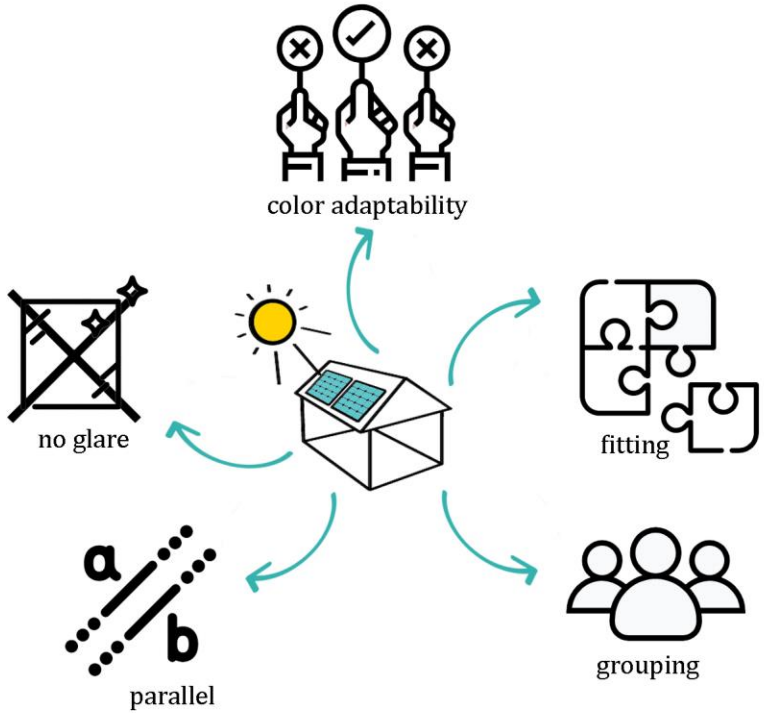
balcony

type			"respecting" the lines	"following" the shape	visibility from... street views	visibility from... height	color difference	installing in ... renovated structure	installing in ... added structure	efficiency(Wp/m²)	energy scenarios #1c	#1p	#2c	#2p
panel	color	transparent		●					●	28-40		●		●
		pattern printed	●	●	●		●		●	28-40	●	●		●
		cell encapsulant			●		●		●	48.9-35.8		●		●
no change			●	●	●			●					●	

Hotel “Diethnes” (International) _Design Requirements for PV Application

Roof Application

- Since there is no visible from street view, **color can differ from the current.**
- The photovoltaic panels should **fit the different parts** of the roof, since its uneven shape.
- The application should be in **groups** in order not to be organized.
- The panels should be **parallel to surface structure** of the plaster.
- Use **non- reflective** outer-surface in the modules.



Hotel “Diethnes” (International) _Design Requirements for PV Application

Facade Application

The parts on the **plaster** should….

- correspond in **shape and color** as the surface that they were going to be applied.
- correspond to the **fragmented façade** (the vertical parts between the pseudo columns and the window frame).
- be mounted in a **lightweight frame.**
- be **parallel** with the surface structure of plaster .
- have **non-reflective** outer surface.

The parts on the **window glazing** should…

- correspond with the **shape** of the window
- be **grouped** as much as possible **or be evenly distributed** in the surface
- be **light weighted**

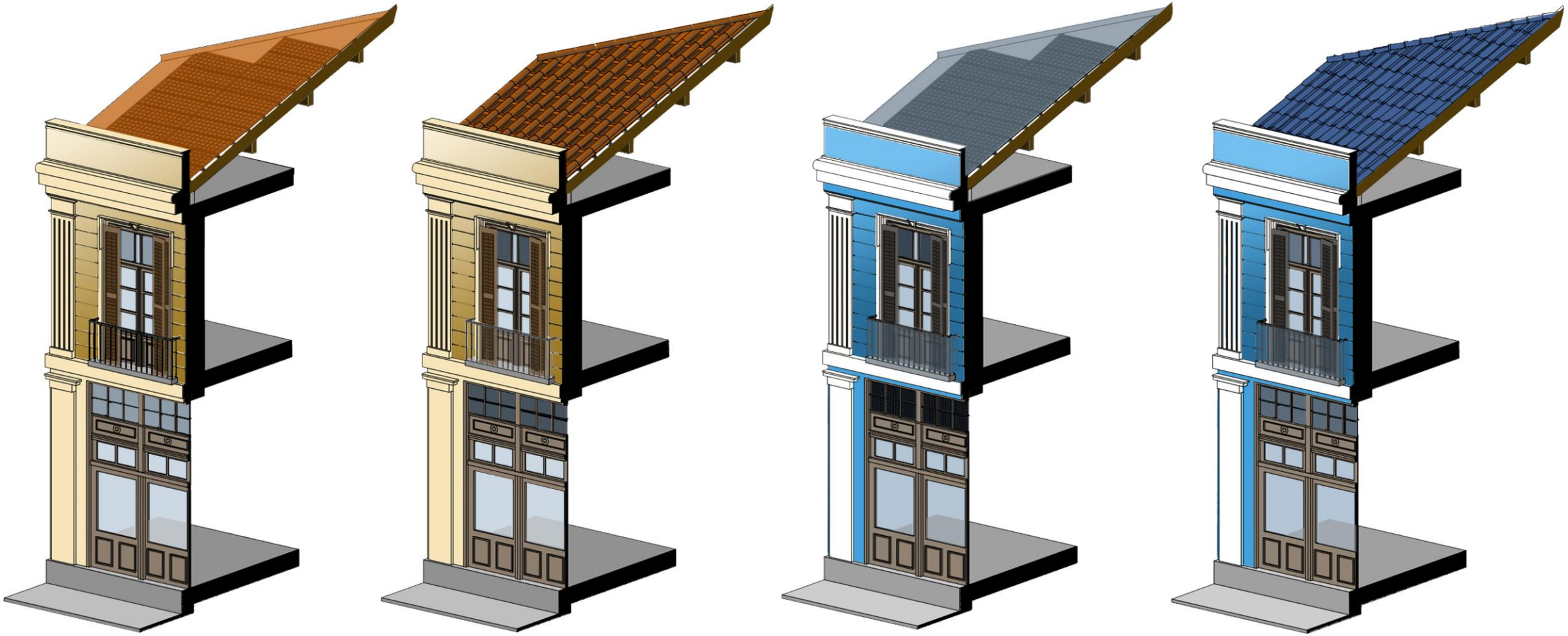
The parts on the **shutters** should…

- be **light weighted**
- correspond in **shape and color** as the shutters which are going to be selected
- be **parallel** to the surface structure of the surface and
- have **non-reflective** outer surface.

Hotel “Diethnes” (International) _Boundary Conditions

- No specific guidelines and regulations for applying PV in a heritage building exists in the Greek Decree.
- The guidelines to be followed are for the Flemish, English and Dutch Decrees
- Changes would happen in the renovation process and are going to be considered as existed
- The image of the building is the most important part of the process and for the final result
- The solutions are not going to consider invading the structure of the building (drilling howls)
- Fragmented facade should be respected.
- Color of modules in plaster is yellow ochre or indigo blue.

Hotel “Diethnes” (International) _Matrix : Results



Design #1 Design #2 Design #3 Design #4

Hotel “Diethnes” (International) _Matrix : Results

Energy Scenarios/ Design			 Design # 1	 Design # 2	 Design # 3	 Design # 4
	Total energy rpoduction per design		26.35 GWh annually	25.55 GWh annually	35.02 GWh annually	25.02 GWh annually
Energy Scenario 1: Hotel Energy demand 366.63 kWh/m2 annually	528.8 m2 (the whole building)	193 GWh annually	13.65 %	13.23 %	18.14 %	12.96 %
Energy Scenario 2 A: Commercial Energy demand 249.77 kWh/m2 annually	275 m2 (ground floor)	64 GWh annually	–	–	–	–
Energy Scenario 2 B: Educational Energy demand 119.9 kWh/m2 annually	271.8 m2 (first floor and attic)	32 GWh annually	–	–	–	–
Energy Scenario 2 : Commercial & Educational	528.8 m2 (the whole building)	96 GWh annually	27.44 %	26.61 %	36.45 %	26.06 %

Hotel “Diethnes” (International) _Matrix : Conclusions

From the above calculations in Matrix variant designs that...

- the roof surface is responsible for the most of the energy production.

- the façade surface has low energy production because of color and surface.

- the energy cover percentages for the first energy scenario in all the designs are lower than in the second.

- the proposals for the second energy scenario are covering more the total energy demand than in the first case.

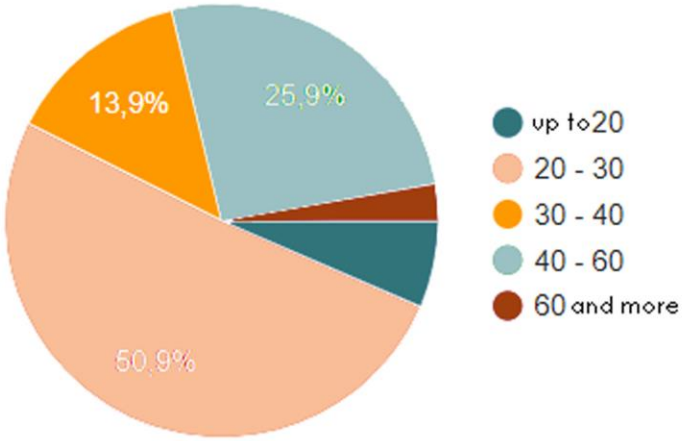
- the building’s energy demand is covered by Design #3.
  - in the first energy scenario can be covered by 18.14%
  - in the second energy scenario can be covered by 36.45%.

- inclination and orientation create different energy productions.

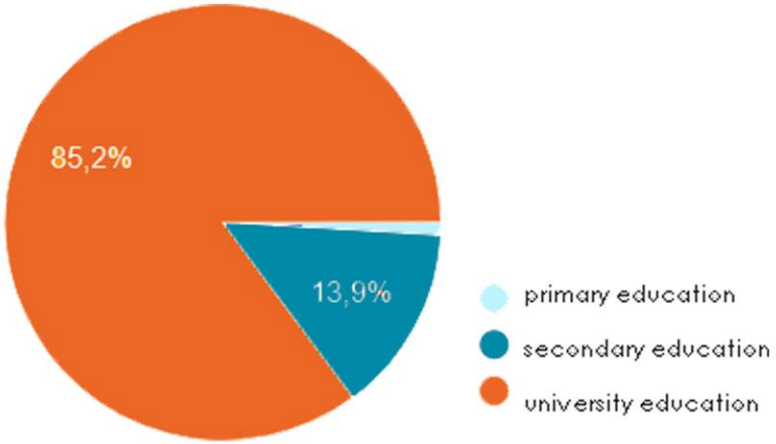
- all the surfaces are not going to be connected in the same energy inverter .

Questionnaire

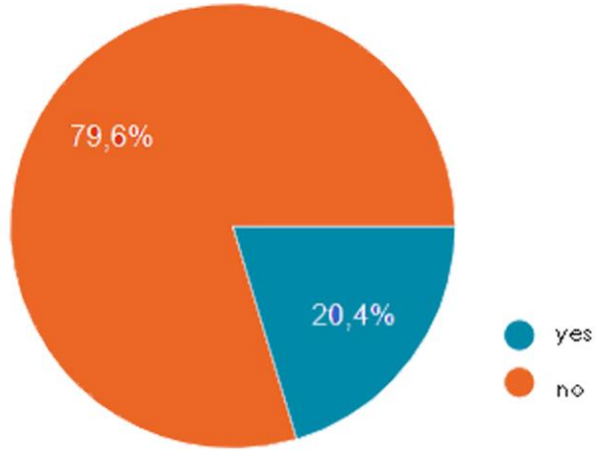
Hotel “Diethnes” (International) _ Questionnaire



Age

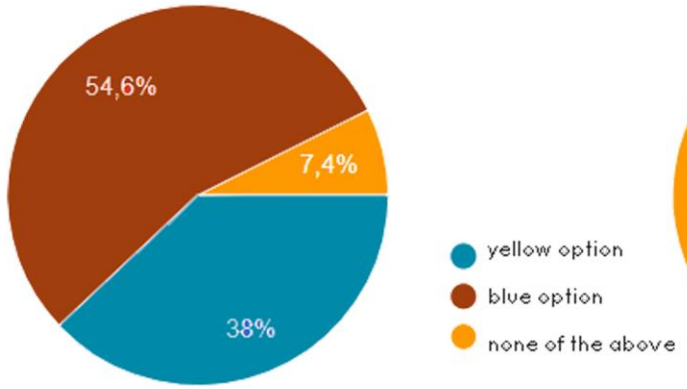


Educational Level

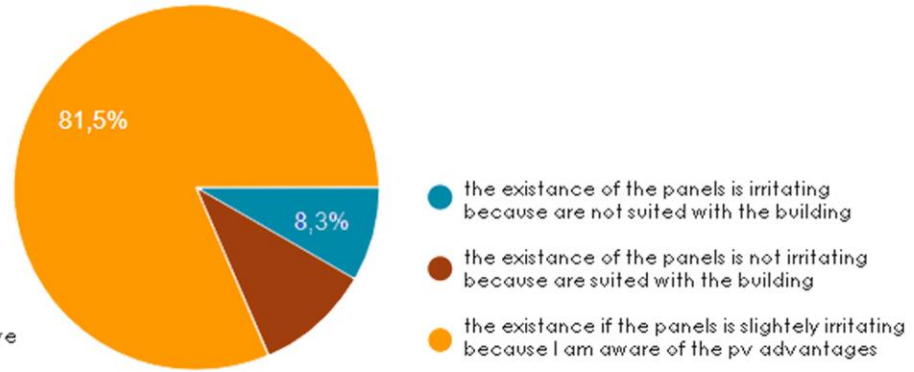


Knowledge of color difference in the building

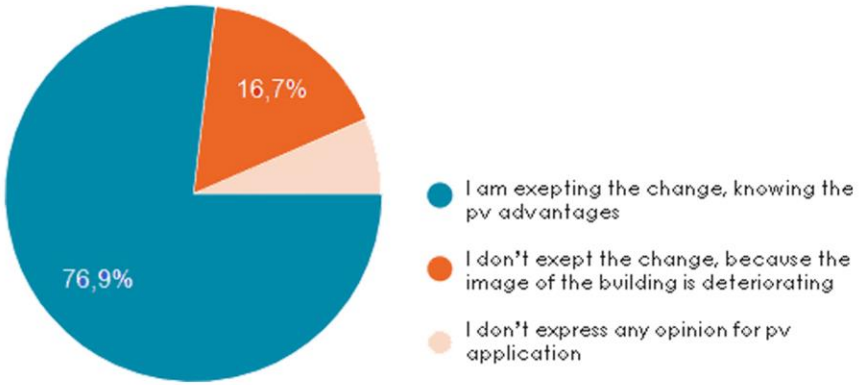
Hotel “Diethnes” (International) _ Questionnaire



Color Choice



Aesthetics of Application

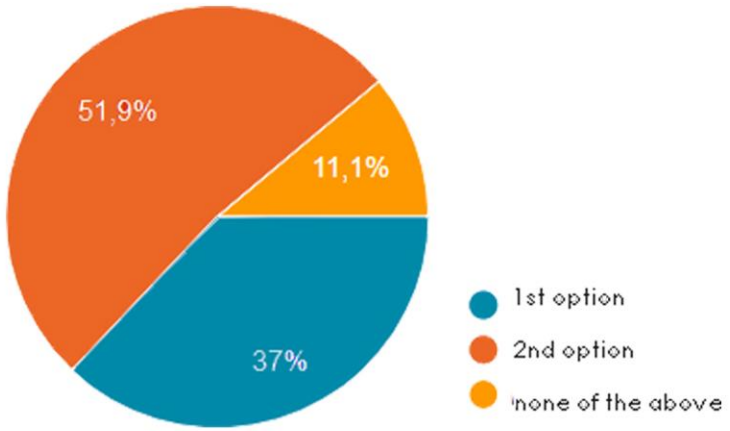


Acceptance of Application

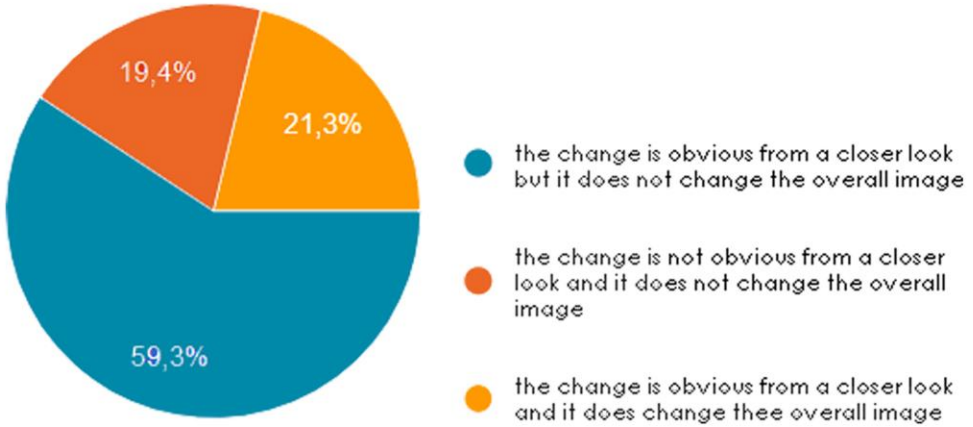
Hotel “Diethnes” (International) _ Questionnaire

Choice of Color

Hotel “Diethnes” (International) _ Questionnaire

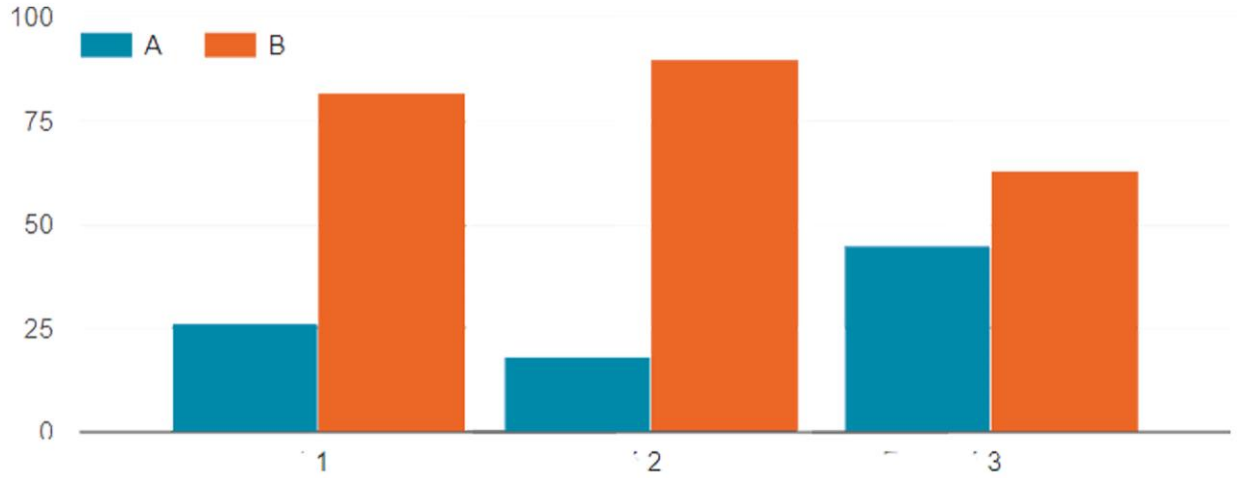


PV Color Choice



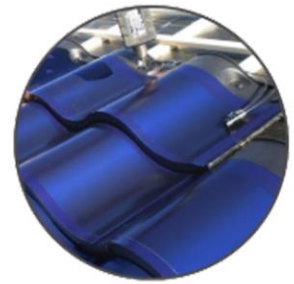
Difference in surface structure

Hotel “Diethnes” (International) _ Questionnaire



Choice for roof Application

1

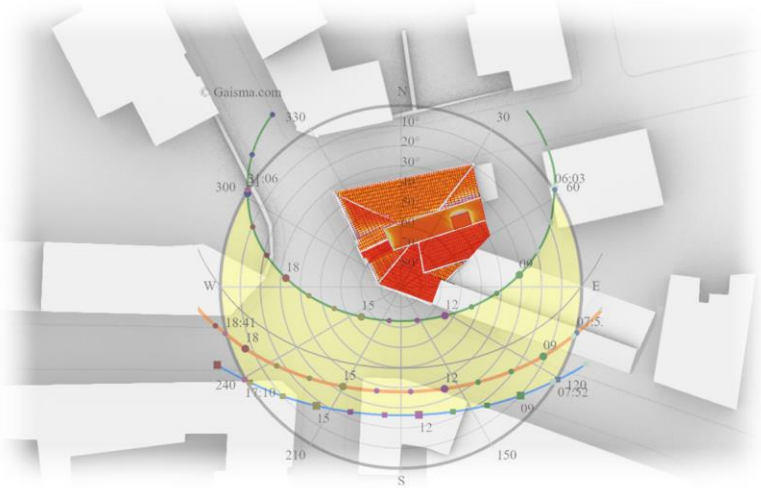


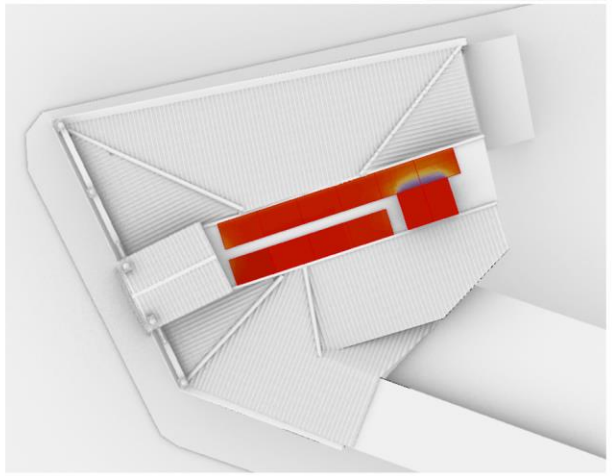
2

3

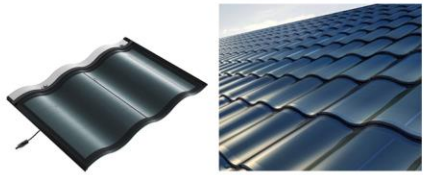
Hotel “Diethnes” (International) _ Design Proposal _ Roof

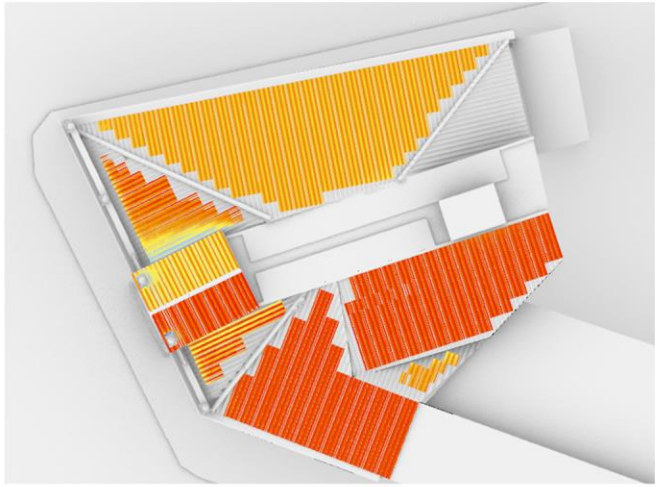
https://tbsspecialistproducts.co.uk/pv/
https://www.zep.solar/nl/
https://www.hanergy.eu/hantile-solar-roof-tiles/
https://sussexsolar.com/solar-pv/



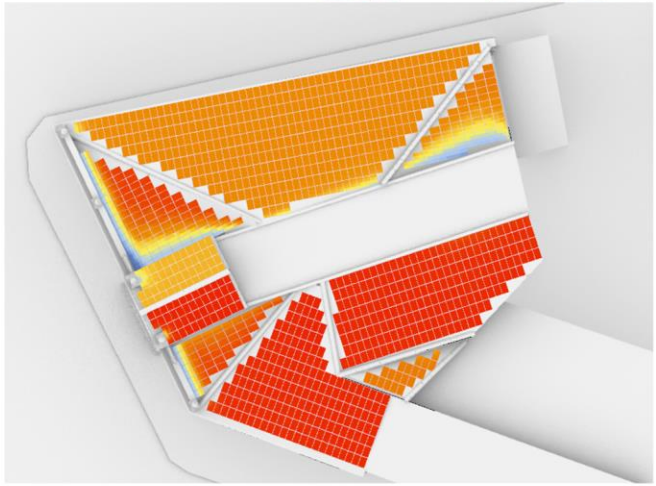


Solar radiation analysis on roof_ Flat Slate module





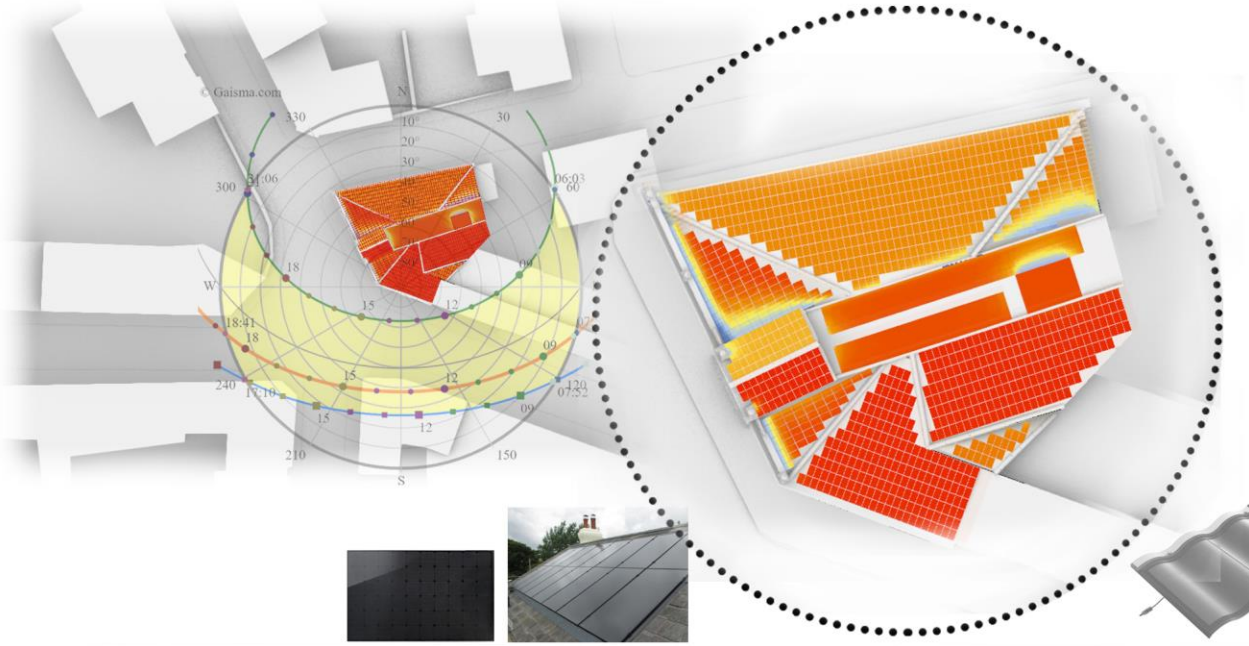
Solar radiation analysis on roof_ wave tile (Hantile)



Solar radiation analysis on roof _ slate module

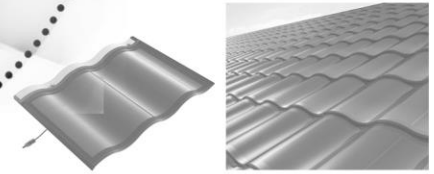
Hotel “Diethnes” (International) _ Design Proposal _ Roof

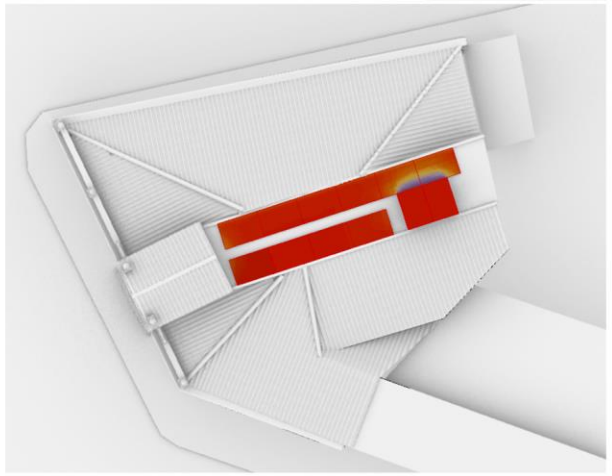
https://tbsspecialistproducts.co.uk/pv/
https://www.zep.solar/nl/
https://www.hanergy.eu/hantile-solar-roof-tiles/
https://sussexsolar.com/solar-pv/



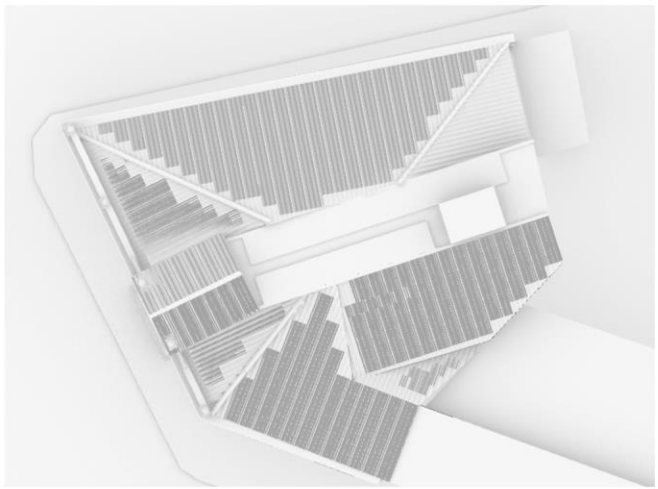
Roof
Energy Production

23.3 GWh annually

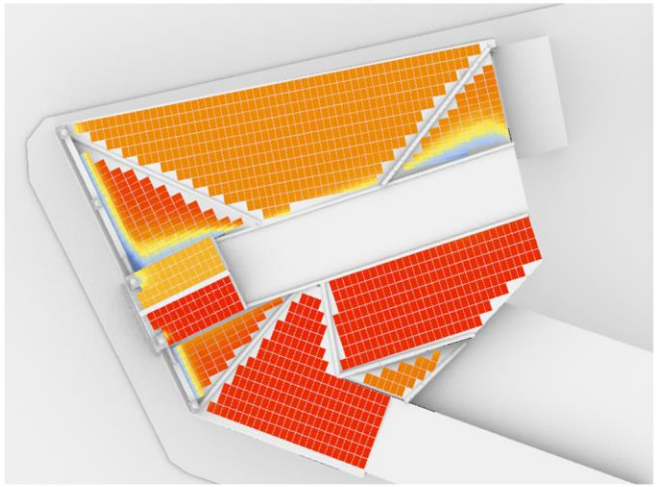




Solar radiation analysis on roof_ Flat Slate module



Solar radiation analysis on roof_ wave tile (Hantile)

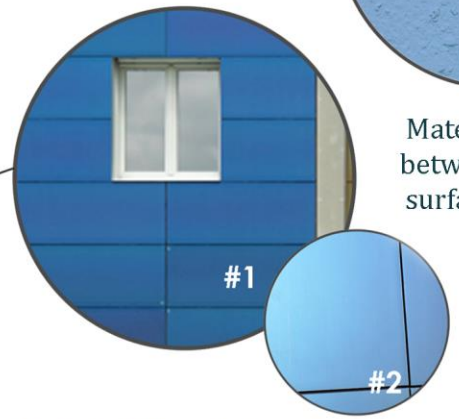


Solar radiation analysis on roof _ slate module

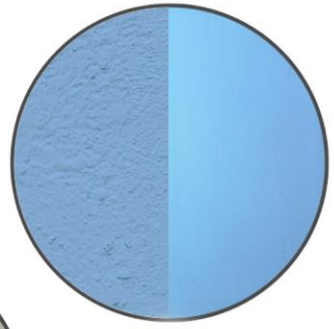
Hotel “Diethnes” (International) _ Design Proposal _ Facade : Plaster

https://kameleonsolar.com/colorblast/

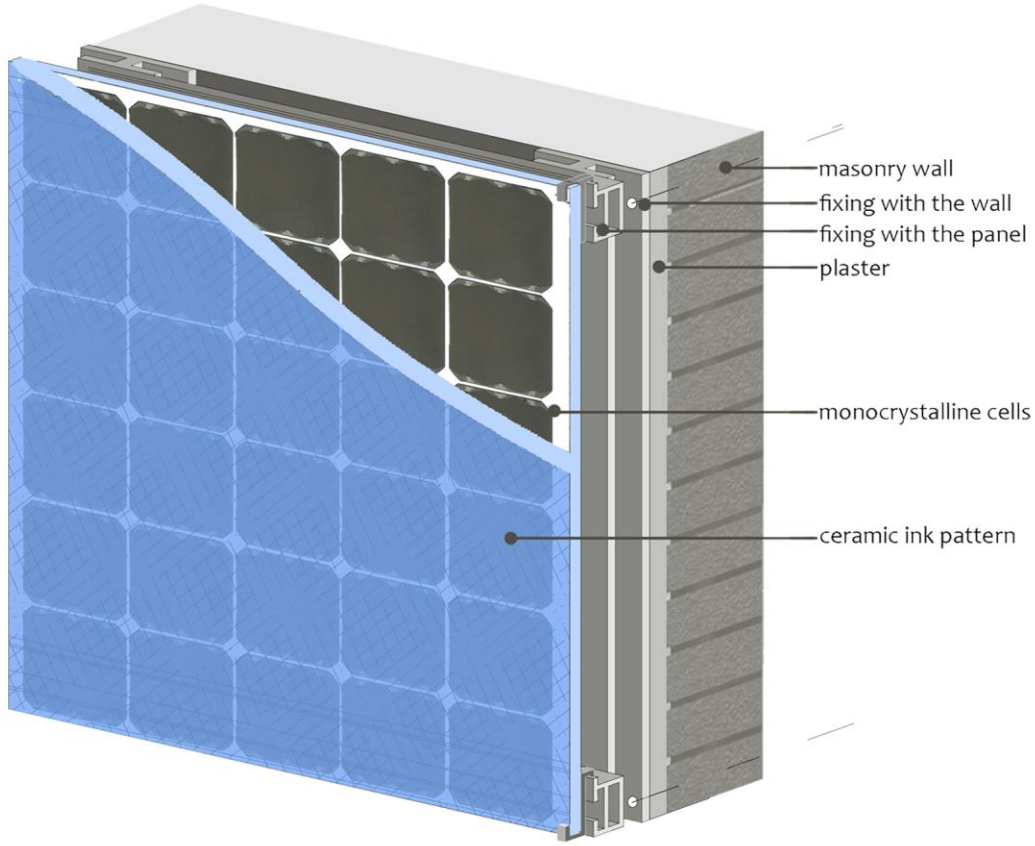
Solar radiation analysis on fragmented facade



Detail of PV module surface



Material difference between PV module surface and plaster



Detail of PV application on plaster

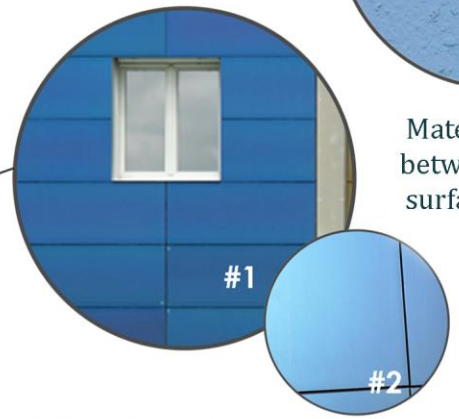
Hotel “Diethnes” (International) _ Design Proposal _ Facade : Plaster

https://kameleonsolar.com/colorblast/

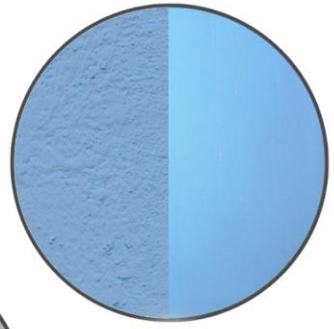
Solar radiation analysis on fragmented facade

Plaster
Energy Production

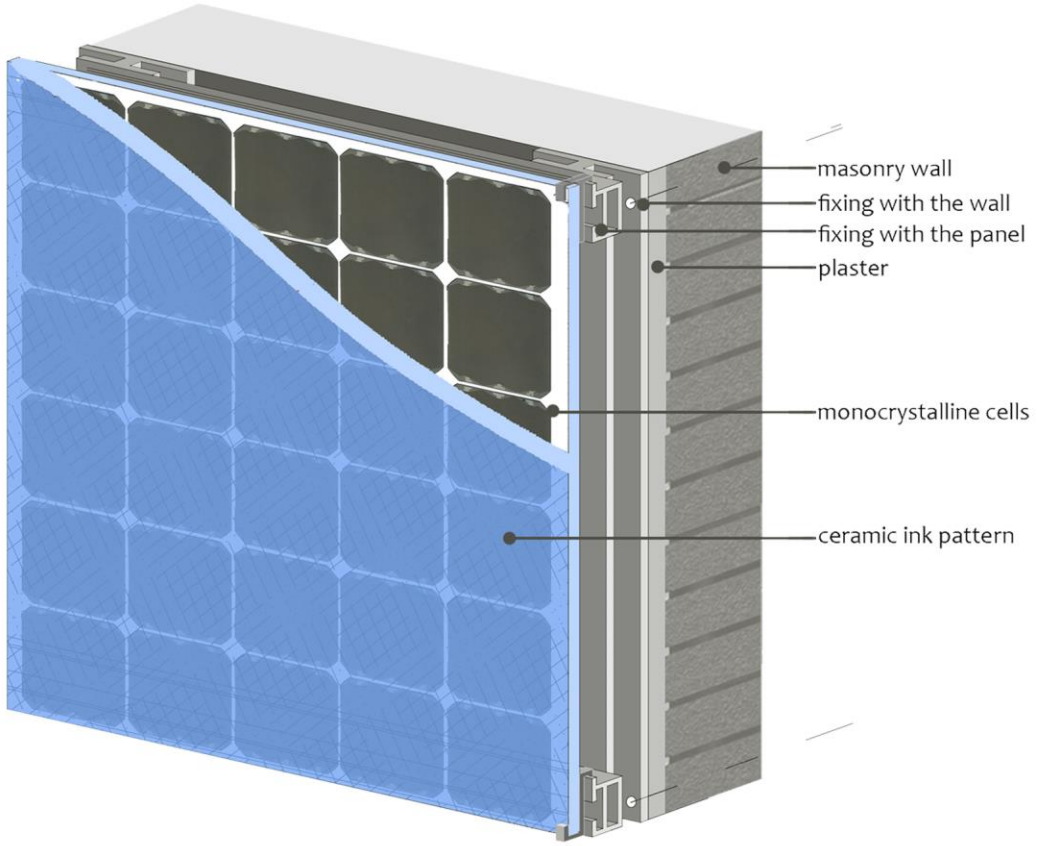
2.18 GWh annually



Detail of PV module surface



Material difference between PV module surface and plaster



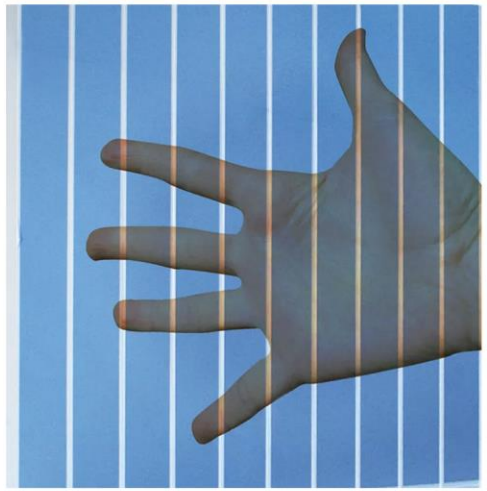
Detail of PV application on plaster

Hotel “Diethnes” (International) _ Design Proposal _ Facade : Window Glazing & Shutters

Solar radiation analysis on window glazing

Solar radiation analysis on window shutters

Application impression & material



https://www.theverge.com/

Application immpression & material

Hotel “Diethnes” (International) _ Design Proposal _ Facade : Window Glazing & Shutters

Solar radiation analysis on window glazing

Window Glazing
Energy Production

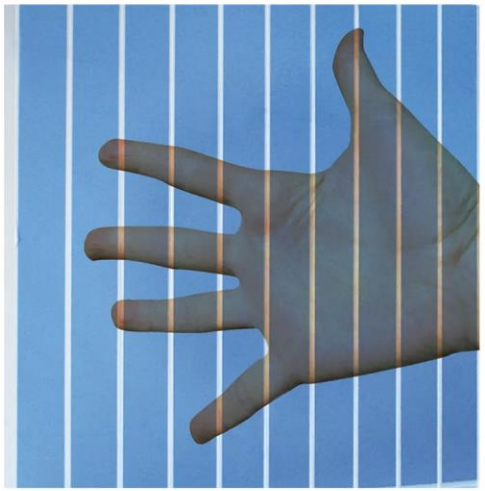
0.23 GWh annually

Window Shutters
Energy Production

0.85 GWh annually

Solar radiation analysis on window shutters

Application impression & material



https://www.theverge.com/

Application immpression & material

Hotel “Diethnes” (International) _ Design Proposal

South-west Facade

Hotel “Diethnes” (International) _Design Proposal _ Overview

South-west Facade

Design Proposal

- Color of the Fcade : Indigo Blue with white details
- Color of the roof : Terracotta

1) Application on Roof : Colored PV Tile

2) Application on Plaster: Ceramic ink Print module in the color indigo Blue, and White panel on the crown

3) Window Glazing : Cell-encapsulant glass (ground floor) and stained PV glass (first floor)

4) Shutters : Bifacial PV stripes on the louvres in color brown

5) Sign at the entrance: Printed PV panel

Hotel “Diethnes” (International) _ Conclusions

South-west Facade

The photovoltaic building design proposal...

- consists of pv application in : **a) roof, b) plaster, c) window glazing, d) window shutters,** and **e) sign**
- can produce **26.56 GWh** of energy annually
- is **13.7 %** of a hotel function scenario
- is **27.6 %** of a multi-functional scenario
- ***highest*** part production : roof **23.3 GWh** of energy annually
- ***lowest*** part production : glazing **0.23 GWh** of energy annually

Hotel “Diethnes” (International) _ Conclusions

How could photovoltaic technology be applied on heritage buildings, without compromising their architectural character ?

- by following legislation guidelines and tools
- by customizing the PV modules
- by customizing their application
- by not applying them extensively
- by following the architectural “lines”
- by immitating existed materials
- by respecting the existed

Hotel “Diethnes” (International) _ Conclusions

How could an pv application on heritage building be evaluated?

How many solutions in design proposal exist in a heritage case study ?

Is the pv application on these buildings worth the investment ?

Where does this research leads ?

Hotel “Diethnes” (International) _Further Research

Further Research

- Renovation of the building based on the Greece’s Energy Performance Regulations (KENAK) in the climatic zone of Florina.

- Research upon further energy reductions in the building’s envelope.

- Research upon forming a micro-energy grid among heritage buildings in the cultural city center, and, furthermore, forming a larger grid combining all buildings in the city’s center.


Thank you for your attention!