EVALUATION OF ADAPTIVE FACADES: AGC BUILDING A CASE STUDY OF AN AUTOMATED GLASS FACADE

INTERVIEWS AND PROCESS MAPPING WITH THE DESIGN TEAM

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REPORT INFORMATION

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Contents

Evaluation of Adaptive Facades: AGC Building a case study of an automated glass facade

implied, of the Sustainable Buildings Design Lab.

FOREWORD AND ACKNOWLEDGMENTS:

This work is part of the European COST Action 1403 on "Adaptive Facades, Work-group 3. The authors would like to gratefully acknowledge COST Action TU1403 "Adaptive Facades Network" for providing excellent research networking.

The audience of this interview is building designers and building energy specialist concerned with the evaluation, testing and monitoring of adaptive facades performance and occupancy behavior.

We would like to thank all those who have contributed to making this report, and we hope you enjoy reading this publication.

The author would like to thank the following organizations and individuals for their contributions for this document:

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- Philippe Samyn, Philippe Samyn and Partners
- Christian Bertrand, Cofely
- Emmanuel Hazard, AGC
- Filip Descamps, Daidalos
- Claude Pimpurniaux, SECO
- Kurt Booms, COLT

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Shady Attia

EXECUTIVE SUMMARY

The evaluation of adaptive facades presents a challenge because there is no established evaluation strategy to systematically reach this goal and many of the available façade performance evaluation tools have limited applicability for such advanced building facades.

This report presents a case study for an adaptive glass façade and evaluates its performance. The evaluation focuses mainly on pre and post construction phase of adaptive facades: The design assist phase (including the durability test, visual mockup, onsite panel mounting and weather stripping), the commissioning phase (field verification and performance testing) and the monitoring phase.

The selected project is a nearly zero energy building with unique façade comprising thermal isolated glass sunshades printed with white silk screen. These louvers respond dynamically and automatically to the angle of the sun which improves the control over energy consumption, solar radiation and glare with the ability to admit natural light into the building.

The report is part of the research activities of working group 3 of the European COST Action 1403 on “Adaptive Facades “.Different methods were used for evaluation, this include: interviews with the architect, façade engineer and technical control specialist, reviews of standard and codes and a systematic process mapping.

A documentation of the case study describing the post construction occupant comfort and façade operation was prepared. This report audience is mainly architects, building façade engineers together with facility managers concerned with the process of design, construction and operation of adaptive glass facades.

The outcome of this report identifies effective strategies for the design and performance evaluation

of optimal adaptive facades.

INTERVIEWEES SUMMARY

The interviewees revealed that the AGC building delivery process went through a linear process with experimental validation approach. The linear approach did not allow a holistic integrated and iterative approach. For example, the glass was selected through material identification session to support the glass box concept for the nearly zero energy targets prior to the identification of the mechanical, thermal and visual performance of the glass. Thus, the selection of the façade glazing was mainly based on aesthetical reasons during the schematic design phase.

The glass façade comprised three layers namely, the primary (internal) curtain wall, the steel structure and the automated glass sunshades. The most critical layer of the façade was the third layer with external automated sunshades. This layer had multi-functional and multi criteria performance requirements including glass transparency, color, weight, size, solar energy transmittance (g-value or SHGC) and movability.

However, the project delivery process forced the architect to select the louvers based on their transparency and color neutrality. Later on, the energy and building physics consultant had to optimize the glass louvers to avoid glare and overheat when the louvers are set to block the sun. The energy and building physics consultant had to conduct several simulations models and experiment with a climate chamber and test bed in the Netherlands, to maximize the g-value and come up with a working prototype (see Table 4-6 and Figure 8). Thus, the façade design was detailed and validated in a late stage of the design process. This was until the façade subcontractor was invited, when the final façade system design decision was made.

The involvement of the glass façade subcontractor at the end of the design process resulted into a complicated situation. Finally, a silk printed glass with a tempered mesh was finally proposed to address the mechanical, thermal and visual performance requirements. It would be optimal if the glass subcontractor was engaged during the concept development. However, the competition based

approached hindered such an approach and kept the responsibility in the hand of the architect. Therefore, it is very important to engage the façade engineers from the beginning of the design to guarantee hands on feedback and follow the shortest and the most cost effective design path.

QUESTIONNAIRE (INTERVIEW WITH ARCHITECT PHILIPPE SAMYN)

A. BACKGROUND INFORMATION

1. **What is your core specialisation?**

The firm's client services include Planning and Programming, Urban Planning, Landscaping and Architectural Design, Interior Design, Building Physics, MEP and Structural Engineering, Project and Construction Management.

2. **What Kind of Projects you have been involved in?**

A wide range of projects : industrial buildings, offices, interiors & sculptures, commercial activities, public services, health & social care, hotels & restaurants, auditoriums & theatres, schools & universities, research centres and housing projects.

3. **How would you describe your main roles in the company? How long have you been in this field?**

He begins his consultant activity as an architect and engineer in 1972 and founds "Philippe Samyn and Partners" in 1980.

B. INTERVIEWEE DEFINITION OF ADAPTIVE FAÇADE:

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4. **How do you define an adaptive façade? What is the purpose of adaptive façade?**

The definition isn't complete. Somehow every building on the planet request some adaptively to be useful. For example, you have a curtain in your sleeping room to adapt it to the fact that the sun is coming and you have a window that open in your house to get air in. So adaptive façade is a wrong concept because a façade is by definition adaptive.

C. ADVANTAGES OF ADAPTIVE FAÇADE:

Definition: Adaptive facades are building envelopes that are able to adapt to changing climatic conditions on daily, seasonally or yearly basis. By adaptive we mean the ability to respond or benefit from external climatic conditions to meet efficiently and more important effectively occupant comfort and well-being requirements.

5. **What kind of projects did you participate in that fall under this definition?**

All my projects, the fact of architecture is designing emptiness (space), but after all what the architect is doing is defining a void and to make that void a reality, you need construction. The adaptiveness of a façade is a fact of construction but it quali-

fies the architecture.

A good example of non-adaptive façade is what have been built the last fifteen years, those reflective office boxes with tinted glass.

6. **What are the adaptive characteristic in those projects? (Active transparent facades, Switchable glazing, Phase change materials, automated louvres) and what was its main added value (reason) (comfort, energy, real state value, image etc...)?**

Firstly: The ability of the building not to get dirty and that implies an obsession for low maintenance cost.

Secondly: respect of the 5 sentences (quality of light, light transmittance, insulation value, etc...).

Thirdly: the order of the magnitude, the quality of touching, smell and the noise and music of architecture (the way the building space and façade interact with sound).

7. **What key performance indicator(s) were used to evaluate those characteristics?**

What you need as a designer is a bright client with a vision and a goal. The projects needs absolutely to be humanistic. The way the brief of a competition is written tell you everything about its morality.

You have to take the time to appropriate the site (quality of earth, wind direction, trees) with the big dream of the client and this is the way to get inspiration and my real device (potential) when going through a project is: discover, invent and create.

8. **When and how did you intervene in this project (AGC Building)?**

- It was a competition lunched by AGC, they were looking for design build team and they call for manifestation of interest. **MATRIciel** helped AGC to write the design brief, I decided with **BEAI** to make 2 projects: a brave one and a serious one, **BEAI** made the one that pleased them and I made the serious one.
- The **BEAI** project was in brick and aluminium and it pleased them in the first meeting. After that I proposed on Emmanuel hazard (De Facto project owner) that we can do the same but with a fully white glass façade: the building will be covered with clear glass vision (which guarantee natural light and a clear vision) and it will have **g factor** equivalent to solid aluminium.
- For the louvres it was my invention and I sold it to AGC which, with the help of the R&D were able to realise it.

All this was in the concept development, when you came with this idea, were not you afraid because it was not validated yet?

I am calculating permanently.

9. **Who were the team members of such a project?**

The consortium was composed of: SAMYN and PARTNERS, BEAI Architects, Van Roey (General contractor), Daidaluz Peutz (Energy and physics consultant)

10. **What modelling tools where used that you consider good tools helped in design?**

None. Even in this time of many possibilities offered by computer simulations, we continue to see models as an important articulation in the development of projects. Models provide an additional security in the testing of what is intended to be built. (Source: http://samynandpartners.be/design-approach)

11. What features would you like to find in future in an adaptive facades?

The white stripes could be replaced by white photovoltaic.

12. How did you test the façade offsite and onsite (fire, blower door)? Which standard did you refer to for testing?

The calculations were made by AGC's R&D centre, **Daidalos** did the simulation work and then **Peutz** in Netherlands made the physical testing. Energy measurements was done in a black room, it was made twice (once in the development with **Peutz** facilities and then with real facade (mock-up) on site.

13. How did you do the commissioning process? What standards did you comply with and which test did you conduct?

Table 1: Thermal Comfort Performance value

	Description	Standard	Category	Performance value
PMV-PPD indices	thermal comfort index	NBN EN ISO 7730:2006 NBN EN ISO 1525:2007	B (Normal Level)	No more than 3% of the building occupancy period
U Value	The thermal transmittance measures the thermal performance of a building component	NBN B 62-002:2008 NBN EN ISO 6946:2008	-	2.5 W/m^2K (overall value for the curtain wall)
K Level	Global level of thermal insulation of a building	NBN B 62-301:2008	Average quality	K36
E_w Level	Annual primary energy use under standard operating conditions	NBN EN ISO 13790:2008	Higher than high quality	$E_w = 42$
The Temperature factor	Is a measure of the risk of surface condensation	Belgium's BBRI	-	Higher than 0.7

Table 2: Air quality Performance value

	Description	Standard	Category	Performance value
Air Change Rate (Envelope) n_{50}	Number of air changes per hour at 50 Pa.	NBN EN 13829	-	$n_{50} = 0.77$
Humidification		NBN EN 15251:2007 Article 57, General Regulations for work protection	Level B, Normal Quality	40%

Table 3: Indoor light quality values

		Description	Standard	Category	Performance value
	Daylight Factor	is the ratio of internal light level to external light level	NBN EN	Level B Strong Daylight Penetration	3% FLJ ≥ 3%
	Light Reflectance	Measure of visible light that is reflected from a surface when illuminated by a light source			41%
	Light Transmittance	The fraction of incident light passing through the glazing			11%
	G-Value	To measure the solar energy transmittance of glass			0.17

14. When you are close to the commissioning, Colt was the company responsible of the automation, would it make a difference if this company was early on the design team?

- No, even the actuators were not created by **Colt**, but by one of my partners, they could not find the proper actuators. We had full control of engineering and drawings here and we design every little bolt.

15. Is it possible to convince clients to pay more for an adaptive façade?

- No, most of my clients accept to pay more in investments to get the return within a couple of

years.

- There is a huge risk about computer driven building is the break of internet. In the case of AGC building, we have a weather station, an automated louvre but there is no internet connection, it is a closed cycle.

16. Do you think that adaptive façade technology is mature to penetrate the market? And Why?

- You don't need technology for having an adaptive façade. Technology is not associated with adaptive facades.

17. Did you consider the life expectancy and maintenance of adaptive facades a challenge? And why?

- I have no idea, but I can reasonably say that it will be higher than a normal office building. It will work perfectly as long as we maintain it. Buildings components have to be low-tech even if they seem like high-tech, and what I mean by low-tech is that every component can be easily produced and assembled

D. THE FUTURE OF ADAPTIVE FACADES:

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18. What is your opinion regarding the specific nature of adaptive facades (coming from component and elements in the factory and getting assembled on a system level in the building)? Is the process smooth enough? What is the most critical phase and why?

- Education

19. What needs to be done for better adaptive facades process and performance quality? Do we need to invent new performance indicators? And new standards?

- No, we do not need new performance indicators.

20. What happens if POE and monitoring becomes obligatory?

- None sense, it is a constrain limiting the freedom of thinking. Just by human behaviour we can reduce energy (turning light on/off …)

21. What is the holy grail of adaptive facades in the future?

- A not driven moving building,

QUESTIONNAIRE (INTERVIEW WITH KURT BOOMS, COLT)

A. BACKGROUND INFORMATION

1. What is your core specialisation? And what kind of projects you have been involved in?

- WS_30001 (00:00 – 01:26)

We are experts in moveable external solar shading systems, we also have fixed systems but we are really specialised in moveable systems: horizontal, vertical, all types of ideas that started from the architect.

Mostly, we are involved in public buildings like office buildings, hospitals sometimes but mostly bigger scale projects.

22. How would you describe your main roles in the company? How long have you been in this field?

- WS_30001 (01:27 – 02:28)

Based in Belgium, I have been fifteen years working in this field and I am responsible for Belgium, Luxemburg, Holland and France. My role is visiting architects and engineers, talking about possibilities and looking at energetic and cost aspects from the first starting point of the project. My aim is to study the possibilities, what are the advantages and on the site of cost, is it feasible to go this way or not?

E. INTERVIEWEE DEFINITION OF ADAPTIVE FAÇADE:

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23. How do you define an adaptive façade? What is the purpose of adaptive façade?

- WS_30001 (02:28 – 04:28)

An adaptive façade is a moveable façade that can give an added value to the energetic point of view of the building, not only regarding solar shading but also in the means of natural daylight entering the building. The reason that it have to be moveable: when you have fixed system, it is nice in summer but when it is a darker day, more artificial light will be needed, then we have to look a little bit more on the cost and the heating of the building, not only on the cooling side but also the heating requirements of the building.

24. Who and what drives the idea (raison d'être) of adaptive facades in most of your projects?

- WS_30001 (04:30 – 05:30)

Energy is our main drive, we are trying to reduce the primary energy needed in the building. Very often the aesthetical aspect in the building for some architects is very important. Nowadays, there are new requirements for building like Zero-Energy and from that point of view, we as **Colt** try to give some interest for that.

F. ADVANTAGES OF ADAPTIVE FAÇADE:

- **Definition: Adaptive facades are building envelopes that are able to adapt to changing climatic conditions on daily, seasonally or yearly basis. By adaptive we mean the ability to respond or benefit from external climatic conditions to meet efficiently and more important effectively occupant comfort and well-being requirements.**

25. What kind of projects did you participate in that fall under this

definition?

- WS_30001 (06:30 – 08:30)

The Berlaymont, the headquarters of the European Commission, SBB Railway Headquarters, bio-reactive façade in Hamburg and the BMW headquarter in Munchen and South-Africa.

26. What are the adaptive characteristic in those projects? (Active transparent facades, Switchable glazing, Phase change materials, automated louvres) and what was its main added value (reason) (comfort, energy, real state value, image etc...)?

- WS_30001 (08:30 – 08:55)

The solar shading and their steering (controls).

27. What were the components of this adaptive façade? And what key performance indicator(s) were used to evaluate those characteristics? (Orientation, snow, solar radiation?)

- WS_30001 (08:56 – 10:35)
- Everything that form the second façade is mostly carried by us.
- **For physical components**: the vertical and horizontal beams, the motorization and then the louvers themselves taking into account the thermal bridging.
- WS_30001 (10:36 – 12:37)
- **For soft components:** the software of the steering, the weather station, the central control panel and everything that need to come together there like HVAC context and fire alarm context from there you go to a secondary panel connected to the motors (11:00). ***A schematic of controls should be included.***
- WS_30001 (12:37 – 15:38)
- Our main indicator is **static calculation** for the structure (wind loads, etc.) to determine in first case what structure do we need in a static point of view that goes stand together with a motor. When this is done you know the force you need with a motor and then you go to the controls. The more force you need, the bigger your component for steering will be.
- It is also important here the individual need of the customer depending on which type of building: for example, in schools they want louvres to be closed for presentations so they want to have darker rooms (manual motorization/override for the individual uses).
- We are looking mainly to secure and guarantee the stability and robustness of the second façade and that it will function, will take the loads and operate from a structural calculation point of view.
- WS_30001 (15:39 – 19:50)
- **Performance Indicator's Matrix for the structure**:
    - **Newton/m2** wind load, we also take into account snow and ice.
    - CP (coefficient of pressure), CF (coefficient of form) (internal and external). Taking into account the form, dimension and the position of the building.
    - Type of material, thermal expansion, colour, shape.
    - Safety rails so people can not fall down especially in high buildings.
- WS_30001 (20:00 – 24:22)
- **Indicator's Matrix for energy:**
    - Light intensity (kilo lux). We don't do a simulation for the whole building, we mainly 1) simulate the light on the façade for the whole year for the whole year, 2) determine the position and intensity of

the sun, then we calculate the **g and e value** and then we give the advice of the total **g value** for the glazing.

- **G value** is determined by the architect and we can deliver a varieties of **g value**. Therefore, our first question to the architect is: which **g value** you want to achieve then we do our calculations and we advise the client for the most suitable solution. We always give this remark: with solar shading system especially **glass louvers**, there is no solution for glare, mostly an internal solar shading has to be used.

- WS_30002 (Start – 02:45)
  - Our static calculations are done with in-house and commercial software's (ANSYS Fluent)
  - Solar heat gain (watt/m2, per day).
- WS_30002 (02:46 – 04:38)
- **Manual overriding/occupant control:** we listen to the occupant, they tell us how they want to run it and we impregnate the operational options into the controlling system. Parameters can be changed for every group of the shading system on different floors. When someone is using the manual overriding: the affected group is programmed to return to its original state after a certain time (ex: one hour).
- WS_30002 (04:39 – 05:50)
- **Static performance indicators that architects/clients would look at :**
  - Louvres Direction (horizontal or vertical).
  - Type of Material and its capabilities (shape, type, colour, texture)
-

28. Can you rank cost, energy, occupant satisfaction (view) in order of importance for adaptive facades?

29. What was the key milestones of the façade design and construction?

30. When and how did you intervene in this project and who were the team members?

- WS_30002 (13:30 – 19:12) (20:25 – 23: 29)

Most of the time, at the beginning of the project with the architect. The procedure can be defined through four main process:

- Before contract: We have a meeting to talk about the possibilities with the architect and the client, they already have the initial drawings, the project concept and description. A second meeting is arranged to give our advice with principle drawings and cost estimation.
- After contract: A mock-up is done to see if everything goes well and after that we deliver the detailed drawings and explanations.
- Approval drawings (signed by the architect): static calculations, dynamic calculations (6-8 weeks).
- Production drawings, then pre-assembly for the moveable parts, components are tested, and then delivered to the site and mounted. We have our own internal commissioning **(Details in our last meeting in Liège)**

31. What modelling tools where used during the design?

- WS_30001 (24:52 – END)

We have our in-house software based on the European standards for the static and dynamic side.

-

32. How did you test the façade offsite and onsite (fire resistance, access to fire, blower door)? Which standard did you refer to for testing?

- WS_30002 (19:13 – 20: 24)

An internal test is done to see if everything goes well. We already have our own test facility, we do wind tunnel, pressure, structure, loads. For the wind tunnel test, we build a louvres' mock-up with 10000 to 20000 cycles that open and close simultaneously. Simulations took up to two or three months)

33. How did you do the commissioning process? What standards did you comply with and which test did you conduct? Did you develop or use a checklist? What was it about?

WS_30001 (24:22 – 24:51)

For static calculation we use the following European regulations:

- NBN B-03-002-2 : Windlasten – Dynamische effecten

- ENV 1999-1-1 : Berekenen van aluminium structuren
- EN 1991-1-4 : Windlasten

34. How do you perform soft-landing or post occupancy evaluation or monitoring? What did you learn from soft-landing?

- We stay at least 2 months with an engineer on site after delivering the building to check the facades and the regulations.
- We sign a maintenance contract: one visit every year, in which we check the façade and if there is something that is not working we replace it.
- We talk to the facility manager and security to make sure that everything is regulated and function well.

35. What standards did you comply with and which test did you conduct? How did you validate the performance?

- WS_30002 (23:45 – 28:25)

The European regulation, but sometimes we set our own maximum deflection of a system which depends mainly on the type of materials: very often 1:200 is the maximum deflection, and 1:50 with glass. **(I will check this for wind, structure-regulation)**

For fire, the fire department ask to have a specific part of the façade that must be able to open separately as an access in case of emergency.

Concerning performance's validation, we don't do it in general unless in some projects, when other special departments (ex: research labs) are involved. Very often in Germany, the **Algea Building**, we were working together with a research institute that did the measurements and monitoring. **(I have to ask for references)**

G. DISADVANTAGES OF ADAPTIVE FACADES:

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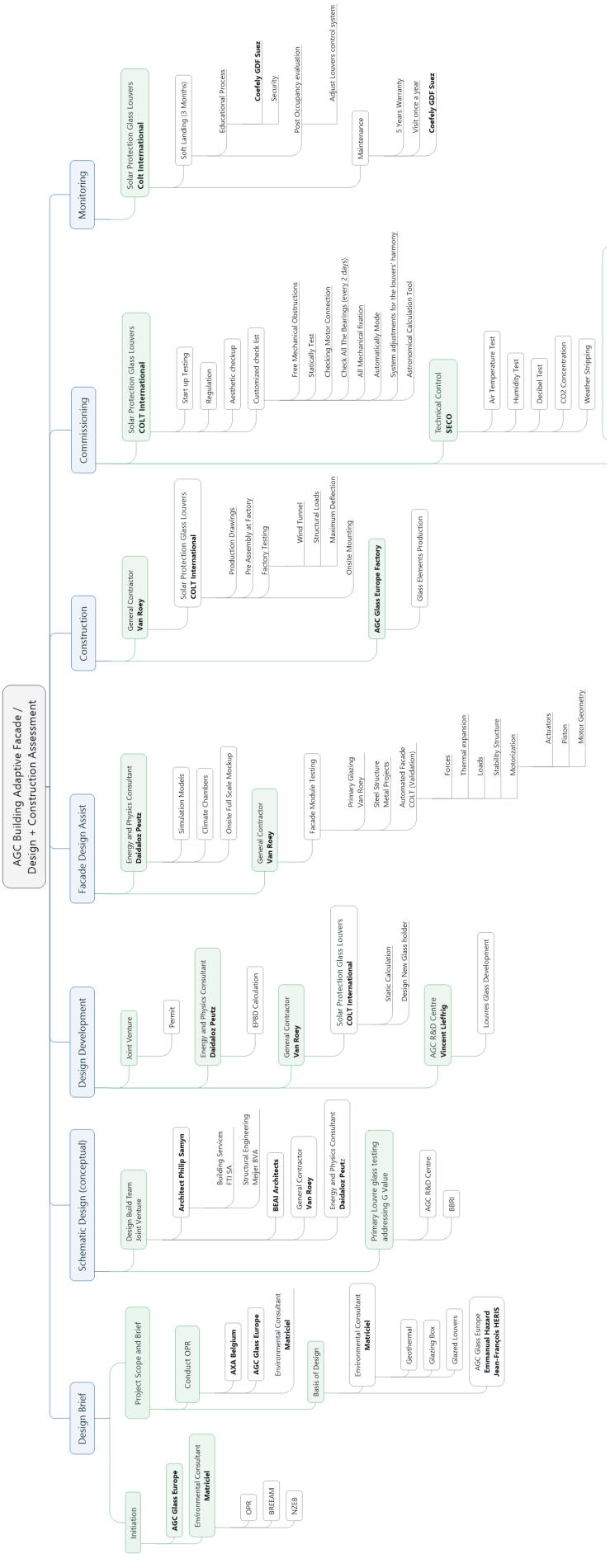
36. In your opinion what will be the fraction of adaptive facades in today's market? Why most of the projects are not having adaptive facades?

- WS_30003 (00:00 – 05:50)

10 to 15 %, I think cost related.

37. What would was the average cost per square meter for the adaptive façade vs a static façade? And does the cost impede the penetration of the market? What is the influence of customisation on cost?

- WS_30003 (25:20 – 26:00)
  - If we compare a fix system with a moveable system: physically, a moveable one will cost 10 to 15´% more than a fixed one.


AGC Building Adaptive Facade / Design + Construction Assessment
Design Brief
Initiation
AGC Glass Europe
Environmental Consultant Matriciel
OPR
BREEAM
NZEB
Project Scope and Brief
Conduct OPR
AXA Belgium
AGC Glass Europe
Environmental Consultant Matriciel
Basis of Design
Environmental Consultant Matriciel
Geothermal
Glazing Box
Glazed Louvers
AGC Glass Europe Emmanuel Hazard Jean-François HEMS
Schematic Design (conceptual)
Design Build Team Joint Venture
Architect Philip Samyn
Building Services FTI SA
Structural Engineering Meijer BVA
BEAI Architects
General Contractor Van Roey
Energy and Physics Consultant Daidaloz Peutz
Primary Louvre glass testing addressing G Value
AGC R&D Centre
BBRI
Design Development
Joint Venture
Permit
Energy and Physics Consultant Daidaloz Peutz
EPBD Calculation
General Contractor Van Roey
Solar Protection Glass Louvers COLT International
Static Calculation
Design New Glass holder
AGC R&D Centre Vincent Lieffrig
Louvres Glass Development
Facade Design Assist
Energy and Physics Consultant Daidaloz Peutz
Simulation Models
Climate Chambers
Onsite Full Scale Mockup
General Contractor Van Roey
Facade Module Testing
Primary Glazing Van Roey
Steel Structure Metal Projects
Automated Facade COLT Validation)
Forces
Thermal expansion
Loads
Stability Structure
Motorization
Actuators
Piston
Motor Geometry
Construction
General Contractor Van Roey
Solar Protection Glass Louvers COLT International
Production Drawings
Pre Assembly at Factory
Factory Testing
Wind Tunnel
Structural Loads
Maximum Deflection
Onsite Mounting
AGC Glass Europe Factory
Glass Elements Production
Commissioning
Solar Protection Glass Louvers COLT International
Start up Testing
Regulation
Aesthetic checkup
Customized check list
Free Mechanical Obstructions
Statically Test
Checking Motor Connection
Check All The Bearings (every 2 days)
All Mechanical fixation
Automatically Mode
System adjustments for the louvers' harmony
Astronomical Calculation Tool
Technical Control SECO
Air Temperature Test
Humidity Test
Decibel Test
CO2 Concentration
Weather Stripping
Monitoring
Solar Protection Glass Louvers COLT International
Soft Landing (3 Months)
Educational Process
Coefely GDF Suez
Security
Post Occupancy evaluation
Adjust Louvers control system
Maintenance
5 Years Warranty
Visit once a year
Coefely GDF Suez

38. Do you think that adaptive façade technology is mature to penetrate the market? And Why?

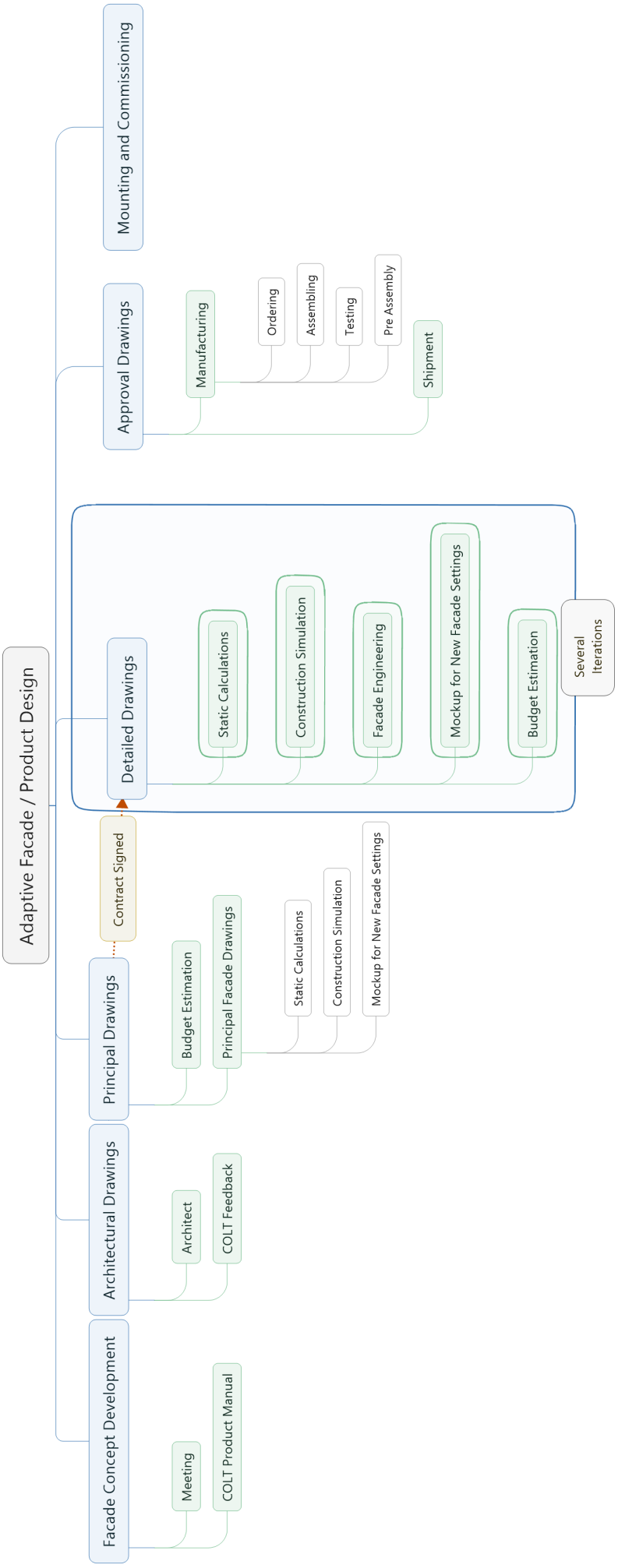
- WS_30003 (05:50 – 06:18)

Yes, we already have a lot of examples and I think it is already proven.

39. What is the life cycle of such an adaptive façade? Did you consider the life expectancy and maintenance of adaptive facades a challenge? And why? (how long is your solution age)

- WS_30003 (06:19 – 07:30) (12:25 – 13:33)

10 years at minimum. We have many buildings with more than 15 years with moveable façade like the


Adaptive Facade / Product Design
Facade Concept Development
Meeting
COLT Product Manual
Architectural Drawings
Architect
COLT Feedback
Principal Drawings
Budget Estimation
Principal Facade Drawings
Static Calculations
Construction Simulation
Mockup for New Facade Settings
Contract Signed
Detailed Drawings
Static Calculations
Construction Simulation
Facade Engineering
Mockup for New Facade Settings
Budget Estimation
Several Iterations
Approval Drawings
Manufacturing
Ordering
Assembling
Testing
Pre Assembly
Shipment
Mounting and Commissioning

EU Barleymont. Maintenance is not a challenge and it is part of our services but it have to be done regularly because if we didn't, later on the system will have a lot of problems because of external factors (temperature difference, wind, etc.) and then cost will be much higher.

40. Do you think there is a real need of adaptive facades? And why?

- WS_30003 (07:31 – 11:30)

Yes, we try to give solutions that work very well on a statically and energetic level but also building's occupants have to be satisfied.

The user satisfaction of the building is very important. For that reason we are moving to glass louvres because it is possible to watch outside of the building even if they are completely closed.