

### 5 to 8 Minutes Introduction

- Collection of information about the interviewee (educational and technical background, field of professional experiences, professional years of experience, involvement in different types of projects).
- Brief introduction about the interview.

### Interviewer

So now I'll move to the opening questions. So [Name of Interviewee 7] of according to your experience, what is your opinion about the current level of knowledge in the building industry regarding the application of multifunctional facade components integrating solar cooling technologies?

### Interviewee 7

If you ask me, just to mention one word, I guess that the right word is poor. You know, I don't think there is a lot of knowledge in the building industry about the different types of solar cooling component. Of course we know about PV panels on the roof, but integrate them in the facade is you know it's just poor.

### Interviewer

OK, in your opinion, what are the motivations regarding the application of multifunctional façade components integrating solar cooling technologies?

### Interviewee 7

You know, I think that the best motivation is of course the legislation. We need a certain amount of renewable energies in our new buildings, and especially in high-rise buildings, we don't have enough space on the roofs to place regular PV panels and that's well sort of traditional system. You know most of the time we are engineering a way of heating and cooling for the building and it's.....Actually the amount of PV panels is the closing product to reach the goals of the legislation. I mean I guess that the products we do and of course we wanted to be as sustainable as possible, but most of our clients asking just to fulfil the rules of legislations and you know we engineer a regular HVAC systems and we put solar panels on the roof as much as we need.

### Interviewer

OK. What about you your concerns regarding the application of multifunctional facades integrating solar cooling technologies?

### Interviewee 7

You know it's I think it's quite difficult because there are two typical branches. You know it's the facade is of course more the building branch and the cooling is more insulation HVAC branch. And that are two different types of....Well at least companies have most of time also on people and engineers and knowledge all about the things.

You know, if I'm from a building service perspective, I'm always saying, you know, if the contractor is just building his building, you know and if it's not leaking....you know if it's not leaking when it rains or it's windy, then we as the building service industry are arranging the right way of comfort. You know that's to get our best a little bigger than it's actually is, but you know they are two typical branches.

**Interviewer**

What are the main issues needed to be considered for such concern?

You means quite difficult. Different types of companies.

**Interviewee 7**

It's the façade and the building services are two different industries with its own engineers, with its own contractors. And if you want to integrate them they have to work together.

**Interviewer**

You mean like a close collaboration between them?

**Interviewee 7**

Yeah, of course that's needed when you want to get it integrated in the façade.

**Interviewer**

OK. Got it. Now let's move to the following question. Can you tell me how different type of projects, such as new building construction or renovation projects, can affect the application of solar cooling integrated facades? We have different test projects, you know, new building construction or renovation projects.

**Interviewee 7**

It's just like the previous question. It's a way of working and what normally happens, and I guess that's really one of the things what makes it quite difficult....In our regular building process, we are asking two types of companies. One to do the facade and one to do the HVAC, and if you want to integrate it....Well maybe the best way might be in a renovation situation because you don't have to be on the design teams. All you know the large problems which all over there. If you focus on...well, maybe that that might be easier, but...Yeah.

**Interviewer**

OK, now let me move to the following question. So now I talked to you about different projects. Now different types of buildings. So what about the effect of different types of buildings, office, residential healthcare on the application of solar cooling integrated facades?

**Interviewee 7**

Well, I really do think that it have its effects. You know if you, for instance, if you have look on a restaurant or a hospital, or just a regular house, you know, they all have different types of requirements for cooling. And what we see from our engineering perspective is that cooling and ventilation are of course most of the time collaborating because we are cooling by air, a lot of a lot of situations. And the restaurants have a different ventilation needs than if you compare it with a house. So if you want just one solution or solar cooling in each façade, then you're not going, I guess, that's difficult to fulfil all requirements.

**Interviewer**

OK, now I have a question about the effect of the building location and the climate conditions. So how different locations of buildings and the climate conditions can affect the performance of solar cooling integrated façades?

### Interviewee 7

I think there are two ways. You know it's not only about....In the Netherlands, it's not only, we are only working in Netherlands, and well luckily it's still not only about cooling, but it's also about heating. You know, so if there's a product being developed, it must be also provide heating. That's one. And on the other side, you know of course it is in every city quiet intensive built. There's a lot of things to do about shadow, of course. I worked on the project in Utrecht and we were also researching the option to integrate vertical solar panels, and not just for cooling or heating, but you know to generate electricity. And what you see in a dense downtown Utrecht there's too much shadow on the building, on the facade to really generate electricity.

### Interviewer

OK, got it. So generally, what are the recommended locations and the climate conditions for applying solar coding integrated façades?

### Interviewee 7

If it's just about cooling, you know, then I think you have to look on more Southern Europe and the regions where you're coming from, of course. You know, I think in Saudi Arabia or in Dubai. You know it's all about cooling and it's never about heating. So the more Mediterranean areas and below.

### Interviewer

Yeah. Can you tell me how different types of solar technologies such as electrically driven or thermally driven can affect the application of solar cooling integrated facades?

### Interviewee 7

Yeah. I do think so and why it's because they are two different types of technique. In the Netherlands, it's quite expensive to use vertical solar panels in the façade. And if you also have two different types of technologies, you know I think it's cheaper and easier to standardize. That's a short answer. If you want to sometimes do one way, sometimes doing the other way and the other way then it's quite difficult to standardize it and to get a good business model on it. Yeah, that's of course a financial part. It's also a technical part. How are you going to deliver the right requirements to fulfil the right requirements from a building perspective, from a comfort perspective. And if you want to combine it all in one, you know I think it's quite difficult.

### Interviewer

OK. Now we'll move to the key questions. So we talked about different technologies, climate conditions, location of buildings. Now we have the key questions. We'll cover three main aspects, technical and product related, financial, process and stakeholder. So let me start with the technical questions. In your opinion, what are the potential solutions that can be considered to address challenges related to product complexities of solar cooling integrated facades, such as the required space availability or interrupting building services?

### Interviewee 7

Difficult question. You know that there are several ways of how you can think about this. From a circular perspective, if you have it all in the local way, you know. If you do every façade for every, you know, for instance a room....if you have an integrated facility in it, you know the then you have

multiple solar cooling facilities in one building, maybe in one room and from circular perspective, I think it's better to centralise it. That's so when you need less raw materials.

On the other side, if you standardize it, I think that's.....what you're doing when you are providing a local option like this integrated option that's my vision on it at least, then there must be less dropouts. I think that's the amount of failures in the cooling system are being reduced by using more. You have a certain way of redundancy....If each facade has its own integrated solution.

#### **Interviewer**

Like from the circularity perspective, it's centralization, but from the other perspective its decentralization?

#### **Interviewee 7**

You know it's sort of paradoxical to each other. You know it's better to use bigger and you know if you have just the whole building being cooled by one solution. From a material perspective that might be better in production, you know. It's not about distribution, maybe, but you know t's not just one thing, it it's more things, but then it might be better to do it in the central way and not using an facade option. On the other side, if each facade has its own facility you know because of the certain way of redundancy. The failure rates will be lower down. And another challenge is that well actually in a positive way I think it really contributes in the way we could standardize shorts and solutions.

#### **Interviewer**

OK, let's move to the following question. Can you tell me what are the important issues needed to be considered for the maintenance and the durability of a facade integration of solar cooling technologies?

#### **Interviewee 7**

Two things which is also affecting previous question. If you're going to standardise, I think you can make better products if it's all being standardized. And what we normally do in the building environment is that we made our calculations for each building very specific you know. My neighbours and I, we do have the exact same house. But ours...we are living in a real Dutch twee-onder-een kap [dual housing / terraced housing], I think you should Google that. You know we are sharing the roof, but they are two separated houses of course.

But ours is sort South wards. And of course my neighbours are North oriented on the north side. So we need more cooling facilities. More than they need. It might be easier if you have it standardized to add a sort of second facility but what we want to do, and that was the main reason to mention this, is what we always calculating into decimals behind the digit. We want to make sure that we need 3.52 kilowatts of cooling. And I think that there's a lot of things to win. You know if we use 2.5 kilowatts and my neighbours also use 2.5 then it in 90% of the time it might be OK. And if you in this types of facilities can standardize a lot. On the other side, if we integrate this sort of solutions into the facade and you know it, it must be....Of course it needs maintenance and that's also like an answer on the previous question. If you centralise it, it's a lot easier to maintenance it, to service it.

#### **Interviewer**

Why in the centralized it's may be easier to maintain it?

**Interviewee 7**

Most of the time it's not on the ground floor and if you have it on each floor...If there is a facility on each floor for a specific room, then you have to service it on more places than just one.

**Interviewer**

OK. Any other additional point before we move to the following question...About the maintenance and durability?

**Interviewee 7**

We haven't talked about durability.

**Interviewer**

Yeah.

**Interviewee 7**

There might be a difference like the example I just gave between our house and the house of our neighbours. You know the cooling facility will be more use in our house than in the house of my neighbours because of the South orientation and the north orientation. So will there be a difference in durability or not and how to handle that. Might be a difficult question I guess.

**Interviewer**

So your point about maybe the durability might vary based on the use of the building?

**Interviewee 7**

Of course it's depending on the use and...Yeah, it might be difficult, but that it's because I have a sort of vision about how this could be. You know how we can integrate this sort of facilities in the facade and I'm not sure if that's the right option so maybe that's affecting my answers.

**Interviewer**

Yeah OK.

So let's move to the following question. So how do you see the role of aesthetics on the widespread application of building facade integrating solar cooling technologies?

**Interviewee 7**

Well, I think it looks good, but I know that most architects do really care about aesthetics.

For me , it's a sort of...You know if I see well, just like in your example...If a building has a solar façade, it looks really high into me.

**Interviewer**

So this is your perception, your point of view?

**Interviewee 7**

That's my perception indeed. And if I see a building with solar panels, vertical solar panels in the facade, it's clear that it's about the sustainability. But maybe that's because I'm working on sustainable buildings. And I'm not sure if that if we ask my wife if she has the same perception, but

you know, I really like it. But of course it's a very important thing to how it looks. Is it just one side? Is it just South-bound?, or Is it also on the other side? I think it's an important thing.

**Interviewer**

OK, now I will move to the second category of questions, which are the financial aspects.

So in your opinion, what are the main issues needed to be considered to develop affordable and financially feasible facade products integrating solar connect technologies?

**Interviewee 7**

I think that the standardization can do a lot in and get it more financial, attractive and of course effective. But on the other hand the decentralized way be negative for the cost effectiveness. You know it's another way of working if we want to cool the indoor environments with local solutions, instead of using a central facility.

**Interviewer**

Ok now I have the other question about the financial aspects. Now, what are the potential financial incentives that can support the widespread application of solar cooling integrated façades?

**Interviewee 7**

I guess that the war in Ukraine do its effect on the electricity prices, and therefore as a positive effect on the business case for solar cooling products. I think that the climate change will affect it and also financially, yeah, it's getting hotter and hotter over here and we want to still maintain the inner climate, as we are used to. Another effect is that that maybe it's also because of the war in Ukraine that material prices, you know, raw material prices are rising and rising. And if you can leave a regular facade behind and replace it by a solar facade and it you know it's just 1 + 1 might be 3 instead of two. So it's not only about building costs, but also about the cost in the use phase.

**Interviewer**

Ok. So now I'll move to the last part before the closing questions, which is as you can see from this chart, we have different stakeholders involved in the facade design and construction industry. So in your opinion, who could be the main potential supporters to the application of solar cooling integrates facades?

**Interviewee 7**

The main supporter.

Well, I think that that the client or user and investor is the most important one. You know that's at first because of the aesthetics. Second, because of the business case.

And the second most important one is, in my opinion, the contractor who needs to learn to work with solutions like this. You know, it's not just about building, but it's also guaranteeing a sort of indoor environment.

That's a different way, you know. Normally it's by two separated like I started. It's just the building contractor and it's the installer. And now you have it just integrated.

**Interviewer**

I got your point but can you elaborate more about the business case?

**Interviewee 7**

You want to know what I mean by the business case?

**Interviewer**

Yeah, yeah.

**Interviewee 7**

It's maybe an assumption, but a solar façade might be more expensive than just the regular facade as we use it nowadays.

**Interviewer**

Ok

**Interviewee 7**

And if we want to do this innovation and to use building products like solar cooling facade, then it must be a sort of business case, you know. The extra investment must be somewhere collected, you know. The extra price must be returned, has a sort of return on investment in the use phase, because of electricity production, cooling production, etcetera. That's what I mean with business case, you know.

**Interviewer**

Yeah, I got your point. So now I will move to the following questions.

Can you tell me how to increase the technical knowledge and experience of architects and engineer about technical aspects related to the facade integration of such technologies?

**Interviewee 7**

I read your questions on yesterday and just in a quarter before this interview. What I'm missing in this scheme and in the different relationships, you know, you have now the decentralized climate units as a supplier. And if you have a look at it from a façade perspective, then you know that this is the right scheme. But if you have a look on it from the HVAC perspective, I'm missing the engineers, the HVAC engineers, like my own colleagues. You know it's what I do is just calculate which cooling facility we need and how many kilowatts we need, etcetera. And this is just only about the facade and now it's been built. And ohh yeah we have to get a supplier who delivers decentralized climate units. It is just more than that. And that's what I also what I mentioned in my previous answer. It's the general contractor is good in building facades and building of course. But it's very important to have it good, a good HVAC system and a good indoor environment integrated in the façade.

**Interviewer**

OK, but I got your point. So it's really valuable. But how we can improve the technical knowledge of architects and engineers about technical aspects related to the complexities?

**Interviewee 7**

Yeah, if you know....That's a good question, but maybe we should educate the engineers not only on how to calculate facades and to engineer facades, but also to let them engineer with HVAC system might be the best one and how big most the cooling facility be.

**Interviewer**

OK.

I got your point.

**Interviewee 7**

It's an integrated question. It's an integral question. You know, it's not only about the facade, but it's more about in our environment and, you know, how many kilowatts of heating and cooling do we need. And then we reach the requirements, the indoor requirements as wanted by the owner, by the user or client.

**Interviewer**

OK.

Now let us assume that...I will move to the following questions. What are the core elements needed to be included in designing standards or guidelines related to the facade integration of solar cooling technologies? Maybe you can add some information about what you just talk.

**Interviewee 7**

Yeah, it's you know, we do have our own guidelines in a way we designing our HVAC systems and if you want them integrated in the facade, you of course, you have to meet that requirements and you need a guidelines to get it all integrated. And for me....

But this may also because of I don't have any experience with solar cooling options other that solar panels combined and I do have experience with solar thermal, but it also been used in a in a heat pump. You know I really wondering how it will look like and how it will function and is it...I guess it will be enough for just the regular housing situations but can it also provide enough cooling in the healthcare situation or in an office situation? And is it then just an addition or is it the main way of cooling? You know, there are so many more questions about what solar cooling might be. And if it's an addition to the regular way of the way we cool and heat right now, then two technologies and two types of engineering has to be combined, I think.

**Interviewer**

OK.

Got it. Yes.

Now is what way can the industry increase the variety of products that would attract customers to apply a façade integration of solar cooling technologies?

**Interviewee 7**

Ohh difficult one. Actually I have no idea. Like I said, I haven't worked with one of the real solar cooling options, so I actually have no idea and. I'm just telling you I don't have an idea, but maybe it's all about marketing and show us what the options are and, yeah, that's it.

**Interviewer**

Yeah. It's OK. Then we can move to the following question so.

What are the potential solutions that can help in improving the future interests of designers, developers and the clients about the integration of solar cooling technologies?

**Interviewee 7**

You know there are a lot of things to solve, but I do see some options in using these type of solutions and that's because of.....maybe it's because from a circular perspective, you know, if we build more buildings which are actually designed for various functions with just changing the façade with integrated cooling, it might be easier to also provide the change of the function of the bill. So that might be a good way to get more of these products.

**Interviewer**

OK. We'll move to the following question. So how would changes in legal legislations affect the widespread application of solar cooling integrated facades?

**Interviewee 7**

Well, yeah, like I said, you know, if the legislation on sustainable energy are moving on to 2030 and 2050, you know. If we have to be carbon neutral, we do need more solar panels and we do need more renewable energy and that's one way to get more integrated.

**Interviewer**

I see.

Now I will move to the last part before the closing. You know we have different phases that we have the processes. We have the design phase, production phase, assembly, operation and the end of life. So in your opinion, do you think there are particular phases that are considered to be the most important ones?

**Interviewee 7**

As an engineer, of course, it's all about design.

**Interviewer**

OK. So why and what are the main issues to be considered in design?

**Interviewee 7**

One it's about aesthetics. You know, how will the building look like. On the 2<sup>nd</sup>, you know, like I mentioned a couple of times before. If you compare a local integrated solution with the central one, you know it's all about the way you engineer the building. You know, if you start with a central option, it might not be easy to change it to decentral one and vice versa of course. So I think the most important phase is the design phase. And on the other hand, if you are going to renovate the building, you need to replace the existing installations. Why not replace it by decentral new ones integrated in a facade. But you know actually that's something in between end of life and design.

**Interviewer**

OK, got it. So I'll come to your point. So you mentioned that like the two different disciplines and I already had the question about how to achieve close collaboration among various stakeholders and disciplines during early design stages? So to create facades...

### Interviewee 7

Well, like I said that there are two different types of engineers. One who's calculating and working on the building itself and its façade and on the other hand my colleagues who are engineering HVAC installations, you know. And there are two different types of engineers with different knowledge. And if you want to integrate it, at first there must be one responsible for that it all functions. Who is it? I have no idea actually. And on the other hand, is a building project with other building products, with the facade integrated solution is that enough for the old building or for the old room where it's attached to. You know is it just the cooling solution or is it an addition on a more traditional one? And I think I can imagine that responsibilities to one another are quite difficult to address, to let the work together.

### Interviewer

OK, now I will move to the second phase. What are the main issues needed to be considered for the production phase of façade products integrating solar cooling technologies? Do you have something in mind?

### Interviewee 7

I do have something in mind. The first one I was thinking about was like I said is it just the main way of cooling, the cooling units? Or is it an additional one? You know, if it's an additional one, of course it must communicate with the other, and I think that's a part of the production phase or maybe it's more about the assembly phase actually.

### Interviewer

Yeah. The following question is about the assembly.

### Interviewee 7

It's yeah, I was also say it's about assembly. I was thinking about production of the building, but sorry.

### Interviewer

Production of the facade product.

### Interviewee 7

Well then I actually have no idea how we can...

### Interviewer

Assembly and installation?

### Interviewee 7

Well, I think that's an important one because if you have an integrated solution in the façade, then it's just more than just placing the facade, you know. It has to be livered in a working system and that's in my opinion, the assembly, you know. It has to function in that way that it meets the requirements of the building and it's more than just assemble a facade.

**Interviewer**

OK, I'll move now to the following questions. What about the important issues for the building operation phase? I think you already talked about some of these.

**Interviewee 7**

I think this is a sort of the same as the maintenance, yeah.

**Interviewer**

Maybe about the end user knowledge. Do you have something in mind about the end user knowledge?

**Interviewee 7**

Well most of the time there's no knowledge. So it's more about specialized companies who can service it and who can operate it. Yeah.

It must be easy to operate. Actually like you see most of the time hotels, you know, you have the option to just one basic temperature and to do it minus one or minus plus and there must be it.

**Interviewer**

I see.

Now what about the end of life of a façade integrating solar cooling technologies? What are the main issues needed to be considered for the end of the life....?

**Interviewee 7**

Well, I think the main issue is the difference in lifespan between the facade and the cooling facility.

**Interviewer**

Difference lifespan between the facade and the technology?

**Interviewee 7**

Yeah.

So I guess that that you have to replace the technology, double the time as the facade itself.

You know, I think I think a good facade can last for years and years and years. And you have to replace the cooling facility just within every 10, 15, 20 years. So it must be at least being very easy to be disassembled. And what we're not talking about is the energy efficiency. You know are there during.....? Imagine that that I have installed a facility integrated to, solar cooling integrated in the façade. Can I upgrade my cooling facility during the use or not? So you know what I think that's quite important.

**Interviewer**

OK, I see now I'm done with all my questions. So I just have one question. So do you have any final remarks about supporting the widespread application of solar cooling integrated facades as building products in the construction market?

**Interviewee 7**

I think it's really difficult and, yeah, I think. I don't think it's about the product itself, but it's more about the way we work and you know it's not only integrate a new building product but it's about integrating a new way of working. You know it's you have to combine the knowledge of the facade engineer together with the HVAC and engineer. And that in one product....Well I think that's quite difficult. And second, in addition to that, you know just one company who is responsible for a functioning façade and at the same time it's responsible for delivering and meeting the requirements which are there for the cooling.

**Interviewer**

OK. I got your point. So the way you working. Yeah. It's just the last question. Do you mind to propose potential participants that can be interviewed?

**Interviewee 7**

Now let me think about.....