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Solar Heating and Cooling: Challenges and Opportunities

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Webinar Presenter

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Toby Couture Welcome to the Clean Energy Solutions Center and International Solar Alliance Expert training series. This session today is going to be on solar heating and cooling, a look at challenges and opportunities in the heating and cooling sector using solar energy. The supporters of this training series include the International Solar Alliance as well as the Clean Energy Solutions Center.

The training series includes a number of different components ranging from policies to market integration, socioeconomic aspects, as well as both off-grid and solar and heating and cooling sector in particular. So this session is the first of three on solar heating and cooling technologies and focuses specifically on challenges and opportunities. You see here the overview. The next we'll look at technologies more in detail and case studies as well as the policy options that are currently being used to encourage investment in the solar heating and cooling sector.

So here's a quick overview of the presentation. We'll look at global overview of where the market is, along with economic opportunities and some of the issues and barriers followed by some concluding remarks. And at the end, as with all of these ISA-CESE training series there will be some multiple choice questions.

So first, let's dive in. Main objectives are to analyze the drivers behind the recent global market trends, understand which solar and heating—heating and cooling technologies exist, what are the main markets as well as some of the barriers that are holding the solar heating and cooling market back from its

full potential, from achieving its full potential. And we'll take a step back and look at some of the bigger picture issues and trends that are emerging.

So there's a wide range of different heating and cooling applications that are being used in the solar sector. Most people when they think solar think of solar PV, solar foldable tags to produce electricity but there is a long tradition of using solar energy to heat in particular water but obviously also space to make residential living space more comfortable. In the building sector, the solar heating and cooling includes also a range of different options from cooking to ambient and water heating as well as even cooling for certain applications. And this applies in the residential-commercial sector, similar dynamics in the industrial sector although with fundamentally different—in many cases different needs and also a range of different issues unique to the industrial applications of solar and heating and cooling.

This includes using process heat, for example, for low temperature applications like in the food industry as well as high temperature applications where you really need large amounts of hot water or just a heat for the cement, iron, for instance, or steel industries. Looking at renewables more broadly, there's a range of different technologies that can support the supply of heat and cooling in the energy sector. This includes solar, geothermal, biomass sources, also biogas can and is used in a number of different heating based applications like combined heat and power plants. And heat is also being used to drive absorption chillers, specifically to meet cooling loads.

And finally it's critical to underscore that most cooling and heating applications, at least many, particularly in the cooling sector, are based on the use of electricity. And if you're using renewable electricity to power say air conditioning units in a large residential block, then effectively that's renewable cooling if the power that's driving that system is fundamentally itself renewable. So it's important to underscore that electricity is a major part of the picture here and although we're talking about heating and cooling, there are a number of applications including even geothermal that actually require electricity in order to operate the systems.

So this is an important interconnect there. Thermal storage systems are also playing an increasingly important role in certain markets around the world in adding demand flexibility. The thermal sector is a massive load, a massive source of demand in the building sector worldwide and represents a major portion of the total electricity demand in many countries. And shifting some of that thermal demand, if it's not already powered by electricity to electricity opens up the possibility to have access to large dispatchable thermal loads in the sector that can be used to help integrate variable renewable energy into the system.

And there's a number of jurisdictions exploring this and starting to actually implement this in practice including countries like Germany, Denmark in its district heating networks as well as islands like Prince Edward Island in Canada where they're using the excess wind power to link up with domestic heating, hot water and space heating applications, so essentially using the excess electricity to heat homes. So there's a range of different applications

here and in this presentation we'll focus more specifically on the solar heating and cooling. But it's important to take a step back and look at this as a broader market segment of heating and cooling of which solar is an important—increasingly important contributor.

So a quick look at definitions. Solar heating and cooling technologies collect the thermal energy from the sun and use this to provide hot water or space heating as well as heating in a range of different applications. There are several different types of technologies in use, including non-concentrating solar thermal with different types of collectors, evacuated tube collectors and a range of other different rooftop systems that many of you have no doubt seen on rooftops and buildings in your areas. And there are concentrated solar technologies that concentrate the solar energy on a smaller heating location that can then be used to power—to pump water through orglycov (sp?), for example, your cooling or heating solution through a network that can actually provide the heat and distribute it through a building.

And we also talk about open and closed-cycle cooling technologies. Heat storage is critical and important to take into account. There are also a number of applications that are focusing on not only small scale residential or say commercial hot water storage but larger scale, a village or even small city scale thermal storage units that can help again integrate or variable renewable energy into the system. So we're seeing throughout parts of Australia as well as parts of North America and Europe a growing number of investments in using solar to heat swimming pools. For example, public swimming pools and similar types of applications. Worldwide, as we will see in some of the slides to come, by far and away the largest market for solar heating technologies remains China. China has been a market leader in solar heating technologies for decades and remains again the overwhelmingly the largest single market worldwide.

Now renewable energy sources used for heating and cooling purposes have received relatively little attention compared to other sectors like the power sector. So we talk a lot about renewable energy policy and strategy, often what we mean by that is renewable electricity policy and strategy, talk about auctions and net metering and feed-in tariffs. These are all electricity-based policies and there's been historically much less focus on what can be done from a policy standpoint to support the heating and cooling sectors. And I think that this is starting to change. We are seeing signs of momentum on this. The UK has gotten increasingly progressive on heating policy and a number of jurisdictions in the U.S. including Massachusetts have been doing a growing amount to encourage more intelligent applications in the heating and cooling sectors. And even established markets like China are also continuing to push for solar in more industrial applications, in more commercial applications and really starting to test out the growth potential of solar heating and cool.

So again, very exciting time for this sector and as the economics continue to improve, the fundamentals get better and better. And we'll see some of that throughout these slides. We'll also see more of that looking at the case studies in the second presentation and there will also be some interesting highlights

out of the policy presentation that looks really broadly at what's being done and what policymakers can do to encourage more investment in this important area.

One of the reasons that it's so important is that heat accounts for an estimated 38 per cent of energy-related CO2 emissions. So heat is a major driver of CO2 emissions worldwide and cooling is also an increasingly critical source of electricity demand growth in a growing number of emerging markets. If you look at parts of Africa, parts of Asia, in major equatorial markets, the heating or cooling demand is a major factor. So there's a really important—this emerges as a really important time to focus on the goal of renewable energy, what renewable energy source is like, heating and cooling for solar can actually do to help address this growing market need. More broadly speaking, heat de-carbonization is increasingly critical for achieving climate targets and has benefits for air pollution, energy security and a range of other areas.

And as we're going to see in many of the case studies in the second presentation, solar heating and cooling in particular can offer a really practical alternative to fossil fuels like natural gas or coal in the heating sector. So looking at this globally, this is data pulled together from REN21 in their global status report. You can see here total final energy consumption and the share that heat alone plays. Much of the heat currently that's provided that's renewable is traditional biomass and you can see here that renewable electricity or renewable heat still is a very—a fairly small portion off the overall market. There's a growing amount of awareness around the potential role that more solar heating and cooling technologies can play in energy security, economic development, mitigating climate change but also for a growing number of countries in keeping more local dollars in the local economy.

The more money that people spend in a given village, citizens, businesses, et cetera, spend on imported fuels, say imported natural gas or imported electricity, that money flows effectively out of the community. And a growing number of states, particularly in the U.S. but also in regions of the Middle East like Jordan are starting to realize that there's tremendous—there are tremendous economic arguments for keeping more of those heating and cooling dollars, so to speak, locally and spending more money on—and creating more intelligent policy and more investment incentives for renewable sources of heating and cooling precisely because these can be produced locally on site and often quite efficiently and quite cost effectively on homes and businesses.

So again, all of these factors against this backdrop, the overall market context is increasingly favorable to the more widespread adoption of renewable sources of heating and cooling. This is particularly the case in countries that are lacking natural gas infrastructure or in countries that are net importers of liquified natural gas, the ability to reduce electric loads in particular at peak times is a major driver. You can see in major countries or major cities around the world like Manila, Lagos, Nairobi, Kuala Lumpur, Bangkok, evening electricity demand driven by cooling by air conditioning needs is a huge

factor and is increasingly leading in certain parts of the world to electricity reliability issues because everybody comes home, flicks on the air conditioning and that new source of demand is really making grids increasingly brittle in markets around the world.

And there's potential for solar heating and cooling technologies to start to mitigate some of that spike in evening electricity demand associated with cooling in particular. So again, more on this in the case studies and in the examples to follow, but it's important just to lay the ground work and understand how this market works, what are some of the key features and what are some of the major issues and trends.

Looking at this globally, you can see here the rise in solar thermal capacity in the blue bars and the total solar energy yield the orange line over time from fairly humble beginnings in sort of the turn of the century. Now a very significant and growing market. But as with many other areas of renewable energy development the market growth is uneven, as are the associated skills. So you can see here based on IEA data, the IEA has been increasingly focusing on solar heating and cooling applications and has been putting out a growing number of publications on this area, one of which is cited here at the bottom. You can see here the total new installed capacity per 1000 inhabitants by market and you get a sense of sort of what are the most active parts of the world.

You can see Brazil, Chile, parts of North America but also interestingly, markets like Turkey, Australia and China of course remain significant players. Germany there in Europe as well as a couple neighboring countries. But you can really start to appreciate that the potential remains very much largely untapped, especially in some of the markets that are part of the International Solar Alliance around that middle belt of the equatorial regions of the world. India, tremendous potential for more development there as well as some of the mega cities in sub-Saharan Africa and the Middle East.

Taking a look at some of the growth markets, you can see here China again remains by far in terms of installed capacity the largest market. But some other interesting players and interesting developments as we mentioned, Turkey, India, Brazil and some other breakdown into the other countries. In North Africa, Tunisia is one of the few that has been really pursuing solar heating and cooling technologies explicitly and you're seeing more interest now from Egypt as well as from countries like Morocco in the region. So again, this is fairly—many countries are starting to realize that this is an untapped potential and that more needs to be done. So worldwide the estimated install capacity amounts to over 450 gigawatts of thermal solar energy corresponding to somewhere on the order of 653 square kilometers of solar collector space worldwide.

The vast majority, as we pointed out a few slides ago, is in China and Europe. You can see here the breakdowns in terms of capacity and again, this underscores the fact that parts of the Middle East, Sub-Saharan Africa, even North Africa and Asia really—Asia outside of China remain very much untapped or underexplored market potentials. Now looking at some of the

trends, of course there's individual—the majority of the market is dominated by individual household and building and commercial applications of solar water heating.

There's a growing market for solar space heating and solar air collectors or in some cases related technologies, large scale solar thermal plants have also been expanding in certain countries, including Denmark. There's also some projects, for example, in Canada in cities like Okotoks in Alberta with large-scale solar thermal storage underneath the village, so essentially a large seasonal form of storage to store heat during the summer months that can then be dispatched and used throughout the cold winter months.

And as we saw, although heating remains the largest source, cooling is actually growing more rapidly than heating demand. So again, tremendous opportunity there and tremendous untapped potential. We're also seeing some examples here and you can see in this picture we will cover this in more detail in the technologies slides. Combined applications for both solar PV and heating or thermal systems integrated. And that's another growing area of interest.

Now form a policy standpoint, policies, as we saw, are still relatively rare. There aren't that many explicit policies for encouraging the solar heating and cooling sector with a few exceptions. A number of solar markets are adopting solar obligations so integrated into the building codes in some cases where they're really—there's an explicit legal obligation to install solar on all new construction, in many cases focusing first on solar heating and applications like solar hot water. But there's also some examples of this on the connection to renewable-based district heating networks, so similar obligations and the district heating networks can also be supplied with solar applications. So we're starting to see that in places like Copenhagen where the network has a growing share of solar power, solar hot water being injected into the district heating system there.

Now let's look at some of the economic issues and some of the barriers. Now as we pointed out, a switch to using renewable sources of heat like solar heating and cooling is a challenge in markets where there is network gas. So natural gas tends to be, in markets at least that have it, the preferred source of residential and commercial and industrial heating. And it makes it more challenging for solar heating cool technologies to compete. It's also more challenging in markets where district heating is scarce because again in contrast to Copenhagen where you have the district heating network that can then be adapted to inject thermal energy from solar collectors, markets without district heating are fragmented from a heating perspective so they need to be treated with—on a rooftop by rooftop basis. And also more challenging in markets where there's more single family home units rather than apartment buildings.

So much of Europe, living space is predominantly on apartment buildings versus single family units. On the other hand, some would argue that you can flip that argument around, that actually the economics of rooftop solar heating and cooling work particularly well for single family residential households

because they have the available roof space and you can then install collectors and meet a portion or all of your heating-cooling needs with on-site installations where that would be quite difficult for an apartment building to achieve. So again, one can look at that from both angles. Commonly with renewable energy technologies, as is the case in virtually every market around the world, the high upfront cost—I mean even if the upfront cost isn't that high comparatively, it's often higher than conventional alternatives like a gas boiler or a wood say biomass spaced heating unit or for that matter an air conditioning unit if we're talking about cooling.

So the upfront cost issue remains and this again underscores the importance of financing, making financing instruments, loans available, low interest loans, for instance, available for solar heating and cooling applications. Investment payback times also tend to be quite long for thermal applications in the renewable energy sector. It really depends on what you're offsetting. If you're offsetting high-priced oil in an inefficient oil boiler, then payback times may be a bit shorter. It also depends on the taxation regime, in some cases home heating oil is exempted from a range of taxes or may have preferential treatment for historical reasons. Same goes with network guests depending on the prevailing tax and regulatory environment, the payback times can be shorter or longer depending again on the unique circumstances of the market.

But the longer payback times does make it difficult, particularly in the commercial sector to justify the switch where in the commercial sector most building owners or company owners are looking more at short payback times go with two, three, four years max whereas some of these in many cases these kinds of investments will have payback more on the order of seven to ten years. So again, important challenges there that continue to hold the market back from achieving its full potential.

Looking at this from a cost perspective, this shows essentially the levelized cost of heating based on ranges for different technologies and you can see here biomass boilers, geothermal district heating, solar thermal heat pumps as well as gas boilers and the range there still remains comparatively higher currently for solar thermal applications than for many other hot water—for example sources of hot water or heating available in the market.

Another key issue is the slow rotation or the slow turnover in the building stock. Often building stock will rotate on a 40, 50, 60, 80-year cycle and heating systems are only updated when they break which means people make decisions under duress or under a great pressure where they really don't have time to look at all of the available options. They simply go with the nearest and most readily available alternative and in many cases that encourages the fact that heating and cooling demand is existential in many markets. It encourages also conservativism in terms of the decisions that are made.

So people, whether homeowners or business owners or apartment building owners are often hesitant to make big shifts like this in the heating system or in the cooling system to a renewable alternative because it's still perceived by many as a risky decision and one that could generate a host of operational

inconveniences in the future if the system doesn't perform as expected. So again, there's still, in contrast to technologies like solar PV where the market is mature, the technology is by and large trusted by decision makers and homeowners, business owners and so forth, the solar heating and cooling technologies don't yet, at least in many markets, benefit from the same level of trust.

So there's important work to be done there in demonstrating the viability and also in demonstrating the performance characteristics of these technologies. Because as the technologies have gotten better, the performance enables them to provide valuable benefits both in terms of cost savings but also in terms of just comfort and livability that without compromising on any of the advantages of a traditional heating and cooling application. It's also important to highlight that solar heating and cooling applications can be used readily in combination with other technologies. So a household may decide to install solar hot water on the rooftop but also have the boiler connected to the electricity so that the hot water can be heated with electricity if there's a long period without much direct sunlight, for example, during cloudy or rainier periods of the year.

So again, there are ways of integrating the systems or providing backup that's sort of complementary sources of heating and cooling that help balance the system out. So many households or businesses will also use a fireplace or a biomass boiler or something to complement again the space heating provided by a solar space heating unit and not rely on it for 100 per cent of their space heating needs. So again, it's these—this doesn't—it's important to recognize that this doesn't need to be an either/or equation that in many cases solar heating and cooling applications in particular are used complementarily with existing heating and cooling applications.

Now there are some other limiting factors, some of which we've touched on, the issue of heat storage, of the lack of availability of commercial scale cooling applications in particular for the solar cooling industry. There is momentum on this in certain markets and a growing number of islands in particular are keen to look at solar cooling applications. This also can make sense for hotels and major industries like that that have fairly low—fairly high thermal energy demand that can be cost effectively met with renewable technologies like solar heating and cooling.

Another major barrier of course is skilled personnel. In many countries the supply chains do not exist or are very thin on the ground and that's a major issue to scaling up the market. This has been one of the things that markets like Tunisia have been focusing on in recent years. There are also efforts in West Africa led by ECREEE, the original agency responsible for renewable energy and energy efficiency in West Africa to support skills development and training program specifically for the solar heating and cooling industry. Much more needs to be done on this to really get to scale. And I think this remains a challenge in almost all markets around the world in this particular sector.

There are also permitting issues. Some of the reluctance issues that we saw in previous slides as well as institutional barriers that make many people hesitate to make the leap to a renewable solar heating/cooling option. And then finally some capability issues also remain where an industry, for example, may need high temperature heat reliably for particular hours of the day and solar again may be a valuable complement to that but may never fully be able to replace that thermal need in an industrial process. So again, this comes back to the point of complementarity.

Many of the technologies are increasingly becoming more mature and reliable, but again, perceptions remain a key factor here and it's really important to again demonstrate more successes, demonstrate the pilot case and the case studies and the examples and to talk about these more widely so that the same level of trust is achieved as in other renewable energy technology areas.

Now there is vast potential across a number of different low temperature heat demands around the world. The supplies in the foods industry, beverages, textiles, agriculture, even in the chemicals industry, tremendous untapped potentials and so far many companies just are at the very beginning of exploring the potential of what solar heating and cooling could do in their factories and in their businesses and this is again why discussing this and talking about these cases, as we'll see in the second slide deck looking at the case studies, is so critical.

2017 was a record year with a recorded 224 projects in industries across seven countries being built for industrial process heat using solar heating. So again, this is a sign that the market is starting to reach maturity for supplying heat in industrial processes too, not just in residential and light commercial sectors. Additionally in certain regions like in the Middle East and North Africa where air conditioning often recounts for the largest portion of household and commercial electricity bills, countries are also starting to remove subsidies for electricity which makes it more attractive to start looking at renewable cooling solutions, including renewable heating solutions for say solar hot water.

So again, this shows tax policy, subsidies can play a very important role in catalyzing the market. As more countries are becoming aware of the importance of this, they're starting to adopt more ambitious targets and strategy. So a couple of examples here, DEU's 2030 targets include a target of 1.3 per cent per year increase in heating and cooling from renewable energy sources. That may not sound like a lot but when you compound hat over years this is significant—will lead to a significant and growing market for heating and cooling technologies.

China established an ambitious target to meet 10 per cent of its industrial heat demand with solar thermal energy by 2020 so again this is a very ambitious target specifically in the industrial sector, underscoring that for mature markets with the supply chain, with the skills like China, this is a very viable and very attractive market segment. As these examples scale up and as we see more and more growth and more and more development around the world,

this ultimately contributes to building investor confidence and in driving economies of scale which can help bring down the investment costs.

Another related application that I'd like to focus on before we wrap up this particular section is use of solar energy in district and heating and cooling applications. So we touched on this with a couple examples like Copenhagen and Okotoks, Alberta will get into some of these more in the technology case studies examples, but it's important to underscore that solar can be used in conjunction with district heating that works. And you can see here a brief illustration that shows how some of this can work in practice. For cities that have district heating networks, this is a very—can be a very attractive way to go and to try to get more distributed heating sources contributing to the network. It enables economies of scale but it also can ensure a higher degree of full cycle efficiency in that there isn't as much thermal energy sitting idle where it's not been used. So the thermal energy can go where the need is or where the demand is at any given time in the network.

Much of the solar use, much of the use of district heating and cooling is currently fossil fuel based, but renewable is really starting to make important in-roads there. You can see here a breakdown. This is from Irena showing the current market and this indeed indicates how much potential there is yet to go. There can be an important role to be played also in making solar investments more attractive, particularly investments in solar heating by being able to connect with district heating network. These are ultimately things that need to be led either by the municipal utility or by the municipality itself where it directly owns the heating network to try to get more participation and contribution from individual citizens and businesses into the district heating networks.

There's an interesting example here recently from Germany where municipal utilities submitted a large number of applications under the new policy regime for district heating. District Heating Network 4.0. The scheme provides grants of up to 60 per cent of the cost of feasibility studies as well as up to 50 per cent of the total investment in new district heating networks. So really an important sign that district heating networks are an important part of the energy transition and the government in this case has really decided to invest significant public dollars to help realize more district heating systems with the condition that these district heating systems in this case are to a significant degree met with or supplied with renewable energy sources like solar. So the opportunity for more mandates like these, more policies that set up clear targets and more public investment directly to make the district heating networks a reality can really help play an important role in further scaling up the market beyond individual households and businesses to more community and networked sources of solar heating.

And obviously as with any sector, there is an ongoing and persistent need for more research and development, more innovation and more improvement on performance and on O&M aspects. There is a growing amount of interest in this from the OEMs, appliance manufacturers and others who are keen to gain a portion of this growing market. And this is likely to continue particularly in

areas where there has been historically less innovation such as in solar-based cooling.

There's also been discussion of more energy positive homes and businesses or sometimes called net zero energy is another term that's used. Energy positive homes produce more energy than they consume, this includes thermal energy. So as the push, as the momentum behind more zero energy homes and more positive energy homes emerges, renewable and solar sources of heating and cooling are going to play an increasingly critical part of that transition.

Now a few concluding remarks before we transition to questions. Sorry, to the questions session. The potential for heating and cooling using renewables, in particular solar, is tremendous. Despite perceptions in many markets that solar heating and cooling technologies are not yet mature or face a number of operational and other issues, experience in markets like China, Germany, Denmark, also Tunisia show that it's an increasingly mature technology and it can provide important benefits to the system particularly in terms of its integration with existing heating and cooling applications such as in district heating networks can also provide a valuable complement to household and business heating and cooling needs.

And as companies start to commit to more ambitious renewable energy targets, more ambitious climate-related targets, it's likely that solar heating and cooling technologies are going to play I think an increasingly important part of the discussion. On the other hand, as we've seen policy making on heating and cooling lags behind the power sector and lags behind even the transport sector. So there's a real need for much more, much smarter, much more thoughtful policy conversations around how to scale up the market. We've touched on a few of these in this brief presentation.

We'll look more at the policy question in greater detail during the following—during the third presentation in this heating and cooling series, looking specifically at the policy options and that will include the classic range of policies such as rebates, tax incentives, investment grants and the like, but also we'll look at some examples of more innovative policies emerging in places like the UK with the renewable heating incentive that's essentially a type of feed-in tariff for renewable sources of heat. And we'll look at some of the markets and again some of the challenges that still remain to really help the solar heating and cooling sector realize its full potential.

One of the major areas that's in the background of all of this that will continue to remain important is the need for more linked up heating and cooling loads that can be used to improve the integration of renewable energy sources on the network, renewable electricity sources in particular on the network. And there's likely to be growing momentum for more—the use of smarter technologies to integrate, for example, home hot water units, home air conditioning units and other major thermal appliances to connect them to the network more broadly so that they can be used in demand response programs and others. And this can be combined of course with solar heating and

cooling technologies and in particular, for example, solar hot water where it requires the installation of a storage tank in most applications.

So the fact that you then have a storage tank in the household enables you to start to control, start to dispatch that load as an active part of the electricity system more broadly. And that's in contrast to many households, particularly here in Europe but also in parts of North America where heating is still provided very much like cooling on a demand basis, so essentially with dispatchable hot water, dispatchable cooling. The more we move to storage based heating and cooling solutions, the more we open up the potential for a really robust district demand response based heating and cooling system that can start to contribute and provide new flexible loads to the integration—the support the integration of variable renewables in the network.

So again, this is all a part of a bigger and broader conversation around how do we achieve higher shares of renewable energy across the power sector, across the heating and cooling sector as well as across the transport sector. And the heating and cooling sector absolutely has a very, very critical role to play. However, high investment costs, long payback times in many cases split incentives between the owner of the building and the people living in the building or using the building have constrained market growth. So we definitely need more businesses, more business models that tackle some of these barriers holding the market back, in particular businesses that allow leasing type options, businesses that allow pay as you go type configurations to emerge, businesses that provide financing bundled with the transaction so that you can sign on, for example, on an escrow type basis where you can sign on for a heating and/or cooling contract.

The more the market can move in that direction, the more sophisticated businesses will be able to become and the more you can unlock—the more easily you can unlock the financing while giving customers, users, businesses the security or even the guarantee that they will have a reliable source of heating and cooling for years to come. And I think that's really one of the biggest barriers that continues to hold the market back is ultimately that reluctance to try out new technologies in areas where it's really critical to a household or business's overall daily use.

Overcoming some of that hesitancy, overcoming some of that reluctance is made a lot easier when you have a business model that's tried and tested and that can essentially guarantee the functioning of the system over a certain period of time such as an escrow type model. So again, there's still lots of—it's still fairly early days and lots of potential for more innovation in that. We'll get into that a little bit more in some of the other presentations and in some of the case studies but suffice to say for the moment that the increase in awareness is critical. And as the economics get better and as the performance of the technologies get better and as the business models in the sector get more sophisticated, the fundamentals of the sector are likely to continue to get stronger and stronger.

So with that, I've provided here some additional reading, some of the source material for some of the presentation, a number of reports from the IEA and

the IEA or ECD as well as Irena and from the European Commission that's been doing a lot more here in Europe to encourage the scale up of heating and cooling technologies. Thank you again for your time. This webinar on behalf of the International Solar Alliance in combination and partnership with the Clean Energy Solutions Center will have three segments on solar heating and cooling and we'll dive into the other two specifically on case studies as well as on the policy aspects in the coming presentations. So thank you very much for your time. I'm Toby Couture. On behalf of E3 Analytics it's been a pleasure to be with you today and we'll shift now to the knowledge checkpoint with some multiple choice questions. Have a great day.