CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Meltemi Community Smart Grid Pilot Site

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For more information, see the clean energy policy trainings offered by the Solutions Center.

Webinar Panelists

Nikos Hatziargyriou Hellenic Distribution Network Operator

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Sean Esterly

Hello, everyone. I'm Sean Esterly with the National Renewable Energy Laboratory, and welcome to today's webinar, which is hosted by the Clean Energy Solution Center, in partnership with the International Smart Grid Action Network, also known as ISGAN. And today's webinar is focused on the Meltemi community pilot site and using a living test field to validate intelligent load management.

One important note I'll mention before we begin our presentations is that the Clean Energy Solutions Center does not endorse or recommend specific products or services. Information provided in this webinar is featured in the Solution Center's resource library as one of many best practices resources reviewed and selected by technical experts.

And I just want to go over some of the webinar features for you. You do have two options for audio. You may either listen through your computer or over your telephone. If you choose to listen through your computer, please select the mic and speakers option in the audio pane. Doing so will eliminate the possibility of any feedback and echo. And if you choose to dial in by phone, please select the telephone option, and the box on the right side will display the telephone number and audio PIN that you should use to dial in.

And panelists, just a reminder to please mute your audio device at any time while you're not presenting. And if anyone is having technical difficulties with the webinar, you may contact the GoToWebinar help desk at 888-259-3826 for assistance.

And if you'd like to ask a question, and we do encourage anyone from the audience to ask questions throughout the webinar, we just ask that you use the questions pane where you may type in your question. Those are then submitted to us, and we'll present them to the panelists during the question and answer session. And if you are having difficulty viewing the materials through the webinar portal, you will find PDF copies of the presentations at cleanenergysolutions.org/training, and you might follow along as the speakers present. Also, an audio recording of the presentations will be posted to the Solutions Center training page within about a week of today's broadcast, and we're also adding recordings to the Solutions Center YouTube channel, where you'll find other informative webinars as well as interviews with thought leaders on clean energy policy topics.

Today's webinar agenda is centered around the presentations from our guest panelists, Professor Nikos Hatziargyriou and Dr. Aris Dimeas. These panelists have been kind enough to join us to discuss the Meltemi community pilot site. And the Meltemi site serves as a perfect living test field that has been employed in several European and national R&D projects. It has been used to validate methods of intelligent load management and of increasing use of renewable energy systems.

And before our speakers begin their presentations, I'll provide a short, informative overview of the Clean Energy Solutions Center initiative, and then following the presentations; we will have a question and answer session where the panelists will address those questions submitted by the audience, followed by some closing remarks, and then a brief survey.

And this slide provides a bit of background in terms of how the Solutions Center came to be formed. The Solutions Center is one of 13 initiatives of the Clean Energy Ministerial that was launched in April of 2011. It is primarily led by Australia, the United States, and other CEM partners.

Some outcomes of this unique initiative include support of developing countries and emerging economies through enhancement of resources on policies relating to energy access, no cost expert policy assistance, and peer to peer learning and training tools, such as the webinar that you are attending today.

And the Solutions Center has four primary goals. It serves as a clearinghouse of clean energy policy resources. It also serves to share policy best practices, data, and analysis tools specific to clean energy policies and programs. And third, the Solutions Center strives to deliver dynamic services that enable expert assistance, learning, and peer to peer sharing of experiences. And then lastly, the Center fosters dialogue on emerging policy issues and innovation around the globe.

And our primary audience is energy policy makers and analysts from governments and technical organizations in all countries, but we also strive to engage with the private sector, NGOs, and civil society.

And this slide shows one of the marquis features that the Solutions Center provides, which is the no cost expert policy assistance known as Ask an Expert. The Ask an Expert program has established a broad team of over 30 experts from around the globe who are available to provide remote policy advice and analysis to all countries at no cost. So for example, in the area of demand and policy evaluation, we're very pleased to have Bruno Lapillonne serving as one of our experts. So if you have a need for policy assistance and demand and policy evaluation or any other clean energy sector, we do encourage you to use this valuable service.

And again, the assistance is provided free of charge. So if you have a question for our experts, please submit it through our simple online form at cleanenergysolutions.org/expert, or to find out how the ask an expert service can benefit your work, please contact me directly at Sean.Esterly@NREL.gov, or at my office number, which is 303-384-7436. And we also invite you to spread the word about this service to those in your networks and organizations.

And so now, I'd like to provide brief introduction for today's panelists. Our first speaker today is Professor Nikos Hatziargyriou, and Nikos is chairman and CEO of the Hellenic Distribution Network Operator and since 1984, he has been with the Power Division of the Electrical and Computer Engineering Department of the National Technical University of Athens. And since 1995, he is a full professor in power systems.

And our second speaker today is Dr. Aris Dimeas. Dr. Dimeas is a senior researcher for the Electrical and Computers Engineering Department at the National Technical University of Athens. He has experience in a variety of applications related to power systems operations, renewable energy sources, artificial intelligence on power systems, smart grids, and control software development. His specific experience also includes development of control software for demand side management and communication interfaces between energy management systems and SCADAs.

And with those introductions, I would now like to welcome Professor Nikos Hatziargyriou to the webinar. And we will be starting off today with a brief video that we're going to try.

Nikos Hatziargyriou Hello, everybody. I'm Nik Hatziargyriou. We'll start with a video of the Meltemi pilot site. This is a community pilot site that has been used for several projects of the European Commission. So Meltemi is a seaside camp in Rafina, near the Athens coast, and it's unique for this type of application, because its habitats are ecologically ____, and so it is a perfect living test site for these applications. We can perform several tests, simulate control issues, and also ____ services to the ____.

The site comprises a number of ____ generators, like photovoltaics. It also, in several places of the camp, it also includes a small diesel machine, which is used mainly for emergency, and together with the renewables, it can be used to isolate part of the network to form some local microgrid. And it also includes a number of wind turbines, small wind turbines that have been developed with the National Technical University of Athens. And we have also developed a wind turbine test site, where we have used it—here it is—where we used it to make measurements and collect the data and analyze it in the UA.

It also has a ____ level substation that connects the Meltemi site to the _____ network, and what ___ done to—what we will show here is the voltaics and controller, which is an intelligent load controller that can be used to monitor the status of the power line, providing voltage, current, and frequency measurements. And this controller is installed in a number of residences, a number of small houses, and can be used to control loads. So in case of emergencies or during normal operation, when we see that the system is overloaded, then there is a management center controller that starts negotiations, and the agents to the intelligent load controllers exchange messages and decide on their own which load to curtail without central coordination.

So you see here, for instance, the ____ ____ consumption, so that the ____ is not ____ loaded, so that shows a small overview of that—what we have done in this—in this project.

Now let me start developing the control agents for—that have been developed in this project, and ___ for other—is also applied in other real microgrids. I'm going to start introduction about smart grids. I will tell you a few things about what are the control concepts and architecture for more microgrids. Then we will look at the control strategies for microgrids.

So let me start by giving an overview of what happens today around the customer. So we have all the appliances, all the storage, micro-generation, energy management. We have the transmission and distribution, then there is storage and generation issues, and then the smart metering, which connects all these components, and where this presentation will mainly focus within the general smart grids concept.

So what we have now is the parts here are vertically integrated. Utility, while now with one—with very few players. Mainly in the integrated utility, you had one company that did everything, while now life has been quite now complicated. We have the suppliers, service providers, _____, transmission, ______, generation, regulators, government, and all these actors. And with this new liberalized environment, ____ liberalized the market environment for energy, we see now the development of the smart grids. This is the classical figure that has been developed by the European Technology Platform for smart grids. That shows the future network, where large generators and large offshore or central or onshore wind parks could exist with distributed generators in the form of photovoltaics, local storage, electric vehicles, and all this is controlled in a distributed, intelligent way.

What has driven smart grids is of course the three main pillars, which is called develop the market, how to secure supply, and the environment, and this is subdivided into—regarding markets, the urge for lower price and higher efficiency, innovation and competitiveness and regulation of monopolies, security of supply, both for primary energy supply and also operation, which ___ reliability and quality of supply and capacities. And for the environment, nature preservation, climate change, and post-Kyoto agreements.

So the future or even the current smart grid in Europe is based on interoperable European electricity networks throughout the continent, based on markets, and having both distributed and central generation, applying demand response, environmental policies, and also ensuring the renewal of the network in a cost effective way. And in the center of all this is the customer, the user, and all these are the owning—all the stakeholders own the smart grid.

Now one basic component of smart grids, the building block of smart grids, are the microgrids. So what are microgrids? They're small, modular generation and storage and flexible loads conducted at low voltage or medium voltage networks that can _____ to the upstream network with a single control unit. They can be connected or isolated from the main network, and so they can ensure higher reliability to the customer.

So the two—the basic ____ ___, the basic distinguished feature of microgrids is that we speak about distribution networks with increased distributed generation that can be organized in a coordinated, controlled way. So we have local organization, and to a large extent self-balanced between local generation and load.

Now why are microgrids important? Because they bring a number of advantages. Regarding economy, since you organize load near production, you lower transmission and distribution assets. And by applying what are DSM policies, you can overall have a more effective and efficient network, and also cheaper network.

You can increase power quality. This is because you can, of course, increase reliability, so if you have an upstream fault, you can isolate and increase capabilities. And regarding environment, since you have a more efficient network, you reduce losses, so you reduce generation and thus CO2. Another important issue is that since markets are based on distributed generators that are mainly renewable energies or very high efficient gas supplied units, then you can have a better CO2—you can reduce CO2 emissions, so have a better environmental effect.

____ the percent of microgrids, we face a number of very high technical challenges. Despite their small size, microgrids have a very large number of technical difficulties. Some of them is, for instance, you have to coordinated and control distributed generators and loads that—you have to do that in an efficient way, because when you island the system, you might face very large differences, which—between production and load, which can create high transience. So you need to have a very good ____ of the load and the DGs so you can have this similar transmission—transition between interconnected and islanded mode.

You also have to use effectively more economic and efficient DGs, and to coordinate ___ storage, which is batteries, fuel cells, flywheels, etcetera. You have a number of power electronics interfaces. Power electronics are, of course, very much more challenging, but also give many possibilities to host control ___ and control techniques.

Protection is quite tricky, because you have now many units that since they interface to power electronics, they don't provide enough full current. Also, during faults, you have to be able to island the system very quickly, so you need a different type of switch, like static switches based on power electronics. Communication is important because, of course, in this small type of systems, you can't expect to have expensive computers or expensive communication systems, so you have to locally communicate all your needs and coordination and coordination activities.

And standardization is another lacking feature. At the moment, there are several ____ standardized microgrids and smart grids, but also microgrids, but there is still a lot of work to be done ____ standards for this area.

We will now—why do we speak about control and coordination? Because if you coordinate distributed generation loads through microgrids, then you clearly increase efficiency. You can get the best benefits from this collaboration. This brings financial and operational benefits to the DG owners and the network, and by applying also these policies, you can help the congestion management, black start. Since you can locally develop generation and balance load, you can defer transmission/distribution network investments. So overall, it can provide a large number of benefits also to the distribution network.

Well, there is a number now of challenges for control. First, at least in Europe, there is a number of legal problems. The market structure, for instance, if the distribution system operator owns the network, he's not allowed also to control distributed generators or own storage in many European countries, so you can't really operate as a DSO the microgrids, unless it is a community microgrid or a local microgrid. Then there are several anyway problems in the legal framework.

One important thing is that having a microgrid at the low voltage, which might be neighborhood, you can't expect to have large computers, to have distribution system operators, very expensive communication network. So the solution should be very low cost. This means you cannot have a dedicated operator. So you must find some kind of decentralized intelligent solutions that are at the same time cheap.

The microgrid, although it is a small system, operates ____ as a small lab system, so it has to have all the operations of a larger system. And having different DGs with different—of different technologies and different principles of operation also ____ how to use—how to exploit ____ control, ____ communication and reduction of costs.

So overall, if you want to control the system, there are two ways to do it. One way is to have a central point, central processing unit, where information would be collected, and all the measurements, the central unit will have a number of optimization routines will run, and will decide about next actions, and send set points to the ____ units. Or you might have a decentralized approach, where you have advanced controllers at local level, at each control node, and then you have the main decisions taken at this decentralized level.

So the important question is where decision is taken. Decision is taken at the central point—you speak about centralized approach. Otherwise, decision is taken at the lower level, you have a decentralized approach.

And this shows also this basic paradigm. The centralized approach, we have perhaps an energy system provider, an ESCo, which might be based on the microgrid central controller. He receives measurements, set points from the field. He runs a number of decision support tools, like he is forecasting, he might have state estimation, unit commitment, economic dispatch, might have any security functions running. And then he sends commands, set points, to the various controlled units.

Or he can have only the ESCo collecting measurements—perhaps have some kind of forecasting and some security monitoring. He might send some signals, some price—some prices and some policies. And then the various control units through their intelligent controllers start some form of negotiation and decide on their own how they operate the system in an almost optimal way.

So one way to implement this decentralized control concept is through intelligent agents. And now I will pass you to Aris to explain to you some basic concepts about the agent theory, and then show you how we implement it, how we have implemented this theory in some practical examples.

Aris Dimeas

So hello, everybody. So the next part of the presentation will include an introduction to agent theory and some practical installations, and I'd say more it's the history, how we find—how we developed the controller that was installed in the Meltemi—the site.

I have many slides. Some of them I will go through them really fast. So let's come in the basic theory. It's what we call multi-agent control system. It's not exactly a technology, but a new approach and evolution of distributed computing. And the main idea is that we have a piece of software that is attached with a distributed generator or load controller, in the case of households, and it might have a certain level of autonomy, meaning that it can take some decisions locally, based on some let's say, for example, price signals or measurements from the field, and can decide by his own mean what are the next actions.

However, there is also the capability to communicate with other agents and form a society. We named this society multi-agent systems. And this is what you saw in the video for Meltemi. You saw some agents exchanging messages. They had the big problem of—to solve the problem of congestion in the transformer. So they decided who is going to set some loads in order to reduce the congestion in the transformer level.

So as I said, the agent could be attached to a physical entity, distributed generator, small wind turbine, battery, a PV station, or could be more let's say virtual entity, representing, for example, the DSO, a database, a market operator, the ESCo, etcetera.

A critical issue is that the agent has only partial representation of the environment. This means that, for example, in the household level, the local agent has measurements from the local measurement units, so it knows the consumption of a household or the consumption of specific appliances, but the agent has no knowledge about the whole network or the whole system. And this is a key part in the development of algorithms, because this way, we are trying to reduce the data exchange between the various nodes. So the agents exchange only the necessary information between them.

I will not go quite—I will pass this quite—I will pass this fast, but it's quite important part of the multi-agent system, is the agent communication levels. It's the system that allows the agents to exchange—not to exchange data, but to start discussions between them, in a similar way that humans do.

Again, this is a graphical representation of the concepts. So in the centralized SCADA, we receive in the central measurement system, SCADA, we receive the measurements, and next, the SCADA sends commands to each one of the units.

In the case of agent control, the idea is that an agent is attached to each one of the elements in the field, a suite. The central system sends let's say a signal, for example, there is a problem in the network, and the agents start negotiating in order to find the optimal solution.

Okay. This slide is a step deeper in the description of an agent. So these are some basic characteristics. It has a behavior. I don't know if you are familiar with game theory and all these theories. So in these kinds of distributed systems, there are two main types of behavior, competitive or they are trying to collaborate. For example, in a competitive behavior, we might have an auction, and the various agents, the households, the distributed generators, trying to maximize their own benefit, but the auction is this way, the algorithm is—allows the whole system to reach the minimum—to reach minimum cost.

And here comes the objectives an agent might have, is to minimize the local cost or maximize the profit of let's say the ESCo or the community. And next to that, the agent takes a decision, taking into account what are the available resources for him. For example, if it's an agent that controls distributed generator or diesel generator, the local resources is the fuel. Or if it's a battery, it's the energy stored in the battery.

And it has some skills, according to the theory, which in our case is the control capabilities to curtail some load or start a generator. And also, a secondary characteristic are some services. For example, the yellow pages, we will have the chance to take this in the next slide. It's the ability to discover in the system agents that can offer a service. For example, if we have a battery agent that wants to store energy, it might search for agents that produce energy, for example, PV generator or wind turbine, and next, start a negotiation and discussion with this agent to buy energy from them.

This slide presents two basic types of agents, are the reactive and the cognitive. Cognitive, in our case, we are dealing mainly with cognitive, are those who have increased intelligence and solve problems through communication and advanced algorithms. Reactive agents are agents that react—have simple reactions to signals from the environment, but the reactions and collaborative scheme creates let's say an intelligent society.

An example for these cases, for cognitive agents, it's the human society. We have—the human himself is quite intelligent, and have an ability to communicate. We form societies, cities, countries, that collaborate and improve the way of their living.

As reactive agents, a simple example is the ants, the ant colony. The ant has no intelligence, and simply reacts to signals, to pheromones, and these kind of signals from the environment. But they form a colony that allows the insect to survive and collect food and make public works.

So next, I will—and I will go a bit fast on this example. So for our—for the implementation of the agents in Meltemi and also in laboratory, we will see it next, we are using an agent platform called Jade, which is compatible with a foundation of intelligent physical agents, and allows to develop algorithms, and provides all the tools for communication it has built in the agent communication language. It also allows to implement behaviors and other type of services.

So the basic structure of a multi-agent system has the agent itself, the message transport system—it's the system in the communication language that allows the agents to exchange messages—and two agents that are the agent management system and directory facilitator, which are supporting the whole operation. We will see next what exactly the directory facilitator does.

So here, you can see shortly the structure of a message. It has a sender, a receiver, type, communication ID—conversation ID, so it's similar to let's say the communication via emails. You have the message, you have the subject, so you can understand in which topic you are going to reply to the sender. And you have the ontology, which is the vocabulary. So the agent should use a common set of words with a common meaning in order to understand exactly what they are saying. For example, if an agent sends a message, I need some energy, the other should understand that this is kilowatt-hours or joules or other measurement unit.

So important role for the conversation is the directory facilitator, which is a type of yellow pages for the agent society. This means that when an agent wants to find some other agents with some specific characteristics, asks this agent, for example, give me all the agents that are controlling photovoltaics or wind turbines. In our case, it's a simple example. The load wants to buy some energy from the battery.

So having this list, it sends a message to the loads that I'm a battery, I'm making a proposal to sell you 100-kilowatt hours. One load agent may accept, or the other may deny.

In order to control appliances in the households, we need to use a load controller. This is a device inside or outside the house that hosts the agents. This means that it should have a type of processor capable to run some piece of software, and also has some capability to control some relays, or in our case, through some electricity plugs, through power line communication.

So the first version of the load controller we developed in NTUA with collaboration with other partners. This is quite old. It was using Windows CE, and has an Xscale processor, and hosts the agents using the Jade library. This controller was initially tested in our laboratory. This is an—this is the microgrid we have in our laboratory. This is a panel with load controllers.

And next, we move to a real installation. This installation [audio glitch 0:45:08 through 0:45:31].

Sean Esterly Hi, Aris, are you still there? Hi, Aris, are you still there? Well, it seems that we might be having some technical difficulties with Aris' connection, so let's give them a moment, see if we can get them to reconnect. I apologize about this.

[Pause]

Sean Esterly Hi, everybody. We're still working on resolving the technical issue. Just give us a couple more minutes, please, and we appreciate your patience.

[Pause]

Hi, everyone. Apparently Aris and Nikos seem to be having some internet connection issues. We're going to give them another minute or two to see if they can reconnect, and if not, unfortunately, we will have to conclude the webinar. I do have a few questions that came in, and so what we will do in case we do have to end early is I will email those along to the presenters so that they may follow up with you. So if you have any questions, please feel free to submit those now while we wait to see if they can reconnect.

[Pause]

All right. We'll give them one more minute, and then we'll have to wrap up quickly. So again, if you have any questions for the panelists, please feel free to submit those now, and I will email those along so that they can respond. And again, we will be making the PowerPoint presentation in its entirety available on the Clean Energy Solutions Center training page.

[Pause]

Great, and we did—it looks like we have them back online, actually. Great. Nikos and Aris—

Nikos Hatziargyriou I'm sorry for that.

Sean Esterly That's all right. I'm going to—

[Crosstalk]

Sean Esterly I'm going to hand the controls back over to you and let you continue where you left off, if that's all right.

Aris Dimeas Great. Thank you.

Sean Esterly Great. And we—just so you know, we have about 35 minutes of presentation time left, so if you could wrap up in probably the next 20 minutes, I think that would be good.

Nikos Hatziargyriou No problem.

Aris Dimeas Okay. So I'm sorry for the problem. We had some difficulties here with the network. So coming back to the presentation, as I said, first real installation was in the island of Kythnos. In this island, there is this isolated settlement, consists of 13 households. So we installed the first version of the load controller. As you see, it's an outdoor system, and in order to reduce caping inside the house, we used power line communication with—in order to control some electrical plugs. In our case, in the case of Kythnos, the main load is a water pump, and the extensive use of water pumps in Kythnos leads to lack of energy in the battery, and startup of the diesel generator.

So the concept of the multi-agent system there is to provide a smart way to save energy within the households to feed the main loads, which is lighting and fridge, and ____ energy, the rest of energy could be used for the water pump.

So again, we have a schematic of our installation. We have some agents controlling or monitoring PVs and the batteries, and some agents hosted in the load controllers we showed previously. This is schematic of—load diagram of load controller. It consists of the main processor, which in our case it's _____ processor. It has a measurement unit, ___ that can measure voltage, current, power, frequency, and can also detect some first events, as ____ or overcurrent, and can also measure some indices about power quality ____. It has a communication interface using Wi-Fi to connect to the internet and communicate with other agents. And in the case of Kythnos, as I said, we have used power line communication in order to control loads inside the household.

And again, here is the basic concept for the case of Kythnos. As I said, the most consuming device in these households are some water pumps, so the idea is that if we have available energy, then we allow the operation of the water pumps. And the time of use—the use between the various houses should be shared equally and in a fair way.

Again, here are—there are some slides about the communication between the agents and the messages that they exchange and the way they make the various conversations, but I will skip that in order to move to next slides.

So now, we are coming in next step, after the work done in the Kythnos pilot site. It was funded within the project of—called More Microgrids. After that, we had another project from EU called Smart House/Smart Grid, and we've used Meltemi, the camp presented in the video, to test the new generation of load controllers. The new device, it's designed for indoor use. We understood that one of the key lessons learned in Kythos, we saw that it's very important to have a small display on the controller in order to give some messages to the citizens that are—the people that live inside the house. For example, messages like you are spending too much, or we are going to control some appliances now in order to increase efficiency, etcetera.

So in this map, you can see the houses that are used for our installation. There are ten houses in total. The structure of the system is a bit more complicated, because we had—we wanted to include new entities, like the ESCo that provides the incentives and flexible tariffs, assuming that he has a connection with a wholesale market and can play with the flexibility. And also, the DNO or the DSO that sends some signals about the status of the network.

So for example, in the case of congestion management, the DNO/DSO can send the message that there is a problem in the transformer, and the ESCo can send the incentives, the tariffs for the load controllers. These incentives will be used in the process to—it will make—it will give profit to the consumer and the household owner if he will allow the saving of some appliances.

So this is also a schematic with the main ___ that we used in the case of Meltemi. This is a schematic of the load controller. As I said, it's a new system for indoor use. Again, we have a unit that takes measurements from the network. It has also the ability to control appliances using power line communication, and also has some relays, digital outputs, has a backup solution for controlling appliances.

This is structure of the communication network. And these are some slides on how the agents take some decision. Next to the measurements, they have also the ability to make load forecasting, so they dictate that there is an increase in the load, and that could lead to a congestion in the transformer. Having these measurements and knowing that equipment problem may occur quite soon, the agents negotiate and also—I forgot to say they also have an estimation of the flexibility. Namely, they know that—how much energy they can set each moment. So knowing the forecast—that a problem is about to occur in the transformer, and having the knowledge on how much energy they can set in a particular moment, they start negotiate in order to cope with the problem.

So to summarize, we are using quite extensively internet-based technology as service-oriented architecture, the platform of Jade for ____ implementation, and all these tools and the process allow us to develop a quite complex structure without—which is also quite cheap.

However, the basic assumption and the big obstacle in our case is the legal framework. And for example, the ability for an ESCo to send flexible tariffs and price incentives to the consumers. Without having these type of ___ tools, it's not easy to proceed with demand response and agent-based control.

Another issue is that we're doing a lot of research in these cases, the consumer behavior, and also the appliance behavior. We are trying to model the household and the house in order to understand exactly how much energy we can shift from an air condition unit or how much—what's the maximum time we can set an air condition without affecting the comfort level inside the house. Also, forecasting modules, although we haven't analyzed them in detail, are also important.

And a final remark is about the hardware and installation costs. From both sides, we saw that to install inside the house, inside the electrical panel equipment, is quite expensive, and we are trying to use next generation of home appliance, air conditioners or refrigerators, that have Wi-Fi interfaces. Using wireless communication with these appliances will reduce significantly the cost.

So this was my presentation, and we tried to explain what exactly we are doing in the Meltemi demo site, and what's behind all this autonomous control system. Thank you.

Sean Esterly Thank you very much, Aris, and thank you also, Nikos, for the presentations, and we'll move quickly now on to the question/answer session of the webinar. Aris, I'm going to let you continue to show that slide with your contact information, so we'll leave that up so the attendees can see that while we go through the questions. And again, audience, if you have any questions for the panelists, you can submit those through the question pane.

So I'll just start with the first ones that I received. And this one asks what is meant by demand side management policies? Could you give some examples? And how are they worldwide—how are DSM policies worldwide, and especially African policies, flexible with microgrids?

Nikos Hatziargyriou Demand side management policies are applied in several countries. The basic—there are two ways of ____ demand side. The one is if the utility or the—or your service provider sends you specific tariffs for special hours during the day so you can increase or reduce your consumption ____ the prices. And the second way, if some utility can directly control your devices. This is—so these are the two ways. One is demand side management. The other is demand response to some external signals that are basically prices.

Sean Esterly Great. Thank you, Nikos. And the second half of that question is how are worldwide and especially African policies flexible with microgrids? I don't know if that's completely relevant, but if you have any insight into that.

Nikos Hatziargyriou African—you said African, from Africa?

Sean Esterly Worldwide, and they were asking specifically for Africa, but you can talk to worldwide.

Nikos Hatziargyriou Well, I know that there are countries or states like California where demand side is very well advanced. They mainly control thermostatic loads through several policies. Now in Europe, it's less advanced in this field, and—well, I have no idea about what happens in Africa, with other continents.

Sean Esterly Right. We can move on to the next question. And the next question asks, on average, is the domestic wind turbine more or less economical than PV for households in the community?

Nikos Hatziargyriou Well, the wind turbines we are constructing at the moment are let's say university-made, so they are model turbines that have not been in industrial use. So clearly, in this aspect, they are more expensive than photovoltaics, so—but however, I have the feeling that if they are industrially produced, they could be competitive to photovoltaics.

Sean Esterly Okay. Thank you. And next question that we received asked how do the agents decide what loads to reduce from which households to achieve the objectives of minimizing costs and maximizing profits? What are the typical—well, let's start with that one, and I'll move on to the next part of that question.

Nikos Hatziargyriou Yeah. There is—there are whole theoretical papers that have been written on how agents negotiate in order to reach an optimal solution. The basic idea is negotiations. So they start a type of dialogue where they make offers, and based on these offers, there is some decision-making that accepts or rejects offers, and these offers then are repeated. Some basic algorithm, called auction algorithms, where there is an ____ that announces price, then the various bidders try to bid for this good, and offering prices, okay, and the—and the biggest offer wins and takes the good.

So typical algorithms are the ending or the Dutch auction and other types of—these kind of dialogues. Another family of methodologies, of methods, applies some kind of decentralized techniques for optimization, where—or other algorithms, what they call gossip algorithms, where the agents exchange messages with the neighbor agents, trying to find some—trying to solve generalized problems, generalized problems. So this is a long theoretical work of how you find optimal solutions through decentralized approach.

Sean Esterly Great. Thank you. And the next two parts to this question are what are the typical loads being curtailed in a household, and then also are they two objectives set by ESCo, or do individual households have their own objectives to be factored into the control algorithm?

Nikos Hatziargyriou In the example showed before, Aris showed before in Kythnos, the basic loads that were curtailed were the irrigation pumps and the air conditioners. And typically, most countries, it is—where these things are applied, is air conditioning or these type of freezers or these type of loads, or dishwashers, that can be used for curtailing. I mean, loads that are non-critical that you can defer for some time without the consumer feeling any discomfort. So what was the question, sorry?

Sean Esterly Yes, the other—

Nikos Hatziargyriou The second part?

Sean Esterly – was asking are the two objectives set by ESCo, or do individual households have their own objectives to be factored into the control algorithm?

Nikos Hatziargyriou Well, every—there are several applications. That very much depends on the application. There are applications where it's—electrical device can have its own agent that can decide on how much it will curtail, depending on the embedded software, or you can also have some intelligent controller, as the one you saw in Kythnos, that is deciding centrally for the house what to set. So the ESCo might send specific set points in centralized approach, or might just indicate that it wants to reduce the total consumption, and then the device ____ the households themselves exchange messages and curtail load with a certain logic.

Sean Esterly Great. Thank you. And does this system control the voltage as well?

Nikos Hatziargyriou There are applications where you could curtail—for instance, in a long co-distribution line, where you have perhaps some distribution generation raising voltage, you could make several units collaborate so that they reduce their ___ production, so they—the voltage is reduced optimally in a decentralized way. So again, this is a problem of decentralized optimization that can be solved applying quite sophisticated techniques, but yes, it is possible to do it.

Sean Esterly Great. Thank you again. And moving on to the next question, it states this is mainly an energy oriented optimization. Is the information about the network topology used in any way?

Nikos Hatziargyriou Not in our application. If you want to solve a problem decentralized, the agent only knows what happens in its neighborhood around it. It does not have a full knowledge of the system. So in order to have a network solution, you must be aware of the whole network. However, applying techniques like the one—like, for example, the gossip algorithm, then by exchanging messages between neighboring nodes, you can take into account the constraints in the network without really having a knowledge of the whole network, because by exchanging messages, you know what happens next to you, and the one next to him, etcetera, so by going forward and backwards, the messages, you can satisfy network constraints without really solving the whole load flow problems.

Sean Esterly Great. Thank you. And we have about four more minutes for questions, so I'm going to group a couple of these together. A few of our attendees just wanted you to explain a little bit more how the agents concretely take decisions, and based on what specific parameters. So is the decision on the amount of curtailable energy based on historical energy consumption in a household, or based on the agreement established with the household? What parameters is it taking in to make those decisions?

Nikos Hatziargyriou Well, again, this is application dependent. In the example that we have shown, it is the—that the central agent, the micro central controller, announces the start of negotiations, and its local agent knows that there is a lack of energy because of—because of the frequency drop or because he has a message that the state of charge of the batteries is low, okay?

So what happens is that the various agents start negotiating how much energy they can use. So they send some signals announcing the energy they need. They negotiate. And then based on their offer, they end up in—the highest bidder, let's say, is the one that wins the energy that he can use.

Now in this internal logic, what we have taken into account in Kythnos, how much energy was used in the ____ allowance, so that all houses save energy in a fair way. This is an example, okay? Other examples might use economic signals, so they optimize energy in the most efficient way, I mean, having the least cost.

Sean Esterly Thank you. And we're going to move on now. I'm going to take those controls back from you, and we're going to move on to the brief survey that we have for our audience today. So in a second I'll be displaying the first question, and you can respond to this directly on your screen, and that statement is the webinar content provided me with useful information. Great. And the next statement for you. And then the final one.

Great. Thank you very much for answering our survey. We do appreciate that. It helps us evaluate how we did and improve for next time. And so on, behalf of the Clean Energy Solutions Center, I would just like to thank your expert panelists again. Thank you very much, and thank you for working through the technical difficulties as well. We do appreciate it. And thank you for our attendees for being patient with us and for joining us for today's webinar. We do appreciate your time.

Nikos Hatziargyriou Thank you very much.

Sean Esterly And just a reminder. We will be posting the slides from today's presentation to the Clean Energy Solutions Center training page. They should be up at some point today. And then we'll also be posting a recording of today's webinar, if you'd like to go back and watch any parts of it, or to share with colleagues. We'll be posting that within about a week of today's broadcast.

Additionally, on the training page, you will find information on other upcoming webinars and training events, and as well as the Ask an Expert service that the Solutions Center offers. So with that, I'd just like to thank everybody one more time, and hope that you have a great rest of your day, and we hope to see you again at future Clean Energy Solutions Center events. And this concludes our webinar.

Nikos Hatziargyriou Okay. Thank you very much.