# Clean energy- the only way!
# Towards a better future with science and clean energy

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Guests:

- Professor **Peter Lund**, Aalto University, Finland,
- Professor **Gatis Bažbauers**, Riga Technical University, Latvia

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**Valters:** Hello, and welcome to the current episode in the podcast series Sustainable Worlds supported by the Nordic Council of Ministers' Office in Latvia. My name is Kārlis Valters. My guests are Professor Peter Lund from Aalto University, Finland, and Professor Gatis Bažbauers from Riga Technical University, Latvia. Today we will talk about energy transitions, and my first question is – what is an energy transition?

**Lund:** If I may start… So, industrialization relates very often to the decarbonisation of our societies – cutting the emissions pathway, what should we do in order to get rid of the emissions? And to be more specific, we should be carbon neutral, meaning that our sources of emissions and the sinks, for instance, forests, which take CO2 from the atmosphere – those should be in balance by around 2050. The transition is really the path from now to around 2050,

where we will have solved the problem of climate change and mitigated it so that we are in some kind of balance.

**Valters:** Why do we need to be carbon neutral?

**Lund:** From a political point of view that relates to the Paris Climate Agreement from December 2015, where all states basically agreed to limit the temperature rise of our globe to about $1.5^0$-$2^0$ by the end of the century. Why do we need to limit the temperature rise, meaning also limiting the emissions? Science says that the changes in our environment, in ecosystems – if we don't do anything with the emissions – may be such severe that that may actually jeopardize the existence of our societies. So, we speak of a very important issue here – about our own existence as societies. So, we need to do something now quite quickly with the emissions, and that's the energy transition.

**Valters:** Right, so the question might even be about the survival of the human species?

**Lund:** I wouldn't be maybe that dramatic, but it's very much about the existence of life, living conditions, societies, as we perceive them at present. If we don't do anything and the temperatures rise, that may cause huge droughts somewhere, flooding – huge kind of weather changes which will affect our food systems and raise the sea level so that coastal cities might disappear. There may be hundreds of million climate refugees coming, for instance, from Asia, from the Himalayan region to Europe. So you can imagine that the societal questions, the change in the societies may be so large that I would like here to quote actually Prime Minister Margaret Thatcher. When she was advised by climate experts on what the consequences might be she said – wow, this seems to be the same as the result of a total nuclear war! It is a really serious issue for the whole society.

**Valters:** Gatis, sustainable energy systems have large importance for the sustainable development. What is a sustainable energy system?

**Bažbauers:** Well, in broader terms we know that the term "sustainability" actually means that we preserve the resources and the environmental conditions also for the next generations to come, so that we ensure that the next generations are able to continue living under the same, let's say, conditions as we do now. The energy systems have to follow the same characteristics basically: we have to care about emissions, the pollution that we create in the atmosphere and also in the local ecosystems, but we also have to take care about the resources that are consumed. We talk about energy resources that should be sustainable in the sense that… or renewable in the sense that we don't deplete these resources. Also we talk about material resources, which are becoming more and more important – that we should not deplete stocks of final or finite material resources. We have to make actually the energy systems or the supply chains circular so that the materials that are used are returned back into the cycle. We can discuss also about land use actually – that energy, especially if we talk about renewable energy… In order to harness renewable energy sources we need lots of land – either for windfarms or for solar systems, and it means that there is also a transformation of the land taking place. So we should also consider this aspect as well, to preserve the land for productive

use. So materials, land resources, energy resources – all these cycles have to be sustainable, preserved for next generations. That would be my explanation.

**Lund:** I think Gatis defined sustainability very well. When I think of my grandparents or their grandparents… Each generation left a slightly better world to the next generation. I think we are actually the first generation on this planet that most likely will leave a *worse* future for the coming generations. I think that would be something very odd in the [history of] humanity, that we leave something worse to our children. And I think sustainability, as Gatis well defined it, is really to leave a better future to our children.

**Valters:** Peter, the majority of world population already lives in cities. What role do cities play in energy transitions? How is it in Helsinki? What are the plans for the future of the city? Would you tell us about that a little?

**Lund:** Yeah, I think cities in general are very important in the sense that you said, because most of the people due to urbanisation will live in cities. And already now two thirds of all the environmental damage or emissions, or energy use comes from the cities. So cities are really the trend also in the coming years. Of course, here in the Baltic Region, the Nordic Region our cities are still small compared to the Asian cities where the problems are there. But still, our cities are important. We have, of course, long traditions of energy use in the cities, which in some way sometimes lock us into some solution. For instance, Helsinki… Finland is trying to reduce emissions very quickly, we still use very much coal for heating and power production here in combined heat and power systems. So we are still hanging on to coal, though the [Helsinki] city has now made a decision that by 2030 coal and fossil fuels need to be removed. And this transition from… We have a very centralized, very fossil-fuel-based energy system in Helsinki, which is now going to transition to a clean, CO2-free system. That's a huge jump. And what we see here now in Helsinki much more concerns the question about decentralization. Heat is very important in the northern cities – more than half of all the final energy goes to heating: the emergence of heat pumps, using the geothermal energy, a waste heat from the buildings, building efficiency, energy efficiency... I know in Riga architecturally fantastic old buildings, but all buildings are always a challenge because we need to reduce their energy use. We have the same issues here in Helsinki. But also, for instance, the city now has legislation that all public buildings being built need to have solar energy. So we are bringing energy much more *into* the city. And the buildings themselves turn into small kind of power plants, so they produce much of their energy themselves. We employ, of course, the energy infrastructures in cities. And this is, I think, an advantage of cities. We have district heating, we have gas pipelines, we have electricity network – and we can use these networks for the next generation of energy technologies which are clean. There's not a single silver bullet which will solve the problems in a city like Helsinki, but there's a multitude of different solutions. And I think each city is individual in that sense that each city needs to find the correct, let's say, manners of different technologies and use different approaches. Cities – that is definitely the key for when we go toward zero emissions.

**Bažbauers:** I think that Peter is absolutely right that probably the most important transformation that will be taking place will concern the building sector, which is a very large consumer. And also, in terms of mobility I think we will see a very interesting transformation of modes of mobility within the cities. We can already observe how fast technologies like electric scooters diffuse into the cities. So walking, cycling, you know, electric mobility solutions will come into cities.

**Lund:** Yeah, Gatis, I think that's completely right! So let's say buildings and transport – for the cities those are the most critical. Of course, we may have wind power somewhere on the shore and then transfer the power to the city and use that for electricity, but also to use electricity for heating – for heat pumps or electric mobility transport sector. So I think that is really… As Gatis pointed out, that's the key – transport and buildings. Focusing on those will solve very much of our energy problems in the cities, definitely.

**Valters:** Clean energy is morally right towards our planet. It makes sense, quite simply. But is it also good business?

**Lund:** I think now, where we stand today, you could say that we are – even though we wouldn't observe that very often – we are in a huge change. There's a paradigmatic change in energy now, in the sense that the new technologies, new clean technologies like solar, wind, heat pumps, etc., clean energy is becoming cheaper than the old dirty energy. Then comes the question; which energy would you invest in? In old dirty energy or in clean new energy? And this change is taking place, and we see that the markets of new technologies – solar, wind, electric vehicles, heat pumps – is really exploding, and this transfer is taking now place globally. Though, for instance, here, if we take the example of solar energy… Unfortunately, in our climates here, in Riga and Helsinki, we have three challenges with the sun – I always say it's November, December and January, which you can't change. But taking, for instance, the Gulf Region, just recent news about solar energy: the price of solar energy to produce electricity is one cent per kilowatt hour – it's the cheapest electricity that you can think of on this globe! This change from old to new will create a lot of economic opportunities. And for young people it means jobs creation, finding jobs here. Technologies also create a lot of services. Solar panels alone are not enough, we need services: somebody has to plan it, we need apps to take care of the solar energy, or maybe somebody has to sell the electricity from the plant… So that's a broad value chain which takes place when the technology comes. And I think here are really great opportunities for our youth to find interesting working opportunities.

**Bažbauers:** Peter mentioned – who would invest in, let's say, in all the dirty technologies now that new renewable technologies become more and more interesting and competitive? And it's very important to understand that actually business will move where the demand is, so business will follow the market demand. And we can see that actually there is a growing demand in the market for green technologies. Let's just mention the example of power purchase agreements that many big companies, like recently Facebook and some other before it, they actually want to purchase their electricity from wind power, for example. The society is also interested in how that power actually is produced. Wind power is not sufficient anymore – they want to see

that the whole life cycle or supply chain of that wind power actually is sustainable, so there is an increasing demand from the society towards, let's say, clean energy sources. On the other hand, business itself creates the market, because they develop new technologies which are demanded by society in turn. So there is a kind of a cycle which increases the rate of development of these new technologies.

**Lund:** Let's say, the global picture now in some of the recent scenarios by the International Energy Agency, which is one of the key scenario makers, the IEA – they now foresee that solar will be the new energy king. So by 2040, which is not very long time from here, 20 years from now – they foresee that solar energy could produce 20%-25% of all electricity globally, which is a huge amount! And wind and solar together maybe 50% of all electricity in the next 20 years. So the change is huge when we think that still 80% of the energy is fossil fuel. And that means that the demand for the new technologies is so huge that they will penetrate the market globally and make a major, major change indeed.

**Valters:** Before we talk more about particular energy technologies… You mentioned this decentralized energy production, and there is also the word "prosumer". What does it mean?

**Lund:** When we speak about new technologies in energy, they differ very much in terms of their physical appearance from the past energy where you have large power plants. Take a solar panel or solar energy system – you can put it on your own roof; or if you have an electric vehicle, it means you have a battery and four wheels. Technology gets smaller. And it means that you could apply those easily in buildings and in houses so that the house owners, if they have a solar panel on their roof, they can sell actually the excess electricity which they don't need to the grids or the neighbour. And in that sense they change from an ordinary consumer that's consuming electricity to a producer of electricity too. We as people, we could be kind of businessmen or businesswomen. That gives you an opportunity also to really… In particular, in cities and urban areas you can very easily then transfer the electricity to the neighbours, if we use blockchain technology or artificial intelligence.

**Valters:** What is a blockchain technology?

**Lund:** Blockchain is very much about the way of making the *business* of prosumerism so to say. In this context, it would be the bookkeeping. So if I sell you electricity, I don't need to take care of the billing: how much did I sell you and how much did you pay? With blockchain you can easily bookkeep and make agreements, sell and buy. And if we add artificial intelligence, you could say there's algorithms that take care of that. If you give your preferences – that you would sell electricity when it's very sunny and not when it's dark – then algorithms could take care of your business. Basically, it's about having the information technology also combined with energy. So this digital revolution, which is another story, is added to energy: you can maybe use your mobile phone to regulate your house, or if you have electricity tariffs you can say – okay, now at two o'clock I will sell my electricity, I shut down my house.

**Valters:** Does it also include so-called big data?

**Lund:** Indeed, big data comes into the picture. In particular, if I would take, let's say, slightly larger entities. So many prosumers, let's say, a block of houses or a suburb or even a city – that's where we have big data that you could kind of optimize, predict energy use and have an optimized energy system. And you could even predict a blackout – maybe we see there's a dip in production or a leap in demand – and that would help us to optimize the energy system. So big data, machine learning, artificial intelligence – these are also very important parts of these new technologies. And people start to see those already in their own applications – maybe when you have some health information on your mobile phone which tracks your health. In the future there might be somebody who tracks your energy and makes some decisions on that because there are algorithms helping you to cope with energy.

**Valters:** In transportation, how important is the shift from internal combustion powered vehicles to electric vehicles and what are the challenges: technological, behavioural or other challenges?

**Lund:** That's a good question, in the sense that mobility is so important for all of us. I mean, not just for everyday life – it's also important for broadening our understanding of the world and other countries. Transportation, mobility by large I would say is one of the key sectors. Where do we need to make a change? Internal combustion engines have been very important in modernizing our societies. But now, because of the emissions that they have we need to make quite radical changes. I would say, you got two pathways. Definitely, some engines or, let's say, combustion may be necessary for long-haul transport, very long-distance transport, and even maybe for aviation, and that's where we need to replace our fossil fuels maybe with biofuels. I know that Latvia is a very important country in this respect, of biofuel and bioenergy production. We would not drink the alcohol but we would put the alcohol as a gasoline, to make it simple… But then in terms of our city transport or personal transportation – cars, vehicles, light-duty vehicles – battery technologies and the progress in battery technologies has helped to create the vacation of transport. We see electrical vehicles now coming rapidly on the market and the price is coming down. Everything that is a shorter-distance and personal transportation, or even having an electric bike – why not going for electric bikes? – that's definitely where electricity and batteries will play a role. These are of course technology changes but in addition to that there may be some structural changes, meaning the role of public transport, the role of railways, trams etc. So it may be that we need also larger, some structural changes – not just changing a combustion engine car to an electric car but also some more structural changes that we may need to do also, in cities in particular.

**Valters:** You both have co-authored a [scientific] paper published in a journal with a high impact factor, a review about energy transitions and particularly using the system dynamics approach. Gatis, could you explain briefly what the system dynamics is and how this method, this modelling can help to understand all the aspects of the driving forces and etc. in energy transitions?

**Bažbauers:** Well, system dynamics is an approach of analysing complex dynamic systems, something that changes with time. In system dynamics you analyse these systems with the help

of stocks and flows – basically what you do is you actually portray, I would say, almost any process in nature or technical systems or societal systems as consisting of stocks and flows. In stocks there is an integration or summation taking place so that stocks can be filled up or depleted, and flows change these stocks. That's the system dynamics in a nutshell. The theory was actually created by Jay Forrester at MIT at the beginning of the last century. Jay Forrester was actually an engineer, and basically there was an engineering approach… The control theory is basically the basis of the system dynamics – it was applied to the managerial and economic problems, policymaking problems… With this approach we can also quantitatively model problems that involve society, in a way. So we can actually quantitatively try to model behavioural aspects of energy transition. And that was the reason we approached system dynamics – to also analyse the potential pathways of energy transition. I would say that it's very challenging, because modelling societies' or people's behaviour is very complex – we don't have enough information, we don't have enough data. You cannot really put a thermometer and measure a temperature in society, so there are different approaches that you have to take. But still, we can get very good insights into what the potential dynamics coming out of a specific structure could be. So we are interested in the system dynamics in order to understand the structure of the system that generates a certain behaviour. We usually address a behaviour we don't like – something which happens in time and that we want to change. We don't like that behaviour, we want to change that trend. And then we try to understand what is the structure that generates that behaviour. If you understand that structure, you can make some changes *within* the structure, and that's the way to change the behaviour. The structure is built with the help of this system dynamics model. That's the approach.

**Valters:** Talking about energy and studying energy transition – there are economic, there are policy, technology, behavioural factors. It is a complex dynamic system, right?

**Bažbauers:** Yes, and "complex" means that there are accumulations in the stocks and that there are delays, because we know that in real life nothing changes instantly and that time is needed for changes to happen. So there are delays, and there are feedback mechanisms in the real systems which we incorporate into these system dynamics models. That's what makes it complex. For us it's actually almost impossible to intuitively say what the dynamics of a complex system could be, so we have to model it in order to understand what the resulting dynamics could be.

**Lund:** Gatis explained the system dynamics in a very good way. I think we should also add that Riga Technical University is one of the leading institutes in Europe on system dynamics.

**Valters:** The Institute of Energy Systems and Environment at the Riga Technical University.

**Lund:** Absolutely. It's always a pleasure to collaborate with them on these models. And indeed, energies is a huge, very complex theme. As you said yourself, it's an interaction between technology, economy, people, environment, politics. And how do you model that? Normal mathematical models don't work here. Everybody understands that one plus one is two, but if I ask you what is one plus B plus black? I mean, you can't say what it is. But the system

dynamics model can tell you what is one plus B plus black. And this is the way system dynamics modelling has helped us, with the help of our colleagues in Riga, to open up relations and interactions between different systems levels – economy and politics - , which we couldn't have done before. So that I think is a very valuable addition to the energy transition science – to bring us an optimal way from where we are to our goals for carbon neutrality in the future.

**Valters:** Peter, you are doing world leading research in different energy technologies. Could you tell us a little about some of the most interesting advances and innovations in energy technologies?

**Lund:** Well, energy as such is a most interesting area today.

**Valters:** Your background is physics, right?

**Lund:** I'm an engineering applied physicist by background but have spent most of my carrier… My chair is still in applied physics but my research area is in energy, and we are working with… from nanotechnology to complex systems like with Gatis. What is interesting is that now we see for the first time, I would say – and I have been working for more than 40 years in energy – for the first time we see that science is starting to penetrate into energy. We are actually opening up a door of a multitude of new scientific discoveries which will change energy. So what we now speak about – solar, wind, batteries – I think this is just the start of something much more interesting and sophisticated in the future. For instance, the new materials and what kind of opportunities they give. In the future, we could just use air, water, sun and some catalyst and we can make basically all the key chemicals that we need: fuels, fertilizers… That may be the ultimate solution – take air, water, sun, and then this catalyst, which I would say is knowledge, and then we can produce what our societies need. So we come back to a very important possibility of a totally closed energy cycle. I think when we think about environment we need more closed cycles that we don't pollute – a closed cycle uses the waste as input. Nowadays waste goes through nature, but in the future there could be more closed energy cycles. They are within reach – we need our youth now to make this true. The science makes this already on a small scale – in laboratories this all works – but we need now a step over to the society, to scale up. We need engineers, we need economists, young people to make it real, but this is already a possibility that we have in front of us. My group works very much also in nanotechnology – we go into the scale of nanotechnology where the science changes, material properties change and we can use things and make things that we never thought of. We go into this very small scale, 10 to minus nine, [what is] one billionth of a fraction of a meter, and we can manipulate the atoms and indeed have properties which we never thought about.

**Valters:** In which technologies exactly does this nanotechnology apply? Is it fuel cells, is it solar?

**Lund:** It is coming into everything. Let's say, now our energy system is very much fuel based: oil, gas, coal. In the future, we will transfer more onto a material-based system: batteries – materials, solar cells – materials, fuel cells – materials. So materials will be very important,

and in all of these materials nanotechnology plays a huge role. An interesting future development, for instance, that we have been looking at is that we could make solar cells which are based on carbon. Carbon is one of the most abundant elements on our planet, so we could make full-carbon solar cells! Now we use silicon, which is also a very abundant material. So what I see as the ultimate result of this new science, so to say, is that it enables us to use very common materials that we have for the benefit of humanity. Nowadays we still sometimes use very critical materials in our energy technology – in batteries we need cobalt, we need lithium, nickel… You may have heard about those, and they are not so abundant. But in the future the science enables us to use really abundant materials, which would be oxygen, air, water, carbon dioxide, which we have in the atmosphere, etc. But we need science! Science and scientific discovery enable us to make a more sustainable future in that sense.

**Valters:** If I understand it correctly, it's about innovations, but often in science it is also about incremental improvements. Do you foresee any breakthroughs in energy – like nuclear fusion, for instance? Is it possible to create a nuclear fusion reactor? What do you think about this?

**Lund:** I would see technology as part of the evolution, in the same way as biological systems. Biology changes all the time – for instance, we don't have dinosaurs anymore. So evolution goes forward, and the same goes for technologies. Evolution works towards the human mind innovations, in the sense that we will always get better and better technologies. It may take time and effort, and sometimes we have setbacks, for sure, but the direction is forward and upwards. Nowadays, of course, we have to be careful with the planetary boundaries. Our planet is too small for the people, and we misuse our planet, and we need to be sustainable. And I think that science, the new innovations enable that. Fusion [that you mentioned] as an example is now still very much a physics problem and we can't use fusion in that sense for energy. But I'm sure that that will be solved and that by the end of this century we will also have fusion in place. But there's a range of other technologies – I'm really looking forward to these kind of new solar fuels which can use air and solar – sun as the base material to create the fuels that we need and much of the chemicals that we need. There's a myriad of possibilities, which we currently may just see on the horizon. We still don't understand them, but they are there. That's where the humankind may pick them up – perhaps in the future. Of course, the key points here are innovation, scientific discovery and human ingenuity. That's why it's important that our youth gets good education, because they are those who will innovate. I'm sure this formula, as it has always worked, will still work in the future.

**Bažbauers:** To give a short answer, maybe I would say that if the solution will not violate the first and second law of thermodynamics, it's potentially possible. So this breakthrough is possible. But I would largely agree with Peter – that every new discovery actually enables the *next* discovery, or some of the technology that has been waiting for that discovery for some time. That's what the history of science shows. You know, there are other interesting ideas appearing… I just recently read that physicists have even been thinking about extracting energy from the black holes! And there are interesting solutions on nanoscale as Peter mentioned – for example, nanofluids, you know, osmotic processes, membranes, in order to extract energy from freshwater rivers at the junction with the salty sea waters. With this concentration of salt and

by using nanofluids you can actually convert the water [flow] into energy! So there is a whole bunch of different interesting ideas that scientists are working on. And I would say that this synergy between the technology and our digital skills and artificial intelligence and machine learning even speeds up the possibility of discoveries. We can see that the potential of modelling that we have now, with the supercomputers and with the algorithms, actually helps us to model things – to, let's say, make models of the real systems – , which accelerates new discoveries. There are self-propelling processes, I would say, that allow us to model and discover new materials, new processes, and move on.

**Lund:** I think it is also important to think about innovation and possibilities in a timeframe. The first energy innovation that humans made was fire, and that was about one million years ago. Now, think about one million years ahead! We are just on the first centimetres of that kilometre-path, and the era of fossil fuels will last just about 400-500 years of that millennium that we have ahead of us. When we look from the perspective of the human history to come, fossil fuels will have been just a 400-500 years' era. I think the future generations will think: "What was that? What were these fossil fuels? How stupid were the people?" I am optimistic about the human progress. We need, of course, have some hope for the future. But in the long term, what we will see is future generations looking at us and thinking: "How on earth could you use those dirty backward technologies where we now have these fantastic clean technologies, sustainable technologies?" Which maybe will enable us to reach the stars one day – to the black holes, as Gatis told us.

**Valters:** Peter, I know that the Nordic countries are among the frontrunners in clean energy in the world. People, societies in the Nordic countries are very aware of clean environment and clean energy solutions and so on. Could you expand on that a little?

**Lund:** I think the whole Nordic-Baltic Region – we share much the same kind of values, and we also have very similar histories and cultures. I think this is one basis, where we share an interest in innovation, an interest in education – that's an engine that generates new ideas and new solutions. But also, in terms of energy resources I think we enjoy a huge resource base of renewable energy – being hydropower in some countries, being bioenergy, wind energy… In terms of sustainable energy I would say we are actually one of the best regions worldwide: our resource base is very good, our markets work well – we have a common Nordic-Baltic electricity market… If we need electricity, we have a lot of wind power – we get it from the market from the hydropower in Norway. That base of having a good infrastructure, a good resource base, but also a mind that looks ahead and appreciates education – I think that's where we have the elements of success. And indeed, our region, the Baltic-Nordic Region, will be the first region worldwide to have carbon-free electricity or electricity zero-emission by 2030, so we are moving in that direction as a pioneering region. And that's because of our mindset, I would say, that we look forward and look for solutions to the problems that we have.

**Valters:** We are approaching the end of our very interesting conversation. A question to both of you – what do you think is the most interesting in science, and what would be your advice to young people who would maybe consider a future in science, a career in science? Peter, you

mentioned the importance of education, but in addition to that – what skills, what mindset should young people have to be able to do science, and what's in it for them?

**Lund:** When we think about our youth in our countries, I think that's where our future lies. Having worked a long time in the education system at university, I appreciate the talent that we have in our youth. Each individual that we have has a talent, and that talent may be different! You don't need to be mathematically talented to do science, but you have to have a certain mindset – you have to be curious about things. Science is in a way just a tool that you need – to knock on the door or get through the door. If you are curious about new things, willing to understand how nature works or how things work, you are already a scientist! Now you just need education – a tool to be able to realize your potential. I think Mark Twain said it quite well: "If the only tool you have is a hammer, everything looks like a nail." So the thing is, the more tools you have, the better you can succeed. I have always been interested in new things, and looking back in perspective I can say that my career in science has opened the door to very interesting things. Science enables you to work each day and be motivated, to be able to look into the future, and I myself feel extremely privileged, actually, that I have had this opportunity. It gives you the possibility to work with interesting things, and that's for the human mind is like a drug in a way – that you really have the possibility to look into the future full of interesting things. I would urge all our young listeners, schoolchildren or students – and their parents, in particular, - whatever you do in science, it should be based on your own interest. To be a scientist in your mind doesn't mean that you need to be talented in some areas – what's important is your curiosity and the way you think. I would also say that we go to universities to read, so that's the talent you should have. You have to be able to sit long hours reading and learning, so that is often the trick of becoming a scientist… But ultimately it comes down to sitting and working hard, like in any area. If you're a musician or if you are a carpenter, you have to devote time to that, and then you become a master.

**Bažbauers:** I couldn't say it better than Peter did. I just want to stress the last thing that Peter said – that you really have to be very patient, because results do not come very fast. But if you are curious and if you like what you do, you can be patient and you can work for long hours and learn. I just wanted to add that with the latest events with the pandemic that we have maybe there is some shift in society, of understanding or perceiving the importance of science. We see that actually we have to rely on science in order to solve the grand societal problems, the global problems that we have. In the future, we will face more and more challenges that we will have to solve with the help of science. So I would say that we need any talent that we can get on this planet to get involved in science – we need more scientists than we have today, actually, because we have a shortage of scientists. I would also urge any young person who is interested and curious about things to get into the field of science and to help solve our big problems and challenges.

**Valters:** Thank you! Any final thoughts? What would you like to say to the listeners regarding sustainability, regarding sustainable energy? A lot of these things that we talked about are being done by scientists and by regulators, but what can ordinary people do in this matter?

**Lund:** I think this is a good question, because without involving us all into the change there won't be any change. So in practice it is ordinary people who make the decisions, on doing or not doing something. It is important to realize that we very often proceed in steps, taking a few steps forward. We don't solve the whole problem of sustainability in one go. In terms of energy, there are very simple things that one can do. Maybe check that all your lamps are LED lamps, energy saving lamps; or check that your television has a switch that you can easily switch off so that your TV is not unnecessarily switched on and wasting energy. Or when you are buying new appliances make sure that they are marked with A++ - an energy marking on the appliances. Just be more aware in your decisions! It doesn't mean that you need to spend huge amounts of money. But be aware when you make decisions where energy is involved. I think that's the first simple step – increasing awareness in your decisions. And then in everyday life, small things here and there which you can do. I would not expect that people change in one day from zero to 100, on/off. No, it's not necessary, but gradually we do move towards our goals.

**Bažbauers:** Yes, I would agree with Peter that big processes take place through small individual decisions. So our individual decisions, day-to-day decisions are very important – our choices, our preferences. And we have to be aware of how these choices affect our planet, affect our energy systems and the consumption of resources. The technologies are already there – we have many good technological solutions. We probably even have to allow ourselves to experiment more – to be brave in trying new things and to experiment with new technologies, to learn how to use them, to adopt them. We discussed prosumerism, for example… We probably at some point could make a decision – maybe we can have our solar cell installed and charge our electric car with that, but it will take time, of course.

**Lund:** With the increasing awareness about the consequences of our decisions – what we buy and what we don't buy – it is also important to broaden our view globally. Even if Latvia and Finland reached zero emissions, it doesn't matter globally, because most of the emissions come from emerging countries, like in Asia and, increasingly, Africa. At some point, as part of the global justice, we will also need to be part of their solutions. Global thinking, that we are all citizens of the same planet – I think that will become very important. It is also an ethical and moral question. Even though technology is growing, we as human beings need to grow as well in a sense – in order to understand our responsibility for this planet and our responsibility for our sisters and brothers.

**Valters:** Thank you very much! This was a podcast in the Sustainable Worlds series, financially supported by the Nordic Council of Ministers' Office in Latvia. My guests were Professor Peter Lund from Aalto University and Professor Gatis Bažbauers from Riga Technical University. My name is Kārlis Valters. Stay tuned for the next episodes. Thank you for listening and goodbye.