Prof. dr. Ad van Wijk

A sustainable energy supply for everyone

Inaugural speech 7th of December 2011
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Inaugural speech delivered on the 7th of December 2011
at the occasion of his acceptance of the position of Professor
Future Energy Systems

at the Faculty of Applied Sciences of the Delft University of Technology
Mijnheer de Rector Magnificus,
Leden van het College van Bestuur,
Collegae Hoogleraren en
andere leden van de universitaire gemeenschap,
Dames en Heren.

A sustainable energy supply for everyone; my mission and my dream. A dream that I share with many of you. A mission that I will fight for with all of my heart, as a person, a businessman and a scientist. Today I would like to tell you that this dream must and can become a reality. For us, for our children and for the countless generations that will follow. I for one am optimistic that we will see a sustainable energy supply for everyone in my lifetime. It will require an enormous effort, courage and willingness to change on the part of all of us. But most importantly, we will have to learn to look differently and think differently about our energy supplies. This afternoon, I would like to give you a preview of this new way of regarding and thinking about energy, and outline a few scenarios for the future of our energy supplies. Let me start by telling you that there is no energy crisis; there is no shortage of energy. This standpoint is supported by three significant observations, namely:

1. We waste roughly 98% of our energy.
2. In just one hour, the earth receives more energy from the sun than the entire world could ever consume in a year.
3. Renewable energy is all around us.

So what is this energy crisis then, we are hearing so much about? We were not even remotely concerned about energy efficiency until the 1970s. We had energy to burn (quite literally), and so efficiency was the last thing on our mind. As a result, we designed products, buildings and machines that took unlimited energy supplies for granted. We found the energy we needed for them in the ground; it simply gushed out in the form of oil, gas or coal. And in the early years, we were blissfully unaware that our consumption patterns would cause major environmental problems. We gradually developed an energy system that would waste vast amounts of energy, particularly fossil fuels. But we have forgotten that we are actually surrounded by huge sources of energy, including the heat from the sun, from ourselves as people and from animals, from wood from trees, from the wind that blows, and from the movements that we all make. But what is the most practical and efficient way to tap into the energy around us? This question is the reason that we must learn to look and think differently about our energy supplies.
98%
The first observation is that we waste roughly 98% of our energy. There have been countless analyses examining the energy efficiency of individual products and of complete systems. But using a few examples, I will show you the meaning of energy inefficiency.

Boiled egg
Take something as simple as a boiled egg. What are the steps involved when boiling an egg? We fill a pan with water and put it on the cooker. Putting in the eggs and five minutes later, we have some lovely soft-boiled eggs. The hot water, which has consumed most of the energy, is simply thrown away. The energy efficiency of this process is at most 5%. If we also turn on the receiving hood and light above the cooker, the efficiency drops to less than 2%. As you can see, a very low efficiency, which we cannot blame directly on the inefficiency of the technology, in this case the cooker. No, it is because we are heating the water and not just the egg. We are doing something fundamentally wrong in this process. We would generate the highest energy yield if we could reduce the amount of water we use, or even refrain from using any water at all. How could this be done? Boiling an egg in a microwave is obviously not an option. A high-pressure or steam pan would use less water and therefore be more efficient. Another possibility would be to recover the energy from the water you throw away. This could be done fairly simply by fitting a second pipe to the drain, a heat exchanger, which would store the energy from the left-over cooking water in the vessel of a boiler, which many of us already have in our kitchen cupboard under the sink.

Car
But what difference does boiling an egg make to our total energy consumption, I can you hear you thinking. Let’s take a look at our car. This car has a combustion engine with an energy yield of around 15%. The rest of the fuel is converted into heat, which makes our car little more than a mobile heater. The turning motion of the engine must be transmitted to the wheels. This doubles the loss factor, leaving just 7% efficiency. As our car is not as aerodynamic as it could be either, the ultimate energy efficiency comes to a mere 3 to 5%. But this is only taking the technology into account, which brings us to the worst part: our car weighs about 1,000 kilos. So we are actually moving more than 1,000 kilos of car to transport, in my case, roughly 100 kilos of passenger. Another loss of a factor 10, which finally brings us to the depressing conclusion that travelling by car, has an energy efficiency of less than 1%.
Door bell

Now for the legendary example of the doorbell. The doorbell is a model example of the many devices that spend most of their time inactive, while still consuming electricity. Our doorbell is hardly ever used; we would need numerous friends and ring-and-run children to get just one hour’s constant use per year out of our doorbell. However, a transformer is on permanent stand-by, waiting to see if anybody presses the doorbell button. Although the transformer admittedly uses very little energy, about 5-10 Watt, this still adds up to some 50 kWh in the course of a year. And it’s all wasted energy, as the energy efficiency is lower than 1%. 

So how much energy do you think all our door bells use when added together? In the EU, we have an estimated 200 million door bells. Assuming they all use an average of 50 kWh, we are consuming around 10 billion kWh per year for door bells. This means that 2 big coal power stations of 600 MW are permanently running to generate the necessary electricity for our doorbells. Of course we could produce this electricity sustainably, on large wind farms, but then we would need more than 20 Princess Amalia offshore wind farms of 120 MW each. It is certainly a sustainable option, but it’s also a very expensive way of producing a commodity that we are wasting. Surely there must be another solution?

How can we look at this differently? Many people respond by saying that we should use old-fashioned knockers, as they are the most sustainable. True, but they are not of much use to the countless people who live on the third floor or higher. If you take a different approach to the problem, one solution would be to attach a small solar cell to the doorbell. This solar cell, about the size of a fingernail, generates a tiny amount of electricity which can be stored in a capacitor. It is now a solar cell that is waiting for someone to ring the bell. And when someone does, the transformer is activated. So the solar cell does not produce 50 kWh per year; it annual saves 50 kWh.
1 hour
The second observation is that we do not actually have an energy problem, as we have an enormous and infinite source of energy; our sun. Just look up, and there it is. An infinitesimal small amount of the energy generated in this nuclear fusion reactor, namely one/two billionths, reaches the earth. This still represents a respectable amount of energy; 5,450,000 EJ per year (1 EJ is $10^{18}$ J). The total global energy consumption in 2010 came to just 535 EJ. So the sun gives us more energy in an hour than the whole world uses in a year.

The Sun gives us 5,450,000 EJ per year

Energy from the sun is the source of nearly all forms of renewable energy. Wind power, hydro power, wave energy and biomass are all in some way derived from solar energy. For example, the condensation of water from our oceans and lakes takes a little less than a quarter of all solar energy that reaches Earth. The water that condenses then returns to earth in the form of precipitation. We collect the precipitation in the mountains and allow it to fall downwards through a turbine. In other words, the electricity we generate from hydro power is actually a derivative of solar energy. There are only two forms of renewable energy that are truly different and not derived from the sun; tidal energy and geothermal heat. Tides are caused by the gravitational force whereby the moon and the earth attract each other. Geothermal heat is the result of radioactive decay in the earth’s inner core.

Everywhere
We have a highly energy-inefficient energy supply system. The sun provides a great deal of energy. And renewable energy is readily available everywhere we look; in the heat from the sun, the wind that blows around our house, the plants and trees that surround us and the energy in our own movement. So what’s the problem? There are many reasons for the delay in changing to a sustainable energy supply. But in essence, the fundamentally different character of renewable energy sources is the main stumbling block. Renewable energy is actually a ‘diluted’ form of energy, less concentrated than fossil fuels. Although renewable energy is all around us, it is not easy to transport to where it is needed. And renewable sources tend to have a ‘mind’ of their own; they are not always there when you need them.
We need a paradigm shift in the way we think about our energy supply. We must learn to look at our energy system from a different angle and find new ways of developing and converting them. In the current system, we approach energy from the traditional energy chain perspective; from energy source to energy service. This chain begins with a source; we delve into the ground and bring oil, gas or coal to the surface. We process it, before transporting it through pipelines or by ship. We then take it to an electricity power station, refinery or another type of conversion plant and turn it into useful forms of energy such as petrol, steam, warm water or electricity. We distribute it to consumers via a grid or tanker, where it is supplied through a meter or in the tanks at filling stations. The final conversion takes place when we fill our petrol tanks and drive off, turn on our electric lights, or use gas to boil our egg. This final step is the energy service; a warm house, a boiled egg.
But in a renewable energy chain, we must look and think differently. As consumers, we are not interested in energy itself, but rather in the energy service; our boiled egg or a nice warm house. So this is where we should begin. By designing an optimally efficient product or system that will provide the required energy service and which integrates sustainable energy conversion technology if possible already at this stage. After all, if renewable energy is everywhere, why not use it everywhere too? The next step is to work out how you and your neighbors or community can exchange energy services or energy. Only then should you start thinking about the energy services and/or energy you need to buy at the supermarket, IKEA, the bank, via Google or maybe even from your energy company.
Green Campus

I started here at TU Delft on January 1st, 2011. The idea was to use this other way of thinking, with a system perspective, to look into ways of designing future sustainable energy systems, to decide which technology we need to develop and how in turn it should be implemented. A lot of fantastic research into the field of energy is already being carried out here at the Delft University of Technology (TU Delft). More than 700 scientists are working on energy-related research projects, many of them focusing on the technological side of energy conversion, or storage technology. But the development of new energy systems from the perspective of the energy service has been somewhat neglected. Who here is exploring the energy efficiency of producing steel or boiling an egg?

With my background in business, I could not help but notice that the level of collaboration with external companies was somewhat disappointing. Obviously, a lot of research here at TU Delft is conducted in partnership with companies, but many of these are major corporations, which already have their own research departments. Much could be gained from collaborating with small and medium-sized businesses. One of the obstacles to forging good relations and partnerships with companies is the physical environment, the TU Delft Campus. But where might you take your guests for a representative meeting, a lunch or dinner? Not here in the Aula Congress Center or the Aula canteen, is it? Where can guests spend a night here on the campus, and where can you organize a good conference, meeting or event? The TU Delft campus is hardly the place for stimulating interaction with the business sector.

And although a lot of the research carried out on the TU Delft campus is about sustainability and renewable energy, we must conclude that very little is actually happening. These are not the inspiring conditions in which we can educate our students to become creative, entrepreneurial people, ready to roll up their sleeves and find solutions to the challenges of the future.

This gave me the idea of not only designing, analyzing and researching sustainable energy systems for the future, but also realizing them. And in such a way that allows us to demonstrate a range of sustainable innovative products, technologies and systems. That enables us to create an inspiring environment where people like to come and in which collaboration between the university and businesses will grow and flourish (www.the-green-campus.com).

Vision

"Creating a sustainable, lively and entrepreneurial campus, where we discover, learn and show how to solve society’s urgent challenges."

A sustainable or green campus is not just a place where the energy supply is renewably produced. A green campus is more than that; we don’t want any more waste or at the very least, should recycle this waste, we want clean water, clean air, smart DC grids, clean lighting, electric transport, cradle-to-cradle products and green buildings. In short, a campus that is sustainable on many fronts. This is why we have defined 12 dynamic missions for the green campus. Not missions to be realized by a certain point in time, but missions that evolve and develop as time goes by.
Missions
1. Sustainable energy producer
2. Green Buildings
3. Electric transport
4. Clean lighting systems
5. Energy efficient
6. Energy/materials from waste
7. Smart heat grids
8. Smart DC electricity grids
9. No Waste
10. Clean water producer
11. Sustainable products
12. Clean air producer

But the green campus must not only be realized, it must be operated and exploited in a feasible cost-effective and profitable way. The green campus must be doubly sustainable, both economically and ecologically, which is why the first step towards designing the green campus is to take a long, hard look at ways of generating income on the projects and activities. First of all, we need a good business plan. The most important aspect is looking at the green campus as one integrated entity and working out how we can make it profitable. This is known as a dynamic portfolio strategy. You spend 80% of your time and money on products, technologies or activities that are definitely profitable, 18% of your time and money on matters that may or may not be profitable, and 2% on real innovations that are not yet profitable. But if the overall operation is affordable and profitable, it will still allow us to realize new, innovative products, technologies or systems.
What do we want to do? We want our campus to be situated on and around the Kruithuisweg in Delft. Arriving on the A13 motorway, the iconic Harp will mark the entrance to the campus. We will build an energy wall along the Kruithuisweg right up to Delft Zuid train station. And along this energy wall, we will realize a green hotel, floating green restaurants, conference facilities, green sports facilities and a green car park, all set in watery, green surroundings, which we will also create.
The Harp is a modern wind turbine and solar energy installation. The net between the legs of the wind turbine contains solar cells, which can be directed at the sun via the net cables. The product was developed by two TU Delft students, who as a result have now started up a small business. But the Harp is also a building, which will house meeting rooms, a visitors’ center, a café and a cockpit. The cockpit will provide an overview of the green campus; the energy consumption and production, the air quality, the activities taking place, the performance of various installations, et cetera. But you will also be able to pilot an unmanned electric helicopter with a camera and fly around the Harp.

At the foot of the Harp is a large square, lined by shops, the green campus store, exhibition rooms, restaurants and cafés, and a disco with a dance floor that generates energy. The undersurface of the solar cell net will be fitted with LED lighting, and form a huge cinema screen. And of course there will
also be LED lighting on the outside of the Harp, allowing you to show advertisements. This is a way to generate income and allow a project like this to operate cost-effectively and profitable.
The Energy Wall

We intend to build a kilometer-long energy wall along Kruithuisweg, between the A13 and Delft Zuid train station. The energy wall will be fitted with solar cells and small wind turbines, which can generate electricity. The Kruithuisweg is a prime location as it runs from east to west and enables us to position solar panels pointing south. Electrostatic wires will be built into the wall, so that we can trap and filter out the fine dust in the air. This technology was developed here at the university. Obviously, the wall will also reduce the noise level. It will be fitted with LED lighting to light up the road, but also to show you all kinds of information. And finally, the wall will include a personal rapid transit system, also designed here at TU Delft, above a covered bike path, thereby allowing people to quickly move around the green campus.

The energy wall is a space-saving, multifunctional structure, which enables you to combine a number of functions (including mobility) in an urban area. It even means that buildings can be built closer to the wall, as both the noise and the fine dust have been reduced.
One of the technologies we intend to implement at various locations throughout the green campus is LED lighting. But LED lighting is more than just another energy-efficient type of lamp. LED lighting is set to start a revolution in the way we use lighting. The lifespan of a LED lamp is much longer than that of an old-fashioned light bulb; 40 times longer. LEDs are also much smaller, produce far less heat and are easy to regulate and control at a distance. So LED lighting is suitable for more functions than simply lighting; you can use it for signposting or creating an atmosphere, you can fit it with sensors and even use it as a monitor or cinema.

In addition, LEDs can be integrated into products, clothing, furniture, walls, windows, pavements and roads. This does not only generate savings by dispensing the need for light fittings, it also saves energy. A lot of energy is currently wasted because we have a light source high above our head, while we actually need the light at eye level. The distance between the light source and our eyes represents a huge waste of energy. Integrating LED into products will generate substantial savings, simply by shortening this distance.
Next to the green hotel, there will be a car park annex mobility center. The aim of the mobility center is to allow people to change onto all kinds of electric transport. You can leave your electric car and get onto the people mover on the energy wall, which will transport you to Delft Zuid train station. Or take an (electric) bike or the Segway to reach your place of work. The hotel will also provide various forms of transport to get into town or the local area, including an electric taxi to take you to the airport. So the car park will actually be a new type of station with all the facilities you would expect to find in a station.

Electric mobility is the way forward. Not just electric bikes and scooters, but also electric cars. The electricity needed will initially be provided by a battery built into our car, which will need regular charging. This is a fairly simple procedure if the car is parked, i.e. in the car park. We will fit regular electric charging points throughout the car park. In addition also quick charging stations and induction charging stations will be present. This allows us to charge our car batteries and even use them as a storage system which will supply us with electricity at other times.
We will generate renewable energy at various locations on the green campus from the sun, wind and movement. Sometimes on a micro scale, like with the piezoelectric elements using movement from the revolving doors, fitness equipment or the dance floor. On a small scale via solar cells and small wind turbines, and on a larger scale via the large wind turbines. The electricity will be used in numerous devices, for LED lighting and for charging the batteries of our electric transport. Between these two stages, there will be a grid system, an electricity infrastructure. But there’s a problem. All electricity produced is direct current (DC); all our equipment, LEDs and batteries work on direct current (DC). But the present grid is alternating current (AC).

The AC electricity infrastructure is actually a historical development. 150 years ago, there was a battle between a Mr. Tesla (AC) and a Mr. Edison (DC). Tesla eventually won because he had the backing of a major company, Westinghouse. But an AC grid is not the best option for the future. If we construct an AC grid, we will have to convert the electricity we generate in our solar cell system from DC to AC. Then when we want to store it in our car battery, we will have to convert it back from AC to DC. If we then want to use some of the electricity in the battery for something else, it will have to be converted again from DC to AC. And then for the LED lighting, it will be converted yet again from AC to DC. This example comprises 4 conversion steps, resulting in an energy loss of around 10-20%. But that’s not all; we will also need expensive inverters to realize all these conversions. These are costs that we can avoid. In a DC environment, we will obviously need to vary the voltage on occasion, but we can do this by using simple and inexpensive step-up and step-down transformers. And DC has more benefits: no reactive power, no higher harmonics, et cetera. For sure we are going to explore how we can realize a smart DC electricity grid on the green campus.
Our car as an electric cash cow

Still of the ‘car park power plant’ animation, which can be found at http://youtu.be/lalK-2t1Z7U

Finally, what will the future of electric cars bring us? There are currently two major bottlenecks regarding electric driving on batteries alone: the range and the long charging time. This is why we are seeing so many hybrid electric cars, which also have an engine that produces electricity from fuel, albeit inefficiently. A lot of hard work and research is going into fuel cells. By means of a chemical process, fuel cells can convert fuel into electricity at a higher efficiency, of approximately 50%. This is higher than the average efficiency of our current electricity generating park, which is roughly 40%.

So fuel cells would actually give us a very efficient electricity power station in our car. When parked, which is approximately 93% of the time, we would be able to use them to generate electricity. The car is normally idle in the car park. So if we were to connect not only an electric cable to the car, but also a fuel
pipe, we would be able to use the fuel cell in the car to generate electricity. In addition to electricity, we also produce a ‘waste’ product, namely clean water: just under half a liter of clean water per kWh. So let’s make a calculation. An average engine has a capacity of around 80 kW. If there are 500 cars in the car park, we will have an electricity power station of 40 MW, 10 times as powerful as the new cogenerating (CHP) power station currently being built here at the university. A power station of this size could easily generate all the electricity TU Delft needs. And we would be producing barrels of clean water as a by-product.

This would give us a highly efficient, flexible, easy to regulate electricity power station. A power station like this is also easy to combine with electricity from renewable and fluctuating sources, such as solar and wind. And do you know what the best part is? Parking would not cost a penny; in fact it would generate income. Could this be our very own electric cash cow?

Using our cars as an electricity power station of the future would give us a huge power station. Every year, the Dutch buy 500,000 new cars. In total, this would result in an electricity production park generating 40,000 MW per year, twice as much as the electricity production capacity of the current Dutch set-up. In fact, we would be creating a tremendous surplus of local, small-scale, flexible production capacity. Would this make our present electricity power stations redundant? And how would this affect our infrastructure?

How would our electricity supply be organized and look like? We generate local electricity using the sun, wind and movement. We produce biogas from our organic waste and biomass. And our cars give us local, highly flexible and small-scale power capacity. Together, we will be producing our own electricity and will own a huge capacity of flexible, efficient electricity power stations. Car manufacturers will produce and supply these electricity power stations. Telecom companies make sure that everything is properly organized, coordinated and paid for. What would be left for the electricity companies to do?

Could this view of the future become a reality? In terms of the technology, there is still a lot to do; better fuel cells with a longer lifespan, proper and efficient production of hydrogen, safe hydrogen storage facilities and infrastructure, et cetera. But we will also need an awful lot more innovation and research, a reorganization of energy supplies, new business models, new legislation, and new control and management systems. And then there are the safety aspects, the environmental and social implications. In short, we still have a long way to go. Here in Delft, we want to take the first step by building a car park that functions as an electricity power station.
**A dream for all to share**

We are going to develop this green campus together with our scientists, commercial partners and students. It will be a living lab, an inspirational place where businesses and university interact, and a place where everyone can get an idea of the energy systems of the future. I see this as the next, important step in realizing my dream; a sustainable energy supply for everyone. A dream that I hope to see fulfilled during my lifetime.

One in which I have been inspired by my parents, Wim and Anny, who brought me up on a small farm and let me experience the enormous power and infinity of nature. A dream that I can, and only want to, realize together with my wife Sonja. A dream in which many people have inspired me and which I am happy to share with others. A dream for all of us; one that we not only want to fulfill, but which we must fulfill, for our children, our children's children and all the generations that follow and are lucky enough to spend their lives on this wonderful planet.

Ik heb gezegd.